Technology and Steel Industry Competitiveness

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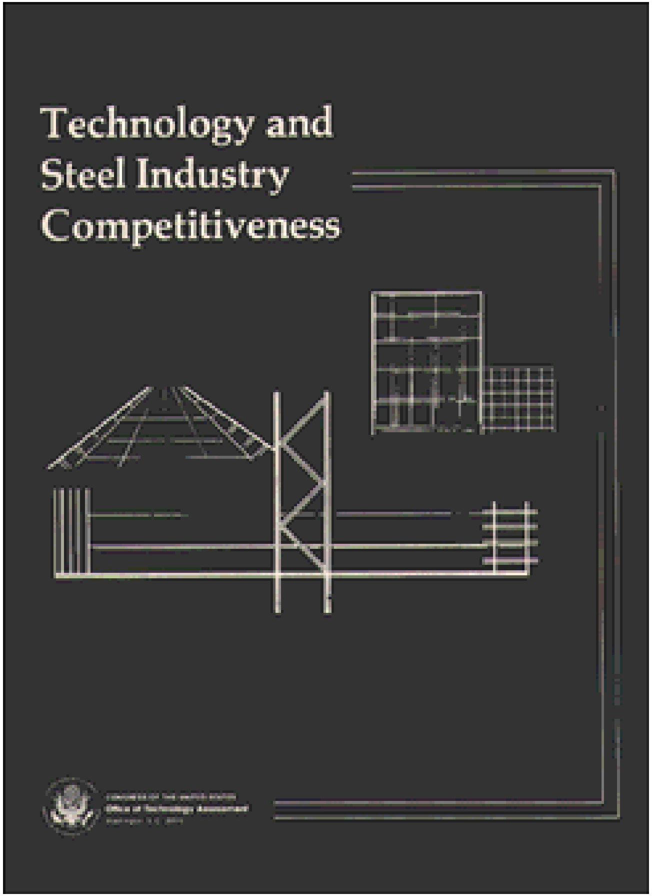

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Foreword

A severe downturn in the domestic steel industry in 1975-76, coupled with continued increases in steel imports, led to widespread concern about the industry's future. In October 1977, the House Ways and Means Committee's Subcommittee on Trade requested that OTA examine how technology might be used to improve the industry's international competitiveness. The brief recovery of 1978-79 appears to be over and, with another downturn on the horizon, the following concern expressed in the Subcommittee's original request seems just as relevant today:

> While it is possible that some short-range solutions to the current world steel crisis may be developed in the near future, the need for a long-range policy will remain,

This report focuses on the creation and adoption of advanced technology in the U.S. steel industry. Although it is not a comprehensive study of the industry, it does examine nontechnological factors that shape the environment in which new technology is created and adopted.

OTA finds that a number of technological opportunities exist for improving the competitiveness of the domestic steel industry. The industry consists of different types of firms with markedly different performances, and this report identifies the opportunities for new technology and new policies that apply to each. It examines the costs and benefits of specific Federal policy options, and constructs several scenarios for the next 10 years to assess how these options would affect the industry and the Nation.

The domestic steel industry remains vital to the economic well-being and national security of the United States. However, technology alone cannot solve all of the industry's problems. Given the complexity of these problems, the technology-related policy options in this report should assist any congressional debate on a national policy for renewal of the domestic steel industry.

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NOTE: The Advisory Panel provided advice and comment throughout the assessment, but the members do not necessarily approve, disapprove, or endorse the report, for which OTA assumes full responsibility.

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*After February 1980 replaced by Dr. Dennis because of retirement from AISI.

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Summary

Summary

Steel will probably remain the world's most important engineering material, and the steel industry is vital to the Nation's security and economic prosperity. It is possible, however, that continued low profitability and some Federal Government policies, such as long depreciation times for new facilities, will cause the domestic steel industry to contract substantially. Many jobs could be lost and the Nation might become vulnerable to scarce and high-priced imports, which by 1990 could account for 40 percent of the domestic market, compared with recent levels of about 15 percent,

The U.S. steel industry can be revitalized through increased investment in research and development (R&D) and the adoption of new technology. For that to happen, however, steelmaker must increase their capital spending on production facilities by at least 50 percent during the next decade, to approximately $3 billion per year (1978 dollars), in order to modernize existing mills, expand capacity modestly, and bring profitability up to the level of most other domestic manufacturing industries. Supportive Federal policies are needed to generate at least $600 million of this additional capital per year. The industry estimate for modernization and capacity expansion is $4.9 billion per year.

Small nonintegrated steel plants that rely on ferrous scrap rather than iron ore to produce the simpler steel products could nearly double their market share (now at about 13 percent) in the coming decade, provided that adequate electricity and scrap are available in specific market areas. Considerable near-term potential also exists for increased exports by the highly competitive alloy/specialty steelmaker in the next 10 years, if the new Multilateral Trade Agreement is enforced vigorously.

After a decade of restructuring, modernization, and expansion, the industry could adopt major new steelmaking innovations if the Federal Government supports basic research in steelmaking (which barely exists today), provides incentives for more industry R&D, and assists in pilot and demonstration projects. Major process innovations around 1990 could then give the domestic industry a competitive advantage, rather than mere parity with foreign industries. This is the type of long-range strategic technology planning that the industry has neglected in the past.

A well-designed and vigorously implemented government policy has nurtured the Japanese steel industry's expansion and adoption of new technology. The U.S. steel industry, on the other hand, has been hurt by a long series of Federal Government policies that have frequently been uncoordinated, contradictory, and inattentive to critical issues. A Federal policy that coordinates the industry's needs, the Nation's interests, and specific technical concerns is an important option.

Neither technology nor capital, alone, will solve the steel industry's problems. New technologies could be adopted by the domestic industry if problems of insufficient capital and uncertain levels of imports are resolved. One such technology already used by major foreign competitors is the continuous casting of molten steel, which reduces energy consumption, increases productivity, and expands steelmaking capacity. Another, the coal-based direct reduction of iron ore to produce a low-cost substitute for ferrous scrap and

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NOTE: Generally, data throughout this report are expressed in metric units for ease of comparison with data supplied by international organizations.

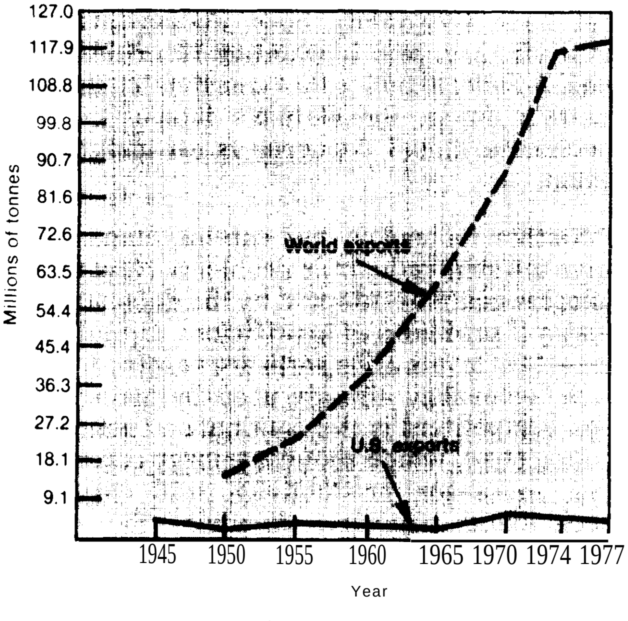
blast furnace iron, may be developed commercially within the next 5 to 15 years. Potential advantages include reduced capital costs, reduced pollution, and increased use of coal.

For a graphic and abbreviated summary of the problems and solutions discussed in this report see the diagram on pages 6 and 7.

International Competitiveness Problems of the U.S. Steel Industry

Although world steel demand has more than doubled during the past two decades, domestic steel production has increased by only 20 percent during the same period and actual domestic capacity has been decreasing recently. By comparison, the Japanese steel industry increased production sevenfold, and Common Market production went up by 70 percent. Substantially increased imports and constant export levels also testify to the declining role of the U.S. steel industry in the international market. (See figures 1 and z.)

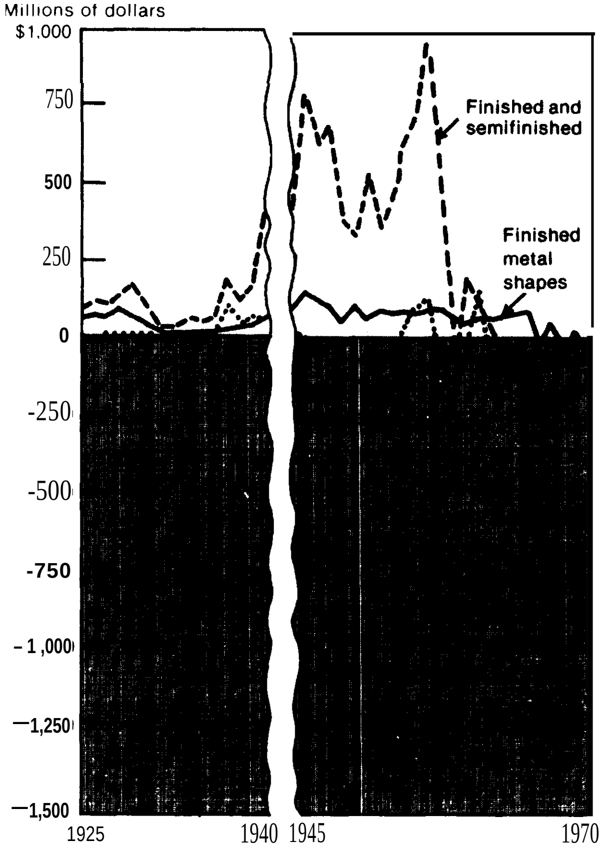
Figure 1.—U.S. Exports—Share of World Steel Trade, 1945-77



NOTE One U.S. ton = 0.907 metric tonne

SOURCES. American Iron and Steel Institute, Sfeel *Industry and Federal Income Tax Policy,* June 1975, p 46; U.N. Secretary of Economic Committee for Europe, *Statistics of World Trade* in *Steel, 1913-59,* Geneva, 1967

Figure 2.— U.S. Trade Balance in Iron and Steel, 1925.70[a]



[a]Excluding the war years 1941-45

SOURCE. W. H. Branson and H. B Tunz, *Brookings Papers on Economic Activity, 2:1971* (based on U.S. Department of Commerce and U.S. Bureau of the Census data)

Unlike foreign firms, domestic steelmaker have financed capital investments largely from retained profits or through equity financing. Foreign governments play a more direct role than does that of the United States in facilitating industrial access to capital markets and public funds. Historically, the domestic steel industry's indebtedness levels have been relatively low compared to foreign steel industries.

The deteriorating world market position of the U.S. steel industry may be attributed to a number of factors. The domestic industry's most recent expansion started earlier and was of much shorter duration than that of competitive foreign industries, particularly Japan's. Furthermore, impeded in part by lack of capital, the industry has been slow in adopting certain productive new steelmaking technologies. Consequently, U.S. plants tend to be older, smaller, and less efficient than the steelmaking facilities of some foreign industries, although there are a number of old, inefficient plants in Western Europe as well. The tradeoff between maintaining employment and losing profitability and efficiency is receiving much attention in the United States and some Western European nations.

Despite major technological and economic difficulties, domestic steel industry profit levels have been higher than those of foreign steel industries, although they are only about half the U.S. manufacturing average. However, the resource-poor Japanese steel industry, benefiting from post-World War II technological, economic, and government policy advantages, has been the world's low-cost producer since the early 1960's. Japan has had extensive steel industry expansion, based largely on new plant construction. This has given it superior technology and cost-competitive steelmaking capability. Some less developed steel-producing countries, such as South Korea, are also becoming increasingly cost competitive.

Raw materials, including energy, continue to be the most costly input factors. Foreign steel industries have brought down their unit costs for raw materials during the past decade, despite major price increases. By contrast, domestic raw materials unit costs have increased. Virtually all steel industries are experiencing declining employment levels. Although it still has high labor productivity, domestic steel industry unit labor costs are higher than those in Japan, though they are still lower than those in Europe.

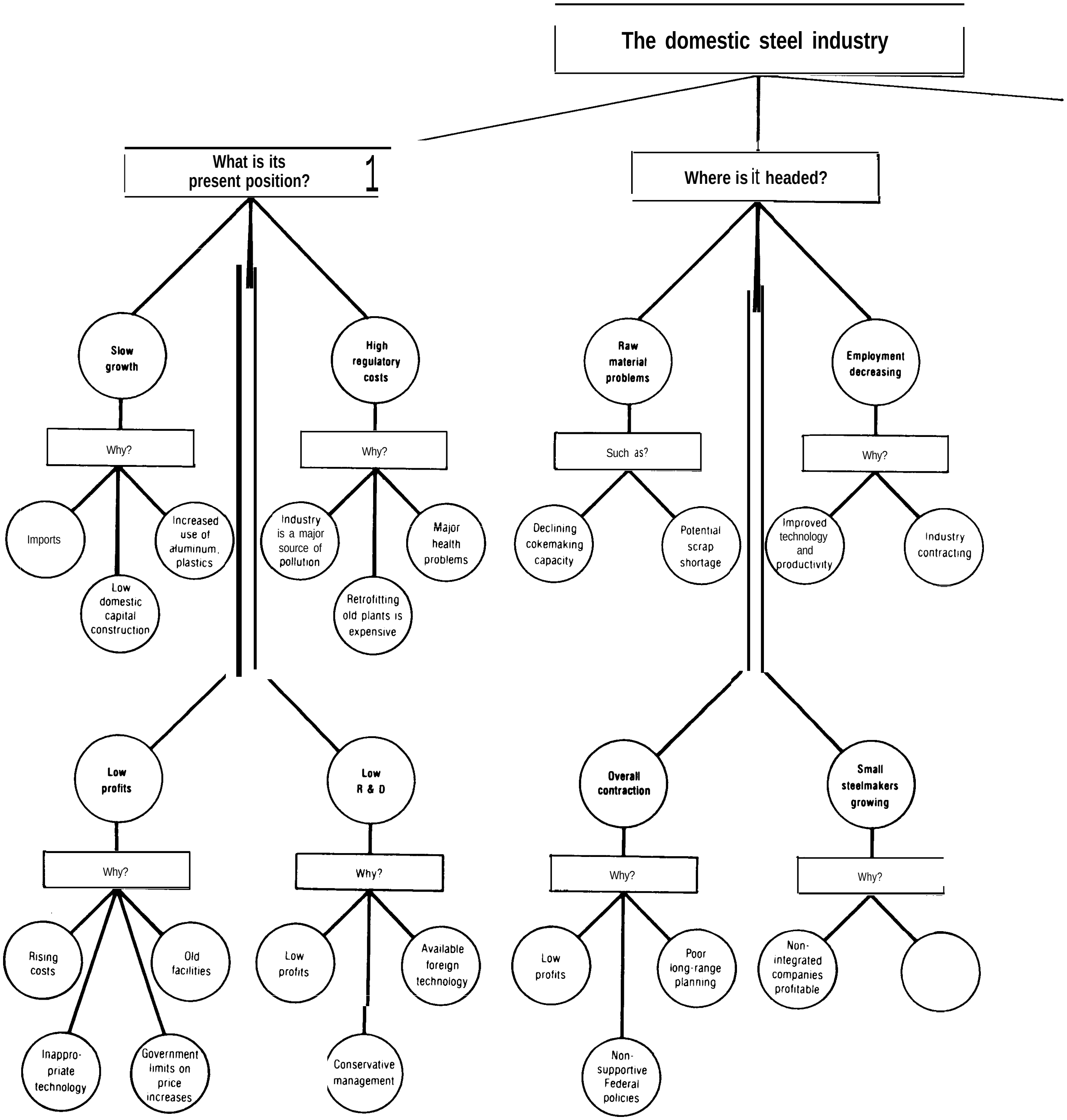
Predictions of future supply and demand for steel products are uncertain, but high steel demand and barely adequate world capacity are possible by the mid- to late 1980's. Under those conditions, if domestic capacity is replaced with modern facilities, the U.S. industry can claim its share of increased demand and thereby finance new capacity. If at least limited expansion and modernization do not start immediately, however, the United States will become dependent on imported carbon steel at increased prices during cyclic periods of high domestic demand which coincide with high worldwide demand,

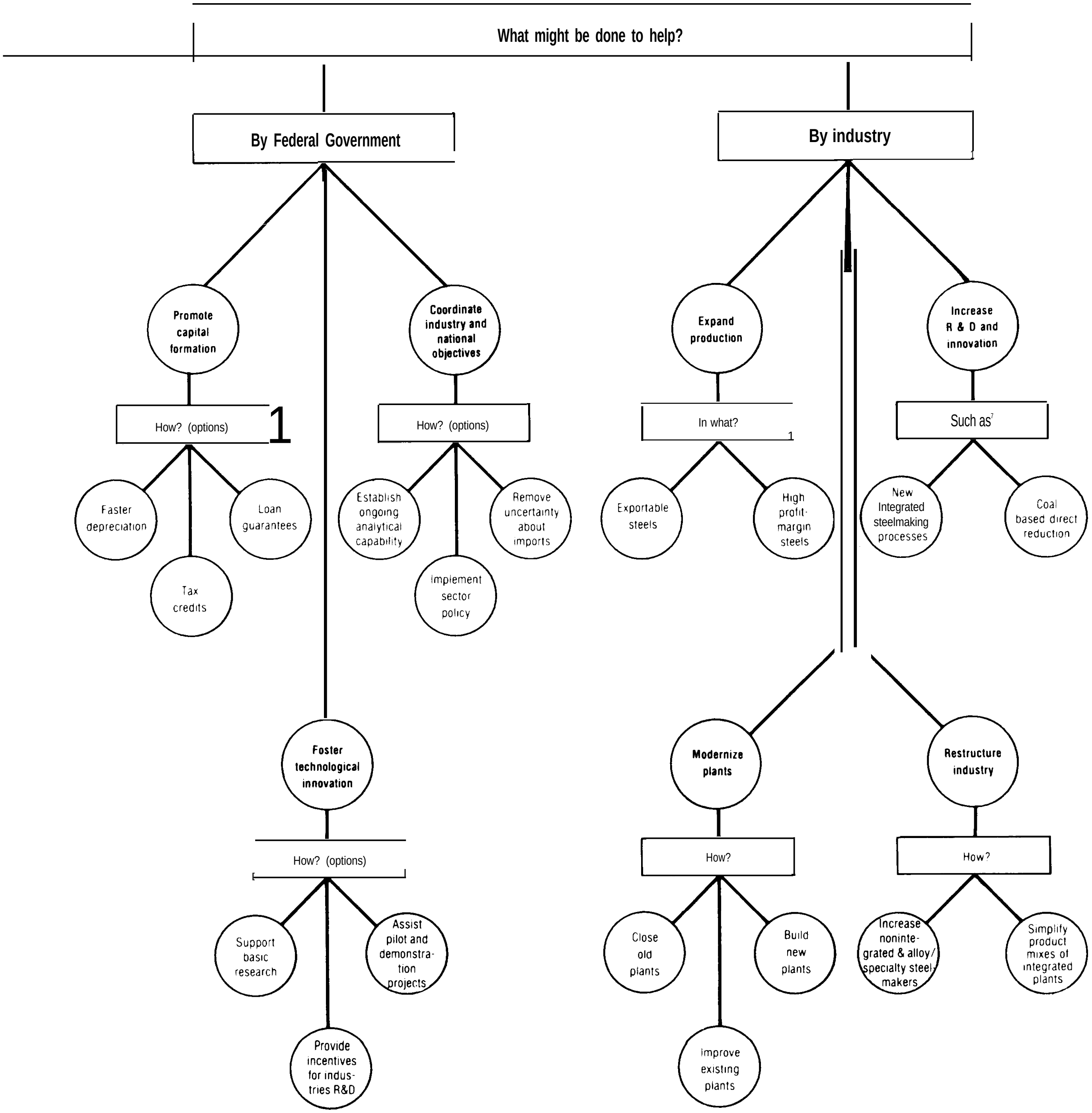
Policy Options

It is in the Nation's interest to have a strong domestic steel industry that makes effective use of domestic iron ore, coal, and scrap. Technology alone is not sufficient to reverse the slow shrinkage of U.S. steel capacity. Nor can new technology immediately help those parts of the industry that use old, inefficient, or poorly located plants.

Nevertheless, short-term Federal policies that fail to encourage technological innovation and modernization would be only temporary and superficial remedies. The ability of the large integrated steelmaker, who have been especially hard hit by aging facilities, poor capital recovery, and high costs of environmental regulations, to supply most of the Nation's steel while maintaining profitability has probably reached its limits. Even those parts of the industry that are profitable, competitive in the domestic market, and well managed, need continued technological modernization to maintain and improve their com-

This diagram is a simplified graphic summary of the major issues and options discussed in the full report. It illustrates the complexity and interrelationships of the problems facing Government and industry.




What might be done to help?
By Federal Government
Promote capital formation
How? (options)
Faster depreciation
Tax credits
Loan guarantees
Foster technological innovation
How? (options)
Support basic research
Provide incentives for industries R&D
Assist pilot and demonstration projects
Coordinate industry and national objectives
How? (options)
Establish ongoing analytical capability
Implement sector policy
Remove uncertainty about imports
By industry
Expand production
In what?
Exportable steels
High profit-margin steels
Modernize plants
How?
Close old plants
Improve existing plants
Build new plants
Restructure industry
How?
Increase nonintegrated & alloy/specialty steelmakers
Simplify product mixes of integrated plants
Increase R & D and innovation
Such as
New Integrated steelmaking processes
Coal based direct reduction

petitive positions, particularly in the international market.

The creation and adoption of new technology are hampered by a number of factors, the most important of which are inadequate capital formation, inadequate R&D, high regulatory compliance costs, and the threat of unfairly traded imports. In a world in which most foreign industries are owned or heavily supported by their governments, the U.S. steel industry is at a disadvantage because it must generate the capital it needs for modernization and expansion from profits. Past Federal policies have affected costs and prices, and hence profitability; yet most steelmaker have been slow to pursue cost reductions through better technology in order to cope with those policies. The superior technological and economic performance of some domestic steelmaker demonstrates the potential for improvement in other companies; but both Federal and industry policies have led to underinvestment in capital plant, R&D, and innovation. The industry itself has not emphasized long-range planning for technological innovation, nor has it kept its costs as low as might have been possible. It has chosen to pay high dividends, even during periods of declining profits. The domestic industry has also been adversely affected by unfairly traded foreign steel, both in the domestic market and in third-country markets where U.S. producers could have competed.

Substantial trade and tax issues exist with regard to the steel industry, and Federal policies on these issues need examination. Policies are also needed to deal directly with technology issues. OTA uses three scenarios for the next decade to examine costs and benefits of policy options. The "Liquidation" scenario implies an extension of present policies and a continued shrinkage of domestic capacity and employment. The "Renewal" scenario considers policy options linked to moderately increased capital spending for modernization and expansion to revitalize the industry. The "High Investment" scenario examines policies compatible with greatly increased capital spending to quickly modernize integrated steelmaking facilities. OTA's analysis suggests the following possible options for Federal policy with regard to the steel industry:

- Provide greater capital formation to be used for investment in steelmaking through, for example, faster depreciation, investment tax credits, loan guarantees, or subsidized interest loans.
- Provide incentives for industrial R&D and increase Federal support of basic research and large-scale demonstration projects, particularly those which use environmentally cleaner technologies.
- Coordinate Federal energy development programs with the needs of industry—for example, the development of synfuel or coal gasification technology might be coordinated with requirements of direct reduction of iron ore.
- Reach a better understanding of the benefits of Federal environmental and occupational health and safety regulations on the one hand and, on the other, of the costs to communities of a shrinking industry, the industry's capital and modernization needs, and the regulatory barriers to technological innovation.
- Examine the costs and benefits of limiting the export of energy-embodying ferrous scrap.
- Examine the feasibility and adverse impacts of Federal targets for ferrous scrap use, and compare these targets with alternative mechanisms such as incentive investment tax credits for adopting new technology that uses less energy.
- Reexamine trade practices, particularly to assess the impact of unfairly traded steel imports on the industry's ability to make long-term commitments to new technology and additional capacity,
- Promote increased exports of high-technology steels.
- Emphasize long-term assistance to steel plants capable of technological rejuvenation, and at the same time provide short-term assistance to workers and

communities impacted by closing old facilities.

New Federal policies, however, would be ineffective without appropriate shifts in the attitudes and policies of industry. For example, industry would have to reexamine its policies of using capital for diversification out of steelmaking, emphasizing short-term benefits from relatively minor improvements in technology, quantifying the costs but not the benefits of regulations, and resisting industry restructuring by ignoring the benefits of expansion by small, scrap-based steelmaker.

The present state of the industry and the pressing need for a critical examination of policy options are, in large measure, a consequence of a long series of uncoordinated Federal Government policies. These policies have not been properly related to each other or to a well-considered set of goals for the industry, goals which satisfy both national interests and industry needs. The lack of policy coordination and the failure to designate a lead agency to implement such policies have led to a situation where policies are often at cross-purposes with each other and thus ineffective, where the interaction of Government and industry is adversarial rather than cooperative, and where critical issues are not addressed. Examples of conflicting Government policies include:

- promoting energy conservation while not allowing adoption of continuous casting (see next section) to qualify for the energy investment tax credit;
- encouraging the domestic industry to use more scrap, which requires capital investment, without providing realistic capital recovery; and
- attempting to hold prices down, while at the same time using the trigger-price mechanism, which leads to price increases.

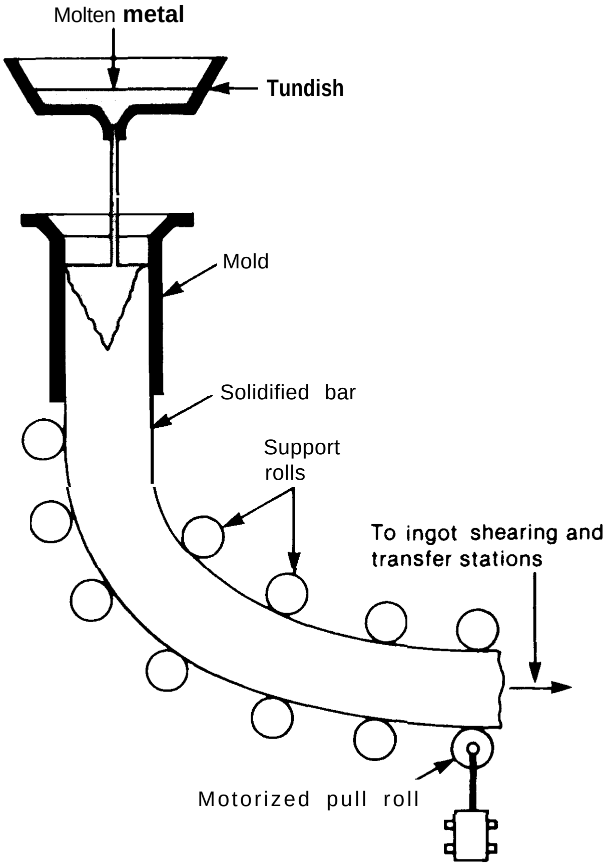
Thus, perhaps the greatest need is for a careful examination of the costs and benefits of a Federal policy for the steel sector that would first establish a set of goals consistent with national and industry needs and then a set of coordinated, reinforcing actions that would effectively and efficiently help achieve those goals. The most important lesson to be learned from the past experience of the international steel industry is that such sector policies may be needed for major domestic industries if international competitiveness is to be achieved. Foreign governments, particularly the Japanese, have adopted sector policies to build competitive industries. Without a coordinated policy, improvement efforts may be at cross-purposes or fail to address critical issues. For example, the steel industry's emphasis on the need to raise adequate capital for modernization and capacity expansion ignores the need for additional efforts in R&D and innovation. Domestic policies that deal effectively with only one of these areas would not help, in the long run, to ensure a profitable and competitive industry, nor would trade policies that deal effectively with import problems but fail to support technology, innovation, and the means of production. The risks of adopting a steel sector policy include an overemphasis on the welfare of the steel industry to the exclusion of other domestic industries, insufficient attention to social or environmental goals and impacts, and possibly insufficient attention to smaller steelmaker.

Future Changes in Technology

Continuous Casting

The most important technological change for integrated steelmaker during the next 10 years will be greater adoption of continuous casting. This process replaces with one operation several steps in steelmaking: ingot casting, mold stripping, heating in soaking pits, and primary rolling. (See figure 3.) Continuous casting also increases the yield of fin-

Figure 3.—Continuous Casting Apparatus



SOURCE: *Technology Assessment and Forecast, Ninth Report,* U.S. Department of Commerce, March 1979.

ished steel. Although it is the preferred process for most steels, the ability to continuously cast some types of steel has not yet been developed.

The main benefits of continuous casting are:

- Considerable energy is saved both by eliminating energy-intensive steps in steelmaking and by increasing yield.
- Capital costs per tonne of output are lower because the increase in yield allows more shipped steel to be produced without increasing capacity.
- Labor productivity is higher because there are fewer process steps, higher yields, better working conditions, and shorter production times.
- The quality of steel is higher because there are fewer steps and greater automatic control of the process.
- Pollution is reduced by eliminating soaking pits and reheating furnaces, using less primary energy, and exposing less hot steel to the atmosphere; also, because of higher yield, less primary ironmaking and cokemaking are required.
- More scrap would be used domestically because it would be needed to replace the home scrap eliminated by higher yields; insofar as scrap embodies the energy that was used to produce it, its domestic use saves energy that might have been shipped abroad.

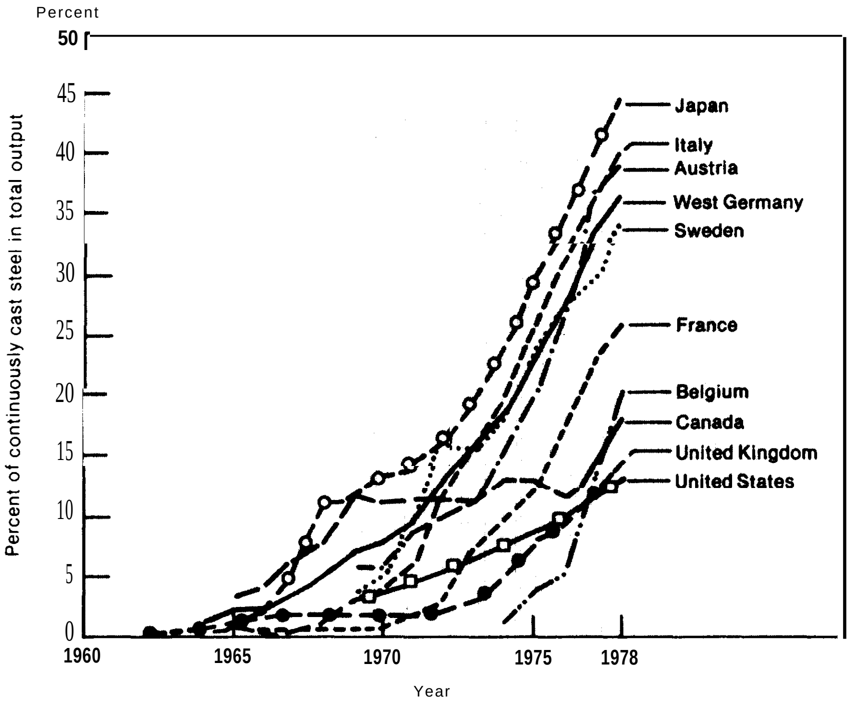
These advantages are not being fully exploited by the domestic steel industry. Although domestic adoption of continuous casting is increasing, the United States has fallen behind almost all other steel-producing nations in the extent to which this process is used. (See figure 4.) For example, in 1978, Japan reached a 50-percent level—that is, 50 percent of the liquid steel made was continuously cast—and the European Community continuously cast 29 percent of its steel; the U.S. level was only 15 percent.

This figure for the United States conceals wide differences in the extent of use in the steel industry. Nonintegrated producers, who make steel in scrap-fed electric furnaces, use more than 50-percent continuous casting. However, integrated producers, who first make iron from iron ore in blast furnaces and then steel from the iron, use only 9-percent continuous casting and account for about 85 percent of domestic steel production. Thus, the adoption of continuous casting lags even more than published figures indicate.

The reasons for the low domestic adoption rate of continuous casting include the following:

- an inadequate amount of discretionary capital with which to replace existing, and perhaps not fully depreciated, ingot casting facilities;
- the costs and difficulties of substantially modifying an operating plant;

Figure 4.—The Diffusion of Continuous Casting, 10 Countries, 1962-78



SOURCE: Organization for Economic Cooperation and Development

- the additional capital costs of downstream facilities to process the increased production of semifinished steel;
- technical problems with using the process for some types of steels and for small production runs;
- difficulties in expediting Environmental Protection Agency (EPA) permits, and the costs of regulatory compliance once the permits are granted; and
- uncertainties over the extent to which future steel imports will capture domestic markets.

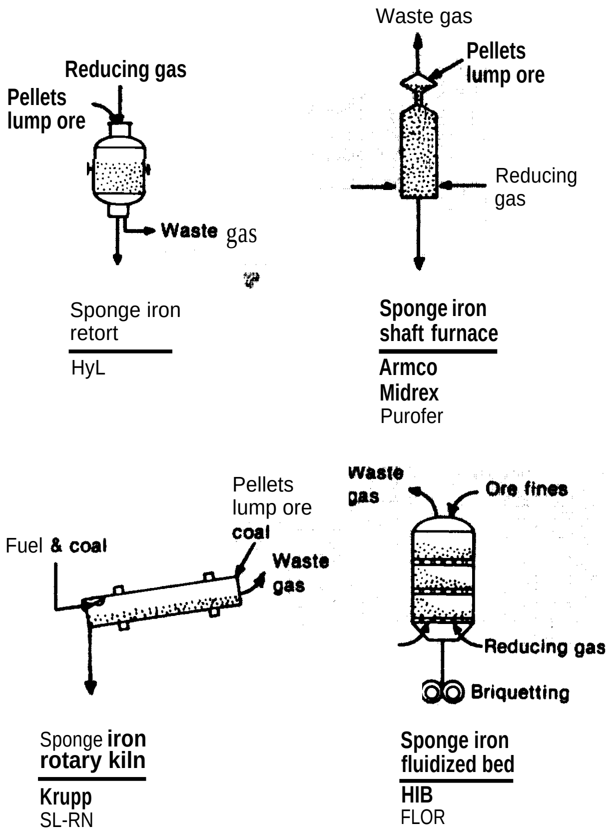
The OTA analysis indicates that, on balance, the overall economic benefits of continuous casting justify increasing its use, although recent economic conditions have to some extent justified industry's short-term focus, which has not favored investments in continuous casting. A key question is how much continuous casting could and should be adopted by the domestic steel industry, and in what time frame. To prevent drastic erosion of cost and technological competitiveness with foreign producers, the whole industry would need 50-percent continuous casting by 1990. This goal appears to be technically feasible.

Even though returns on investments in continuous casting could be 20 percent or more before taxes, there is probably insufficient capital now and in the foreseeable future (with present price levels, import levels, and Federal policies) for this increased adoption of continuous casting.

Direct Reduction of Iron Ore

Another important new steel technology is direct reduction (DR) of iron ore. DR refers to a number of processes (four of which are illustrated in figure 5) that are alternatives to the blast furnace and coke oven for the pro-

Figure 5.—Schematic Diagram of Direct Reduction Processes



SOURCE K H. Ulrich, “Direct Reduction by Comparison With the Classical Method of Steel Product ion,” Metallurgical Plant *and Technology,* No. 1, 1979

duction of iron. These processes typically operate at lower temperatures than blast furnaces and they convert iron ore to iron without melting. DR is compatible with other new technological developments, and direct reduced iron (DRI) can also be used as a substitute for scrap.

DR is undergoing rapid expansion, particularly in the Third World and in nations with abundant natural gas (see table 1). The size of some foreign gas-based DR plants, including one being built in the Soviet Union, has reached that of large integrated plants—several million tonnes annual capacity.

Natural gas is the simplest reductant for making DRI, but low-grade coals can also be used directly as the reductant, as can the products of coal gasification. A number of foreign firms are aggressively developing new coal-based processes, some of which offer significant energy savings. Several of these processes have already been used for a number of years with varying levels of success, particularly in South Africa and Brazil.

Table 1 .—Projected Growth in Direct Reduction Capacity, 1975-2000 (millions of tonnes)

Year	North America	Japan	EEC	Third World	Mid East
1975. . . .	2.0	1.2	0.7	‘4.0	0.0
1980. . . .	2.9	4.1	3.6	11.2	4.4
1985. . . .	5.3	6.3	6.6	21.2	9.6
1990. . . .	9.5	7.7	9.4	33.9	15.3
1995. . . .	13.3	9.0	11.9	45,2	20.3
2000. . . .	15.3	9.7	13.2	51.2	22.9

SOURCE: G.S. Pierre for OTA

When these coal-based processes are more fully commercialized, the capital costs of DR may become more attractive to domestic producers, particularly for small plants presently using scrap. The extent to which the United States can and should use DR based on low-grade coals (which the United States has in abundance) or coal gasification is still unclear. Much depends on the pace of technical advances in DR and in the competitive process of blast furnace reduction.

The Nation could benefit from greater use of DR in a number of ways:

- DRI can be used in combination with scrap in the increasing number of electric furnaces as well as in basic oxygen furnaces. The partial substitution of DRI for scrap could help to prevent a potential shortage of domestic scrap and consequent steel price rises. It would also allow the production of higher quality steels in electric furnaces.
- DRI can also be used in blast furnaces to substitute for some iron ore, which would improve furnace productivity and reduce coke consumption; it might also be possible to base DR on available coke-oven gas, with a further net economic advantage.

- Increased use of DR would reduce the growing dependence on imported coke and reduce coke-related pollution.
- DR might be used by integrated steelmakers in conjunction with coal gasification plants to create new steel capacity at competitive cost and with fewer steelmaking pollution problems.

DRI, like steel and scrap, is already becoming a world-traded commodity. Its availability will increase greatly in the years ahead, especially from the developing nations of the Third World. If the U.S. steel industry does not build domestic DR facilities, DRI may have to be imported as scrap becomes more expensive and nonintegrated mills expand production. Conversely, the huge domestic reserves of coal could be used to satisfy U.S. steelmaking needs and perhaps to develop and export coal-based DR technology. Instead of exporting scrap, the United States could export DRI.

There are several reasons why there has been relatively little domestic interest in coal-based DR: 1) integrated companies are committed to blast furnaces and coking, which uses company-owned metallurgical coal; 2) the supply of relatively low-cost scrap has thus far been plentiful; 3) future DRI import levels are uncertain; and 4) limited capital is available for R&D.

Other Future Technologies

In addition to wider use of continuous casting and DR, several radical changes in steelmaking could occur during the 1990's:

- direct casting of sheet and strip from molten steel, which would save considerable energy, time, and labor;
- direct, one-step steelmaking (from ore to molten steel), which might reduce all costs;
- plasma arc steelmaking, which may offer a lower capital cost alternative to the blast furnace, particularly suitable for making alloy steels and for use by small plants; and
- formcoking, which offers the possibility of an environmentally cleaner way of making coke from low-grade coals while still producing valuable byproducts.

Capital Needs for Modernization and Expansion

Inadequate capital has frequently been cited as the most critical barrier to the increased adoption of new technology by the domestic steel industry. The historical record —declining capital expenditures, coupled with trends of decreasing capacity, decreasing technological competitiveness, very modest gains in productivity, and increasing age of facilities—offers some support for this assertion. However, the real issue is the extent to which capital spending actually results in new technology and new capacity.

Capital spending has declined during the past two decades in terms of real dollars spent on productive steelmaking facilities per tonne of steel shipped. However, such capital spending has been cyclical, with peaks occurring every 7 to 8 years, following peaks in net income by 1 or more years. Increasing amounts of capital have been used to expand nonsteel activities and to maintain cash dividends to stockholders even in periods when sales and profitability have been depressed,

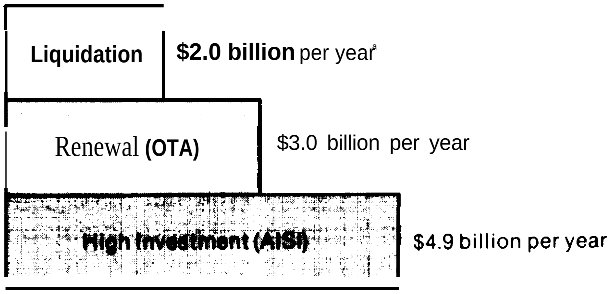
There are three routes to revitalizing the technological base of the industry: 1) modernization and replacement; 2) expansion of existing facilities; and 3) greenfield (new plant) construction. OTA's analysis of the minimum modernization and expansion needs for the coming decade indicates that the most cost-effective approach may be to expand capacity at existing integrated plants and to construct more electric furnace facilities, particularly in nonintegrated companies that produce a limited range of products. The high capital costs of building new integrated plants based on best available technology are not sufficiently offset by reduced production costs. Major technological changes in integrated steelmaking may change this situation in the long term. Should massive rebuilding of the large integrated segment of the domestic industry take place in the near term—an option favored by the integrated steelmakers—the large capital costs would have to be offset by a combination of Federal policy changes promoting greater capital recovery plus sanctioning of real price increases for domestic steel.

Different Estimates of Capital Needs

The steel industry, in the High Investment scenario of the American Iron and Steel Institute (AISI), finds a need for a 150-percent increase in capital spending during the next 10 years over the average for the past decade. OTA, in its Renewal scenario, projects a minimum 50-percent increase in spending to achieve the same increase in productive steelmaking.

Because AISI, the major trade association for the domestic steel industry (its members represent about 90 percent of domestic production), has performed a detailed analysis of the future needs of the industry as seen by the industry itself, OTA included AISI's scenario as one of the three scenarios it analyzed (figure 6). But where AISI's High Investment scenario predicts that a $4.9 billion annual capital expenditure will be required, the OTA Renewal scenario calculates that approximately $3 billion annually could meet the minimum goals for modernization, replacement, and expansion. Both scenarios attempt to increase the profitability of the industry to make it comparable to other domestic manufacturing industries, and both scenarios project additional nonproductive capital requirements of $1.5 billion annually. The chief differences between the two, which account for the lower capital needs of the OTA scenario, are that: 1) where AISI has emphasized expanded capacity in the integrated segment of the industry, OTA has stressed the expansion of capacity in the scrap-based nonintegrated plants, which have lower capital costs; and 2) OTA has assumed lower capital costs in general for modernization and replacement.

Figure 6.—Annual Capital Costs for Productive Steel making Facilities Under Three Modernization Scenarios (1978 dollars)



[a] Represents a continuation of capital Investment trend for the past 5 to 10 years

SOURCE Office of Technology Assessment

The OTA analysis of capital sources and needs indicates a capital shortfall of at least $600 million per year through 1988. The larger projected deficits of the AISI scenario would have to be offset by substantial price increases, even if a much accelerated depreciation schedule became available. If modernization and expansion lead to the modest 2-percent saving in production costs assumed in the Renewal scenario, then return on equity could increase to about 12 percent (from the 1978 level of 7.3 percent) and could provide a basis for more vigorous long-term growth and expansion. However, under the OTA scenario, there would be a substantial need at the end of the decade to invest in new integrated plants because of the relatively low spending for replacement of integrated facilities during the preceding period. AISI believes that deferring investment for a decade in new integrated plants would lead to an unacceptable level of obsolescence in plants producing the preponderant share of the U.S. supply of steel.

OTA also finds that the international capital cost competitiveness of the domestic industry has suffered relative to Japanese and

European steelmaker. Some reasons for this are outside the control of the industry; other factors, such as design and equipment supplier choices, are within its control.

Industry Restructuring

A permanent restructuring is taking place in the domestic steel industry. The size and importance of the nonintegrated carbon steel producers and alloy/specialty steel producers are increasing. These companies tend to be more profitable and are expanding more rapidly than the larger integrated steelmaker, whose capacity is actually decreasing. Nevertheless, integrated steelmaker account for approximately 85 percent of the domestic shipments and, even though this may decrease during the next decade, they will remain the source of most domestic steel.

Both profitability and growth stimulate the adoption of new technology, which further enhances profitability and cost competitiveness by improving productivity and reducing production costs. Nonintegrated and alloy/specialty steelmaker use, and are continuing to adopt, more continuous casting than do integrated facilities. Both have also been quick to adopt new and efficient electric furnace steelmaking,

The nonintegrated companies are moving in the direction of supplementing ferrous scrap with DRI and may spur coal-based DR technology in the United States. Nonintegrated producers are also expanding their range of products to include higher quality and higher priced steel products, formerly made only by the integrated companies. The potential development of small-scale rolling mills to make flat products not currently made in these plants will further expand their markets. During the past decade, this segment's capacity has tripled. If adequate scrap and electricity are available, much of the domestic growth in steel capacity could come from these producers, whose tonnage increase for the next decade could equal the increase for the past decade. Significant foreign investment in these companies has already taken place and assisted growth; this may accelerate in coming years.

Alloy/specialty producers will benefit from ever-increasing use of high-technology steels. Demand for these steels is growing and the emerging steel-producing countries have little capability to produce them; this creates export opportunities for U.S. producers. If the new Multilateral Trade Agreement is vigorously enforced, domestic alloy/specialty steelmaker are sufficiently cost competitive to enter this world market.

The favorable prospects for exporting high-technology steels are based on U.S. comparative advantages over many other countries' industries, including:

- a large supply of relatively inexpensive coal and iron ore;
- a sophisticated industrial base, including substantial science and technology skills and R&D activities; and
- domestic labor costs that are now competitive with those of European industries.

The major problems in developing greater exports in this area are:

- dependence on foreign sources for most important alloying materials,
- lack of experience and infrastructure for exporting, and
- less governmental support for steel exports than is found in other industrialized nations.

The United States was, in fact, a net exporter of alloy and specialty steels in 5 of the last 15 years, although it has been a net importer since 1974. Domestic producers are most competitive for 90 percent of the steels in the alloy and specialty category, and least for tool and stainless steels. They have done well in the remaining alloy and specialty steel export markets, and domestic markets for these steels have been impacted least by imports. In 1978, for example, imports amounted to just over half of domestic shipments for tool steels and almost 17 percent for stainless steels, but only 6.5 percent of the remaining alloy and specialty steels. However, this was when quotas were still in effect for some of these steels. (Imports of carbon steels were nearly 22 percent of domestic shipments in 1978.)

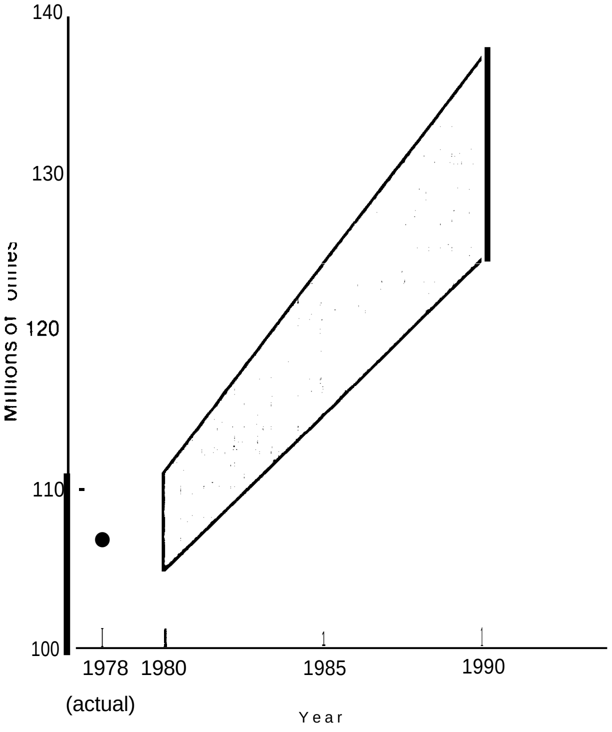
Finally, the United States has an opportunity to export more high-technology steel because worldwide demand is rapidly increasing. Higher quality and performance capabilities are justifying the greater use of these more costly steels in a broad range of applications, including advanced energy production, manufacturing, and higher quality consumer products.

Steel Use and Future Demand

Steel remains the most important engineering material in American society. There is literally no aspect of private or public life that does not in some way depend on steel. Nevertheless, steel is usually taken for granted. It is not generally considered to be technology intensive, changing in nature, or particularly critical for economic or military security. Yet, steel is all these things. It plays a pervasive and vital role in all primary manufacturing and construction, and it is and will remain a strategic material for the Nation.

Domestic consumption of steel continues to increase (see figure i’) but at a slower rate than during the early phases of industrialization. The use of aluminum and plastics has greatly increased in the past several decades, but the per capita consumption of these materials is only about 60 and 140 lb, respectively, compared to steel consumption of approximately 1,000 lb per capita. Steel may be better able to compete in the materials market as a result of future changes in energy and raw material costs, which will have stronger adverse impacts on aluminum and plastics than on steel.

Figure 7.— Range of Projected Domestic Demand’ for Steel, 1980.90



aDemand = total consumption = domestic shipments – exports + imports

SOURCE Off Ice of Technology Assessment composite of projections from Government Industry and academic sources See table 66 of the main report for detailed data

Although it may appear, according to some measures, that the use and role of steel are declining, for many applications there are no cost-competitive performance substitutes for steel. For example, steel is essential in bridges, buildings, railroads, primary manufacturing facilities, and many other physical structures. Many observers believe there will be a surge in domestic steel demand for construction as structures such as bridges, buildings, and manufacturing facilities wear out.

A frequently mentioned area in which substitutes for steel are being used increasingly is the automotive industry. Driven by energy conservation measures to produce lighter vehicles, automobile manufacturers are reducing the amount of steel used in each automobile, and steel consumption for this use is likely to be steady or decline. It is possible, however, that a reduction in the steel content of automobiles could be offset by an increase in the number of cars manufactured in the United States by foreign companies, which may use domestic steel.

A Future Steel Shortage?

It is distinctly possible that the demand for steel will increase enough in the future that domestic steelmaking capacity will be inadequate to reverse the trend of increasing imports. Modernization and expansion programs for the next decade (discussed in chs. 2 and 10) assume that domestic demand for steel will increase by only 1.5 percent per year. Should that projection be too low, the capacity planned would be inadequate. If demand-growth forecasts of 2 percent or more prove accurate, the United States would have to import 20 percent of domestic consumption, or 27 million tonne/yr. This would be about 50 percent more than any previous maximum tonnage of imports. Without any modernization and expansion, and assuming the higher demand level, domestic capacity would likely be so low by the end of the 1980's that more than 44 percent of the steel would be imported, compared to 15 percent over the past several years. The current overcapacity in the world steel market may soon disappear, and such a degree of steel import dependence would raise economic and national security problems for the United States not unlike those now encountered with petroleum.

Problems With the Creation, Use, and Sale of Technology

The domestic steel industry has a well-established record for internal generation of product innovations, but this record does not extend to the internal creation of new production processes. The industry prefers to adopt proven technologies that have a record of successful commercialization and, to the extent that this strategy reduces risk and R&D costs and provides near-term payoffs, it is a useful approach. It does have major drawbacks, however: it leads to dependence on technologies that may not be well suited to domestic needs, it reduces learning opportunities for innovative applications, and, most importantly, it does not enable the industry to stay ahead—or even abreast—in the international market.

That domestic steelmaker lag in adopting new process technologies, such as continuous casting and the basic oxygen furnace, can be explained by: cautious attitudes about new technology, an aging steel industry plant, sluggish industry growth rates, and lack of capital.

New technology increases the potential for reducing raw materials use and production costs, and for improving quality. Independent creation of new technologies and their successful application would enable the domestic industry to gain technological advantage, rather than merely the delayed parity that would result from the adoption of foreign innovations. The industry's competitive position in domestic and international markets would be enhanced if such an advantage were achieved.

Research, development, and demonstration play an important role in the creation of new technologies. Domestic steel industry R&D expenditures, as a percentage of sales, have declined over the years, and they are lower than for most other basic industries in the United States (see table z). Expenditures for basic research are particularly low. There is no trend of declining dividends as a fraction of aftertax profits comparable to the trend of declining R&D spending, even though these uses of funds are related. For example, R&D investments can be viewed as a means to improve future earnings and capital gains to stockholders, and thus an alternative to dividends. The industry's reluctance to invest in R&D may be attributed to a number of factors, including: low profitability, cautious management attitudes towards research, high costs of demonstration projects, and the downward trend in the industry's share of the domestic market. Industry R&D, including environmental technology research, is matched by an even more limited amount of steel R&D in the Federal Government and academic sectors.

Foreign steel R&D is generally more vigorous because more money is devoted to it, because industry places more emphasis on it, and because steelmaking has more prestige in the academic sector. It also receives government support, particularly for high-risk projects whose benefits promise to be widespread. Many foreign steel industries support and carry out steelmaking research through multisectoral institutes.

Japan, West Germany, Austria, and Great Britain develop and transfer significant amounts of innovative steelmaking technologies to other countries, but U.S. technology exports are limited. They are largely handled by equipment firms and are mainly in the area of raw materials handling. Foreign steel industries are increasing their efforts in technology transfer in order to offset their declining exports of steel products. To a much greater degree than domestic steelmaker, foreign companies have design, consulting, and construction departments that aggressively pursue the sale of both hard and soft technology to other nations, particularly the less developed countries.

Table 2.—U.S. R&D Intensity and Trade Performance

Description	R&D intensity (percent)	Trade balance exports-imports, 1976 (millions of dollars)
Above-average R&D intensity		
Communications equipment. . . .	15.20	$ 793.7
Aircrafts and parts	12.41	6,748.3
Office, computing equipment . . .	11.61	1,811.4
Optical, medical instruments . . .	9.44	369.6
Drugs and medicines	6.94	743.5
Plastic materials.	5.62	1,448.0
Engines and turbines	4.76	1,629.2
Agricultural chemicals.	4.63	539.3
Ordinance (except missiles)	3.64	553.0
Professional and scientific instr.	3.17	874.8
Electric industrial apparatus	3.00	782.5
Industrial chemicals.	2.78	2,049.4
Radio and TV receiving equipment	2.57	– 2,443.4
Average	—	1,223.0
Below-average *R&D* intensity		
Farm machinery	2.34	696.2
Electric transmission equipment	2.30	798.1
Motor vehicles.	2.15	-4,588.6
Other electrical equipment	1.95	311.2
Construction, mining	1.90	6,160.4
Other chemicals	1.76	1,238.5
Fabricated metal products.	1.48	1,525.7
Rubber and plastics	1.20	– 478.8
Metalworking machinery	1.17	736.4
Other transport	1.14	72.1
Petroleum and coal products. . . .	1.11	NA
Other nonelectric machines	1.06	3,991.3
Other manufactures	1.02	-5,137.4
Stone, clay, and glass.	0.90	-61.3
Nonferrous metals	0.52	-2,408.9
Ferrous metals	**0.42**	-2,740.4
Textile mill products.	0.28	40.3
Food and kindred products	0.21	-190.0
Average	—	2.0

[a] Measures of R&D intensity and trade balance are on product-line basin the ratio of applied R&D funds by product field to shipments by product class, averaged between 1968-70

SOURCES: Department of Commerce, BIERP Staff Economic Report, U S Bureau of the Census

Raw Materials Problems

Coke and ferrous scrap are among the raw materials essential to steelmaking. Unlike other materials, such as iron ore, which the United States possesses in abundance, the adequacy of future supplies of both coke and scrap is uncertain, but for different reasons.

Coke and Coke Ovens

Most coke is produced by the integrated steel companies in byproduct ovens using high-grade metallurgical coals. The coke is then used as a feedstock in ironmaking. Domestic consumption of coke has been higher than production during 3 of the past 6 years; in 1978, domestic consumption was 51.7 million tonnes, 16 percent more than U.S. production, with the gap filled by imports. The shortfall was caused not by a shortage of metallurgical coal, which the United States has in abundance, but by declining coke oven capacity. (See table 3.)

About one-third of all domestic coke ovens are considered old by industry standards. These older ovens are less efficient, more polluting, and tend to produce poorer quality coke than the newer ones. The domestic industry has a much higher coke oven obsolescence rate than do the industries in other major steel-producing countries. The productive capability of U.S. coke ovens has declined by close to one-fifth since 1973, primarily because the construction of new ovens has been discouraged by high capital costs and by regulatory requirements. The shortage of ovens has contributed to rising coke imports and to declining employment in this phase of steelmaking. It has been estimated that by 1985, the coke oven shortage will increase to about 9.1 million tonnes, or 20 percent of domestic production, because of continuing capacity decline and demand growth.

There are several technology and business choices that, with varying degrees of effectiveness, could help stabilize or reduce current coke shortages. These include: constructing more coke ovens, importing more coke, developing formcoking, using DRI, importing more semifinished or finished steel products, increasing the use of electric furnace steelmaking, and improving the coke rate in blast furnaces. Federal policy changes which would alleviate coke shortages include improved capital recovery and greater incentives for developing environmentally cleaner coke-free ironmaking processes. Relaxation of environmental standards to deal with the shortage, although possible, would imply that increased carcinogenicity of coke oven air pollution is the appropriate way to achieve adequate steelmaking capacity.

Ferrous Scrap

The steel industry is a major consumer of ferrous scrap, and most near-term technological changes in steel production will tend to increase the use of scrap: growing use of electric furnaces and continuous casters, changes in the basic oxygen furnace that in-

Table 3.—Estimated Decline in Actual Productive Capability of Coke Oven Plants in the United States: 1973 v. 1979a (millions of tonnes)

	Capability			Capability change			
				1973-79		1979-85 est.	
	1973	1979	1985 est.	Tonnes	Percent	Tonnes	Percent
Capacity in existence.	**68.0**	57.5	52.7	10.5	15,5	4.8	8.3
Capacity in operation.	61.2	51.8	—	9.4	15,4	—	—
Actual productive capability	57.6	47.6	42.6	10,0	17.3	5.0	10.4

aComparison of estimated average levels for 1973 and levels on July 31, 1979, as determined by Fordham University survey

SOURCE: William T Hogan, *Analysis of the U.S. Metallurgical Coke Industry, 1979.*

crease the proportion of scrap used, and the growing demand for high-performance specialty steels. Scrap prices have doubled since 1969, and there are some concerns in the steel industry about the future availability, price, and quality of scrap, Other factors, such as scrap industry processing capability and the availability and cost of railroad cars to ship scrap, either are not problems for scrap suppliers or are problems that are being remedied. The main concern is physical availability of high-quality scrap.

Scrap supply projections range from adequate at much higher prices, to inadequate at any price. Demand for scrap does not decline significantly when supplies decline and prices increase. This places the steel industry in an increasingly difficult position, because it has few potential substitutes for scrap. The nonintegrated domestic producers will be most severely affected by price and supply problems.

Options to offset scrap supply problems, in addition to maintaining existing inventories, include expanding DRI use and monitoring exports or imposing export controls on scrap. Scrap exports have been relatively stable thus far, but they are expected to increase because of worldwide increases in electric furnace use. Favorable exchange rates have made U.S. scrap attractive to many foreign buyers. Increasing domestic use of scrap has prompted steel industry interest in controlling exports, but the scrap industry is opposed to such a measure.

Statutory resource-conservation targets attempting to increase the use of domestic scrap have not been well directed in the past. They fail to differentiate scrap-use opportunities and problems by industry segment. Furthermore, on a plant basis, these targets are not always feasible for economic or technical reasons. The targets may also act as a disincentive for development of beneficial coal-based DR technology.

Impacts of EPA and OSHA Regulations on Technology Use

The steel industry is one of the largest sources of pollution in the Nation, with the integrated steelmaker accounting for close to one-fifth of all domestic industrial pollution. The industry also has very high rates of occupational injury and illness. The harmful emissions of steel plants are a greater hazard for steelworkers than the general population; consequently, the Federal and State Governments have created a large number of regulations to protect workers as well as the public. There can be no argument against the goals of reducing environmental pollution and occupational risks; however, the impact of these regulations on the creation and use of steelmaking technology merits examination. For technological innovation, regulations can act as either a barrier or an incentive. While industry has tended to emphasize the barrier effect, there are opportunities for the regulations to serve as incentives for technological innovation. Because of the scope of this study, the impact of regulations on the steel industry has been emphasized. But this does not mean that the impact of pollution on workers and the general public is thought unimportant.

Thus far, EPA policies have had a greater impact on the steel industry than those administered by the Occupational Safety and Health Administration (OSHA). However, OSHA policies will grow in importance as more of its regulations become operational. Applicable regulations administered by EPA and OSHA will impose major capital investments and operating changes on the industry by the mid-1980's. The various environmental statutes and the Occupational Safety and Health Act encourage the use of technology-based performance standards, but although these standards allow for industry flexibility they do not provide direct assistance for industrial innovation. Available regulatory incentives, such as delayed compliance, do not appear to have been used effectively by industry in promoting innovation.

Impacts of Regulations on Industry

Regulatory requirements have accelerated industry decisions to phase out and replace aging facilities. Economic and regulatory forces have thus tended to reinforce each other. Regulatory policies have had the most severe impact on integrated facilities, which generally have a higher proportion of aging cokemaking, ironmaking, and steelmaking equipment as well as high production costs. The impact on relatively new nonintegrated electric furnace plants has been less severe. Furthermore, they have been able to comply in a more cost-effective reamer by installing abatement equipment at the time of construction.

Three policies are favorably affecting the adoption of new steel technology:

- the revised offset policy, which allows tradeoffs of pollution from different sources within geographical regions;
- the bubble policy, which extends the offset concept to a particular steel plant; and
- the limited-life facilities policy, which gives a steelmaker time to prepare a solution to a compliance problem or prepare for closing down a plant by a certain time (usually 1982-83).

The revised offset policy creates difficulties for companies wishing ‘to expand, because they will be required to create a pollution reduction or somehow “buy” emission reductions from another source of pollution within a given region. The bubble concept, which is being debated in Congress, could make facility replacement and modernization more feasible and cost effective. However, the tradeoff between more and less hazardous pollutants within a bubble area requires assessment. The limited-life policy forces hard decisions between modernization and shutdown for older plants generally having the poorest profitability; these decisions are now generally in favor of plant closing.

Cost Effectiveness of Control Technologies

There has been considerable disagreement concerning the economic and technical feasibility of regulatory technologies that Federal agencies consider attainable at specified control levels. Judicial decisions have directed EPA to give greater weight to economic considerations when identifying feasible control technologies for nontoxic pollutants. If a pending Supreme Court decision supports the private-sector position, OSHA may be the first Federal agency required to undertake cost-benefit analyses of major proposed regulations. With respect to technological feasibility, EPA continues to have fairly broad authority that allows for diffusion of the latest environmental technologies; OSHA’s technology-transfer authority is much more limited.

Congress has expressed a strong interest in improved regulatory technologies that will be more cost effective and will further reduce public health hazards. It is the steel industry’s position that available control technologies are generally capable of meeting regulatory standards; Federal agencies suggest that considerable R&D is still needed. Regulatory technology R&D by the private sector suffers in part because of the high costs and limited private gains associated with it, Steel industry environmental R&D spending is rather modest—about $75 million per year, a considerable amount of which appears to be engineering work. EPA spends less than $1 million per year on steel-specific R&D but much larger sums on environmental R&D that is applicable to the steel industry, yet even these amounts may still be inadequate for the rapid changes in the industry which the regulations demand.

Industry Expenditures on Controls

Without adjusting downward for regulatory overlap, EPA- and OSHA-related capital investments during the 1970's were about $365 million per year, or about 17 percent of total annual steel industry capital investment. These expenditures have placed greater limits on steel industry modernization than has been the case with other basic industries. Annualized capital and operating costs for environmental requirements presently add about 6 percent to steel production costs and prices.

Industrial development bonds (IDBs) have in the past been used for half of all environmental capital spending by the steel industry. Assuming this pattern continues, the steel industry will need to generate between $235 million and $400 million annually, in addition to IDB financing, to meet EPA and OSHA regulatory requirements through the mid-1980's. These expenditures are relatively modest compared to the massive total capital needs that the industry expects during the next several years.

Employment Practices and New Technology

Technical Workers

A technical manpower shortage is now developing in a few areas in the steel industry, and it could become more serious and more widespread if the industry were to embark upon vigorous modernization, R&D, and innovation programs. The most likely shortages would be of metallurgists, electrical engineers, and computer scientists.

The number of research personnel in steel declined during the early 1970's and has since slowly climbed back to 1970 levels. Only about 18 percent of all steel industry salaried technical personnel are now engaged in engineering R&D, and even smaller numbers in steelmaking R&D. This is partly because considerable research manpower is absorbed in environmental R&D. Research personnel are primarily engaged in market-oriented research leading to evolutionary changes in process and product, rather than in fundamental research that might produce radical changes.

Steel-related research in foreign nations provides more long-term intellectual and professional opportunities for R&D personnel than is the case in the United States. This may be attributed to greater foreign government support for research and also to the greater involvement of foreign steel companies in the sale of machinery and technology. Sabbaticals and industry-university-Government exchanges are not very common in the domestic industry. In addition, there is only a negligible movement of technical personnel from other high-technology industries into steel. These deficiencies limit opportunities for personnel-based technology transfer.

Hourly Workers

The training, skills, and performance of steelworkers have not, on the whole, impeded the development and use of new technologies, The industry has developed and marketed new products successfully, although its record of process improvements is not as strong. But when new equipment is introduced, steelworkers are generally cooperative. Prevailing manpower-use patterns reflect the industry's concern with production capability rather than an emphasis on changing and improving technology.

Job classification schedules for hourly workers appear to have incorporated most of the changing skill requirements associated with technological change. Furthermore, the 2-B "local practices" clause that is in most steel industry labor contracts gives management the right to change unilaterally past practices concerning crew size and other staffing arrangements when required by “changed conditions, ” including technological innovation. However, it appears that the 2-B clause makes it difficult to extend new practices to adjacent production areas not directly involved with the new equipment; such changes are subject to negotiation with the local union affiliates. National union leadership is concerned with technological displacement, but does not resist the introduction of new technology. With the possible exception of a few plants, difficulties with the work force have no limiting effect on industry’s adoption of new steelmaking technologies.

Notice to the Reader

The reader should be apprised that the General Accounting Office (GAO) will complete a complementary study of various aspects of steel industry problems during the summer of 1980. GAO’s study will place specific emphasis on: an evaluation of the effectiveness of past and current Federal programs and policies related to steel, and an in-depth evaluation of steel consumers and their attitudes and concerns regarding problems of the domestic steel industry.

CHAPTER 2

Policy Options

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Policy Options

Summary

It is in the Nation's interest to have a strong domestic steel industry that effectively uses domestic resources such as coal and scrap materials. However, technology alone is not sufficient to reverse the decline in steelmaking capacity, nor can new technology immediately help those parts of the industry that use old, inefficient, or poorly located plants.

Nevertheless, Federal policies that at least indirectly facilitate technological innovation and modernization are necessary to avoid temporary and superficial remedies. Even those segments of the industry that are profitable, competitive in the domestic market, and well managed need more and continued technological modernization to maintain and improve their competitiveness in the domestic and world markets.

The creation and adoption of new steel technology are hampered by a number of factors, the most important of which are inadequate capital formation, inadequate R&D, high regulatory compliance costs, and the threat of unfairly traded imports. In a world in which most foreign steel industries are either owned or heavily supported by their governments, the U.S. steel industry is at a disadvantage because it must generate from profits the capital it needs for modernization and expansion. Past Federal policies have affected steel costs and prices, and hence steel industry profitability, Most of the industry has been slow to adopt cost-reducing new technology as a means of coping with Federal policies. The superior technological and economic performance of some steelmaker demonstrates the potential for improvement in other companies. Both Federal and industry policies have contributed to industry's underinvestment in capital plant, R&D, and innovation.

The industry has also been adversely affected by imports of steel and has had its export potential affected by foreign steel industries. For the most part, however, steel imports have led to complaints about Federal policies rather than to increased emphasis on R&D, innovation, and improved competitiveness. Some domestic market imperfections have resulted from foreign government policies favoring their steel industries, and it is apparent that substantial trade and tax issues exist with regard to the steel industry. Federal policies on these issues need examination, but policies are also needed to deal directly with technological issues.

OTA uses three scenarios for the next decade to examine costs and benefits of policy options. The Liquidation scenario implies the slow shrinkage of domestic capacity and employment. The Renewal scenario considers policy options linked to moderate increases in capital spending for modernization and expansion to revitalize the industry. The High Investment scenario examines policies compatible with greatly increased capital spending to quickly modernize integrated steelmaking facilities, OTA's analysis considers the following possible options for Federal policy toward the steel industry:

- provide greater capital formation through faster depreciation, investment tax credits, loan guarantees, or subsidized interest loans;
- increase support of basic research and large-scale demonstration projects, and provide incentives for industrial R&D;
- coordinate energy development programs with the needs of industry—for example, development of synfuel or coal gasification technology might be coordinated with requirements of direct reduction processes;

- reach a better understanding of the benefits of Federal environmental and occupational health and safety regulations on the one hand and, on the other hand, the costs to communities of a shrinking industry, the industry's capital and modernization needs, and the regulatory barriers to technological innovation.
- explore the controversial issue of limiting the export of energy-embodying ferrous scrap;
- examine the feasibility and adverse impacts of targets for ferrous scrap use, and compare targets with alternative mechanisms such as incentive investment tax credits for adoption of new technology that may use more energy;
- reexamine trade practices, particularly to assess the impact of unfairly traded steel imports on the industry's ability to make long-term commitments to new technology and investment in additional capacity;
- promote the export of high-technology steels; and
- emphasize long-term assistance to steel plants capable of technological rejuvenation, and at the same time provide short-term assistance to workers and communities impacted by closing old facilities.

New Federal policies, however, would be ineffective without appropriate shifts in the attitudes and policies of industry. For example, industry would have to reexamine its policies concerning using capital for diversification out of steelmaking, emphasizing short-term benefits from relatively minor improvements in technology, wanting to quantify the costs but not the benefits of social regulations, and resisting industry restructuring, including the expansion of small, scrap-based nonintegrated steelmaker.

Perhaps the greatest need is for a careful examination of the costs and benefits of a Federal policy for the steel sector that would first establish a set of goals consistent with national interests and industry needs and then initiate a set of coordinated, reinforcing actions that would effectively and efficiently help achieve those goals. The most important lesson to be learned from the past experience of the steel industry is that such sector policies may be needed for major domestic industries if international competitiveness is desired. Foreign governments, particularly Japan's, appear to use sector policies to achieve competitive industries. Without such a sector policy, improvement efforts may be at cross-purposes or fail to address critical issues. Isolated policies that deal effectively with capital formation or imports, but fail to encourage additional efforts in R&D and innovation, would not ensure a profitable and competitive industry in the long run.

The risks of adopting a steel sector policy include an overemphasis on the welfare of the steel industry to the exclusion of other domestic industries, insufficient attention to social goals and impacts, such as pollution abatement and worker safety, and possibly insufficient attention to smaller steelmaker.

Understanding the greater support that foreign governments give their private and public steel industries provides important insights for the examination of U.S. policies. Foreign governments have coordinated sector policies that link support for R&D and innovation with capital formation, protection of home markets, and the export of steel technology. The United States provides a much lower level of direct and indirect support than Japan, Western Europe, and Third World nations. The U.S. steel industry may never achieve international competitiveness unless Federal policies become more comparable to the policies of other countries towards their steel industries.

Reconciling Congressional and Industry Concerns

The past several decades have witnessed a reversal in the condition of the American steel industry. Before World War II, and for the decade following, the domestic industry was the world leader in steelmaking technology and production. It supplied domestic needs and was a net exporter of steel, Its profitability, though rarely as high as most domestic manufacturing industries, was markedly better than in recent years, During the last 10 years, however, a turnabout has occurred. The domestic industry shifted from technology leader to follower and from net exporter to dependent importer. Its profitability, moderate in the 1950's, became unacceptable by domestic standards in the 1970's. Domestic steelmaking capacity declined and a substantial percentage of this capacity (about 20 percent) became obsolete, All this happened during a period of phenomenal world growth in steelmaking capacity and demand, New technology, as a means to reduce costs and energy consumption, received greater attention abroad than in the United States.

Japan has emerged as the new world leader in steel technology and production, and it exports much of both. Although European steel industries have generally followed the U.S. pattern of decline, a number of developing nations have acquired considerable modern steelmaking capacity, much of it purchased from Japan. Japan, Europe, and Third World countries have used their steel exports to sustain domestic employment and obtain foreign currency; their industries have not been particularly profitable, however, even by U.S. steel industry standards.

The American steel industry, faced with increasing foreign capacity as well as unprecedented technological and cost competition, must also face a variety of Federal policies, carried out by a variety of agencies, that address a variety of national concerns. These policies, with their disparate but relatively narrow individual objectives, have added to the industry's problems. The Federal Government has contributed to the loss of international competitiveness in the following ways:

1. Cost-price policies:
   - formal and informal limits on domestic steel prices;
   - long capital-recovery periods that do not recognize the rising costs of building new steelmaking capacity; and
   - environmental and worker health and safety regulations that increase the costs of steelmaking.
2. Trade and monetary policies:
   - international trade policies that have allowed steel imports to capture a large share of the domestic market; and
   - little monitoring or control of the export of domestic ferrous scrap, a valuable source of both iron and energy.
3. Very low levels of support for research in steelmaking.
4. Contributions to international sources that make loans to foreign steel industries, which then export steel to the United States.
5. A loan policy aimed at maintaining employment in troubled companies, rather than modernizing or expanding steel capacity.
6. Monetary policies that, until recently, had the effect of keeping the dollar overvalued relative to major foreign currencies and thereby made domestic steel less competitive in world markets.

On the other hand, events and policies in the steel industry itself have also contributed to the industry's problems:

1. The cost-price squeeze and profitability:
    - a tendency to emphasize the size of steelmaking facilities rather than their profitability;
    - wage increases that have exceeded increases in productivity and have therefore resulted in higher real labor costs;
    - the tendency of some major companies to pay high dividends even during periods of low earnings;
    - insufficient attempts to reduce capital costs through the use of lower cost foreign steelmaking equipment, less costly designs, and more inhouse engineering and design;
    - costly attempts to delay compliance with environment regulations;
    - slowness in maximizing the use of domestic scrap; and
    - minimal attempts to export the technology-intensive steels in which the industry is technologically and cost competitive.
2. Technology:
    - minimal spending on R&D;
    - an emphasis on product rather than process R&D, and on short-term payoffs rather than long-range benefits from higher risk, major innovations;
    - few attempts to employ technical and managerial personnel from other domestic industries that have been successful in technological innovation and exporting;
    - insufficient long-range strategic planning for technology to minimize future production costs; and
    - insufficient matching of steelmaking processes with product characteristics to obtain optimum product mixes.

All these public- and private-sector actions and policies together, have shaped the industry's current problems and congressional concerns about them. The present time is critical in the history of the domestic steel industry—modern, competitive steelmaking capacity takes years to build, so what happens now will determine the shape of the industry for decades to come.

Congress has diverse and sometimes conflicting concerns about steel. Table 4 contains a summary of congressional concerns without reference to particular geographical, economic, social, or trade problems. The table also lists industry needs drawn from a major policy statement by the American Iron and Steel Institute (AISI), whose member companies produce about 90 percent of domestic steel. (Not all of the nonintegrated scrap-based steelmaker, who account for about 13 percent of domestic production, belong to AISI.)

Rising imports, for the most part, are an issue on which the Government and industry are in accord. Dependence on steel imports would threaten national security because of the critical role of steel in this society. The steady loss of employment caused by imported steel is also of major concern to the Nation, particularly for regions with concentrations-of older steelmaking facilities. Steel imports also contribute significantly to the trade-balance deficit. Imports may offer a low-price source of steel during brief periods of world oversupply, but their long-term net effect on the economy will probably be negative. Industry wants to limit imports in order to improve its domestic competitiveness and increase its profitability so that it can expand and modernize. As long as there is great uncertainty about future imports, however, industry will be reluctant to make major investments in steelmaking technology. For corollary reasons, increasing steel exports is an issue on which Congress and industry should also have common interests.

The increasing age and obsolescence of domestic facilities should be a matter of concern both to industry and Government insofar as it affects competitiveness. But compared to the risks of building new, modern plant capacity which imports might leave idle, operating old facilities can appear attractive for the short term. In some cases, the continued operation of older facilities, even at low levels of

Table 4.—Congressional Interests and Steel Industry Needs

Congressional interests		Industry needs			
Trend	Effects	Maintain/ improve cost competitiveness	Increase capacity	Modernize technology	Increase profitability
Rising imports	National security loss Increased competition Lower prices Potential inflation Trade deficit Unemployment	Accord	Accord	Accord	Accord
Declining exports	Trade deficit Unemployment	Accord	Accord	Accord	Accord
Aging facilities	Productivity loss	Accord	Conflict	Accord	Accord
Decreasing capacity	National security loss Unemployment	Conflict	Accord	Conflict	Conflict
Diversification out of steel making	Competitiveness loss Diversion of capital	Conflict	Conflict	Conflict	Conflict
Declining R&D and innovation	Competitiveness loss	Accord	Conflict	Accord	Conflict
Rising steel prices	Inflation	Accord	Conflict	Conflict	Conflict
Improved environmental effects of steelmaking (increased regulatory compliance)	Public well-being Increased costs of steel making Force new technology	Conflict	Conflict	Accord	Conflict

SOURCE Off Ice of Technology Assessment

profitability, provides a cash flow to support diversification out of steelmaking. To the extent that such diversification reduces capital investment, R&D investments, and capacity, it adds to congressional concerns.

In many cases, companies do not continue to operate old facilities, nor do they replace them with an equal or greater amount of new capacity. Some companies choose to become competitive and profitable by closing marginal or unprofitable facilities and modernizing only their best plants. These companies are among the largest steelmaker, and although the smaller companies are expanding, the net effect, of concern to Congress, has been a loss of domestic capacity and jobs,

There are areas of both conflict and accord with regard to declining R&D and innovation. Willingness to develop and use innovations in steelmaking can improve competitiveness, consistent with congressional concerns. However, the industry's desire to increase profitability by investing in modernization and expansion may actually reduce investments in R&D and innovation.

Nor is the industry sympathetic with congressional desires to limit inflation by holding down steel prices. To the extent that controlling prices improves demand for domestic steel and thereby contributes to high rates of plant utilization, this policy supports cost competitiveness. But to the extent that it diminishes profitability and thereby discourages capacity expansion and modernization, it will undermine long-run competitiveness.

Similarly, the congressional interest in enforcing Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) regulations conflicts with industry's concerns about cost competitiveness, profitability, and capital formation. Technology, however, may be a better way to reduce costs than relaxing these regulations.

Learning From the Steel Industry

The steel industry may be only the first of several domestic industries to face a decline in technological preeminence and economic prosperity. As the less industrialized nations begin to produce at lower costs and to consume more, they become more attractive than highly industrialized countries as a location for industry. The decline of established industries in advanced nations may also result from a partial loss of domestic markets through product substitution; moreover, these industries may not produce sufficient technological innovations to reduce production costs markedly or improve products dramatically. These explanations may not appear as valid in today's world economic order as they once did: the policies of various governments have introduced so many imperfections to the free-market and free-trade system that the role of traditional economic factors in international competition has been fundamentally changed, When each of the above factors is examined for the domestic steel industry, it is found that none of them can adequately explain its decline,

In the first place, no major foreign steel industry has had a more advantageous combination of labor costs, energy costs, raw materials costs, and industrial and technological infrastructure than the United States. At best, foreign steel industries have had slight advantages in one or two of these factors. Generally, such advantages have been short-lived and insufficient in themselves to account for those industries' penetration of export markets, particularly the U.S. market. What has occurred is that foreign governments have adopted policies that provide many direct and indirect benefits to their steel industries: many foreign steel industries have been built with public funds to serve social and political goals, Even though foreign demand for steel has increased substantially, foreign-produced steel is often exported rather than used to satisfy domestic needs.

Secondly, although steel has faced increasingly stiff competition from other materials—notably aluminum, concrete, and plastics—it still possesses a unique combination of properties, forms, and costs that ensures it substantial and growing markets. There has been no major technological displacement of steel in the marketplace.

Thirdly, contrary to accepted wisdom, there have in fact been major technological changes in domestic steelmaking and products during the past several decades, and all signs are that this will continue. Unfortunately, some domestic firms have justified their lack of progress with the "mature industry" concept, and have become defensive and antagonistic toward Federal Government policies rather than changing their corporate policies to meet changing social, economic, and political conditions. Others, in the meantime, have moved ahead with optimism and even boldness—taking risks, investing in the newest technology, and capturing the profits that are there to be made.

The lesson to be learned from the steel industry's experience is that private industries can find themselves losing price competitiveness because Federal Government policies are not comparable to those of other nations. Foreign government policies have distorted the workings of the marketplace, sometimes in ways unique to a particular industrial sector. The steel experience has shown that Federal policies can actually improve the profitability of foreign industries while having adverse impacts on domestic producers.

A Governmental Steel Industry Sector Policy

Steel market imperfections have led to underinvestment in three areas—equipment, R&D, and innovation—and policy changes that dealt with only one of these areas of underinvestment would be inadequate in the long run, The choice of policy options is further complicated by the fact that the domestic steel industry is undergoing a restructuring. The impact of policy options on this restructuring process requires careful examination.

It is often contended that the steel industry should not be singled out for Federal help and that legislation affecting all domestic industry is sufficient. However, steel has a unique combination of problems and assets, and it has already been uniquely and adversely affected by many Federal policies. Singling out the steel industry for a sector policy presents policymakers with difficult choices and opportunities for several reasons:

- The industry is essential to both the domestic economy and national security, but it is contracting and diversifying out of steelmaking. which can only result in increased imports.
- The industry's cost-price squeeze and capital shortfall are the result of prices that are too low to provide adequate return on investment, or costs that have not been kept low enough, or both; of Federal policies that have led to high regulatory costs; and of unfairly traded imports, which have captured a large share of the domestic market and contributed to artificially low prices.
- There is a nucleus of companies whose plants are highly competitive in costs and technology and who could contribute positively to the trade balance by exporting more steel.
- There are many short- and long-term technological opportunities for strengthening the industry and recapturing the premier status it once possessed.
- The industry has available to it the domestic material resources of iron ore, coal, and ferrous scrap, and a highly competent labor force, a large domestic R&D infrastructure, and a reservoir of managerial and entrepreneurial talent.

The most critical policy option may be that of a governmental steel industry sector policy, that is, for a coherent set of specific policies designed to achieve prescribed goals. The present state of the industry and the need for critical examination of policy options are, in large measure, a consequence of a long series of uncoordinated policies. These policies have not been properly related to each other or to a well-considered set of goals for the industry, goals that satisfy the needs of both the Nation and the industry. The lack of a sector policy and the designation of a lead agency to implement such a policy has led to policies that often conflict with one another, create an adversarial relationship between Government and industry, and fail to address critical issues. Examples of conflicting policies include: 1) the attempt to have domestic industry use more scrap, which requires capital investment, without providing realistic capital recovery; 2) the use of the trigger-price mechanism, which leads to price increases, while attempting to hold down prices; and 3) the promotion of energy conservation, while not allowing continuous casting to qualify for the energy investment tax credit.

A recent attempt by the Government to formulate a sector policy for the domestic steel industry was the report by Anthony M. Solomen, Undersecretary of the Treasury, entitled “A Comprehensive Program for the Steel Industry, ” which was issued in December 1977. A number of this report’s recommendations materialized, notably the trigger-price mechanism for steel imports, the loan guarantee program of the Economic Development Administration (EDA) of the Department of Commerce, and a slight reduction in the depreciation schedule for new machinery and equipment (from 18 years to 15 years). However, the Solomon report paid little attention to issues related to the development and adoption of new technology, and it formulated no clear strategy for the future development of the domestic steel industry. Although it recognized the problem of providing more capital for modernization, it made no detailed analysis of what those modernization needs were or of what the costs would be. Events of the past 2 years have shown that the policy changes stemming from the Solomon report have not succeeded, even though they were a promising attempt at a sector policy.

The report was an attempt to deal quickly with a crisis situation; as such, it contained little independent analysis of the situation and it made no recommendation for a centralized coordination of the diverse Government policies affecting the industry, The agencies playing dominant roles in steel policy as a result of the Solomon report were the Departments of Commerce and the Treasury, neither of which concentrated on problems relating to R&D, innovation, or restructuring. The establishment of the Tripartite Committee of industry, labor, and Government, while satisfying a need for better communication, has not facilitated decisive policymaking in Government, nor has it provided a mechanism for detailed and independent analyses of critical issues and options, focused on long-range problems and opportunities.

At present, a large number of people and agencies in the Government deal with steel, but they do not reinforce each other’s work nor do they provide an accessible source of expertise and guidance for the industry or facilitate its efficient interaction with the Government. The waste of resources by both Government and industry in dealing with such divided and compartmentalized bureaucracies is enormous. The preeminence of the Japanese steel industry is in large measure due to the creation and execution of an effective steel sector policy. The Federal Government may seek reasons for the loss of international competitiveness in the steel industry, but its own lack of a sector policy also deserves examination.

The chief difficulty in establishing a steel sector policy is obtaining qualified personnel who are acceptable to all parties involved, and who could perform an ongoing analysis of the industry. There is also the jurisdictional problem of obtaining sufficient cooperation between existing agencies and whatever office or agency is assigned the responsibility for designing and implementing such a policy, The historically prevalent inattention to technology by both the Federal Government and industry would have to be addressed. Finally, there would be a risk that the interests of large steelmaker would dominate those of smaller companies, that the benefits of social regulations would be obscured by their costs, and that the interests of the steel industry would overshadow the interests of other industries.

The OTA Study

The overriding theme of OTA’s study of the steel industry has been how technology enters into both its problems and their solutions. OTA interprets technology broadly technology includes the specifics of technical knowledge, the means for implementing that knowledge, and the factors that promote or discourage its creation and adoption. Consequently, technological issues cannot be isolated, This OTA study deals with related issues, such as trade, capital allocation, and profitability, to the extent that they affect technology, Detailed aspects of marketing and pricing have not been pursued, nor have the details of the literally thousands of Federal policies, regulations, laws, and agreements that affect the steel industry. The purpose of the following analysis of policy options is thus to deal with major trends, goals, and alternatives, rather than to give a detailed, quantitative analysis of current and future policies. The OTA analysis is more conceptual and strategic than it is tactical. It presents a framework, based on analysis, assessment, and forecasts of technology, in which Congress can examine its opportunities and its policy choices with regard to the U.S. steel industry.

A critical methodological feature of the OTA study is its treatment of domestic steel industry as three segments, based on a combination of process and product differences, rather than as a single entity. These segments are:

- Integrated steel producers, who make commodity carbon steels with conventional ironmaking and steelmaking technology: iron ore is converted to iron in blast furnaces using coke; the iron is then converted into steel in either a basic oxygen, open hearth, or electric furnace. To a limited extent, ferrous scrap is used with virgin iron in the first two types of furnace; the electric furnace uses ferrous scrap exclusively. These companies also produce a limited amount of higher quality, higher priced alloy/specialty steels.
- Nonintegrated steel producers, who primarily make simple carbon steels with scrap-based electric furnaces. Their product range is more limited than the integrated steelmaker; their plant capacities are generally about 10 percent of the size of integrated operations.
- Alloy/specialty steel producers, who primarily use scrap-based electric furnaces to produce relatively small quantities of the highest priced, most technology-intensive steels. Neither they nor nonintegrated producers engage in primary ironmaking.

Three Scenarios for the Future

OTA has developed three scenarios that postulate future possibilities for the domestic steel industry. Summary information on these scenarios is provided in table 5. The time frame for each is the next 10 years—there are too many uncertainties about general conditions to go beyond that period, except in the most qualitative terms. Nevertheless, events in this time period will have implications for the years beyond, and these are also examined.

Liquidation Scenario

In this scenario, no substantial changes in Government policy, improvements in industry profit; profitability, or changes in corporate objectives occur during the next decade. The trends of the past 5- to 10-year period continue. Faced with low profit levels, many of the larger steel companies diversify out of steel making, and capital investment in productive steelmaking facilities declines. * Profit levels themselves signify a decreasing real-dollar investment level.

Industry restructuring continues. The integrated steel producers' share of domestic production continues to decline, and that of the more profitable nonintegrated and alloy/specialty producers expands, depending on how effectively the new Multilateral Trade Agreement is enforced.

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*The following examples illustrate the trend to diversification. According to Armco's 1979 Annual Report and public statements of company officials, the percentage of the firm's net alssets related to steel was 73 percent in 1976 and 62 perrent in 1979, and will be 49 percent by 1983. Armco has been the leading large integrated steelmaker using diversification to improve corporate profits. The Nation's largest steelmaker, U.S. Steel Corp., also has been experiencing large losses from its steelmaking operations; according to its 1979 Annual Report, 37 percent of its invest mens during the past 5 years have been for expansion and growth of nonsteel businesses. In the industry's High Investment scenario, 11 percent of total capital spending is allocated to nonsteel investment.

Table 5.—Characteristics of Three Scenarios for the Next 10 Years of the Steel Industry

	Scenario		
Characteristics	Liquidation	Renewal	High Investment
Degree of capital investment	Low[a]	Moderate	High
Degree of Government assistance	Low	Moderate	High
Need for policy change	None	Moderate	High
Investment in R&D	Very low	High	Uncertain
Capacity change	Decrease	Moderate increase	Moderate increase
Degree of new technology			
Short range (1980-90)	Low	Moderate	Moderate
Long range (post-1 990)	Low	High	Moderate
Furtherance of industry restructuring	High	High	Low

[a] High restructuring means increasing market shares for non Integrated and alloy/specialty steelmaker

SOURCE Off Ice of Technology Assessment

No new Government policies provide direct or indirect assistance to the industry: no loan guarantee programs, no revisions in capital-recovery periods, no substantial change in import protection, no increase in Federal support of R&D or demonstration projects, and no great freedom to increase prices to levels that would raise return on investment in steel to the all-industry average or provide sufficient capital to allow extensive modernization and capacity expansion.

Only relatively small technological improvements are made, and these are concentrated in the best of existing facilities. Thus, though capacity would probably decline, remaining capacity steadily improves in technological competitiveness. However, the long-term prospects for creating and adopting major new technology would not be good,

If domestic capacity does not expand significantly and domestic demand grows at even moderate rates, it is possible that, by the end of the 1980's, imports could more than double. Domestic demand could range from 122 million to 132 million tonnes: domestic shipments might be only 82 million to 91 million tonnes, Steel employment would decline by about 20 percent, or some 90,000 workers, from the 1978 level. At 1978 prices ($440/tonne), the steel trade deficit would rise to between $14 billion and $22 billion annually, compared with under $6 billion in 1978. * (By comparison, the total balance-of-payments deficit in 1978 was $13,5 billion.) Moreover, forecasts of world demand and capacity suggest that by the mid- to late 1980's there will likely be little overcapacity. Hence, steel imports, if obtainable, could be priced much higher than domestic steel; past experience in 1973-74 suggests that, in such circumstances, prices of imports could be 15 to 35 percent higher than domestic prices.

Although the money not invested in steel would go to other domestic uses, which would partially offset steel-related losses in employment, capital investment, and taxes. the net economic effect of this scenario is unlikely to be positive. The trade deficit would weaken the dollar, aggravate inflation, and drain domestic capital; the real increase in steel import prices would add further inflationary pressures. Since steel employment in older facilities is geographically concentrated, employment substitution would be difficult. Capital would be diverted to manufacturing sectors with lower labor and capital intensity than steel. Moreover. because capital markets set rates on the expectation of future events, anticipation of higher trade deficits, prices, and unemployment. and of steel shortages affecting other domestic industries, could raise capital market rates and increase current capital costs.

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*All sums in this chapter are expressed in 1978 dollars unless otherwise noted.

Renewal Scenario*

In this scenario, the level of capital investment for modernization and capacity expansion is sufficient to accommodate a relatively modest (1.5 percent per year) increase in domestic steel demand while keeping imports to 15 percent of domestic consumption (approximately the same tonnage as 1978). Capital investment in productive steelmaking facilities is 50 percent higher than the prior decade's annual average (approximately $3 billion per year, versus $2 billion). The capital shortfall for minimum renewal amounts to at least $600 million per year, which could be obtained through a number of Federal actions such as reducing capital recovery time from the present 15 years to 5 years. A slightly higher 2-percent-per-year increase in domestic demand, which is possible, could raise the capital deficit to $1 billion per year. A reduction in depreciation time could also generate this much additional capital, and other means of Federal assistance, discussed below, might be used as well.

Under this scenario, the next 10 years see the adoption of continuous casting increase from the present 15 percent to about 50 percent, primarily through the modernization of old integrated mills and the construction of additional nonintegrated plants. Production costs are not reduced sufficiently, relative to high capital costs, to justify constructing new integrated plants, The market share for the nonintegrated companies rises from their 1978 level of 13 percent to as much as 25 percent (an addition of almost 10 million tonnes of shipments) as they broaden their product mix, adopt new production equipment, and begin using direct reduced iron (DRI) to supplement ferrous scrap (see table 6). This expansion of the nonintegrated segment is contingent, however, on adequate supplies of ferrous scrap and electricity in specific geographical areas.

Domestic steelmaker maintain their market share under the Renewal scenario, and they improve their technological and cost competitiveness. Profitability also rises: given a modest 2-percent reduction in production costs as a result of modernization and expansion, return on equity should rise from its 1978 level of 7.3 percent to the average level for all domestic manufacturing industries, about 12 percent. Although no major new technology is adopted during the lo-year period, the domestic steel industry becomes profitable enough to participate in the development of new technology for the 1990's; by that time period, new integrated processes should reduce production and capital costs enough to justify building large new integrated plants at a time when the limits for nonintegrated steel mills are being reached. Under this scenario, the 1980's are the decade of growth for the smaller nonintegrated steelmaker and the 1990's--with increased capital investment—the decade for growth of larger, integrated producers.

High Investment Scenario

AISI recently created a scenario for the next 10 years that is based on the same assumptions about domestic demand and shipments as the Renewal scenario,[1] although its

Table 6.— How Scenarios Affect Three Industry Segments

	Industry segment		
Scenario	Integrated	Non integrated	Alloy/specialty
Liquidation	Very harmful	Slightly harmful	Uncertain
Renewal.	Beneficial	Useful	Useful
High Investment, ...	Very beneficial	Useful	Useful

SOURCE Off Ice of Technology Assessment

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*See ch. 10 for an estimate of future capital needs based on this scenario.

[1] American Iron and Steel Institute, *Steel at the Crossroads: The American Steel Industry in the 1980's*, 1980. OTA purposely used the same basic production parameters in designing its Renewal scenario to permit close comparison of the two: both scenarios are described in detail in ch. 10.

modernization and expansion paths differ considerably. The AISI scenario forecasts a need for $4.9 billion per year for modernization and expansion, a nearly 150-percent increase over the previous decade's average annual spending. The main reasons why AISI found greater capital requirements than OTA are: 1) AISI assumed higher unit capital costs in calculating the total needed for modernizing and increasing the capacity of integrated plants (nearly as costly as building new plants), 2) it assumed fewer nonintegrated plants would be built and at higher cost, and 3) it allocated greater sums to reducing the average age of facilities.

The capital shortfall in the High Investment scenario is approximately $2,3 billion per year, assuming no increase in industry debt or equity and no change in existing capital-recovery rules. The industry would require considerable financial and policy assistance from the Government to meet its capital needs. AISI favors faster capital-recovery periods and marketplace steel pricing; the combination of price increases and improved capital recovery should give a return on equity comparable to other domestic industries.*

The long-term consequences of the High Investment scenario, however—with its greater capital spending level and its emphasis on replacement and expansion of integrated facilities during the 1980's—make the adoption of major new integrated steelmaking technology in the 1990's less likely than under the Renewal scenario. The additional $2 billion per year investment would create enough new integrated capacity (using present technology) to satisfy future demand without constructing new facilities in the 1990's. The Renewal scenario, on the other hand, by delaying new integrated construction, ensures that these facilities will incorporate the newest technologies when they are built. This conclusion is based on a relatively constant, low rate of growth in steel demand for the next several decades; should demand growth be higher, opportunities for new integrated plants in the 1990's would exist under both scenarios.

The High Investment scenario leads to less restructuring of the industry than the Renewal scenario. There is no indication that the market share for nonintegrated companies (as opposed to the nonintegrated plants of integrated companies) would increase significantly, if at all (see table 6). Should nonintegrated companies fail to expand during the 1980's, they might do so in the 1990's, further discouraging the construction of high-cost improved-technology integrated facilities.

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*The price increase would be at least 10 percent of the 1978 average price per tonne of steel. Such an increase would greatly increase the profits of nonintegrated producers, or allow them to capture a greater market share with more competitive prices than integrated producers. More importantly, greater trade protectionist measures would be necessary to prevent lower priced foreign steel from entering the domestic market.

Implications of the Scenarios for Congressional and Industry Concerns

The impacts of the three scenarios on the congressional concerns discussed earlier are summarized in table 7. The Liquidation scenario fails to deal satisfactorily with most congressional concerns; all of the adverse trends that have led to those concerns continue. At best, steel exports might improve slightly because of the already enacted Multilateral Trade Agreement, which would open up foreign markets for the alloy/specialty steels in which U.S. producers have cost and technological competitiveness. Rising and inflationary steel prices would be stabilized, consistent with present policy. The impact on regulatory compliance is uncertain; there is continuing debate on the benefits of demanding increased compliance, and a congressional role that acknowledges the costs of compliance might slow the loss of capacity in the integrated segment.

Table 7.— How Congressional Concerns Are Affected by Three Scenarios

Congressional concerns	Scenario		
	Liquidation	Renewal	High Investment
Rising imports	Worsens	Stabilized	Stabilized
Declining exports	Improves slightly	Improves	Improves
Aging facilities	Worsens	Improves	Greatly improved
Decreasing capacity; decreasing employment.	Worsens	Improves	Improves
Diversification out of steel making	Increases	May decrease slightly	May increase slightly
Declining R&D and innovation	Worsens	Improves	May improve
Rising steel prices—inflation.	Uncertain	Constant	Increases
Increasing compliance with EPA/OSHA regulations	Uncertain	Improves	Improves

SOURCE Off Ice of Technology Assessment

The Renewal scenario generally deals with congressional concerns in a satisfactory manner. By improving profitability and encouraging modernization, expansion, and R&D without the need for real-dollar price increases, it strengthens the industry sufficiently in the near term to reverse most of the threatening trends of the past decade.

The High Investment scenario, with two exceptions, also deals with congressional concerns quite satisfactorily. Those two exceptions are continuing diversification out of steelmaking and rising steel prices. Under the High Investment scenario, more capital is planned for diversification than in previous years. Moreover, the lack of emphasis on technology and R&D suggests either a weak long-range commitment to steelmaking, or shortsightedness. Financing the rather large annual capital deficits that result from this scenario's high spending will require significant price increases, even after the most favorable anticipated reduction in capital-recovery schedules.

The impacts of the three scenarios on industry needs are summarized in table 8. The Liquidation scenario meets only one of the stated industry needs; that is, profitability would increase for the portion of the industry that survives the continued contraction, because capital spending would have been focused on the best plants. Long-range profit ability is less certain. With rising imports and declining technology and R&D, the integrated sector can hardly expect to retain its competitiveness or profitability; the nonintegrated and alloy/specialty companies might remain reasonably profitable. The argument that more imports at low prices would benefit consumers and help fight inflation may be flawed; a variety of factors suggest that major foreign steel production responds more readily to world market prices than to costs.

The Renewal scenario would satisfy all industry needs, and for the 10-year scenario period the High Investment scenario would satisfy them even better. But because of the combination of higher prices, reduced long-

Table 8.— How Industry Needs Are Satisfied by Three Scenarios

Industry needs	Scenario		
	Liquidation	Renewal	High Investment
Maintain/improve cost competitiveness.	Worsens	Improves	Improves greatly
Increase capacity	Worsens	Improves	Improves
Modernize existing plants	Worsens	Improves	Improves greatly
Increase profitability.	improves	Improves	Improves greatly

SOURCE Off Ice of Technology Assessment

term R&D commitments, and minimal restructuring of the industry, most of the benefits of the High Investment scenario accrue to the integrated companies. Foreign creation and adoption of major new steelmaking processes might well lead, in the long term, to a further loss of competitiveness and the need for additional Government assistance at a later date.

Major policy options for the Renewal and High Investment scenarios are summarized in table 9. Options in each of the policy areas except pricing (capital formation, R&D, regulations, raw materials, and trade) are discussed and analyzed in detail in the following section. The policy aspects of the two scenarios differ considerably in the amount of freedom they accord to the industry. The industry faces a tradeoff between corporate freedom and supportive Government intervention. From a national point of view, the social returns on Government investments in the domestic steel industry must be traded off against industry's freedom to choose its own course of action, including asking for interventions it thinks beneficial. The Renewal scenario, together with its policy options, is an attempt to channel Government assistance into those industry segments and technologies that offer both near- and long-term benefits to

Table 9.—Major Policy Options for Two Scenarios

Policy-area	Renewal scenario	High Investment scenario
Capital information .	Improve through one or more of the following: . more rapid capital recovery, . loan guarantees, . industrial development bonds, • investment tax credit, . subsidized interest loan, or • emphasize technological rejuvenation of viable plants.	'–More rapid capital recovery.
R&D	Increase Government support of basic research and demonstrate ion of major new technology. Provide incentives for industry R&D.	Increase Government support of research and costly pilot demonstration plants.
EPA/OSHA regulations .	Correlate regulations with industry's capital and modernization needs.	Regulatory framework be modified to mandate only those requirements that are demonstrably necessary to protect public health, and that can be rationally justified on a cost-benefit basis.
Raw materials	Explore the controversial issue of limiting the export of energy-embodied ferrous scrap. Examine the feasibility and adverse impacts of Federal targets for ferrous scrap. Compare targets with alternative mechanisms such as incentive investment tax credits for adoption of new technology which uses more scrap.	Let market forces rather than Government mandate determine international trade.
Trade	Reexamine trade policies. Assess the impact of unfairly traded steel imports on the industry's ability to make long-term commitments to and investment in new technology and additional steelmaking.	Need vigorous enforcement of U.S. trade laws and improved mechanism for keeping import levels consistent with other nation's limits. Trigger-price mechanism should be changed. Favors International Safeguards Code, use of OECD Steel Committee, bilateral trade policies with LDCs and centrally planned economies, international commodity trade policy.
Steel prices.	Not examined	Market forces would establish the level of steel prices, rather than Government price controls.

SOURCE: Office of Technology Assessment

the Nation and the industry. It does impose some constraints on industry—for example, with regard to diversification out of steelmaking and long-term commitments to R&D—and these are legitimate issues for discussion. The dangers of superseding the discipline of the market are considerable, and the fears that increasing Government intervention will have unfavorable impacts on the private sector are legitimate.

Both the Renewal and High Investment scenarios accept as a basic premise that longstanding market imperfections have caused underinvestment by the domestic steel industry in capital plant, R&D, and technological innovation. These market imperfections have resulted from foreign and domestic Government policies that have affected investments, costs, and prices.

If the international competitiveness of the American steel industry is to be markedly improved, Federal policies, which constitute the socioeconomic environment in which the industry operates, must be comparable with those of other governments, To be effective, the policies must also address the totality of underinvestment. The industry emphasizes its need for Federal assistance in redressing underinvestment in capital plant, but OTA finds an equally great need to deal with underinvestment in technology—in R&D and innovation.

Implications of the Scenarios for the 1990's

The Liquidation scenario would probably make it difficult for the domestic industry to rejuvenate technologically at the end of the 1980's. A large degree of its capability for technology improvement would be lost, particularly the R&D personnel and facilities needed to originate innovations. Most negatively affected would be integrated steelmaking which is vital for the large-scale processing of iron ore,

The High Investment scenario requires spending enough capital on existing technology to ensure a relatively modern industry by the end of the 1980's. The industry would then be more efficient and productive by today's standards, but the real issue is whether the industry might by then be technologically obsolete because of newly developed technology, or whether (having already spent so much on new plants) its opportunities for adopting new technology in the 1990's would have been lost. Only very rapidly rising demand for steel would reverse these adverse effects,

The Renewal scenario, on the other hand, sets the stage for a major rejuvenation of the industry in the 1990's based on basic innovations in process technology. This would necessitate high capital expenditures in the 1990's, particularly for new integrated steelmaking facilities. There is no guarantee that a radical change in integrated steelmaking will occur. But there are indications that it may, because the seeds of radical change are already planted.

Basic innovations, which create profoundly new industrial processes, products, and industries, occur not in a continuous manner but in clusters.' Research on coal-based direct reduction (DR), direct one-step steelmaking, and plasma steelmaking suggests that a radically different way of making steel might be commercially possible by 1990 (see ch. 6). Furthermore, major breakthroughs in any of the several areas of energy production (such as economical large-scale coal gasification, magnetohydrodynamics, or even fusion) could create an opportunity to combine steelmaking with energy production and gain unprecedented efficiencies.

The risks associated with the Renewal scenario appear to be minimal. Even if no wave of basic innovations in steelmaking occurs, the domestic industry should be well positioned for an expansion based on the best available technology. The ability and readiness to take advantage of new technology in the **1990's** could lead to a considerable competitive advantage over foreign steel industries. The Japanese and European steel indus-

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G. Mensch. Stalemate in Technology--Innovations Overcome Depression Cambridge Mass.: Ballinger Press, 1979).

tries both have invested heavily in new plants in recent years; they already have considerable excess capacity as well as poor records of profitability. Third World steel industries will likely expand considerably during the 1980's using current technology; this investment will make it difficult for them to adopt radically new technology in the 1990's and it will be some time before their scientific and industrial infrastructures actively contribute to the adoption of basic innovations.

Problems will develop under the Renewal scenario if demand grows faster than anticipated, if shortages develop in electricity or ferrous scrap, or if nonintegrated producers fail to expand their product mix. All of these would lead to insufficient domestic capacity during the 1980's, which would result in the same negative effects anticipated for the Liquidation scenario.

If the United States is to reap maximum benefits from basic innovations in steelmaking in the 1990's, it must participate in their development during the 1980's. Adopting innovations developed by foreign steel industries would at best give the domestic industry technological parity, not technological advantage or leadership. This points to the need to link economic assistance with efforts to spur domestic development and early adoption of basic innovations. Government policies that fail to encourage technological innovation and modernization, at least indirectly, would only be temporary and superficial remedies.

With the moderate capital spending of the Renewal scenario there would be a need at the end of the decade for substantial investment in integrated steelmaking plants, particularly for new facilities to replace old plants which are too costly to modernize. The scenario delays investment in integrated plants by emphasizing expansion in the nonintegrated segment and by minimizing facility replacement. Although the rate of growth for nonintegrated mills is the same as for the past decade, the implementation of this scenario is contingent on the availability of ferrous scrap and electricity in specific market areas. Data on domestic scrap supplies indicate that if present export tonnages are used domestically and a few million tonnes of DRI becomes available there should be no major problems, although the price of scrap might rise substantially. The increased demand for electricity would amount to less than 1 percent of current domestic industrial usage; spread over a number of plantsites during a 10-year period, with some concentration in the South and Southwest, this is unlikely to be a major barrier to nonintegrated growth, except for firms in the industrialized areas of the Northeast and Midwest.

The Renewal scenario is linked to a coordinated set of policies encouraging R&D and capital formation. AISI's High Investment scenario gives less weight to remedying current deficiencies in R&D efforts; its economic scenario runs linearly for 25 years, apparently without emphasizing the creation or adoption of profoundly new technology during that period. The executive summary of the AISI policy report does not mention R&D; its three requests for Government action do not include R&D; increased Federal R&D assistance is discussed in three pages of an appendix.

Overview of Possible Policy Options

Steel's competitive problems are primarily in the areas of technological innovation, capital formation, regulatory compliance, raw materials, and international trade. The following sections discuss policy options that could be instrumental in improving the industry's competitiveness. These options are aimed at:

- increasing R&D and innovation,
- encouraging pilot- and demonstration-plant testing of new technologies,

- facilitating capital formation,
- reducing the adverse economic costs of regulatory compliance,
- improving the availability of scrap, and
- constraining steel imports and facilitating certain exports.

R&D and Innovation Activities

Investment in R&D and innovation activities in steelmaking would be stimulated by the following Federal policy options:

- increased support of basic research,
- increased support of large-scale demonstration projects for new technologies,
- changes in antitrust policies to permit greater industry cooperation in applied R&D activities,
- improved coordination of existing Federal programs with industry needs, and
- change in tax laws to provide an incentive for industry R&D.

All available data show that the amount of funding for basic research in steelmaking is very low, The industry itself spends very little on basic research, just 7 percent of its total R&D budget, which itself is a very low fraction of sales compared to the R&D spending of other domestic industries. However, the industry's R&D spending as a percent of profits is relatively high. Federal support of basic research also appears minimal, not only in industry but in the academic sector and in Government laboratories; total annual spending on basic steelmaking research by all sectors is probably less than $5 million. The factors that have led to the generally low levels of basic research are discussed in chapter 9.

A bill has been introduced (H.R. 5881, the Basic Research Revitalization Act) to provide a tax incentive for basic research sponsored by industry and carried out in the academic sector. The Act provides a tax credit for 25 percent of the amount contributed in cash to a basic research reserve, with the maximum credit limited to 5 percent of the taxpayer's business income. An income deduction is allowed for payment from the reserve. This Act could provide approximately $50 million per year for basic research for the steel industry, a tenfold increase over present spending. There has been little public discussion of the Act's potential utilization by industry or problems with implementing it, but it is a good example of a creative policy approach to a critical problem.

The option of providing the steel industry with an incentive to carry out its own R&D activities also merits examination. One approach would be to increase investment tax credits for R&D facilities; another would be to allow rapid depreciation of such investments; both could be contingent on the activities being steel-related, Because the level of steel R&D is so low, even substantial increases in R&D activities would cause a relatively minor loss of tax revenues.

Federally Sponsored Research Centers

It is widely accepted that the Federal Government is justified in correcting private-sector underinvestment in basic research, and OTA finds ample evidence that basic research in steelmaking could have substantial benefits in the long term. A feasible and attractive option would be the creation of federally sponsored research centers at universities. Such centers should have close working relationships with industry to ensure that research leads to results that are useful. Added benefits would be university/industry personnel exchanges and the maintenance of an adequate academic base for training technical personnel for industry (both are important manpower benefits—see ch. 12). Industry could help support such centers, although most of the funds would likely have to come from Government; funding for each such center would be $1 million to $3 million annually.

Several such centers could be designed around specific technologies such as integrated or nonintegrated steelmaking processes, the use of low-grade coals, and the use of new energy forms. The National Science Foundation is already well organized to pursue such activities: it has sponsored a planning grant for a center dealing with research in nonintegrated steelmaking, although in this case the center appears oriented toward applied research.

Pilot and Demonstration Plants

Because of the scale of steelmaking and its reliance on well-established technologies, the need for pilot-plant demonstration of new technologies is great, In recognition of the industry's limited profits and its underinvestment in demonstrations, the Federal Government could provide more funds than the small sums it now devotes to such activities. Further, the present focus of demonstration support is energy conservation, only one of many industry needs; other worthy goals include shifting to different resources, reducing capital costs, reducing pollution, improving labor productivity, and using new forms of energy generation.

Although direct grants for demonstration purposes are an accepted means of support, other options should also be considered. Some of these options might help to minimize the Government's role in deciding which technologies to support. For example, where Government funds the demonstration directly, an alternative especially important for small firms would be buyback arrangements for the recovery of Federal costs after the technology is proven.

Changes in patent and antitrust policies might also effectively promote demonstration projects. Although progress has been made in patent and licensing arrangements between the Government and industry, such arrangements still appear to involve confusion and bureaucratic delays. There is little doubt that industry expects to obtain some form of proprietary ownership or advantage to justify its cosponsorship or use of personnel in such demonstration projects. By promoting licensing, the Government can deal with the objection that Federal assistance can lead to unfair competitive advantage for some companies.

Large demonstration projects are extremely expensive, and it is difficult for any one company to justify an investment of that size and nature. In some cases, a joint industry effort might eliminate the need for direct Federal support, but the legality of joint participation by several companies needs clarification with respect to antitrust regulations. The antitrust issue also applies to the feasibility of joint industry efforts in traditional R&D activities: there are a number of areas, such as energy conservation and pollution abatement, in which the social returns would be sufficient to sanction joint efforts that would not be particularly anticompetitive.

Other Federal Options

There are opportunities for the Government to coordinate existing Federal R&D and demonstration programs more closely with the needs of the domestic steel industry. Large sums are now being allocated to a number of energy-related technologies without much apparent attention to their possible application to steelmaking. For example, Federal activities in coal gasification and synfuels could be examined for their ability to supply the necessary technology for providing gaseous reductant fuels for direct reduction of iron ore. Similarly, a systems approach to the combination of steelmaking with energy generation could lead to low capital costs and high efficiencies.

There also appears to have been inadequate examination of the potential ways in which Bureau of Mines facilities, formerly used for research in steelmaking, could be resurrected for R&D activities and possibly used for pilot plants as well. The apparent policy shift away from joint industry/Government work and the present Bureau policy of not performing ironmaking and steelmaking investigations appear to preclude using this means to assist in the modernization of the domestic steel industry.[*]

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[*] "One example of the lethargy of the steel industry toward R&D is last April's shutdown of the experimental blast furnace at Bruceton, Pa., a cooperative venture involving the Bureau of Mines, and a consortium of private steel companies organized as Blast Furnace Research, a nonprofit corporation. This furnace had been responsible for most of the developments in ironmaking in recent years. In the 4 years of its existence, it was credited with saving the iron industry some $350 million per

Scenario Differences

The Liquidation scenario would maintain the current low levels of Government and industry support for R&D and demonstration plants. The most likely consequence of this policy would be further loss of technological and cost competitiveness for the domestic steel industry. Both the Renewal and High Investment scenarios would support more pilot and demonstration testing of new technologies. The High Investment scenario does not differentiate between basic and applied research, nor does it specifically consider R&D policies. The Renewal scenario emphasizes near-term basic research to support long-term innovation, with greater Government support for R&D. The Renewal scenario also sees a need for policies to support more industry R&D, coordinated with policies affecting capital formation and trade.

Capital Formation

Four Federal policy changes could increase capital formation in the domestic steel industry without sanctioning significant price increases:

- reduced capital-recovery periods (accelerated depreciation),
- investment tax credits,
- loan guarantees, and
- subsidized interest loans, including industrial revenue bonds.

Summary information on these four approaches is given in table 10.

Faster Capital Recovery

Accelerated depreciation continues to receive the greatest amount of attention from both the steel industry and Congress. The Jones-Conable Capital Cost Recovery Act of 1979 (H. R. 4646) typifies the interest in reducing capital-recovery times for all industry. If enacted, this proposal would allow steelmaking machinery and equipment to be depreciated over 5 years instead of the present 15. Because the Act applies to all industries, however, its cost to the Federal Government in lost tax revenues would likely be very high. The administration has forecast a net revenue loss of $35 billion annually by 1984,

Continued (from p. 44)

year, or $5/ton of iron. Present technology developed at Bruceton is capable of reducing costs another $2.50/ton.

"In spite of this *record of achievement*, the government, for reasons of economy, declined to make its $470,000 contribution to the $1 million needed to run the furnace this year, and the companies refused to make up the difference. It is hard to ignore investments that yield a 350-fold rate of return, but in this case the steel industry and the federal government appear willing to do so because of shortsighted budget economies and ruffled pride." (R. S. Thorn, "The Trouble With Steel," *Challenge*, July-August 1967.)

Table 10. —Features of Four Federal Options for Increasing Capital Formation in the Domestic Steel Industry

Federal option	Government cost	Administrative burden	Bias against small firms	Promotion of new technology	Applies to steelmaking only
Accelerated depreciation					
Jones-Conable	High	Low	Yes	No	No
Certificate of necessity	Moderate	Low	Yes	No	Yes
Investment tax credit					
Increase capacity	Moderate	Low	No	No	Yes
Modernization	Moderate	Low	Yes	No	Yes
Innovation	Moderate	High	No	Yes	Yes
Loan guarantee					
Increase capacity	Slight	Moderate	Yes	Yes	Yes
Modernization	Slight	Moderate	Yes	Yes	Yes
Innovation	Moderate	High	Yes	Yes	Yes
Subsidized interest loan					
Increase capacity	Slight	Moderate	No	No	Yes
Modernization	Slight	Moderate	Yes	No	Yes
Innovation	Slight	High	No	Yes	Yes

SOURCE: Office fo Technology Assessment

which would rise until 1988 and then stabilize, assuming the measure takes effect in 1980.[3]

The administration forecasts that by 1984 Jones-Conable would give the steel industry a tax saving of around 16 percent of projected investment, or some $1 billion for a projected investment of $6.7 billion per year,[4] a level corresponding to that of the High Investment scenario. Based on the Renewal scenario investment of $3 billion per year on productive steelmaking, the tax saving would amount to approximately $500 million in 1984, but presumably would rise thereafter. Thus, the level of capital-recovery increase accomplished through the reduction in depreciation time from 15 to 5 years is almost the same as the $600 million per year capital deficit projected in the Renewal scenario.

The Jones-Conable Act has the advantage of creating a relatively low administrative burden, but it can be criticized on several other grounds, One is that this approach does not promote investment in truly new, high-risk technology. Another is that it does not take into account the idiosyncrasies of any particular industry. For example, this general approach to improving capital formation is biased in favor of the large integrated steelmaker and against the smaller nonintegrated producers, The integrated companies already have a large capital base and could direct a large amount toward modernizing their facilities. Though they are less profitable than many small companies, they have larger absolute profits against which the increased tax offset can be applied, For smaller companies, with smaller capital and profit bases, the increased capital recovery cannot offset enough taxes for the large investment needed for a rapid rate of growth. That is, in a high-growth situation profits lag behind capital investment, and thus the faster depreciation cannot be fully utilized when it becomes available. Accelerated depreciation is biased in favor of a linear rate of capital investment growth. Furthermore, many large steel companies have nonsteel business that is more profitable than steelmaking, so they can write off more profits than smaller, less diversified companies. An indirect, but very substantial, benefit for the steel industry of a general reduction in capital-recovery schedules would be the overall national increase in capital spending. Nearly two-thirds of steel use is for capital projects, so domestic demand for steel should be boosted.

An alternate accelerated-depreciation option would be to use a limited-term approach that would apply to steelmaking investment only. This corresponds to the existing certficate-of-necessity reduction in capital-recovery periods during times of national emergency. This would place a limit, perhaps 10 years, on the time for taking advantage of accelerated depreciation, and it would pertain to steelmaking investment only. This option would have the same built-in bias against small steel companies, and it would not specifically promote investment in innovative technology, Applied to a particularly troubled industry like steel, however, it could make a large difference in profitability in the long run. Hence, the long-term costs to the Government would be low, because it would more than recoup in additional taxes whatever the measure had cost in initial tax losses,

A third option for accelerated depreciation would be to apply it to certain types of investment in steelmaking, Admittedly, this increases the administrative burden and influences the industry's freedom of choice. Nevertheless, criteria could be established for investment objectives such as capacity expansion or the adoption of innovative technology, energy-saving technology, and technology making greater use of abundant domestic resources.

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[3] Testimony of G. William Miller, Secretary of the Treasury, before the Subcommittee on Taxation and Debt Management of the Senate Finance Committee, Oct. 22, 1979. The loss is after an assumed feedback effect by which some 30 percent of the static revenue loss is turned into additional tax receipts as a result of the economic expansion induced by the tax reductions.

[4] Jones-Conable could lead to even greater tax savings. Using the 5-year writeoff for equipment on an accelerated basis, coupled with the existing 10-percent investment tax credit, would lead to greater tax savings than if the equipment were expensed in the first year. (*Iron Age*, Nov. 12, 1979, p. 30.)

Investment Tax Credits

Investment tax credits are another tax approach to increasing capital formation, General investment tax credits have proven effective in raising the Nation's investment rate, and more narrowly focused tax credits have also been recognized as a useful means to accomplish specific aims like conserving energy. For the steel industry, several types of investment tax credits are possible, including credits for increasing capacity, modernizing facilities, or introducing innovative technology (see table 10). Focused tax credits would cost the Government less than general ones.

Clearly, the innovation option could be used to promote investment in new technology, although defining such activities would be a substantial administrative burden. A greater credit might be offered for high-risk innovative activities. The modernization option would be more advantageous to large integrated companies than to smaller companies with a smaller capital base, but credits for capacity increases and adoption of innovative technology would be less biased against sma11 companies than the accelerated-depreciation option. Under current procedures, however, credits cannot be taken until the investment project operates, so it could still be difficult for companies with high debt-to-equity ratios to obtain capital.

A further advantage of tax credits over accelerated depreciation is that they could more easily be designed to accomplish the specific goals Congress deems most relevant to improving capital formation in the steel industry: however, they would be more difficult to administer. Industry clearly prefers the Jones-Conable approach, which provides maximum flexibility to industry to use additional capital for whatever purposes it chooses, Companies could even choose to diversify out of steelmaking and realize a tax advantage from diversification.

Guaranteed Loans

The third major option for increasing capital formation in the steel industry is the loan guarantee. Unlike tax approaches, which shift revenues from the Government back to the private sector and have little advantage for low-profit industries, loan guarantees place the burden of capital supply on the private money market and better meet the needs of less profitable companies. Moreover, a loan guarantee enables companies who would otherwise have trouble obtaining reasonable loans, if any at all, to borrow capital at low interest rates. In this respect, it favors the less profitable steel companies over more profitable ones; in the context of steel, that would amount to a bias against the small, profitable nonintegrated and alloy/specialty companies.

The costs to the Government of a loan guarantee are slight (assuming no defaults), because borrowers pay a small interest fee to the Government. Loan guarantees can easily be designed to apply to steelmaking only and, defined in terms of specific objectives, could be aimed at the objects of particular congressional concern. Even nonspecific industry loans would promote the introduction of innovative technologies, however, because the Government shares the risk of failure.

EDA Special Steel Program.—The administration established a loan guarantee program for the steel industry in 1977, under EDA of the Department of Commerce. This program, which is just now ending, did not focus on the adoption and development of new technologies, and it has been criticized by a number of steelmaker because of its orientation toward helping unsuccessful companies.

The EDA special steel program was established in response to recommendations by the 1977 Interagency Steel Task Force. Its purpose is to help improve the efficiency and competitiveness of financially troubled steel companies. The task force stated that:

> The use of EDA loan guarantees (would be) the simplest and most direct way to assure that viable modernization projects of (eligi-

ble) firms actually receive the funds necessary for their completion.[5]

The program has no mandate to promote innovative technology; its primary objective is to stabilize or increase employment levels in certain designated areas, *

The EDA program represents a substantial amount of Government assistance. Nevertheless, its funding level of slightly more than $500 million is modest compared to steel industry capital investment needs. At the present time, the Department of Commerce has no plans to extend or expand the EDA steel loan guarantee program: to do so would require a specific budget request and congressional appropriation, and no such special request was included in the administration's proposed budget.

During its year of operation, the special steel program has had mixed results. Implementation has been slow, in part because of industry concerns about the program's possible anticompetitive effects in the marketplace. Section 702 of the Public Works and Economic Development Act prohibits EDA from providing assistance to companies if that assistance might lead to unfair competition in the marketplace. Unfair competition could be brought about if Government-supported corporate investments in new technologies gave the assisted firms an undue cost or price advantage, As a result, the program has not encouraged industry to adopt innovative technologies: instead, it has emphasized pollution control equipment and incremental improvements in existing facilities and conventional technologies.

On the whole, the program can be best described as one of tradition-oriented renewal aimed at responding to contemporary economic and environmental problems. This should come as no surprise. The umbrella Office for Business Development Assistance, itself, does not have a "modernization'" mandate. Furthermore, the Interagency Steel Task Force recommendations, and particularly the implementing guidelines, make it quite clear that genuine modernization can never play more than a limited role in the special steel program.

Loan Guarantees—A Summary.—It would be desirable to examine the benefits of a limited-term loan guarantee program that would require: 1) evidence of the company's inability to raise capital through any conventional means, including new stock issues; 2) a degree of risk and innovation that is proportional to relative profitability, so that successful firms would be encouraged to develop risky, long-range, major innovations, while still allowing the less profitable firms to share in the Federal assistance program; and 3) commitments to delay diversification out of steelmaking until companies meet certain mutually agreed-on objectives for such factors as capacity, productivity, energy use, or pollution abatement. This approach, though complex, would least disturb the relative competitiveness of domestic companies, while providing a means of restoring domestic steelmaking capacity and technological leadership compared to foreign industries.

Subsidized Interest Loans

The fourth major option for increasing capital formation is the use of subsidized interest loans, including industrial development bonds, which could be designed for specific purposes. Like loan guarantees, this approach places the financing burden on the private money market and costs the Government a relatively modest amount. Here too, to the extent that this approach increases the borrowing ability of unprofitable companies, it is biased against those that are profitable or have not reached a debt-to-equity ratio private lenders consider the upper limit for borrowing,

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[5] Interagency Task Force, *Report to the President: A Comprehensive Program for the Steel Industry*, 1977, p. 12.

*The program guarantees loans and leases financed by private lending institutions at favorable interest rates to SIC 3312 firms with facilities having an annual production capacity of at least 225,000 tonnes of raw steel. The minimum capacity requirement eliminates a number of minimills. Eligible firms have to be located in redevelopment areas with an unemployment rate of at least 6 percent, or in special impact areas having either substantial unemployment or an actual or threatened abrupt rise in unemployment due to the closing or curtailment of a major source of employment. (13 CFR parts 302-304.)

Considering the level of capital shortfall under the Renewal and High Investment scenarios, loan guarantees or subsidized interest loans might not be well received by the private financial sector. The increased burden on the private money market could be inflationary. However, the same argument can be made for accelerated depreciation and investment tax credits, which lead to reduced Government revenues and, under the assumption of unaffected Government spending levels, increased Government borrowing. Loan guarantees and subsidized loans bypass the normal budget process, because they are not expenditures and do not cause losses in tax revenues.

Summary of Capital Formation Options

In summary, all four of these approaches to improve capital formation within the domestic steel industry involve costs and benefits. Quantifying them for the near and long terms would require considerable analysis. Qualitatively, OTA finds that focused investment tax credits, or accelerated depreciation for capacity expansion and technological innovation, or risk-related loan guarantees could be used to raise the capital called for in the Renewal scenario. The additional capital required by the High Investment scenario would have been raised through steel price increases. There is a minimal risk in these options that capital will be used for purposes that would not address congressional concerns and that would have adverse impacts on small steel companies. The costs and difficulties of administering focused Federal assistance would be significant, but not insurmountable. Helping already healthy companies is best done through tax relief programs, The near-term direct costs of any of these programs would likely be offset by increased tax revenues after the rejuvenation of the domestic industry.

Scenario Differences

The Liquidation scenario would extend present policies and capital spending on productive steelmaking facilities would continue to decline, which would lead to further loss of capacity and increased obsolescence of facilities, The High Investment scenario is based on obtaining the benefits of the accelerated depreciation for facilities and a substantial increase in steel prices in order to maximize near-term investment in current technology. The Renewal scenario is dependent on policy changes that would generate at least $600 million annually; it considers a number of policy options that could accomplish this goal, but would be best accomplished by those options that assist modernization and expansion of steelmaker that are profitable. The Renewal scenario also favors policy changes that promote technological innovation in the long term and relatively low investment in current technology in the near term.

Regulatory Compliance Costs

The steel industry is one of the largest sources of pollution in the Nation, with the integrated steelmaker accounting for close to one-fifth of all domestic industrial pollution. The industry also has very high rates of occupational injury and illness. The harmful and toxic emissions of steel plants are a greater hazard for steelworkers than the general population. Consequently, the Federal and State governments have created a number of regulations to protect both workers and the public. There can be no argument against the goals of reducing environmental pollution and occupational risks; however, the impact of these regulations on the creation and adoption of new technology merits examination. Regulations can act as either a barrier or an incentive to innovation, While industry has tended to emphasize the barrier effect, there are opportunities for the regulations to serve as incentives for technological innovation. Because of the nature of this study, the impact of regulations on the steel industry has been emphasized; but this does not mean that the impact of pollution on workers and the general public is thought unimportant.

Complying with Federal environmental and, to a lesser extent, occupational hazard regulations has imposed additional capital and operating cost demands on the steel industry. These promise to increase because of more stringent requirements that will become effective during the coming years. Furthermore, EPA is in the process of reviewing Ambient Air Quality Standards and steel industry effluent guidelines, And finally, the number of EPA and OSHA regulations applicable to the steel industry is steadily increasing.

States and regions have some flexibility in considering economic and technical constraints facing individual steel plants. However, industrywide changes would require Federal action, The trend of increasing regulatory costs may be halted or reversed through changes in regulatory policies or through increased Federal support of steel industry efforts to meet current standards. In addition to reducing the regulatory costs, some available options could also foster replacement or expansion of steel capacity, The major options for changes in regulatory policies are:

- congressional endorsement of the "bubble concept, " which allows air quality control on a plant rather than a point-by-point basis:
- more even distribution among different industries of the cost of offset policy tradeoff requirements;
- relaxation of the limited-life facilities policy for plants owned by companies committed to replacing facilities or otherwise providing for regional economic growth:
- relaxation of fugitive air emissions requirements;
- use of administrative penalty payments for environmental technology R&D fund;
- improved coordination of OSHA compliance deadline when a company is considering innovation;
- improved coordination of EPA innovation waivers; and
- cost-benefit analysis of major proposed regulations.

The major options for increased Federal support are:

- additional acceleration of the depreciation schedule for pollution abatement equipment;*
- increased investment tax credit for pollution abatement equipment;
- loan guarantees, provided on a continuing basis;
- extension of industrial development bonds to cover in-process changes; and
- increased regulatory technology R&D and demonstration.

Regulatory Change

Regulatory cost impacts would be reduced under both sets of options, but changing enforcement approaches would not affect direct Federal costs. A few of the changes could also promote new regulatory technologies or facilitate replacement or modernization (table 11). Small integrated companies would benefit from such policy changes more than other industry segments.

Congressional endorsement of the bubble concept, which allows pollution offsets within a plant, would improve EPA's ability to apply this approach across the board to existing and replacement facilities. By varying the degree of control with the costs involved for individual point sources while still attaining air performance standards on a plant basis, companies could reduce their compliance costs by 5 to 20 percent (see ch. 11). However, the tradeoff between more and less hazardous pollutants within a bubble area requires assessment.

The offset policy requires that companies adding new, polluting plant capacity in a given geographical area offset that addition to the area's pollution by reducing pollution from another facility in the same area. Because of the steel industry's complex industri-

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*Suggestions also have been made to eliminate the sales tax on pollution abatement equipment. Such changes would have to be made at the State level.

Table 11.— Regulatory Change: Policy Options and Consequences

Regulatory change	Social impact[a]	Promotion of new technology	Regulatory cost impact	Capacity
Bubble concept	Modest	Yes	Reduction	Facilitates replacement
Distributing cost of tradeoff requirements (offset policy)	None; increased equity among expanding firms in nonattainment areas	No	Reduction	Facilitates expansion
Extension of limited-life facilities policy while replacing steel facilities or otherwise providing for regional economic growth	Modest; at least partially offset by strengthening regional economy	Yes	Reduction	Replacement/ expansion
Fugitive emissions	High	No	Slow down growth rate	NA
Use of administrative penalty payments for environmental technology R&D fund	None, but goal change in favor of R&D	Yes	Transfer of costs	NA
Improved coordination of OSHA compliance deadlines	Modest	Yes, if given as condition for extended deadlines	None	NA
Improved coordination of EPA innovation waivers	Modest	Yes	None	NA
Cost/benefit analysis	Varies with cost-benefit tradeoff	No	Potential reduction	NA

NA - not applicable
[a]Social impact is defined as increased environmental degradation or occupational risk resulting from regulatory relaxation
SOURCE Office of Technology Assessment

al processes, it has paid a disproportionately high price (compared to many other industries) for economic growth and capacity expansion in industrialized areas. Redistributing the "purchase cost" of emission offsets could help improve the steel industry's unfavorable compliance cost position. The Department of Energy's (DOE) energy entitlement program, aimed at equalizing the cost of expensive imported oil among domestic refiners, is one approach that could be considered.

The limited-life facilities policy calls for the phaseout of marginal facilities by 1982-83 unless they have been retrofitted with abatement equipment. Relaxation of this policy would enable steel companies to benefit from an extended period of continued operation. This approach could coupled with replacement, modernization, and expansion programs, perhaps at other plants.

Relaxation of fugitive air emission standards regulating conventional pollutants from steel plants would help slow down anticipated increases in compliance costs (see ch. 11), Such relaxation could put undue pressure on regional air quality, however, and inhibit economic growth potential as a result. Relaxation of standards or compliance dates could be especially problematic in heavily polluted regions of the country.

Administrative penalty payments made by the steel industry for noncompliance with environmental regulations are presently received by the U.S. Treasury. These funds could be used for public- or private-sector regulatory technology RD&D in presently underfunded fields such as research on innovative process or control technologies capable of improved protection or regulatory cost reduction.

OSHA compliance schedules and deadlines lack uniformity and are inconsistent in their consideration of industry economics and technology development. EPA innovation waivers for air and water also lack uniformity. Improved coordination could encourage the industry to make use of innovation waivers and technology development provisions.

A cost-benefit requirement for major regulatory policies could help clarify the tradeoff between the economic costs and the social benefits by placing the economic impacts in a broader social framework, To the extent that it is difficult to quantify the social benefits of regulations, such an approach may not be feasible.

Increased Federal Support

Some options, if applied without any accompanying regulatory relaxation, would increase Federal costs in varying degrees. Regulatory costs would be reduced in all cases, and new regulatory technologies would be promoted in a few cases (table 12), Capacity would not be affected by any of these policy options, except to the degree that they improve capital formation. These options would indirectly tend to benefit small integrated companies more than any other industry segment because of those companies' proportionately greater regulatory costs.

Industrial development revenue bond (IDB) financing is presently a more attractive option for pollution abatement equipment than is the use of available fiscal incentives. IDB financing makes large sums of capital available to industry at relatively low cost to the Treasury. Thus, one option would be to expand the scope of IDB financing to include specifically the financing of in-process changes for environmental compliance purposes whether or not there are cost savings. However, increased use of IDBs would increase pressure on the municipal bond market, which could inhibit capital projects for local governments.

As an alternative, some IDB financing could be replaced by a continuing flow of federally guaranteed loans or by more effective fiscal incentives. Fiscal incentives could include allowing higher investment tax credits for regulatory investments (currently 10 percent) or further reducing the accelerated depreciation schedule for regulatory compliance equipment (from the present 5 years to perhaps 1 year). Fiscal options would likely entail higher Federal costs than either increased IDB or federally guaranteed loan financing.

RD&D of innovative regulatory technologies and cleaner steelmaking technologies are not receiving sufficient public- and private-sector support. Consideration should be given to a strengthened program to increase direct Federal cost-sharing support of regulatory technology RD&D not readily undertaken by the steel industry.

Scenario Differences

The Liquidation scenario assumes a continuation of current policies—continued strict enforcement of existing laws and standards. The likely effect would be a moderate increase in capital spending and production costs related to EPA and OSHA regulations, which would influence the profitability of domestic steelmaker. For those firms with older, inefficient facilities, this could contrib-

Table 12.—increased Federal Support for Regulatory Compliance and R&D: Policy Options and Consequences

Increased Federal support	Federal cost	Promotion of new technology	Regulatory cost impacts
Improved accelerated depreciation	High	No, unless specified	Reduction
Increased investment tax credit	Modest	No, unless specified	Reduction
Loan guarantees	Modest	No	Reduction
Extend IDB coverage for regulatory equipment to in-process change	Modest. pressure on municipal bond markets	Yes	Improves capital availability
Increased Federal regulatory technology R&D	Modest	Yes	Reduction

SOURCE: Office of Technology Assessment

ute to plant closings and a further loss of domestic capacity. The High Investment and Renewal scenarios both make use of the cost-benefit approach to determine the extent to which the social goals of EPA and OSHA regulations are also consistent with the goals and needs of industry modernization and expansion. The Renewal scenario provides a more thorough examination of policy options that would reconcile industry and national needs, with particular attention to the need to promote technology change and innovation leading to cleaner steelmaking technologies.

Raw Materials

Potential future shortages of coke and ferrous scrap have raised the general problem of inadequate data and analysis of such supply problems. In the cases of coke and scrap, the Government has had to rely on limited data from different segments of industry. Because of differing interests in the problem, there are contradictory findings concerning future domestic supplies. This uncertainty is acting as an incentive for the development of DR and other technologies. Existing legislation relating to ferrous scrap affects both demand and supply, but not necessarily in a cons is tent manner.

Scrap Use

On the demand side, two legislative acts have been passed that attempt to maximize the use of scrap and other waste sources of iron genera ted in steel plants. The requirements of the two acts may he summarized as follows:

- Section 461 of the National Energy Conscrvation Policy Act (Public Law 95-619) of 1978 mandates that DOE set targets for the use of recovered materials for the entire ferrous industry —ironmakers and steelmaker, foundries, and ferroalloy producers. Such targets, now set, are voluntary, but steel producers are concerned that they might become mandatory.
- Section 6002 of the Resource Conservation and Recovery Act (Public Law 94-580) of 1976 amends the Solid Waste Disposal Act and deals with Government procurement, It requires that Government procuring agencies shall procure items composed of the highest percentage of recovered materials practicable, and it instructs the EPA Administrator to promulgate guidelines for the use of procuring agencies in carrying out this requirement. It also requires suppliers to the Government to certify the percentage of recovered materials used in the items sold. As yet, EPA has not set these guidelines, nor has it proposed a schedule.

Although instigated by the scrap industry, these acts have satisfied neither scrap users nor suppliers, Users believe that targets or guidelines for scrap use do not make economic or technical sense on an industrywide basis, and suppliers believe that the Government targets have been too conservative. OTA finds both are correct.

Although it is in the national interest to maximize the use of recovered materials in order to save energy, the setting of scrap-use targets or guidelines presents a number of problems; it may not be technically or economically feasible in all cases to use recovered materials to the extent suggested or required by the Government. There has been no apparent recognition by DOE and EPA of the differences between steel industry segments and the unique constraints and opportunities they have in regard to scrap use. Another problem is that a numerical target rests on many assumptions about future scrap availability and use, as well as total steel demand and changes in technology, all of which are highly controversial in themselves.

Targets could, in fact, be counterproductive to the original goals of maximizing recovered materials use and saving energy, 'Unrealistic targets could be circumvented, for example, by companies selling their home scrap to others and purchasing other firms' home scrap.* If targets and guidelines increase de-

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* This could be a paper transaction unless prohibited by the target legislation since physical transport of scrap would be costly in most cases. See ch. 7 for a full discussion of future supply, demand, and uses of scrap.

mand for scrap, and thereby raise prices, the impact on nonintegrated companies would be much worse than on integrated steelmaker; if this led to a decrease in nonintegrated output, it could result in even less total scrap use. Technically and economically, it would be extremely difficult for integrated steelmaker to increase substantially their use of recovered materials in existing facilities; and if they modified their equipment to use more scrap in basic oxygen furnaces, they would probably use more oil or natural gas as well. Targets and guidelines are irrelevant for electric furnace steelmaking; this process presently uses nothing but scrap.

With the advent of DR and the availability of DRI, a technology that may offer benefits for both the industry and the Nation (see ch. 6), electric furnace steelmaker could use less scrap. Hence, targets or guidelines could actually discourage the introduction of DR. Even though the percentage of scrap used per unit of output would decrease in electric furnace shops using DRI, it can be argued that the use of DRI in conjunction with scrap would promote an expansion of electric furnace steelmaking, with the net result that the total use of purchase scrap would increase.

Is it necessary for the Government to set any targets or guidelines for ferrous scrap use? OTA finds no compelling reason to legislate broad goals for the industry. The economic advantages of using scrap have been sufficient incentive to increase scrap use, especially by the nonintegrated producers who rely solely on ferrous scrap. Even the integrated companies have changed their attitudes and recognized the economic benefits of maximizing their use of scrap to the degree their facilities and capital permit. A more direct and fruitful approach to increasing domestic use of domestic scrap would be to provide a financial incentive for adopting scrap-using processes. For example, a special investment tax credit could be offered for adoption of equipment that allows an existing plant to use more scrap. Because scrap is embodied energy, it might only be necessary to redefine some terms to qualify such equipment for special energy conserva tion investment tax credits.

Ferrous Scrap Exports

Perhaps the most critical area for policy analysis is the issue of ferrous scrap exports-. Domestic steelmaker are uncertain about future scrap supply and maintain that exports greatly influence domestic prices. The scrap industry favors free export of scrap. It contends that there is sufficient domestic scrap for export, that more scrap becomes available as market forces increase prices, and that historically the integrated steel producers have not attempted to maximize their use of scrap, To some extent the latter has been true, although the situation appears to be changing.

The importance of examining policies affecting the supply and demand for ferrous scrap is shown by data demonstrating the inflationary effect of scrap on steel prices. During the past 2 years, when scrap exports have reached very high levels, so too have scrap prices, The increase in the producer price index for ferrous scrap from 1977 to 1979 was 52 percent, compared to increases of 21 percent for labor, 6 percent for metallurgical coal, 16 percent for iron ore pellets, 18 percent for electrical power, and 33 percent for fuel oil. For the same period the price increase for the entire steel mill product mix was 21 percent, but the price for reinforcing bars (which unlike the other products are made entirely from scrap) rose 37 percent. Available data point to direct relationships between scrap exports and domestic scrap prices and between scrap prices and finished steel prices.

Scrap exports make a positive but relatively small contribution to the Nation's trade balance; for 1979, they equaled only about 15 percent of the net steel-related trade deficit. By exporting scrap, moreover, a valuable source of both iron and embodied energy [about 17 million Btu/tonne) is being exported. The more scrap used domestically, the less energy, time, money, and labor will be expended to mine, process, and reduce iron ore. When scrap is exported, these savings are realized instead by foreign steelmaker, whose government-subsidized steels then return to compete in the domestic market. To the extent that steel and steel-intensive products are imported, such as automobiles, the Nation may eventually add to the domestic scrap supply at the expense of that in steel-exporting nations, like Japan; at present, however, these nations are able to buy back their scrap from the United States. These scrap exports cause the domestic price of scrap to rise, giving foreign producers a net price advantage because of the devalued dollar and their inherently greater energy costs.

Present-day steelmaking processes use more scrap and produce less, than did previous methods. Steelmaker are becoming more dependent on purchased scrap, which is declining in quality. The domestic demand for scrap is so great, and increasing so rapidly, that the scrap industry may have no long-range economic need to export; it is even possible that a domestic shortage of ferrous scrap may develop during the next decade unless DRI becomes available. Perhaps the most significant long-range consequence of continued scrap export is the possible detrimental impact on the nonintegrated steel producers, who depend on electric furnace steelmaking. If formal or informal Government price controls on steel cannot be released quickly enough to offset quickly rising scrap prices, these companies may be caught in a cost-price squeeze that could drive them out of the market. This impact is particularly acute now, when DR is in the early stages of domestic introduction and DRI is not yet readily available as an import.

The Export Administration Act of 1979 offers a means for monitoring and controlling scrap exports. To the extent that substantial market imperfections exist as a result of U.S. and foreign government policies, interference with free trade can be rationalized. The long-range consequences of permitting unlimited exports of scrap for the competitiveness of the domestic steel industry are sufficiently serious to warrant responsible implementations of the Export Administration Act. The welfare of the domestic scrap industry must also be considered, however, and to this end any limits placed on scrap exports could, in the near term, be balanced by appropriate Federal incentives for increased domestic use of scrap by, for example, special investment tax credits for the adoption of continuous casting and certain modifications to steelmaking furnaces.

Scenario Differences

The Liquidation scenario implies a continuation of existing policies with regard to ferrous scrap, resulting in continued problems due to uncertainty about future supply and demand. Moreover, policies related to scrap could remain controversial and to a large extent contradictory. There is particular need to balance control of scrap exports with promotion of domestic scrap use. The High Investment scenario allows market forces to determine raw material supply and demand and does not deal with specific policy changes. The Renewal scenario emphasizes better coordination, which would include examination of policy changes that link incentives for increased domestic use of ferrous scrap with appropriate monitoring and, if needed, control of scrap exports. The Renewal scenario also supports DR technology, which would offer a substitute to ferrous scrap in electric furnace steelmaking in the future.

Trade

Although worldwide trade in steel is not the central focus of OTA's study, certain aspects of that trade do affect technological levels in the industry. OTA has addressed two of these aspects:

- the impacts of the new Multilateral Trade Agreement* on the export of technology-intensive alloy/specialty steels, and

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*This new international trade treatv. signed by most of the industrialized and increasing numbers of Third World nations, promotes trade under equitable, competitive conditions.

- the impact of uncertain levels of steel imports on investment decisions relating to modernization, capacity expansion, and innovation.

Vigorous enforcement of the Multilateral Trade Agreement, which will govern much of the world's trade and other domestic trade laws and policies, such as the trigger-price mechanism, * is necessary but not sufficient for bringing about a revitalization of the domestic steel industry. Lax enforcement, however, is sufficient to perpetuate present trends and to assure the slow but inevitable demise of much of the industry.

Even if the new trade agreement is vigorously enforced by the United States and its trading partners, it could do little to solve the fundamental problems of the domestic steel industry. At best, there would be an uncertain amount of decline in imports and an increase in exports. The most important benefit of an effective trade agreement would be to reduce domestic steelmaker' uncertainty about both their potential for capturing growth in domestic demand and their rewards for long-term investments in technology, If the new trade agreement is not vigorously enforced, other policy changes aiding the industry could be nullified by surges in unfairly traded imports, or by the producers' fear of such surges.

Of the issues related to the Multilateral Trade Agreement, the subsidy issue is the most critical. Domestic steel producers have expressed concern that the definitions and implementation of the subsidy provisions will result in increased penetration of the domestic market by imports at prices kept low by foreign government subsidies of their steel producers, According to C. William Verity, Chairman of Armco.

> The steel industry's other major concern has been about the effect of the negotiations on our domestic laws governing international trade. We're specifically concerned that the international codes on subsidies and countervailing duties and anti-dumping, and the legislation necessary to implement these codes, could weaken our present statutory defenses against dumped, subsidized or otherwise damaging imports—thus making it more difficult for American manufacturers to obtain relief from unfair or injurious imports.'

The proposed process to establish whether a subsidy is illegal is complex:

> The (subsidies) Code provides for two routes (or tracks) of redress for parties who claim they are being injured by foreign subsidy practices or claim that their international trading interests are being prejudiced by the payment of foreign subsidies in violation of the Code's obligations. The first track is domestic action intended to prevent injury to national industries through the traditional means of countervailing duties. The second track provides a multilateral mechanism through which signatory countries can enforce their rights under the Code. The second track would be used, for example, when a country is losing a share of a third-country market to subsidized exports from another signatory country.“[7]

This issue arises because, increasingly, most industrialized countries are subsidizing their exports by providing loans, loan guarantees, interest subsidies, and related assistance to exporters. A recent report by the Congressional Research Service provides a comprehensive summary of such subsidies.” In brief, the programs of major exporting countries are as follows:

- France. The report judged that the French "have the broadest and most confessional' program. Private banks can make medium-term, fixed-interest-rate export loans and then borrow against such loans under "attractive refinancing arrangements" at the French central bank. In addition, the govern-

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*This procedure attempts to detect dumped steel quickly by setting a price below which imports are examined for dumping,

' C. William Verity, "International Trade Pact—Steel's View," Trade Negotiation Panel, AISI Press Conference, May 1979.

*"Wrapping Up the MTN Package. " Business America, Apr. 23, 1979, pp. 4-5.

"Congressional Research Service, *Export Stimulation Programs in the Major Industrial Countries*, Washington, D. C., 1979.

ment provides direct loans to finance up to 85 percent of long-term (over 7 years) loans. Exporters can also often obtain foreign-aid loans with 3-percent interest rates and 25-year repayment periods for some shipments to developing countries. Finally, the government offers insurance to protect exporters against political risks and the impact that inflation or exchange rate changes could have on their costs.

- Japan. The Japanese Export-Import Bank offers direct credit for about half the value of exports financed with medium- and long-term loans; the interest rates (6 to 9 percent) are close to market rates. The Japanese also mix foreign-aid credit [with interest rates of 4 to 6.75 percent and maturities up to 25 years) with normal export loans and guarantee private banks against losses on export loans.
- Great Britain. The Export Credit Guarantee Department (ECGD) provides subsidies on private bank loans to exporters; that is, the private bank makes a fixed-interest-rate loan at below-market rates, and the ECGD makes up the difference. The ECGD provides such subsidies not only in pounds but also in other currencies, including the dollar. It also provides insurance and guarantees against losses on export loans.
- Italy. “On paper, ” the report says, “the Italians have a highly confessional export financing system, but in practice the actual level of government support is limited by budget shortages in the administering agencies, ” The Italians provide interest-rate subsidies for private bank loans as well as insurance against export loan losses; in 1976, however, only about 9 percent of Italy’s exports benefited from insurance protection.
- West Germany. Most export financing is handled privately through a consortium of private banks, but some medium-term credits (generally 2 to 5 years) can be refinanced through the central bank. A government agency provides up to 45 percent of long-term export loans to developing countries, and Hermes, a private company supervised by the government, writes insurance and guarantee policies.
- Netherlands and Switzerland. Both countries leave export financing largely to private banks, although the Dutch have a small program that allows export loans to be refinanced at the central bank and the Swiss Government writes export insurance. In 1976, however, only about 9 percent of Switzerland’s exports used this insurance.

In the past, the United States’ attempts to subsidize exports have been relatively limited. Recently, there has been significant change in this policy by the Export-Import Bank of the United States (Eximbank).[9] In summary,

> The Eximbank offers both direct loans and protection against losses on private loans. Through the Foreign Credit Insurance Corporation (FCIA, a consortium of the Eximbank and private insurance companies), it offers insurance for U.S. exporters that finance their own overseas sales; if the foreign buyer doesn’t meet its payments, the insurance will cover the exporter’s losses. There’s a similar guarantee program for banks if the foreign buyer doesn’t repay the loan, the Eximbank makes up the loss. Banks can also discount loans at the Eximbank; that is, they can borrow at the Eximbank against one of their own export loans. And finally, there are direct loans, which the Eximbank makes either to foreign buyers or foreign banks.

Eximbank’s role in providing export support has been increasingly significant in recent years. In the fall of 1979, its outstanding commitments were about $27 billion, but these were concentrated in only a few manufacturing sectors of the economy: powerplants—$7 billion; civilian aircraft—$6 billion; and heavy industry—$5 billion. The domestic steel industry has had no support from the increased Eximbank activities.

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[9] See: Robert J. Samuelson, “The Export Credit Subsidy Game—If You Can't Lick ‘em, Join 'em,” *National Journal*, Apr. 14, 1979, pp. 597-602.

Scenario Differences

Since there is so much going on at present in the trade policy area, it is difficult to tell what the Liquidation scenario (based on continuation of existing policies) implies in this area. The main problem has been the uncertainty domestic steelmaker face with respect to future imports of steel. Vigorous enforcement of the new Multilateral Trade Agreement could remedy this uncertainty; both the Renewal and High Investment scenarios require such enforcement, as well as other trade policies that promote greater certainty about steel imports in order to make capital investments rational, but this is not an area that the OTA analysis has dealt with in detail. The Renewal scenario places some additional emphasis on the potential for increased exports of the high-technology steels in which the United States already has technological and cost competitiveness.

Foreign Government Policies Toward Steel Industries

It is not within the scope of this study to give an exhaustive review and analysis of foreign government policies toward their steel industries. However, it is clear that other governments have played a very large role in the international steel market and that their policies tend to be better coordinated than are U.S. policies.

Table 13 uses eight general factors to rank relations between government and industry in four geopolitical regions. Japan emerges as having the most beneficial policies toward its steel industry; following Japan, but with less difference among them, are Third World nations, the European Community, and the United States. The ranking system uses the perspective of industry and what would be most desirable from the corporate viewpoint toward maximizing management's freedom of choice, minimizing costs, and maximizing profits.

International Comparison of Cost Recovery Allowances

Table 14 presents a more specific international comparison of capital cost recovery allowances for major steel-producing countries. The table includes all special allowances, investment credits, grants, and deductions generally permitted in each country; regional incentives, if any, have been excluded.

The data presented in the first column, "representative cost recovery period, " refer to the total number of years required to recover 100 percent of the cost of an asset, in-

Table 13.—Ranking of Factors for Government-Steel Industry Relations

Factor	United States	EEC	Japan	Third World
Stature of steel industry	1	2	3	3
Good Government/industry relationship (adversarial v. cooperative)	1	2	3	3
Minimum Government involvement in steelmaking decisions.	3	2	3	1
Government protection of domestic steel markets	2	3	3	3
Availability of emergency funds	1	2	3	3
Government support R&D	1	2	3	1
Producer's pricing freedom	3	2	3	
Low pollution abatement requirements	1	1	1	3
Ability to lay off workers	3	2	1	1
Total	16	18	23	19

NOTE Ranking has been interpreted from the perspective of what is desirable from Industry viewpoint, with the highest numerical value representing the most advantageous Government policy.

SOURCE Office of Technology Assessment

Table 14.—Comparison of Cost Recovery Allowances in the Steel Industry

	Representative cost recovery periods (years)	Aggregate cost recovery allowances (percentage of cost assets)		
		First taxable year	First 3 taxable years	First 7 taxable years
Australia [a,b]	10	35%	59%	88%
Belgium [a,c]	9	26	55	86
Canada [a,d]	2	63	109	109
France [e,f]	7	41	78	105
West Germany [g,h]	10	25	58	87
Italy [a,j]	6	25	75	100
Japan [j,k]	11	31	55	84
Netherlands [m]	8	37	57	97
Sweden [a,n]	4	48	86	118
United Kingdom [o,p]	1	100	100	100
United States [q,r]	11	35	57	86

[a] No special relief provisions are available for pollution control facilities

[b] Capital cost recovery is computed on a straight line or accelerated (150-percent D.B.) basis with an additional 20-percent deduction available in the year of acquisition (40 percent prior to 6/30/79) 150-percent D B depreciation over a 10 year period plus the additional first year depreciation has been assumed Australia s sole steel manufacturer may have negotiated a special cost recovery arrangement

[c] Capital cost recovery is computed on a straight line or accelerated (200-per cent D B.) basis As a temporary measure to promote Investments, a onetime special deduction of 15 percent is allowed on certain acquisitions of fixed assets made during 197980 The special deduction will be allowed to the extent that 1979 or 1980 investments in fixed assets exceed the average annual investments for the years 197476 The 15 percent deduction is applicable to a maximum of 40 percent of the total new investments 200. percent D B depreciation over a 10 year period plus the additional first year depreciation has been assumed

[d] Capital cost recovery may be claimed at a rate of 50 Percent in the Year of acquisition and the remainder in the next succeeding year A 7-percent (5 percent if certain legislation is not extended during 1979) Investment tax credit may be claimed in the year of acquisition and has been Included in the table computation Investment tax credits reduce the cost of property for purposes of computing cost recovery allowances Based on proposed legislation, Investment tax credits of up to 20 percent may be available depending on the location of the asset

[e] Capital cost recovery is computed on a straight line or accelerated (250 per-cent D.B.) basis. Based on proposed legislation an additional 10 percent deduction may be claimed on the net increase in assets over the preceding year without reducing the Increase in assets over the preceding year without reducing the basis for regular depreciation Over an 8-year period 250 percent D B depreciation plus the additional 10-percent deduction has been assumed

[f] Through 1980. pollution control facilities attached to building in existence prior to 1/1/76 will qualify for a 50 percent special cost recovery allowance in the year acquired The tax basis of such facilities are reduced by the special allowance for purposes of computing regular cost recovery If the pollution control facilities do not qualify for the special allowance described above, regular cost recovery may be claimed *over* a shorter useful life than is generally allowed for other assets (e. g , 6 Instead of 10 years)

[g] Capital cost recovery is computed on a straight line or accelerated (250-per-cent D.B.) basis Regional Investment grants of up to 20 percent of the cost of certain assets may be claimed in the year of acquisition. Over a 10-year period 250-percent D.B. depreciation has been assumed

[h] A special Capital cost recovery allowance is available for Pollution control facilities purchased or constructed between Jan. 1, 1975, and Dec. 31, 1980 A capital cost recovery of 60 percent may be claimed in the year of acquisition and 10 percent in each of the 4 following taxable years

[i] Capital cost recovery is allowed at a rate of 10 percent per year plus an additional deduction of 15 percent for each of the first 3 taxable years

[j] Capital cost recovery is computed on a straight line or accelerated (206-percent D B) basis A 10-percent Investment tax credit is available in the year of acquisition Over a 14-year period 206-percent D B depreciation plus a 10-percent investment tax credit is assumed

[k] A sspecial capital cost recovery allowance is provided in lieu of Investment tax credit for pollution control facilities at one-third of the cost in the year of acquisition This special allowance reduces the cost of the facility for purposes of computing regular cost recovery discussed in footnote (j) above

[l] Capital cost recovery is computed on a straight line basis Investment tax credit ranging from 7 to 23 percent is available in the *year* of acquisition depending on the type of asset Straight line depreciation over a 10 year period plus a 13-percent Investment tax credit is assumed In addition, where production capacity or the number of jobs is increased grants of up to DF L 5 million are available

[m] If a particular business is subject to air pollution regulations which are more severe than would be expected for the type of business, the government may indemnify the business for the extra cost Incurred This subsidy is determined on a case by case basis, without limitation and reduces the cost of the facility for purposes of computing the Investment tax credit discussed in foot. note (1) above

SOURCE: Richard M. Hammer. National Office, Price Waterhouse & Co , June 1979

eluding the tax benefit of any investment tax credit or other allowances. The useful lives used are considered representative for the country for which the depreciation computation is made. The present value of cost recovery allowances has not been taken into account. Note, however, that in some countries investors must agree with the tax authorities as to the rate of depreciation and other benefits available before they invest in fixed assets; such agreement would, in many cases, have the effect of substantially increasing the allowances presented in the table.

The data indicate that the United States and Japan have the largest representative cost recovery period—11 years. In Canada, the representative period is only 2 years, in Sweden, 4 years. The aggregate cost recovery allowance (percentage of cost of assets) for the first 3 taxable years is a significant measure of the attractiveness of capital investments in steel. The United States, with a 57-percent recovery, has a lower rate than most other nations. Only Japan and Belgium have smaller recovery allowances; a number of countries have much larger allowances.

Europe

The EEC Commission

The discussion of government policies for the steel industries of Europe is made complex by the combination of individual policies of nations and the presence of the Commission of the European Economic Community (EEC), which has absorbed most of the policy functions of the European Coal and Steel Community (ECSC). Management of the European steel industry is now conducted through the EEC Steel Directorate. The supranational policies of the group are discussed first. It should be noted, however, that the policies of the ECSC and EEC are not always followed by member nations, although there appears to be increasing agreement on policy implementation.

The Davignon Plan.—Current policies of ECSC have one major emphasis—that of overcoming the crises of the European steel industry, which resulted in job loss for more than 100,000 workers between 1974 and 1979 and may lead to an additional 80,000 lost jobs in 1980. The state of the European steel market in the spring of 1977 was described in these words:

> The present situation is that production is falling, new orders are continuing to stagnate, the rate of utilization of production capacity is running at no more than about 60 percent, prices are low, exports slack and stocks large, and short-time working is at almost the same level as during the most difficult period of the earlier recession,[10]

At a special meeting on March 16, 1977, the Commission adopted a new set of policy guidelines which set forth the group of steel policy measures that came to be known as the "Davignon plan." The proposed policy was accepted a few days later by the European Council—the heads of state and government—which issued the following declaration:

> The European Council has considered the situation in the steel sector, on the basis of a communication from the Commission. This sector is experiencing a depression more serious than at any time in the history of the Coal and Steel Community, The heads of state and government have taken this opportunity to reaffirm their resolve to restore to the steel industry through the appropriate measures, the viability and competitiveness essential to the maintenance of a truly European industrial potential.
>
> The European Council expresses its appreciation of the efforts being undertaken by the Commission to put forward at an early date practical proposals and initiatives for short-time remedial measures to stabilize the market, for a longer term structural reorganization of the European Steel industry and for measures in the social field to assist workers adversely affected by such reorganization.
>
> The European Council expresses the wish that the Council of Ministers gives its urgent attention to the Commission's proposals and initiatives on these issues.[11]

The new policy guidelines, aimed at strengthening the Community's crisis measures, were grouped into four main categories: 1) preservation of the unity and openness of the market, 2) accomplishment of a modernized production capacity, 3) market intervention, and 4) retraining and redeployment of workers.[12] Most (but not all*) of the policies of the Davignon plan have been accepted by the European steel-producing countries, and the Commission has obvious strength in formulating and executing supranational policies affecting the steel industry in Europe.

The present powers of the EEC Steel Directorate include:

- veto power over new investments in steel;
- the power to enforce or waive major antitrust rules;
- setting minimum prices;

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[10] *Bulletin of* the European Community, No. 3, 1977, p. 28.

[11] Ibid. p. 29.

[12] Ibid.

*For summary of the problems facing Davignon plan see: "Davignon Plan Fate at Stake," American *Metal Market*, Aug. **16, 1979,** pp. 1-4.

- setting production quotas for each country and suggesting production ceilings for each company;
- negotiating voluntary quotas for exports of steel to the EEC by Japan and Eastern European and Third World nations;
- consolidating industrywide confidential data on their operations and plans;
- making projections of planned capacity set against likely demand for every category of steel;
- providing supplemental funds to deal with displaced workers; and
- veto power over all government subsidies to steel; however, the Steel Directorate cannot force a company to close a facility.

In addition to the policies to minimize problems arising from the currently acute overcapacity of European steelmaker, the Commission has implemented other important policies. It has for many years helped finance capital investment programs. As an entity, the Commission is able to borrow funds at lower rates of interest, in part because of its authority to levy a tax on the value of steel and coal produced within the EEC. It then loans the funds it borrows in the open market to steel enterprises within the EEC at lower interest rates and longer payback terms than they could otherwise command on the basis of their individual credit. Between 1954 and 1974, the Commission granted a total of $2.4 billion in low-interest loans to EEC endeavors. This averages $120 million annually, including $65 million that is distributed directly to the iron and steel industry. During 1974 alone, the Commission granted low-interest industrial loans totaling $42.2 million to finance such production facilities for high-grade and specialty steels, environmental equipment for the steel industry, modernization of coal facilities and iron ore mining, and a research center for specialty steels.

The Commission also has significant long-range planning functions and has recently formulated its "General Objectives for 1980-85" for the iron and steel industry. This statement sets priorities and establishes guidelines for the EEC iron and steel industries through 1985, with particular stress on the areas of specialty steel and raw materials (scrap, iron ore, and energy). The objectives were developed by a steering committee composed of representatives from major iron and steel producers, national governments, and the Commission. While these objectives are described as "guidelines," they are nonetheless real objectives since they constitute the framework for the Commission's extensive financial investment program.

The Commission has also extended its influence beyond Europe by establishing formal ties with the Organization for Economic Cooperation and Development (OECD). The OECD Ad Hoc Working Party on the Iron and Steel Industry, set up at the request of the EEC to provide a forum for discussions of the world steel crisis, was transformed into a permanent Steel Committee[13] a year later for the following stated purposes:

- continuously follow the evolution of national, regional and world steel industries with regard to employment, profits, investments, capacity, input costs, productivity, and other aspects of viability and competitiveness;
- develop common perspectives regarding emerging problems or concerns in the steel sector and establish, where appropriate, multilateral objectives or guidelines for government policies;
- regularly review and assess government policies and actions in the steel sector in the light of the current situation, agreed multilateral objectives and guidelines and the GATT and other relevant international agreements;
- identify deficiencies and gaps in existing data needed by the Committee with a view of improving national inputs to the Committee and cross-national comparability of data.

OECD's responsibilities for policymaking are distinctly limited. Nevertheless, OECD can advocate certain policies related to steel in-

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[13] See "Problems of the Steel Industry: And a Search for Solutions,'" *OECD Observer*, November 1978.

dustries in member countries, including the United States and Japan.

Regulatory Policies.—Regulatory compliance costs for European steel companies have generally been at levels similar to those experienced by domestic producers. However, European steelmaker enjoy rather favorable fiscal incentives and attractive financing to help them meet those costs. Furthermore, there is a considerable level of public support for regulatory technology R&D in all areas of steelmaking.

The less competitive steel industries of Belgium and France have experienced relatively low environmental compliance costs. Should European steel-producing nations, as expected, adopt future environmental requirements similar to those in the United States, then French and Belgian regulatory costs will gradually approach U.S. levels. ”

European steelmaker generally benefit from preferred rates for accelerated depreciation of pollution abatement equipment. This places these industries at a significant advantage over U.S. producers, particularly because their general depreciation schedules for industrial equipment are already more favorable. They also have ready access to loans made available by the ECSC or national governments. Moreover, since 1975 the ECSC has supported research on environmental protection and occupational risk reduction technologies at levels two to three times higher than U.S. levels. *

R&D.—The ECSC has funded a considerable R&D “effort, particularly in the technical aspects of steel production and in pollution abatement and occupational health issues. Funding of production-related R&D activities was initiated shortly after ECSC was established in 1951. The basic purpose is:

> .,. to encourage the development of new technology for subsequent incorporation in the construction and operation of steel plant and equipment and to advance the quality of the wide range of semifinished and finished products that are manufactured within the Community’s industry. The ultimate objective of this effort is to enhance the ability of the European steel producers to compete in both home and export markets.[15]

ECSC support for R&D activities has varied over time but has averaged from $15 million to $20 million per year. The funds are allocated through the Iron and Steel Technical Research Committee, staffed by ECSC member country iron and steel experts who evaluate R&D proposals and make recommendations. The scope of the research is considerable: in 1979, for example, ECSC allocated $24.75 million to 73 different R&D projects whose total costs were $79 million; table 15 provides a partial breakdown of these projects. ECSC funding does not rule out direct support by individual governments.

National Policies

There is extensive government ownership of European steel industries. For example, approximately 80 percent of the United Kingdom’s and 70 percent of France’s steelmaking capacity is government owned. These industries are far from profitable. The approximate 1978 losses per tonne of shipped steel were $55 for the United Kingdom and France. These and other foreign steel industries are sustained by the favorable financial, export, and tax policies of their governments.

Conflicts Between National Subsidies and EEC Policies.—In light of relatively weak demand for steel products worldwide, most if not all subsidy and procurement policies in the EEC have been directed towards reducing capacity by early closure of older mills and by

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‘‘OECD, “Emission Control Costs in the Iron and Steel Industry,’” Paris, 1977. p. 95-96; and Hans Mueller and E. Kawahito. “The International Steel Market: Present Crisis and Outlook for the 1980’s.’” Middle Tennessee State University, conference paper No. 96, 1979, pp. 26-27.

*From 1974 to 1978, ECSC provided $2.2 million annually for this purpose, For the next 5 years, starting with 1979, ECSC has made $3.8 million annually available for regulatory technology R&D. (Official Journal of the European Communities: Information and Notices, June 13, 1979, No. C147.)

‘Commission of the European Communities, “Memorandum on the Implementation of an Iron and Steel Research Program, With a View of Obtaining Financial Aid Under Article 55(2)(c) of the ECSC Treaty, ” February 1979, p. 1,

Table 15.—Distribution of R&D Projects Funded by ECSC, 1979

	Funding total (millions of dollars)	ECSC aid (millions of dollars)	Subject area percent of total
Ironmaking	$ 7.5	$ 4.50	9.5%
Steelmaking	47,8	6.70	60.5
Rolling mills and related areas	2.3	1.38	2.9
Measurements and analysis.	4.6	2.76	5.8
Properties and service performance of steels	16.8	9.41	21.3
Totals. ., ...	$79.0	$24.75	100.0%

SOURCE: Commission of the European Communities'. Memorandum on the Implementation of an Iron and Steel Research Program With a View of Obtaining Financial Aid Under Article 55(2)(c) of the ECSC Treaty.' February 1979.

early retirement of workers. These policies are in direct conflict with those of some member countries, however. The British Steel Corp. (BSC), for example, has had plans for considerable expansion. In June 1978, BSC's expansion plans involving continued investment of $2 billion annually were slashed by the Labor Government. But since then, a new investment revival has taken place, and the Conservative Party plans to continue it.

> British Steel's investment plans are not likely to be halted by the conservative government. The corporation is near completion of the biggest spending program on steel plants ever seen in Europe. Work is so far advanced that it could not be stopped. Spending will continue at a rate of about $1 billion a year until 1980 but should fall away sharply in the early 1980s. British Steel will be the biggest and most modern equipped steel company in Europe with more than 22 million tons of highly productive capacity. It will also be the third biggest steelmaker in the western world, after U.S. Steel and Nippon Steel. ”

In Belgium, where government policies are controlled by labor unions, a new policy toward the steel industry has been adopted that clearly conflicts with the ECSC plan for member countries. The key elements of this policy are increasing employment levels, lowering nonwage labor costs such as social security contributions, keeping wage increases in line with inflation, and linking public spending to gross national product levels.

Likewise, but to a lesser extent, the Governments of West Germany, Austria, and Italy have been under union pressure either to continue and even expand operations of their steel mills in order to provide employment opportunities. This in turn has resulted in significant national subsidy payments in various forms to the steel industry.

Loans and Subsidies.—National governments are extensively involved in financing steelmaking production. The Fond de Development Economique et Social (FDES) is an important source of low-interest, long-term credit in France. FDES loans, which are advanced by the national treasury, are given to private borrowers through the Credit National. Applications must be approved by the Regional Development Agency or the Ministry of Industry. As a basic industry, iron and steel receives special consideration in granting these loans; for example, FDES is lending roughly one-third of the total project cost of a $1.75-billion steel complex at Fos-en-mer. These loans bear an interest rate of only half the market rate and require no payment of principal or interest charges for 5 years.

Italy is another country where the government is extensively involved in the iron and steel sector. The Instituto per la Reconstruzione Industriole (IRI), a state holding institution, is contributing 80 percent of the capital (in the form of government-guaranteed low-interest loans) to increase the capacity at the Taranto steel complex at a cost of $2.5 billion over a 5- year period. The $1,6-billion Calabrin steel complex at Giora Taura is also heavily funded by IRI. Loans for these proj-

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“ Steel Week, May 7, 1979, p. 7.

ects are classified as being used for regional development purposes.

In Belgium, government has for a number of years aided the steel industry under a program administered by the Comite de Concertation de la Politique Siderurgique (CCPS). Under the CCPS program, approximately $101.6 million in grants and low-interest loans has accrued to the Belgian steel industry during the lasts years.

In 1972 the British Government reduced the equity obligation of BSC by writing off almost $480 million of public dividend capital held by the government. Thereafter the government also wrote off the equivalent of $360 million in loans that had been due to the National Loans Fund. The statutory corporations bill (financial provisions), published in May 1975, will raise British Steel's borrowing limit by $1.7 billion to a total of $4.5 billion.

Export Incentives.—Export credits financing and export insurance are widely employed methods of stimulating exports that have been particularly effective in Western Europe. For example, the British Government has set interest rates for export credit finance since 1972. Clearing banks that provide export credit are furnished with refinancing for any such lending beyond 18 percent of their current account deposits; more importantly, the government guarantees that banks can earn a return on export loans that is 1.25 points above the average of their rates on treasury bills and loans to nationalized industries. Interest rates for export credit are much lower than those charged for domestic working capital, with the government making up the difference.

British insurance is primarily handled by an autonomous government agency that maintains credit ratings for foreign firms. Insurance is available against default by the buyer, government action that blocks or delays transfer of payments, imposition of new import-licensing restrictions in the country of purchase, war, or "any other cause" of loss occurring outside the United Kingdom and not within the control of the exporter. There are also policies to cover goods being processed or goods being held in stock abroad,

Italy offers export credit/financing through several banks and institutions and keeps medium- and long-term export financing at favorable rates. Export credit rates are currently about 6.5 percent, in contrast to 10.25 percent for nongovernment financing. This form of preferential or export financing must be approved by the Ministry of Foreign Trade, with extensions for longer than normal periods of time requiring approval by the Treasury. Insurance at low premium rates is granted by a public agency that implements decisions adopted by an interministerial committee, which in turn operates within the framework of the Institute of Foreign Trade.

In Belgium, the central bank helps firms obtain export credit at preferential rates by issuing special "visas, " which make the acceptances eligible for rediscounting with a semipublic organization. Interest rates for export credit range between 5.2 and 6.0 percent. Credit Export, an organization formed as a financing pool by public agencies and private banks, operates in the field of long-term export financing. Insurance at favorable premiums is available for exporters from a public institution that insures against commercial and political risks.

The French Government actively encourages exports through low-cost export credits. Medium- and long-term credit is available at a special Bank of France rediscount rate of 4.5 percent for exports destined to countries outside the EEC. Insurance is granted by a quasi-public firm, at government-guaranteed premiums, and covers commercial and political risks, currency fluctuation, unretrieved costs of advertising and promotion in foreign countries, and increases in costs of production.

The West German Government grants export insurance through an authorized syndicate, which receives applications and prepares them for approval by the Interministerial Committee for Export Guarantees. This committee includes representatives from the Ministry of Economics, the Ministry of Finance, and the Ministry of Foreign Affairs. Coverage includes both commercial and political risks.

Tax rebates are another way foreign governments stimulate exports. The value-added tax rebate, which is prevalent in Western Europe, provides a competitive edge for exporters, because it permits them to avoid conventional income tax as well as the value--added tax. The following list reflects the percentage of value-added tax rebate on exported products by European governments:

Austria	16
Belgium	18
France	20
Italy	12
Luxembourg	10
Netherlands	16
Norway	20
United Kingdom	8
West Germany	11

Other forms of direct export assistance in the United Kingdom include financial support for trade missions, exhibitions, market research, and export promotion schemes. Grants are also available to United Kingdom-based exporters to set up offices, warehousing, and related sales facilities for joint overseas marketing ventures.

Raw Material Supply.—In the United Kingdom, the National Coal Board operates a system of direct government subsidization which averages between $20 million and $30 million annually. Added to this are substantial sums being received from the ECSC, which has also subsidized coking coal production for several years. In 1973, the EEC Commission authorized the Governments of the United Kingdom, Belgium, West Germany, France, and the Netherlands to grant subsidies to the coal industries in their respective countries. The more than $800 million in subsidies granted in 1973 was significantly higher than previous years.

Japan

The socioeconomic and cultural environment in which industrial policies are made and carried out by the Japanese Government differs markedly from that of the United States. This affects their steel industry in several ways. First, the Japanese steel industry, like most other sections of the Japanese economy, specializes in its own area of business to a much greater degree than does its U.S. counterpart. Second, there is considerable cooperation between Japanese steel firms and related enterprises. Third, although the Japanese Government does not own its steel industry, it has close relations with it through the Ministry of International Trade and Industry (MITI), which guides the operations of the industry and creates financial conditions that enable it to compete effectively in the world market. These unique aspects of the Japanese steel industry's socioeconomic environment are well summarized clearly in a recent book by Ezra F. Vogel:

> Virtually all major Japanese firms specialize in a single sector like banking, trading, real estate, department stores, heavy industry, electric appliances, petroleum, and textiles. This pattern—developed partly through bureaucratic guidance—to encourage the most competitive performance is very different, for example, from American conglomerates, which spread over several sectors and leave and enter various industrial sectors with relative ease. Given the specialization of Japanese firms in a given industrial sector, the aggregation of interests can take two directions. One is the organization of all firms from a single industrial sector, which maximizes the cooperation that comes from looking after their common interests in building up their sector. The second is the organization of firms into "groups" consisting of one firm from each sector. A firm in a group has the advantage of special Zaibatsu (literally, "financial clique") groups (like Mitsui, Mitsubishi, and Sumitomo) link firms formerly united under their prewar holding

> company, and non-zaibatsu groups (like Fugi, Sanwa, Daiwa, and Dai-ichi Kangyo) center around large banks.
>
> In addition to these two types of organization, a third type combines virtually all firms of given size in all sectors: Nikkeiren (Japanese Federation of Employers), for example, deals with labor problems of all large firms, Keidanren (Federation of Economic Organizations) and the either other regional associations deal with all issues aside from labor confronting big business, and the Chamber of Commerce (composed of all companies) includes all firms but now particularly represents small business.
>
> Depending on the issue and the extent of common interests, trade associations, or ad hoc groups of companies in a sector, look out for a range of interests impossible to represent in the United States, where antitrust laws are more rigid, To make sure that they have entree when politicians consider issues like tax rates, consolidation and rationalization of firms, industrial and safety standards, and protection against foreign industrial threats, they make regular collective political contributions as a sector. On more detailed issues they deal regularly with the bureaucracy, and major trade associations include staff members who were elite bureaucrats in big ministries, creating smooth relationships with the bureaucracy, The associations discuss virtually every issue considered by MITI in their sphere, for even if MITI eventually resolves the issues, it would not do so without fully understanding the dominant views of the sector. [17]

As a “priority sector, ” Japanese steel producers obtain loans from private lending institutions with relative ease and apparently with implicit assurance of government support in the event of default on such loans. The Japanese Government also has provided its domestic steel industry with government loans during crucial time periods such as the early reconstruction period after World War II and during the first modernization program (1951-55). In the 1960’s, the aid fell to a low level but then rose again beginning in 1971, mainly for environmental protection expenditures. Until 1961 these loans were made at interest rates that were typically 1.3 percentage points lower than the prime rates charged by private long-term credit banks; in subsequent years, the rates were the same. In Japan, however, loans are allocated through an informal rationing system applied by the Bank of Japan and the large city banks, a system that has assured the Japanese steel industry the capital it needs for modernization and expansion.

Because of this financial leverage, MITI and other government agencies play a major role in all other aspects of steelmaking. For example, MITI’s long-term forecasts of demand govern the expansion of the steel industry. As a rule they are submitted on a periodic basis to the Industrial Structure Deliberation Council (an advisory body to the Prime Minister), and the Council’s decisions normally become established as government policy in the industrial sector. Another planning technique is the “target production goal:” MITI establishes quarterly and annual production levels after consultation with steel industry representatives and a review of market conditions. Although this is referred to as a “guideline, “ in practice it allows the government to coordinate production and stabilize prices.

MITI is also instrumental in the procurement of supplies and in the creation of cartels. In order to assure a supply of raw materials, MITI has established the Stockpile Council, which makes industrywide recommendations for raw material acquisition. At the beginning of 1975, under the guidance of MITI, the industry established a Japanese Ferrous Scrap Stockpiling Association, which handles both imported and domestic scrap. It is expected that in the first 3 years a total of 450,000 tonnes of scrap will be stockpiled. Proposals call for purchases and releases to be arranged among steelmaker, the Ferrous Scrap Council, and scrap processors.

In addition to economic stockpiling, the Ministry of Finance and MITI have also funded surveys and studies of overseas min-

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[17] Ezra F. Vogel, *Japan* Has Number One Lessons *for* America, Cambridge, Mass., (Harvard University Press, 1979), pp. 108-199,

eral development, sea-bottom mineral resources, metal deposits, and stable import sources. They also grant credits, issued through the Bank of Japan, to domestic producers of raw materials that are hard hit by rising inventories of ore and concentrates imported under long-term contracts.

Beyond these financial assistance and planning functions, MITI also funds and directs the activities of the Agency of Industrial Science and Technology (AIST), one of the principal R&D centers in Japan, which undertakes large-scale R&D projects and encourages industry to innovate. Four policies have been enacted and are administered by AIST for this last purpose:

- subsidies for R&D effort,
- tax credits for increased R&D expenditures,
- low-interest loans for the commercialization of new technology, and
- establishment of a research association to promote mining and manufacturing technology.

AIST itself operates 16 research laboratories with a staff of 3,800 and annual budget of 32 billion yen ($133 million at 240:1).

Another policy area in which the Japanese differ substantially from the United States is the promotion of exports. The cornerstone of Japanese steel export policy is an orderly international market in steel, with stable prices controlled by the governments of steel-producing countries. The Financial *Times* of London has commented that:

> The Japanese were among the first to be converted to the idea of controlling the world steel trade, a notion which is anathema to emerging low-cost steel producers such as South Korea. In fact, it was Nippon Steel chairman Yoshihiro Inayama who many years ago introduced the term "orderly marketing" to the world trade vocabulary.
>
> Yuzuru Abe, the executive vice president of that same company, in a recent U.S. speech went so far as to say, "Until the current significant demand-supply gap can be closed . . . some coordination is necessary in order to maintain fair international trade. Conventional principles of free trade are not enough to cope with the additional tonnage from the emerging nations or the continued flow from government controlled steel producers, "
>
> The trigger price mechanism "can be looked upon as the notable first step forward," Mr. Abe said, adding that some loopholes and drawbacks remain.
>
> Higher U.S. prices under controls, steel men argue, will help the U.S. industry generate the revenues needed to carry out much needed large-scale replacement and improvement of plant and equipment. In the long run, the Japanese say this will benefit consumers even though they are now complaining bitterly about the high steel price. At the same time, the Japanese chide the U.S. industry for not having taken full advantage of previous periods of Japanese self-restraint to strengthen its position in the late 1960's and early 1970's.[18]

In addition to the export of steel products, the Japanese policy has also been to export steelmaking technology, particularly to less developed countries. In this regard the following statement by T. Dahlby is of considerable interest:

> In the steel industry, the guiding philosophy now is to beef up divisions handling design and to build integrated steel works for developing countries by offering package deals, including technology licensing, feasibility studies, construction and engineering advice. By selling experience gained in building their own highly-efficient industry, Japan's Big Six steelmaker are hoping to makeup for the expected low levels of crude steel demand in the coming years . . . .
>
> Restrictions now in effect on exports to the U.S. and Europe, as well as the strengthening of the yen, have cut deeply into steel companies' earnings. Severe price competition from South Korean and Australian producers has registered an additional blow, though Japanese makers feel safe in the short term since the capacity of these rivals is still relatively small.

‘financial Times of London, "Steel Japan No. 1 and Still Gaining, " vol. 2, No. 17, Apr. .30-May 6, 1979.

> “At times of recession, ” says Hisao Kuzuoka, general manager of Kawasaki steel’s international department, “competition naturally intensifies, but we also realise that we cannot continue to export large amounts of crude steel. Therefore, the industry is putting emphasis on exports of technology to countries like China, Brazil and those in Southeast Asia, ”[19]

This drive for technology export, conducted by several Japanese firms working in consortium and with significant assistance from MITI and other government agencies, has achieved considerable success.

Regulatory Policies

From 1971 to 1977, Japanese capital costs for environmental compliance were 65 percent higher than U.S. levels. These higher investments were closely linked to capacity expansion taking place during that time; more recent expenditures have been below U.S. levels.[20] As is the case in Europe, Japanese steelmaker also benefit from favorable fiscal and loan policies for industrial equipment in general, and pollution abatement equipment in particular.

Third World and Developing Countries

The two principal policy tools of the developing countries are long-range planning and direct government assistance. Mexico, for example, has established a Steel Coordinating Commission to organize and advise both private and public companies engaged in the production of iron, coal, coke, and steel. The commission includes representatives from the Council of Non-Renewable Resources, the Ministry of Industry and Commerce, the Ministry of Finance, and the Office of the Presidency. The commission has helped plan two large steel plants, including the development of raw material supplies, transportation facilities, and housing. Significantly, the capacity of these and other steel facilities, when completed, will exceed the present demand for steel products within Mexico, and it is expected that much of it will be earmarked for export markets.

Brazil’s Conselho Nacional de Nav Ferrosos e de Siderurgia coordinates and supervises the national steel plan, which aims to increase steel capacity to 20 million tonne/yr by 1978-79. To reach this goal the Brazilian Government is expanding its holdings into the remainder of the private steel sector and is involving itself extensively in raw materials through the National Department of Mineral Production,

Venezuela, Peru, India, Iran, South Korea, Turkey, and Egypt have all developed 5-year plans aimed at expanding steel productions. Most of these plans are initiated, monitored, and implemented by the governments.

Financing

Mexico provides an excellent example of how developing countries use government-financed assistance in support of their steel industries. Both national and international financing organizations invest in Mexican steel. Siderurgica Lazaro Cardenas—Las Truchas SA (SICARTSA), a Mexican public-sector enterprise established in 1969, is building a steel plant with a first-stage production capacity of 1.2 million tonnes. Financial arrangements include a World Bank loan and a long-term loan, guaranteed by the Mexican Government, from a group of industrial nations. Related facilities, such as a railroad spur, enlargement of port facilities, and housing for workers, will be financed directly by the government. SICARTSA is 51-percent controlled by the government, 25 percent by National Financier (a government financing agency), 12 percent by Altos Hornos de Mexico SA (71.5 percent of which is government controlled), and 12 percent by private capital sources,

Specialty steel production in Mexico is being expanded by the same type of financing arrangements. Mexinox SA, a joint French-Mexican venture to establish Mexico’s first integrated stainless steel complex, has ob-

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“Tracy Dahlby, “Japan Seeks a Long-Term Strategy for Prosperity,” For Eastern Economic Review, Aug. 25, 1978,

‘(’Hans Mueller and K. E. Kawahito, op. cit., p. 27.

tained financial assistance from the International Finance Corporation (IFC), a World Bank affiliate, and the National Financier.

Brazil has initiated a broad program to increase its raw steel production capacity from 7.2 million to 20.2 million tonnes by 1980. The program will be carried out by three government-owned mills. Participants in the financing of these projects include the World Bank, the Inter-American Development Bank, the Agencia Especial de Financiamento Industrial (a Brazilian government agency), other local sources, and (by credits) certain foreign governments. Loans are guaranteed by the Federal Republic of Brazil.

CHAPTER 3

Problems, Issues, and Findings

Contents

CHAPTER 3

Problems, Issues, and Findings

Introduction

This chapter discusses 40 topics which, taken together, give a detailed view of the entire report supplementing the brief summary in chapter 1. Each of the 40 discussions is self-contained and usually draws from several chapters of the report.

Because each topic stands alone, the reader may tackle them in any order and may skip questions without sacrificing comprehension. Within each of the eight groups of topics, the higher priority problems or issues are addressed first.

The question-and-answer format should promote a fresh look at a number of longstanding and much publicized topics. Moreover, by defining a relatively large number of questions, attention is given to important problems, particularly of a long-range nature, which are normally hidden by short-range, crisis-type questions facing Government and industry.

Reasons for Congressional Concern

1 What does competitiveness mean?

The term "competitiveness" does not have much meaning when it is taken out of context. One oversimplified meaning of competitiveness is how much of a product is sold by one producer relative to another; in this sense, market share becomes the dominant measure of competitiveness. There are, however, many ways to sell more of a product than a competitor does, especially if maximizing profit is not a goal.

If profits are a secondary consideration, then prices are not necessarily linked to costs. A steel company may be price competitive and, indeed, may have a price advantage over other firms in the same marketplace, rather than mere parity with them; but it still may not be cost competitive. Cost competitiveness is determined by many factors, only one of which is the production technology; other factors include management, labor, capital investment, financial structure, marketing strategies, strength of national currency, Federal regulatory costs, and ownership of physical resources and technology. In many complex ways these other factors are also linked to technology.

Technological competitiveness refers to the type of technology used, the extent to which new technologies have been adopted, and the resources and infrastructure related to the creation of new technology, such as R&D facilities, staff, and funding levels.

In addition to price competitiveness, cost competitiveness, and technological competitiveness, there are considerations of product quality, performance, dependability, consistency, and range. Technology plays a role in some of these factors, too, particularly in the sense that the technology used to make steels will, to some extent, determine the physical and chemical characteristics of the steels produced. Customer service, including technical services, financing, and deliverability, is also important.

Lastly, Federal Government policies can affect competitiveness, particularly in the international market. Direct and indirect Federal support to steel producers can easily offset any competitive disadvantage a company or industry may have (see Topic 30). Policies that have the effect of limiting increases in capacity also limit the opportunities for adopting new technology and achieving maximum technological competitiveness.

2 Is the U.S. steel industry homogeneous?

Three factors can cause confusion in an analysis of the U.S. steel industry:

- There are a great number of companies involved in ferrous materials that are best not considered as part of the domestic steel industry.
- The domestic steel industry is not homogeneous.
- Some companies usually treated as steelmaker have diversified out of steel and are continuing to do so.

Companies not considered part of the domestic steel industry in this analysis include: foundries, ferroalloy producers, steel distribution companies, steel fabricating companies, companies producing or processing raw materials only (e.g., coal, iron ore, scrap, coke); and the design, construction, consulting, and equipment companies that serve steelmaker. In this analysis, the U.S. steel industry includes only those firms that at one point in their production sequence make molten steel and subsequently sell mill forms and perhaps some primary products.

Because the industry is not homogeneous, OTA has found it useful for purposes of analysis to distinguish three major segments:

- integrated steelmaker,
- nonintegrated steelmaker, and
- alloy and specialty steelmaker.

The first group, integrated steelmaker, convert iron ore to molten iron in blast furnaces, with coke as the reducing agent, and then convert the molten iron to commodity carbon steels in either basic oxygen, electric arc, or open hearth furnaces. The second group, nonintegrated steelmaker, do not have ore conversion facilities; they depend mainly on ferrous scrap to feed electric arc furnaces, and produce a relatively small range of simple, low-price carbon steels. The third category, alloy/specialty steelmaker, use a variety of processes to make higher priced, higher performance steels than those produced in the other segments.

Some companies may have plants in more than one of these three categories, and this makes company classification difficult: some integrated companies are installing scrap-based electric furnaces, and both integrated and nonintegrated facilities may also make alloy or specialty steels, Nonintegrated companies may be able to install direct reduction (DR) facilities to convert iron ore into solid iron that is substitutable for and superior to some grades of ferrous scrap in electric furnaces (see Topic 16). A company taking this route could become integrated, whereas a company purchasing direct reduced iron (DRI) would remain nonintegrated.

It is also difficult to classify steel producers by size. The term “minimill” was originally coined to describe nonintegrated producers who made relatively small amounts of steel, on the order of 45,000 tonne/yr. Many of these companies have grown substantially and now produce in the same range as the smaller integrated companies (up to 1 million tonne/yr); these facilities are now sometimes called “midimills” or market mills.

Diversification of steel companies out of steelmaking has made analysis of some issues even more difficult, particularly analysis of financial performance and R&D activities. (See Topic 8.) How a steel company that produces its own raw materials, such as coal and iron ore, figures its steelmaking costs greatly affects its profitability. Its input costs may be based on market price, actual production cost, or something in between. For some companies, the profitability of their steelmaking business is actually much worse than available data indicate, because the profits from their nonsteel operations offset steel losses. For example, according to one analysis, U.S. Steel Corp., the Nation's largest steelmaker (with 21 percent of domestic shipments), actually lost over $15/tonne shipped in 1978, although the corporation as a whole showed a net profit on investment of 5.3 percent.

3 Are other engineering materials displacing steel?

Steel has been and remains the most important engineering material in American society. It plays a vital role in all primary manufacturing and construction and is a strategic material that is especially and increasingly critical for economic and military security.

Domestic consumption of steel continues to increase, though at a slower rate than during the early stages of industrialization. In real terms, however, the consumption of steel has declined: during the 1950's, 230 lb of steel were consumed annually per $1,000 of gross national product (GNP) (in constant 1971 dollars), 194 lb during the 1960's, and 176 lb for 1970-77. The consumption of aluminum and plastics per $1,000 of GNP increased substantially during the same period. In recent decades, the growth rate in steel consumption has been approximately 2 percent per year; in aluminum, 6 percent; and in plastics, 8 percent. Nevertheless, the per capita consumption of aluminum and plastics is only about 60 and 140 lb annually, respectively, compared to approximately 1,000 lb of steel.

Although the use and role of steel appear to be declining according to some measures, many analysts believe that there will be a surge in steel demand as the steel-using structures, such as bridges, buildings, railroads, and primary manufacturing facilities, built in the United States during the last 50 years wear out. Furthermore, in many applications, there are still no cost-competitive performance substitutes for steel.

One frequently mentioned case in which other materials are being substituted for steel is in automobile manufacture. The need to reduce vehicle weight in order to meet fuel-economy standards has driven manufacturers to substitute plastic and aluminum for steel, even though these substitutes may increase costs. Much of the steel in an automobile cannot be economically replaced or eliminated, however, and the use of steel alloys to make strong, lightweight components is limiting further substitution of nonferrous materials. If automobile sales grow enough to outweigh the reduction in steel per automobile, there might even be a small net increase in steel consumption. If foreign automobile companies continue to increase their U.S. manufacturing operations and use domestic steel, this too could increase the consumption of steel for automobiles. It is still likely, however, that the use of steel in the automobile market will be steady or decline.

To the extent that aluminum, plastics, and cement can be substituted for steels, the consumption growth rate differences among these materials may reflect price differences. During the past two decades the average price for steel increased by about 30 percent in constant 1971 dollars, while prices for cement and aluminum stayed about the same, and prices for plastics decreased by about 40 percent. However, prices vary greatly within each material category.

Steel's future price competitiveness with other materials may improve as a result of energy and raw material cost changes, which have much stronger adverse impacts on aluminum and plastics. Aluminum prices have already started to increase sharply and will continue to do so as electricity costs increase in the future. The aluminum industry also is very dependent on imported raw materials, although new technology and increased recycling may lessen this dependence. Prices of plastics are dependent on natural gas and petroleum prices. Here, too, technological changes may improve the situation. In contrast, cementmakers can switch from oil and gas fuels to coal, and new cement technology reduces energy use by nearly half. Steelmaking already depends primarily on domestic coal and can use domestic ore and scrap as raw materials.

4 To what extent has the U.S. steel industry lost its ability to compete in domestic and foreign markets?

On the basis of price, product quality, customer service, and dependability, all three segments of the domestic steel industry are still competitive for the vast majority of steels in most domestic markets (see Topic 2). European steelmaker have higher production costs than U.S. companies, and although some foreign producers, such as Japan and a few developing nations, may have lower production costs for some steels, these cost advantages are not great enough to offset transportation and other costs associated with exporting to many inland U.S. markets. But other nations sometimes sell steel below costs—and possibly below their domestic prices—suffering economic losses in order to achieve social goals such as maintaining employment levels. Domestic trade laws and policies have not, from the industry's perspective, successfully eliminated "dumped" or unfairly traded steels from the market.

U.S. technological disadvantage, while serious, is not yet overwhelming; most innovations are not so unique as to rule out competition from older processes or products. Thus, although the domestic steel industry has very low levels of adoption for a number of new technologies and a very high percentage of obsolete facilities, it does have market and product competitiveness at the present time. The industry could be on the brink of losing its competitiveness in domestic markets, however, because it has little proprietary technology, low adoption rates for existing technologies, and insufficient capital for an ambitious program of plant modernization, expansion, and construction. In contrast, some foreign steel industries have already modernized considerably and are still expanding, using the latest innovative technology. In a few cases, where foreign producers also have abundant resources of energy, raw materials, and relatively low-cost labor, they could soon achieve a cost and price advantage over American producers in some domestic markets. Currency exchange rates also play an important role; a declining dollar in world money markets somewhat reduces foreign cost and price competitiveness.

The domestic industry's future ability to compete in its home markets will depend on: 1) the degree to which old, obsolete facilities are closed, 2) the level of investment in modernizing remaining plants, and 3) the rate of construction of new facilities based on technologies innovative enough to offer net cost reductions. With present limits on capital for investment, these steps can be carried out only with a net reduction of domestic steelmaking capacity; the remaining capacity, however, will probably be cost competitive in the domestic market. The closing of obsolete facilities is most likely in the integrated segment of the industry; in the other two segments, continued modernization and expansion are far more likely.

Domestic steelmaker are not competitive in foreign markets, with the exception of some technology-intensive high-priced alloy and specialty steels. Domestic producers of most commodity carbon steels do not have sufficiently lower production costs to be competitive after adding transportation costs and other costs of marketing in a foreign nation. Domestic producers of the high-technology steels lack experience in exporting and face trade restrictions in many nations, as well as stiff competition from other nations whose industries are often less profit-motivated than U.S. companies. Many foreign steel industries are directly or indirectly supported by their governments, especially in export activities (see Topic 32). Currency exchange rate changes may also favor the competitiveness of some foreign industries, and the unpredictability of these changes tends to dissuade domestic firms from developing export business. Nevertheless, the recently completed Multilateral Trade Agreement could facilitate exports by domestic steel companies; much depends on how effectively this agreement can be implemented and enforced (see Topic 33).

5 How does the R&D effort of the U.S. steel industry compare to that of foreign industries?

There has been a steady decline in domestic industrial R&D in steel (see Topic 25). The current emphasis is on using existing technology to solve immediate problems in order to secure a fast payoff rather than creating new knowledge, new technology, and major new opportunities. In this respect the United States is more similar to the Japanese steel industry than to the West German, French, British, or Swedish. These European industries place great emphasis on new knowledge and major innovations. Japanese "innovation," on the other hand, is more an efficient (and often brilliant) application of technical knowledge to a particularly well-chosen problem, in order to obtain maximum economic benefits rather than a profoundly new scientific concept. But despite this conceptual similarity, the United States lacks Japan's closely integrated, symbiotic industry-government-university R&D infrastructure, and this may prevent its reaching the level of success the Japanese enjoy.

In the U.S. steel industry, R&D personnel usually do not have a major role in the strategic planning decisions of the firm, not even those regarding adoption of new technology (see Topics 24 and 26). The R&D function is not well integrated into the corporate structure: the emphasis is on new products, and R&D is more closely connected to sales and marketing than to production or corporate planning. Production problems may be worked on and solved by R&D, because production problems quickly manifest themselves in poor corporate performance; but the strong, continuous flow of creative ideas and useful information from production to R&D, which could stimulate innovative work, is lacking. This is in marked contrast to Japan and some developing nations, where there is a much closer relationship between production and R&D personnel. R&D programs have the prestige to attract capital and talent in Japan; except for a few companies in the United States, R&D is regarded as a service function, particularly technical service to customers, rather than a long-term investment for the future.

In European steel industries there is more mobility of technical personnel among firms, universities, and government facilities than in this country. Working on R&D is highly regarded in all of these sectors, and the very best scientific and technical personnel are attracted to R&D activities. The economic plight of these industries seems to intensify their use of R&D, rather than to diminish its importance as in the United States. Much of R&D effort in European universities and research institutes is government funded; in the United States, there has been a decline in academic steelmaking programs largely because of a lack of Government support. There are no national institutes for steel R&D, such as those in West Germany, in which companies join with university personnel in long-range R&D projects, including a great deal of basic research.

Consequences of Continuing Loss of Competitiveness

6 In future periods of strong world demand, what would be the consequences of contraction of the U.S. steel industry and increased imports of steel?

Contraction of the domestic steel industry can improve the profitability of individual companies. However, increased dependence on imports could, in periods of strong world demand, place the United States in a shortage and price situation similar to that stemming from the dependence on foreign oil. Many analysts contend that consumers benefit from low-priced imported steels and that imports should be allowed to increase. The attempt to hold down unfairly traded imports through the trigger-price mechanism has also had the effect of raising import prices.

The industry view is that, except in times of world oversupply, domestic steels are cheaper than most imports and that, in times of tight world supply, import prices are markedly higher than those permitted for domestic steels. This was the case during 1973-74, when import prices were as much as $110/tonne higher than domestic prices. The industry also notes that increasing dependence on imports reduces domestic employment, makes long-term investments in technology difficult, affects national security adversely, and contributes significantly to the trade deficit.

The cyclical nature of the domestic and world steel industries determines import prices. During the past several years, imports have risen to relatively high levels—about 18 percent of domestic consumption, not counting the steel in imported products such as automobiles. Domestic demand and capacity utilization have been relatively high, but world markets have been depressed, foreign capacity utilization has been low, and steel has been in oversupply. Thus, after the 1973-74 short-supply period, imports have been relatively cheap.

However, there is a distinct possibility that worldwide supply will tighten within the next 5 to 10 years. Even as demand steadily increases, many industrialized nations (including Japan, apparently) will be maximizing capacity utilization and profitability by closing obsolete facilities, reducing the number of products made, and designing modern capacity for largely domestic demands. Many steel industries, particularly in Europe, would like to avoid the large losses that have occurred in the past, when capacity was geared to exports and peak demand levels. The large increase in Third World steelmaking capacity will also turn traditional exporters toward their domestic markets. The result could be a very tight supply situation in the worldwide export market, with excess capacity to be found only in a few energy-rich less developed countries (LDCs). Even if steel imports should be available in such a period, their price would probably rise dramatically, both because of normal market forces and because steel from recently built plants (with high fixed financial costs) will cost more than steel from old plants.

7 Do the low profits of the domestic steel industry make it an unattractive investment?

The profitability of the steel industry, compared to other domestic manufacturing industries, is poor and getting worse. The average return on equity for the steel industry during the 1950's was 10.7 percent; during the 1960's, 7.8 percent; and during 1970-78, 7.6 percent, as compared to 11.3, 11.2, and 12.5 percent, respectively, for all manufacturing, Thus, the ratio of steel profitability to that of all manufacturing industries was 95, 70, and 61 percent for the above periods. Even though steel sales and profits are cyclical, the industry's better years do not offset its poor years.

Compared to those few foreign steel industries operated for profit, however, the U.S. industry is one of the most profitable. Comparisons with Japan are difficult to make because the Japanese industry is so highly debt financed, almost twice as much so as the U.S. steel industry, with banks having ownership in the form of loans so that return payments take the form of interest rather than dividends. Only the much smaller Canadian steel industry, with its much shorter depreciation schedule (2-1/2 years v. 12 years in the United States) is significantly and consistently more profitable than the U.S. steel industry.

When the industry is disaggregated into its three major segments, the financial data reveal that the nonintegrated and alloy/specialty producers have markedly higher profits than integrated companies. For example, in 1978 the average return on investment for 12 integrated companies (accounting for 63 percent of domestic shipments) was 6.2 percent; for 6 nonintegrated producers (accounting for 61 percent of their segment's shipments) the average was 12.3 percent; and for 9 of the major alloy/specialty companies the average was 11.1 percent. (For the last segment import quotas were in effect for several years.)

The financial data for the integrated companies are somewhat misleading because substantial nonsteel business is generally included. Without nonsteel profits, financial results for integrated companies would be substantially worse; indeed, for some companies steelmaking itself generally loses money. In contrast, the best performing of the nonintegrated and alloy/specialty companies have profitabilities considerably above the averages for their segment and are often considered growth companies. (For example, an outstanding nonintegrated producer has had an annual growth rate of close to 40 percent for earnings and production during the past 10 years.) These are precisely the companies that use the latest technology.

Most steel companies have increased their borrowing, although their debt limits may have been reached. The low-profitability companies are generally viewed as poor investment opportunities, but it can be argued that this is a consequence rather than a cause of their underinvestment in new technology, since investment capital is generally linked to perceptions of future success rather than past performance.

There is considerable evidence of continued financing of foreign steel industries by U.S. banks and financial institutions. However, it is not clear that, as some industry leaders have asserted, domestic steelmaker have been unable to secure comparable financing from the same sources. During the past 10 years, the debt-to-equity ratio for the entire steel industry rose from 36.5 to 44 percent, indicating that financing has been available. In this same period, stock dividends remained relatively stable and high, totaling $5.3 billion as compared to $4.1 billion for interest and charges on long-term debt.

Foreign investments in and purchases of domestic steel companies have been increasing as a result of undervalued stocks, a weak dollar, decreasing domestic competition and capacity, increasing domestic demand, relatively abundant domestic resources. and highly efficient labor. This trend toward increased foreign participation in U.S. steel companies is likely to accelerate, particularly for nonintegrated companies with good profitability.

8 What will be the impact of continued diversification into nonsteel operations by domestic steel companies?

There is some controversy about the impact of diversification on steelmaking capacity and investment in new technology. On the one hand, industry maintains that nonsteel profits help finance steelmaking. On the other hand, critics outside the industry contend that diversification siphons off investment capital needed for new technology and contributes significantly to the decline of domestic steelmaking capability.

For the past 2 years, domestic capacity has declined by at least 1.8 million tonnes, or 1.5 percent of raw steel capacity, per year. It appears likely that this rate of decline will continue for the next several years as unprofitable plants continue to close. The actions of the Nation's two largest steelmaker, U.S. Steel Corp. and Bethlehem Steel Corp., accounted for much of this capacity reduction. During the past 3 years, U.S. Steel's nonsteel assets grew by 80 percent, to $4.7 billion, while steel assets increased only 13 percent, to $5.9 billion, and capacity actually decreased. Although Bethlehem Steel has not undertaken major diversification, it has reduced its steelmaking capacity by closing obsolete facilities to improve its profitability. U.S. Steel is apparently now doing the same,

Diversification out of steel is likely to continue. This contributes to declining, but more modern and competitive, domestic steelmaking capacity. The net result, however, is likely to be a further increase in imports. The nonintegrated producers (whose profits are healthy) may continue to expand, but they are too small to reverse the decline in overall capacity.

Industry argues that, without diversification into profitable nonsteel activities, more plants and perhaps whole integrated companies would simply shut down. In this case, the demise of the Nation's steel industry would be much faster and more dramatic than if present slow shrinkage continues, and the social dislocations would likely be severe enough to require substantial Government intervention.

9 Does the domestic steel industry have the capability to innovate, or has it become dependent on buying proven foreign technologies?

Innovation requires new knowledge, inventions, capital, highly competent and creative people, risk-taking, determination, and excellent insights into existing and potential markets. The steel industry knows enough about domestic markets and its own process needs to utilize market-pull insights, but it does not appear to have sufficient profitability to support a level of capital formation that would create an R&D base strong enough for future innovation. Considering the low levels of basic research and R&D in the industry itself, as well as in universities and Government laboratories, it is doubtful whether the domestic industry now has the capability to create major process or product innovations (see Topics 5 and 25). However, it undoubtedly has a significant capability to create incremental innovations.

Because the industry lacks adequate capital for high-cost innovation, it leans towards purchasing patent rights, technology, and know-how from foreign steel companies, from foreign research, consulting, and technology transfer companies, and from domestic design, consulting, construction, and equipment companies. Often, these latter domestic companies are acting as agents for foreign-owned technology. Foreign technology, if adopted at a sufficiently rapid rate, can provide competitive parity, but not competitive advantage.

Paradoxically, during the past few years, when the U.S. steel industry has been more profitable than almost all foreign steel industries, foreign R&D and innovation have accelerated. There has been a steady stream of foreign inventions and innovations that are likely to place foreign industries at a distinct advantage and to exacerbate American dependence on foreign technology. Developing nations have produced impressive numbers of innovations that place great emphasis on suiting their fast-growing industries to the efficient use of local resources and conditions. Some developing nations are pursuing strategies of exporting their production rather than merely using this production at home and reducing imports. These countries also export technology to industrialized and less developed nations.

Factors Affecting Competitiveness

10 What factors are most important in determining total production costs, both domestically and abroad?

Unusually large cost increases for raw materials were responsible for most of the 133-percent increase in domestic steel production costs during the 1970's, Although hourly employment costs are higher than the all-manufacturing average and recent increases have been considerable, the relative significance of unit labor costs is declining as a result of skyrocketing raw material costs, particularly for energy. During the past decade, raw materials (including energy) were responsible for almost 60 percent of the total costs of producing a tonne of steel in the United States; labor, for slightly more than 30 percent; and financial costs, for about 9 percent.

Although financial expenditures are generally a small fraction of production costs, they have important indirect effects on the productivity of equipment, labor, and energy. In turn, improved factor productivity plays an important role in determining total production costs. Thus, the indirect impact of financial costs on total costs is much greater than their share of total production costs would indicate, because increased capital expenditures decrease the per-unit costs of other inputs. American steelmaker have also benefited from high operating rates and a declining dollar over the last decade (see Topic 13).

Foreign steel industries have a roughly similar breakdown of production costs. During the early 1970's, both materials and financial costs abroad were a somewhat larger share, and employment costs a smaller share, of total production costs than in the United States. During the past decade, however, despite major increases in raw material costs, particularly for energy, all major producing countries except the United States have slightly reduced the proportion of raw material costs in total costs. Only in the United States have materials and energy costs increased at a much faster rate than either employment or financial costs. This is probably a consequence of lower domestic energy prices (which are only now reaching international levels), smaller energy conservation improvements than in some other countries, and greater foreign financial costs.

Major European and Japanese steelmaker, since at least the late 1960's, have made larger capital investments than U.S. producers relative to their total steelmaking costs. In Europe, financial costs hovered between 13 and 17 percent of total production costs during most of the decade. Japan, already burdened with a financial cost component of 20 percent, was the only major producing country in which financial costs increased faster than either employment or raw material costs.

Many of these differences result from the high debt-to-equity ratios of foreign industries and the higher value of new assets requiring financing. This is particularly true of the Japanese steel industry, whose accelerated investment has resulted in the construction of larger plants with optimum layout and process control and, consequently, higher productivity of raw materials, energy, and labor. The fact that Japanese producers continue to have lower production costs, despite currency changes favoring U.S. producers, can be explained largely by their investment strategies.

The average 1978 cost of Japanese steel (f.o.b. Japan) was about $385/tonne (materials, labor, capital costs) —some 10 to 20 percent below U.S. production costs. But the additional costs for exporting the steel—including transportation, warehousing, sales, and marketing— must be added to production costs. These costs are substantial, and transportation costs in particular are steadily increasing, These export costs may offset any advantage in production costs, as is usually the case for Japanese steel exports to the United States, especially for inland locations.

During the next several years, total production costs (in dollars) for the major producing countries are expected to draw closer, with an approximate 15-percent margin between the highest (France) and lowest costs (Japan). In local currencies, Japanese and West German total production costs have increased at a much slower rate than U.S. costs. Japan is expected to retain its present leadership in total production costs, and West Germany and Japan are expected to continue as leaders in the more efficient use of raw materials, with cost increases at only about half the U.S. rate. Furthermore, materials costs in these countries are expected to remain a smaller proportion of total costs than in the United States.

With respect to near-term capital investments, Japan is expected to continue its current strategy of slowing down its plant construction program, while continuing to introduce more energy-saving equipment. Depending on actual operating rates, Japanese financial expenditures will decrease or only marginally increase during the next few years. Relative to their current production costs, the French and British steel industries are expected to be the major benefactors of restructuring and modernization among major steel-producing nations. Nevertheless, these countries will likely remain noncompetitive.

11 What are the impacts of environmental regulations on the competitiveness of the U.S. steel industry?

Compared to other basic industries, steel is faced with a major environmental cost burden. This may be attributed in part to the fact that most steelmaking processes were developed (and most facilities constructed) during a time when environmental considerations were an insignificant factor in equipment design. There has been little recent construction, which might allow the incorporation of environmental technology, and the industry has been forced to follow the less efficient retrofit approach.

The steel industry has reported environmental equipment expenditures from 1969 to 1978 averaging $280 million per year, or about 13 percent of annual capital investments. Future regulatory investments will increase to between $550 million and $800 million annually, according to Federal and industry estimates respectively. In addition, the industry will incur substantial costs in operating and maintaining environmental control equipment, particularly for increased energy use. Steelmaker have estimated that future environmental costs will be about 20 percent of the industry's total capital investments per year.

Industry claims that regulatory costs have contributed to low profitability and capital formation, particularly because the regulations apply to the large number of old plants, not just new ones. This claim cannot be disregarded, but neither can the important benefits of health and environmental regulations for steelworkers and society as a whole. New plants benefit from optimal control technologies and lower compliance costs, but the U.S. industry is not likely in the foreseeable future to build completely new integrated plants like those in Japan and the LDCs. To some extent, compliance with environmental regulations can even be used by management to justify reduced investments. The Environmental Protection Agency (EPA) stresses compliance, while the industry is concerned about modernization. Both are worthy social goals, and it may be possible to reconcile them through innovative technology that is environmentally cleaner than existing processes.

U.S. regulatory costs are expected to increase over the next several years because firms are still in an earlier stage of compliance; Japanese steelmaker, whose pollution abatement investments have until recently been higher than U.S. levels, are beginning to enjoy an opposite trend. If other major steel-producing countries should in the future face similar levels of environmental costs, the financing of environmental expenditures could become an important factor affecting international competition. In the United States, environmental costs are borne directly by producers and indirectly by consumers only to the extent that Government and the marketplace permit these costs to be passed on in the form of higher steel prices. Industry claims that Government has not permitted enough of the costs to be passed on, and to the extent that Government has limited price increases and allowed the entry of unfairly traded imports, industry's claim is justified. Steel producers in other major industrialized nations generally do not need to rely on the market mechanism to distribute their environmental costs, because those industries often are government owned or financed. Direct or indirect government support programs help them finance environmental expenditures, perform environmental R&D, or gain more favorable tax laws.

As steelmaker from developing nations, such as Venezuela, Mexico, Brazil, and South Korea, increase their share of the international market, these producers will join those in the European Economic Community (EEC) in having an international trade advantage over the United States in the form of lower environmental costs or greater government assistance to meet compliance costs. In a world industry in which profits are low or absent, environmental costs can be significant even though they may amount to only a small percentage of total costs.

12 What are the potential impacts of OSHA regulations on the steel industry?

The Occupation Safety and Health Administration (OSHA) was established by Congress in 1970, but thus far OSHA regulatory costs have been rather limited. They are the steel industry's greatest regulatory uncertainty: the costs to industry of OSHA regulations are not well understood, and information on future costs is speculative. As enforcement activities gain momentum and regulatory costs increase during the next several years, more detailed reporting systems and analyses will probably be developed.

The industry reported OSHA-related expenditures of about $4 I million for 1977, Expenditures in 1978 and 1979 are estimated to have totaled about $80 million, When judicial challenges are settled, and the Agency begins actively enforcing major regulations affecting the steel industry, these expenditures may increase considerably. In a number of cases, however, environmental and occupational regulations overlap, so that combined regulatory costs will be less than those for EPA and OSHA evaluated separately and summed. Cokemaking will remain the industry's main occupational health hazard for the foreseeable future. Thus, integrated producers, especially the older and smaller ones, will be affected more severely than others in the near future. However, anticipated revisions in noise and metallics standards could have a substantial impact on all industry segments.

OSHA has little specific statutory guidance on questions of technological or economic feasibility. It can require the transfer of promising abatement technologies between industries, but it cannot require major private-sector R&D to develop such technologies. Its standards may not be "prohibitively expensive" or disrupt a whole industry, but OSHA is not required to consider the impact of its regulations on the profit margins or viability of individual companies. Under these circumstances, the industrial sector has developed a strong interest in cost-benefit analysis. Although the industry is able to provide cost data, the Government and labor interests have had difficulty providing a dollar figure for safety and health benefits. A Supreme Court ruling is expected soon on this controversial subject.

Another problem is how the costs of OSHA regulations should be distributed. To the extent possible, the industry passes these costs on in the form of higher prices. However, industry claims that Government policy restricts price increases.

There is inadequate information on the effect of OSHA's regulations on international competitiveness. On the whole, producers in other industrialized nations are also faced with increasingly stringent regulations, but they generally enjoy government assistance or tax privileges in financing health and safety expenditures. Thus, for comparable requirements, U.S. steelmaker are typically at a competitive disadvantage. At least for the time being, producers in developing countries have the greatest advantage because they have the fewest occupational health and safety requirements.

13 What is the impact of domestic labor productivity on international cost competitiveness?

There is considerable disagreement on international comparisons of labor productivity. However, most sources suggest that the U.S. steel industry no longer leads its international rivals in labor productivity as measured by man-hour requirements per tonne of steel. Japan has overtaken the United States as the world's leader in labor productivity because of differences in labor/management relationships and because of Japan's greater investment in new technology.

Since at least the early 1960's, the U.S. steel industry has had a lower labor productivity growth rate than the average either for other U.S. manufacturing industries or for foreign steel industries. Nevertheless, actual domestic labor productivity levels remained competitive with international rivals until the mid-1970's. Japanese steel labor productivity probably exceeded that of the United States for the first time in about 1975.

Looking into the mid-1980's, it is expected that labor productivity growth rates will be the highest in Europe, followed by the United States and Japan. Even assuming a continuing phaseout of older U.S. plants, Japan is likely to maintain its lead in labor productivity. Between now and the mid-1980's, Japanese man-hour requirements are expected to be reduced by 3 percent per year; by then they will be only 90 percent of U.S. requirements. Of the major European countries, only West Germany is in a position to approach overall U.S. labor productivity levels by the mid-1980's.

Because labor productivity is closely related to the capability of the equipment being used, it is a good measure of the technological competitiveness of the domestic steel industry. What matters even more on the international market, however, is the interaction between labor productivity, hourly employment costs, and currency values. These factors, taken together, determine unit (per tonne) labor costs,

From 1969 to 1978, the declining value of the dollar has had a major offsetting impact on high hourly employment costs, and U.S. steelmaker experienced small improvements in unit labor costs compared to other steel-producing countries. U.S. labor productivity improved modestly compared to its major competitors, but foreign hourly employment costs (in dollars) rose 1-1/2 to 3 times faster than in the United States. As a result, U.S. unit labor costs moved from highest to second lowest, and they are currently only about 25 percent higher than Japan's, which remained the world's lowest during the entire period.

The United States generally has enjoyed more favorable capacity utilization rates than its competitors during recent years. During the past 7 years, U.S. operating rates have been very high—more than 85 percent —while EEC and Japanese rates averaged slightly more than 70 percent. High operating rates increase equipment and labor efficiency and reduce unit labor costs.

The United States is not expected to maintain its favorable international position with respect to unit labor costs into the mid-1980's. Assuming the European steel industry reduces capacity and narrows its product lines, West Germany and perhaps England are expected to reduce their cost below the United States; Japan is expected to continue its clear lead until well into the mid-1980's.

Depending on actual operating rates, U.S. near-term productivity growth rates will continue to be no more than half of Japanese and West German growth rates. Furthermore, some foreign currencies are expected to increase in value relative to the dollar at a much lower rate than during the past decade; if so, international monetary changes would favor U.S. steel producers less than they have previously.

New Technologies for U.S. Steel making

14 Can new technology help solve major industry problems of competitiveness, capacity, and capital?

Long-range planning for and expedient adoption of a variety of new steel technologies could effectively reduce production costs, thereby improving competitiveness and slowing the rate of decline in domestic steelmaking capacity. The new technologies also might have lower capital requirements than more conventional technology for similar levels of capacity replacement or expansion.

There is particular need to recognize the self-fulfilling aspect of the description of steel as a "mature" industry (see Topic 24). The industry must recognize that the economic, social, and political world in which it operates is changing and that technology must be used to cope with externalities as well as to produce steel. There are substantial opportunities for change and innovation. New technologies, some already commercially available and others with significant likelihood of successful development and demonstration, could potentially reduce energy consumption, improve yield, reduce use of coke, improve labor productivity, reduce capital costs, allow greater use of domestic ferrous scrap and low-grade coals, permit faster construction of new plants, and offer greater flexibility for importing certain raw materials and semifinished steels rather than finished steel products.

15 What is the most important technological change for domestic steelmaking during the next decade?

Two major changes in steelmaking have developed since World War II. Basic oxygen steelmaking has already been widely adopted by the integrated segment; continuous casting has not, even though it is a well-proven and accepted technology.

Simply put, continuous casting replaces with one operation the several steps of ingot casting, mold stripping, heating of ingots in soaking pits, and primary rolling of ingots into various shapes. The basic concept in continuous casting is the use of an open-ended mold to cast an indefinite length of the desired cross section. The molten steel solidifies from the outer cooled surfaces inward during the casting process, and the semifinished slab, bloom, or billet that emerges can be cut into desired lengths.

The main benefits of continuous casting over ingot casting are:

- It saves a considerable amount of energy directly by eliminating energy-intensive steps and indirectly by reducing scrap and thereby increasing yield; the sum of direct and indirect energy savings is approximately 3.3 million Btu/tonne cast, or almost 10 percent of total steelmaking energy consumption.

- It increases process yield, in that more finished steel is produced from the same amount of liquid steel, thereby reducing all unit costs.
- It improves labor productivity by eliminating a number of steps, increasing yield, improving worker conditions, and sharply reducing production time.
- It produces a better quality of steel because it requires fewer production steps and allows greater automatic control of the process.
- It reduces pollution by eliminating soaking pits and reheating furnaces, reducing primary energy requirements, reducing exposure of hot steel to atmosphere, and requiring less primary ironmaking and cokemaking because of the increase in yield.
- It reduces capital costs compared to ingot casting and, considering the overall yield and economic advantages, compared to other means of increasing steelmaking capacity.
- It increases the use of purchased scrap (where iron output is constant and steel output increases) to replace the scrap lost because of improved yield (see Topic 21).

These advantages are not being fully captured by the domestic steel industry, because it has fallen behind almost all other steel industries in the adoption of continuous casting. For example, in 1978, Japan continuously cast 50 percent of its steel, the European Community 29 percent, but the United States only 15 percent. Although U.S. adoption is increasing, so is that of foreign industries.

Nonintegrated facilities, by and large constructed quite recently, continuously cast at least 52 percent of their raw output in 1978, but they produce less than 10 percent of domestic raw steel. For the integrated companies who produce approximately 87 percent of raw tonnage, the lag in adoption of continuous casting is even worse than the published figures indicate.

The reasons for the low domestic adoption rate of continuous casting include the following:

- The industry has inadequate discretionary capital with which to replace existing, and perhaps not fully depreciated, ingot casting facilities.
- Substantially modifying an operating plant is difficult and costly.
- Additional capital costs would be incurred in constructing downstream facilities to process the increased semifinished steel production.
- There are technical problems with some types of steels and perhaps with small production runs.
- There are difficulties in expediting EPA permits and compliance costs linked to the granting of such permits.
- Uncertainties exist about the extent to which future steel imports will capture domestic markets.

Nevertheless, the overall economic benefits of continuous casting justify greater adoption. A key question is how much continuous casting could and should be adopted by the American steel industry, and in what time frame. OTA finds that, to achieve increased technological competitiveness at a minimum cost, 50-percent continuous casting is needed for the whole industry by 1990. Technically, this goal appears to be feasible; but even though returns on investments in this technology could be approximately 20 percent or greater, there is probably insufficient capital now and in the foreseeable future (given present price levels, import levels, and Federal policies) for this large an increase in the use of continuous casting.

16 What other major new technologies could aid the domestic industry during the next 10 to 20 years?

During the 1990's, several radical changes in steelmaking could occur:

- direct casting of sheet and strip from molten steel, which would save considerable energy, time, and labor;

- direct, one-step steelmaking (from ore to molten steel), which might reduce all costs;
- plasma arc steelmaking, which may offer a low-cost alternative to the blast furnace, particularly suitable for making alloy steels and for use by small plants; and
- formcoking, which offers the possibility of an environmentally clean way to make coke from low-grade coals, while still producing valuable byproducts (see Topic 20).

But the technological development with the greatest advantages and best possibility of limited commercial adoption within 5 to 15 years is coal-based DR of iron. DR refers to a number of processes that are alternatives to blast furnaces for converting ore to iron. DR processes typically involve lower temperatures than do blast furnaces and use solid-state ore conversion. Natural gas is the simplest reductant to use, but low-grade coals (which the United States has in abundance) can be used directly as the reductant, as can the products of coal gasification. The capital costs of DR plants would be relatively low, and by replacing both blast furnaces and coke ovens DR could revitalize integrated plants. DR might have a greater impact on nonintegrated steelmaking than continuous casting, particularly if small units become commercialized, if merchant DR plants are constructed, or if imported DRI becomes readily available.

There are several ways in which the Nation could benefit from greater use of DR:

- DR might be used by integrated steelmaker in conjunction with coal gasification plants to create new ironmaking capacity at competitive cost.
- DRI can be used as a substitute or complement for scrap and could have a moderating effect on scrap prices as demand rises and less usable scrap is generated.
- DRI also can be used as a substitute for ore in blast furnaces to improve their productivity and thus reduce the amount of coke required to fuel them; greater use of DR would reduce our growing dependence on imported coke and would reduce pollution from coke burning, the greatest source of dangerous pollution in steelmaking; DR might also be based on available coke oven gas, with a net economic advantage.
- DR can be used with other technological developments that are on the horizon, including nuclear steelmaking, which the Japanese are developing for the year 2000, and magnetohydrodynamic steelmaking, expected in the 21st century.

Yet, there has been little domestic investment in DR, largely because: 1) integrated companies are committed to blast furnaces and coking, which uses company-owned metallurgical coke, 2) relatively low-cost scrap is readily available, 3) future steel import levels are uncertain, and 4) R&D capital is limited. Some domestic companies have studied DR technology and have attempted to develop gas-based processes, but thus far the results have not compared with those of improving blast furnace efficiency.

Gas-based DR is undergoing rapid expansion in nations with abundant natural gas; several such plants exist in Canada and Mexico. Several coal-based DR processes have been used for a number of years on a relatively small scale, particularly in South Africa and Brazil, with varying levels of success. A number of foreign firms, especially in Sweden, are aggressively developing new processes based on coal, some of which promise energy savings. A very attractive American coal-based DR process—the Calderon Ferrocal process—is now ready for demonstration.

DRI is likely to become a world-traded commodity in the years ahead, especially by nations like Venezuela and Mexico that have large supplies of natural gas, If the U.S. steel industry does not build domestic DR facilities, it may find itself importing DRI in great quantities as nonintegrated mills expand and scrap becomes more expensive. With DR facilities and huge reserves of coal, the United States could satisfy its own steelmaking needs and perhaps export coal-based DR technology; instead of exporting scrap, it might export DRI.

17 What incremental or evolutionary technological changes will be significant for the next several decades?

Literally hundreds of incremental technological changes are likely during the next several decades, including the creation of new steels. The following are most significant on the basis of likelihood of successful development, economic benefits, energy savings, and large-scale applicability to most of the domestic steel industry:

- External desulfurization, which removes sulfur from molten pig iron rather than having it removed in the blast furnace, could be used very widely. This process can use high-sulfur coal and thereby reduce coke use.
- High-temperature sensors would allow better control of crucial variables during the finishing stages, and thus offer improved quality control, increased yield, energy savings, and improved labor productivity y.
- Energy recovery techniques are possible—for example, the use of blast furnace top-gas pressure to generate electricity, the use of steelmaking furnace gases, and the recovery of waste heat from furnaces.
- Continuous (direct/inline) rolling could avoid intermediate cooling and reheating of ingots, slabs, or billets by rolling or forming continuously cast products without any break in the processing sequence.
- Self-reducing pellets, which are a combination of finely divided iron oxide from ores or wastes, carbonaceous material, and fluxes, can be used in blast furnaces or in DR furnaces to obtain iron in relatively short times.
- Computer process control (automation) can improve process efficiency and product quality.

Impacts of New Technologies on the U.S. Steel Industry

18 How **would technological changes affect the restructuring of the domestic steel industry?**

Industry restructuring refers to shifts in methods of production, nature of products, size of firms, rate of technological change, raw materials used, or types of markets served. A significant restructuring of all three segments of the industry—integrated, nonintegrated, and alloy/specialty producers—is already in progress. Technological changes are playing an important role in this restructuring, which is best understood as a change in the relative importance of each segment and a trend toward decentralization of the industry. Restructuring is also shaping technological needs.

The dominance of integrated plants is declining. This results from increasing advantages of plants of the other two types and from structural changes in the integrated firms themselves. These changes include: 1) shifts in the raw material used, primarily from original domestic sources of iron ores to the lower grade taconite ores and to imported ore; 2) shifts in markets from the Northeast and North Central States to those in the South and West; 3) increasing concerns over heavily concentrated sources of pollution; 4) greater oscillations in market demand; 5) a gradual physical deterioration of old plants and inadequate capital to construct new plants; and 6) significant changes in the technology of steelmaking, which require a fundamentally new plant layout to achieve maximum efficiency.

The steadily increasing growth of nonintegrated firms is difficult to quantify precisely because accurate and comprehensive data distinguishing nonintegrated from integrated producers are not collected by Federal agencies or trade associations. However, during the past decade this industry segment has roughly tripled its output. In 1978 the nonintegrated producers accounted for approximately 10 percent of raw steel tonnage and 13 percent of all domestic shipments; their dollar share is smaller because their plants produce lower price steels.

Factors promoting growth of the nonintegrated segment include: 1) markedly lower capital costs per tonne of annual capacity and much shorter construction times than integrated plants; 2) the availability of relatively low-cost, local ferrous scrap; 3) increasing numbers of large local markets; 4) rising transportation costs, which improve competitiveness of local suppliers using local resources; 5) relatively low-cost electricity (in comparison to integrated steelmaking fuels) and low energy consumption; 6) highly efficient, and improving, process technology consisting primarily of electric arc furnaces and continuous casters; 7) use of nonunion labor in less industrialized regions; 8) high labor productivity; 9) less import competition among the lower value steels; 10) fewer environmental problems and lower control costs; 11) an advantage over integrated producers in times of slack steel demand because the cost of scrap declines, whereas the cost of iron ore does not; and 12) relatively low entry costs,

The future growth of the nonintegrated segment will depend on shifting their production to more complex and higher priced steels, including perhaps alloy and specialty steels. This trend is already beginning, but it would be accelerated by introducing DR facilities in nonintegrated plants; by increasing the number of merchant DR plants, which serve many steelmaker; or by importing DRI. The use of a combination of DRI and scrap would have technical and economic benefits that would promote the expansion of nonintegrated firms. The next most important technological development would be the introduction of small rolling mills for sheet and strip suitable for nonintegrated plants, which do not now make flat steel products. This is beginning. Even in the absence of flat product manufacture, nonintegrated firms could greatly increase their production, perhaps by 100 percent in the next 10 years, but cost and availability of scrap and electricity will be important determinants. Very low R&D levels may inhibit future growth and cost competitiveness.

The alloy/specialty segment is increasing largely because of the ever-increasing use of such steels for demanding applications. During the past 10 years, shipments of alloy steels increased from 9.4 to 12 percent of all domestic shipments. Technologically, the firms in this segment are advanced, innovative, responsive to market demands, and competitive with any foreign industry. Apparently, they used several years of import quotas effectively to improve their competitiveness. They tend to be the lowest cost producers for the domestic market and for many foreign markets as well. Specific new technologies that offer promise for these companies are: powder rolling for the direct production of sheet and strip from alloy powders, plasma arc melting furnaces for improved melting and alloying efficiencies, and greater use than at present of recycled high-alloy-content waste materials. It is noteworthy that some integrated companies have shifted toward producing more alloy and specialty steels.

The alloy/specialty segment might also be able to export more of its products, although there is some uncertainty about the future. Quotas on imports of steels in this segment are being removed; foreign producers would like to export these higher priced, higher profit products, and significant excess foreign capacity exists for producing some of these steels. Domestic companies are concerned that the Government vigorously enforce the new Multilateral Trade Agreement to support exports and prevent the entry of unfairly traded imports (see Topic 33).

19 How will future technological changes affect the amount and type of energy used by the domestic steel industry?

The steel industry is the single largest industrial user of energy in the Nation, accounting for close to 5 percent of total consumption. Just over 60 percent of the energy used in steelmaking derives from metallurgical coal, approximately 20 percent comes from natural gas, somewhat more than 5 percent is from oil, and about 5 percent is purchased electricity. The steel industry is the second largest user of electricity after the aluminum industry.

In 1978, integrated plants used an average of 35 million Btu/tonne of shipped products, whereas nonintegrated plants making carbon steels used an average of 10 million Btu/tonne shipped. It must be noted, however, that nonintegrated plants do not reduce iron ore to iron and generally make simpler products which require less processing than others. A goal established pursuant to the Energy Policy and Conservation Act is to reduce the steel industry's energy use by 9 percent by 1980. The industry indicates that it will meet that target. Even without that motivation, the industry has a financial incentive to reduce energy use. Ten years ago, energy accounted for about 10 percent of steelmaking costs; today, it is more than 20 percent.

A great many technological changes are helping the industry to reduce energy consumption. The most significant is the increasing use of continuous casting, which can lead to almost a 10-percent reduction in energy use for integrated plants. The second most important change is the ever-increasing use of scrap-based electric furnaces, which, because they do not require the production of new iron units from ore, use considerably less energy than integrated production. The shift to more continuous casting reduces coal, fuel oil, and natural gas consumption; and although the shift to electric furnaces increases the industry's use of purchased electricity, it reduces total energy use.

One of the factors pushing the industry to more electric furnace use is the substantial increase in the cost of constructing new coking facilities; these are largely environmental compliance costs. Replacement of old coking facilities has lagged so much that a considerable amount of coke is being imported (see Topic 20).

The increasing costs of coking and of metallurgical coals have also made the potential use of DR (which uses the cheaper, lower grade steam coals) increasingly attractive. Critics of DR point out that the process offers no apparent energy savings, but large-scale coal-based DR technology is only in its infancy and further experience could lead to energy savings. Moreover, numerous innovations are taking place in this technology, some of which should lead to significant improvements in energy efficiency. Developments in coal gasification and synfuels could also promote DR; Brazil and West Germany are investing in development of coal-gasification-based DR.

Many other incremental and major technological changes during the next several decades should do much to reduce steel industry energy consumption. Greater adoption of available new technologies could reduce energy consumption by one-third. The continued closing of old, obsolete, and energy-inefficient plants will perhaps have an even more significant effect on the industry's energy consumption.

The degree to which improved technology and energy conservation measures can reduce energy consumption is illustrated by the remarkably low energy use of the Japanese steel industry. In 1976, Japan used 70 percent as much energy as the United States on a per-tonne-shipped basis, and West Germany 85 percent as much. The Japanese attribute much of their energy savings to continuous casting and concerted energy conservation efforts.

20 To what extent can technological changes reduce increasing U.S. reliance on foreign coke?

In 1972, the United States imported 168,000 tonnes of coke, mostly from Canada; in 1978, 5,190,000 tonnes were imported, 70 percent of which came from West Germany. Coke imports contributed nearly $500 million to the U.S. balance-of-trade deficit in 1978, and this amount increases as imported coke prices rise. Moreover, when coke is imported, there is a loss of increasingly valuable cokemaking byproducts, such as coke oven gas, tars, and distillates, which the steel industry uses itself or sells. Domestic cokemaking capacity decreased from 55.9 million tonnes in 1974 to 47.6 million tonnes in 1978. Associated with this decrease has been a loss of 5,000 jobs in the steel industry and 9,500 jobs in the coal industry. Forecasts indicate a further loss of 4.8 million tonnes of coke capacity by the end of 1985, with a possible domestic shortfall of 7.3 million to 10.9 million tomes. Other analyses, however, predict no shortage of domestic cokemaking capacity in the near future,

The industry's explanations for decreasing domestic cokemaking capability include: 1) a large fraction of domestic cokemaking facilities are very old and reaching the end of their useful lives, 2) the cost of a new coke plant has increased 150 percent in the last 10 years and 40 percent in the last 5 years, 3) from 22 to 30 percent of the plant costs are for unproductive regulatory compliance, 4) many old plants cannot be cleaned up at reasonable costs, 5) enforcement of EPA regulations has reduced plant capacities and efficiencies, 6) there are limitations on sites for new plants, 7) capital is scarce and uncertainty exists about long-range opportunities to meet domestic demand, and 8) there is uncertainty about future regulatory requirements and their impacts on technology choices.

In addition, relatively cheap foreign coke has been available on the world market because most foreign steel industries, particularly those in Europe, have been in a depressed state. But as foreign steel industries reach higher levels of capacity utilization, domestic producers fear that coke will become less available and much more costly. If coke is not available from foreign sources in sufficient quantity, steel imports might have to increase instead.

Other than importing more coke and steel, or constructing more conventional coke facilities, the ways in which coke shortages can be alleviated include: 1) increasing the use of scrap-based electric furnace steelmaking to the extent that scrap is available; 2) introducing coal-based DR to supplant blast furnace technology based on coke; 3) modifying blast furnace processes to reduce the amount of coke used; and 4) promoting the use of cheaper nonmetallurgical grade coals, including high-sulfur coals, by adopting new, environmentally cleaner formcoking technology.

Formcoking is the generic name given to a number of processes, as yet unproven on a large scale, to convert low-grade coals into coke. It is possible that these processes may offer economic benefits to domestic steelmaker, and environmental advantages for some formcoke processes are possible. Large sums will be required for demonstration plants, however, and it will be a considerable time before results are sufficient to affect domestic cokemaking.

21 **How** will technological changes affect the cost and availability of ferrous scrap?

There are four technological developments that will affect the demand for and availability of ferrous scrap: 1) an increase in the use of electric arc furnaces by integrated and nonintegrated steelmaker; 2) the introduction of DRI, which can substitute for scrap; 3) greater use of continuous casting and other process changes that will allow more use of purchased scrap; and 4) continuing increases in the use of alloy steels and nonferrous materials in automobiles and certain improvements in domestic manufacturing, both of which may reduce the supply of readily available and easily processed scrap.

Technological changes within integrated steelmaking will increase the demand for ferrous scrap. The two most important changes are: 1) the increased use of continuous casting, which reduces inplant scrap generation and makes it necessary to use more purchased scrap to supply steelmaking furnaces, and 2) changes in basic oxygen steelmaking furnaces that allow them to use more ferrous scrap, at perhaps a 40- to 50-percent level rather than the present 30 percent, but also increase energy consumption.

Electric arc furnace processes use significant amounts of scrap, and the use of electric furnaces by integrated and nonintegrated steelmaker is increasing at a rapid rate. During the past 10 years the amount of domestic carbon steel made in electric furnaces has nearly doubled, and the trend is similar around the world. This has offset the decline in scrap use that resulted from open hearth furnace shutdowns. Many steel analysts believe that one-half of the domestic capacity installed during the coming decade will use electric furnaces, assuming that adequate electricity is available. Electric furnace steelmaking is certainly not a new technology, but for several reasons its benefits are more significant today than ever before. These reasons include: 1) a relatively low cost for ferrous scrap during the past several decades, although users have found it difficult to cope with the large gyrations in scrap prices; 2) a relatively low energy requirement, because scrap embodies energy (nearly as much energy is used to convert iron ore to iron as to make steel from iron); 3) a high labor productivity, which has improved more for electric furnace steelmaking than for any other process of the steel industry—nearly 50 percent during the past decade, compared to 13 percent for blast furnaces and 26 percent for other types of steelmaking furnaces; 4) minimal pollution problems; 5) very low capital costs; and 6) relatively short construction times.

Because the competitiveness of electric furnace steelmaking depends on the cost and availability of ferrous scrap, domestic nonintegrated steelmaker are sensitive to the uncontrolled export of ferrous scrap. Historical data show a connection between exports and cyclic changes in scrap prices. It is also believed that exports of scrap help feed foreign steel exports to the United States and threaten future domestic availability of scrap. The scrap industry argues that there is a large domestic supply of scrap, particularly a great deal of obsolete scrap, such as discarded automobiles and appliances scattered around the Nation, and scrap in wastes and garbage. The cost of retrieving such scrap is very high, however, and ferrous scrap in general is becoming more costly to collect, process, and distribute. The increasing use of alloy steels, especially in automobiles, is making scrap processing more difficult and costly, and impurities and minor alloy additions build up as more and more scrap is repeatedly recycled. The general trend in manufacturing—to improve process efficiency and reduce raw material and energy costs—means that less industrial scrap will reach the market.

The most likely competition for ferrous scrap is DRI, which offers a number of technical advantages over scrap and has greater price stability. As scrap prices rise, DRI becomes more competitive; conversely, low scrap prices act as a disincentive to the development of DR. Thus, the price of DRI, whether imported or manufactured domestically, is a potential way for the marketplace to stabilize scrap prices. In the long run, DRI availability will likely be a decisive determinant of increased electric furnace use (see Topic 16).

22 How does changing technology affect the timing and strategy of capacity expansion?

The technological and cost competitiveness of domestic integrated companies suffers from the exceedingly small amount of new facilities added during the past several decades. Industry argues, and correctly so, that optimum technology and efficiency require new plants with proper layouts that will allow new technologies to be introduced and integrated into all phases of the steelmaking process. The major obstacle to the construction of new integrated plants is their extremely high capital cost (about $1,320/tonne of annual capacity) and the large plant size needed to capture economies of scale; capital costs could reach many billions of dollars per plant. Considering the industry's capital shortage, uncertainties over future Government policies affecting capital formation, and the continuing problem of imports capturing domestic markets, it is quite unlikely that new integrated plants, based on modern blast furnace technology, will be built in the near future.

Even if sufficient capital and financing could be obtained, it can be questioned whether such costly capital projects should be built. Such plants take many years to complete, and by that time new and innovative technology, with greater production cost savings, and possibly with reduced capital costs, may be available and perhaps may even be adopted by foreign steel industries. It can be argued that this is exactly what happened to the domestic steel industry in the 1950's and 1960's, when considerable plant construction and expansion took place before basic oxygen furnace and continuous casting technologies, the two most important developments after World War H, were proved on a large scale. Important technological developments may be commercialized within the next several decades. One distinct possibility is the large-scale use of some form of DR (see Topic 16). There are so many current developments in this area that success is likely, especially if U.S. companies, much like the Japanese, creatively apply available foreign research to develop major innovative technologies by the end of the century.

An alternate strategy, then, is to modernize and expand capacity at existing plants. The capital cost per tonne of annual capacity for this approach is generally about half that of building a new plant, but varies considerably. Naturally, there are limits to the amount of new capacity that could be added by this means. When coupled with new plant construction in the nonintegrated segment, which is proceeding at a significant pace, this would probably create enough additional capacity for the next decade. Capital costs of new nonintegrated plants range from $154 to $275 per annual tonne today—about 10 to 20 percent of the cost for new integrated plants —and although they cannot produce the full range of steel products, expansion of their product mix is occurring with moderate increases in capital costs.

A domestic strategy based on modernizing and expanding existing plants and constructing new nonintegrated plants during the next decade could lead to a distinct technological advantage. There will be little steelmaking capacity expansion in Western industrialized nations, and the present large-scale expansion of steelmaking in the Third World and Communist-bloc countries is based on either blast furnace steelmaking or first-generation gas-based DR processes. Thus, by developing one or more major domestic technological innovations before building new integrated plants, the United States could gain technological superiority. By adopting foreign innovations, the domestic industry would avoid repeating the past mistake of investing in rapidly outdated technology that it could not afford to replace quickly. Thus, even the worst case means the United States obtains technological parity with foreign industries, something it does not have now.

Financial, Regulatory, and Institutional Barriers to the Adoption of New Technology

23 To what extent is insufficient capital a barrier to the increased use of new technology?

Industry contends that its problem is not lack of adequate technology to improve cost competitiveness, but rather insufficient capital to adopt new technology. This position has considerable merit. Industry argues that if companies had sufficient capital, they could select and use the best technology for modernizing existing plants and constructing new ones. Industry also maintains that Government policies have contributed to low profitability and insufficient capital for new technology by: 1) keeping steel prices too low, 2) requiring high, nonproductive regulatory expenses, 3) permitting unfairly traded imports, and 4) not providing adequate tax incentive for investment, such as faster depreciation schedules. Capital is surely necessary to utilize technology, and there have been relatively low levels of capital available to the industry from its own profits.

Both OTA and the American Iron and Steel Institute (AISI) have analyzed the industry's capital needs for a major program of modernization and expansion for the next 10 years. Both analyses assume the same increase in shipment tonnage capability by 1988, both agree on the need to improve profitability, and both assume no radical technological changes. They do assume a very large increase in continuous casting, elimination of open hearth furnaces, substantial modernization of blast furnaces and finishing mills, and replacement of about half of the present coke ovens.

The differences between the scenarios are more instructive. The OTA analysis assumes: 1) a greater expansion of nonintegrated steel companies at relatively low capital costs, and 2) lower modernization and replacement costs for integrated plants. The AISI analysis projects a need for nearly $5 billion per year (in 1978 dollars) during 1978-88 for investment in productive steelmaking, an increase of 150 percent over the annual average for the past decade; OTA finds a need for only $3 billion per year, an increase of 50 percent. The OTA analysis of future capital formation leads to a projected deficit of at least $600 million per year for the modernization and expansion program. Unlike the OTA scenario, the AISI analysis concludes that substantial real price increases will be needed, regardless of other impacts on capital formation, in order to achieve improved profitability at the higher levels of investment.

The real issue is not whether the industry buys any modern technology with its available capital for modernization and new plants, but rather how much of what types of new and innovative technology its limited capital will buy. A key issue is whether new technology can reduce production costs sufficiently to justify large capital expenditures. The OTA scenario delays investment in large integrated plants until the 1990's, which is made practicable by renewing the industry in the 1980's through minimum-cost modernization and replacement and maximum expansion of nonintegrated companies.

Integrated companies, particularly the largest ones, have the lowest propensity among the three industry segments to use capital for risky, major types of innovative technological changes. Nonintegrated steelmaker generally show more inclination to adopt rapidly the newest types of technology; however, their technological opportunities are fewer because of their dependence on scrap and their smaller range of products. The alloy/specialty producers generally exhibit the greatest tendency to use capital for rapid adoption of major technological changes and for development of proprietary innovations for both processes and products; however, the demanding applications for their products are more conducive to technological change than is the case for the other segments. The greater inclination of both the nonintegrated and alloy/specialty producers to use new technology is also linked to their greater profitability and, to a lesser degree, to their more rapid growth. Profitability and expansion may be a consequence of using new technology, however, rather than a cause of it.

Virtually all calculations of likely levels of capital formation indicate that, for the next 10 years, domestic integrated steel companies will not have sufficient capital (at current levels of profits and borrowing) to create and adopt enough new technology to maintain domestic capacity and competitiveness. The four most likely means of providing this additional capital are: 1) raising domestic steel prices substantially, 2) changing tax and depreciation laws, 3) providing direct Federal support such as loan guarantees or industrial revenue bonds, and 4) greatly reducing regulatory demands. Raising equity capital, increasing borrowing from the private banking and financial community, and greatly reducing dividends are also possible, but most analysts doubt that these methods could be effective, Foreign investment is increasing, however, and could be a significant (if uncertain) source of equity capital. Should the capital shortfall not be met by any of these means, however, it is possible that steel imports (if available) will claim 40 percent or more of the U.S. market by the end of the 1980's.

24 Do steel companies use effective long-range strategic planning for technological innovation in order to gain competitive advantage over domestic and foreign producers?

More often than not, steel industry executives express a desire to be second with proven technology, not first with new technology. This attitude is clearly a barrier to innovation that does not exist in many other industries. Under the currently accepted definition of innovation—the first successful commercial use of a technological invention—most domestic steel companies, with the exception of some alloy/specialty producers, do not appear to emphasize innovation in their long-range strategic planning.

The steel industry apparently perceives the advantage of innovation (over "modernization" with available new technology) as insufficiently rewarding. This is evidenced by the industry's relatively low levels of spending for R&D and for the more expensive stages of pilot and demonstration work, as well as its historical record of importing foreign innovations. These factors combine to form a second barrier to innovation. The ease of buying new technology from foreign sources encourages reemphasis of domestic innovation, and lack of sufficient capital is used to justify this trend. Domestic firms also tend to sell whatever innovative technology they do create, as quickly as possible, in order to maximize immediate profits, instead of keeping the technology proprietary and thereby gaining a competitive advantage. Industry claims that this is also done by foreign firms.

This lack of emphasis on technological innovation may be symptomatic of a generally low level of planning by steel management or simply unsuccessful planning that does not sufficiently appreciate the potential of technology. Historical studies of the domestic steel industry have examined several issues indicative of poor planning: 1) the rapid decline of profitability and eminence after World War II, 2) the lack of response to rapidly rising steel demand in Third World and industrialized nations, 3) the lengthy and costly resistance to compliance with environmental regulations, and 4) the large integrated producers' lack of attention to demographic changes and opportunities for local markets. One explanation for these and other such shortcomings is a lack of dedicated, long-range strategic planning by domestic steel companies, particularly by integrated producers.

Industry needs to develop appropriate scenarios, risk/reward analyses, and corporate options in order to anticipate and respond to major changes in both the domestic and world economies, as well as to changes in Federal policies. The AISI scenario is a first step in this direction. Domestic steel industry management must examine the consequences of continuing to concentrate on low-risk, incremental technological changes; defensive rather than aggressive business strategies; product rather than process changes; traditional domestic markets rather than exports; promoting from within, rather than recruiting personnel from other industries, universities, and Government; and making profits from their raw materials (iron ore and metallurgical coal) investments. It appears that much of the industry, and particularly the integrated segment, has endorsed the self-fulfilling notion that steel is a low-technology, "mature" industry, with little potential for growth or substantial technological changes. The consequences over the last 20 years have been a decline in capacity, a fivefold increase in imports, and numerous missed opportunities in both technology and foreign trade. Neither the industry nor the Nation can afford the consequences of another 20 years of poor planning and missed opportunities.

25 **Is there sufficient steel-related** R&D in the United States to meet the goal of future technological competitiveness?

The total amount of industry, Government, and university R&D devoted to steel in the United States is woefully inadequate for future technological competitiveness. Within the industry itself, what little R&D exists is focused on short-range, quick-payoff activities; very little goes into basic research. The industry does not aggressively pursue major technological changes and innovations for long-term growth, and even spending for incremental improvements is minimal. What is often termed R&D in the steel industry would not be accepted as such in other industries because the work is too applied and tied so closely to manufacturing or sales. The industry does emphasize R&D in raw materials processing and products, but for research in ironmaking and steelmaking processes it depends on foreign producers and domestic equipment suppliers.

The steel industry insists that it lacks adequate funds to invest heavily in long-range R&D, both because of generally low levels of available capital and because of other demands on that capital. R&D spending levels in steel appear to be geared to the low part of the business cycle; when net income is markedly greater than in preceding years, there is no corresponding increase in R&D spending.

The total amount of steel industry spending on R&Din 1978 was $259 million. In 1977 and 1978, steel industry R&D spending was 0.5 percent of industry sales; in 1975 and 1976, it was 0.6 percent; and during 1963-71, it was 0.7 percent. These are very low figures: the only domestic manufacturing industry with a lower level of R&D spending is the textile industry; the aluminum industry spends about twice as much. Steel R&D spending measured as a fraction of industry profits appears more reasonable, but it is still about half of the national industry average. In addition, much steel R&D is aimed at dealing with Government regulations; about 20 to 25 percent of R&D personnel work on environmental problems (see Topic 27).

Steel-related R&D in universities and Government facilities also appears to be minimal. AISI funds only about $1 million of research per year at universities, and Federal funding is also very low, accounting for only 1.5 percent of steel R&D in 1977. By comparison, the Federal Government funds 9 percent of R&D for the chemical industry, 14 percent for the machinery industry, 47 percent for the electric equipment industry, and 78 percent for the aircraft industry.

There are no hard data available to delineate the difference among the three industry sectors with regard to R&D spending, but it appears that at least some alloy/specialty producers are much more involved in R&D

than most firms in the other two segments. The integrated steelmaker spend very little on R&D; the nonintegrated producers, who have become quite dependent on equipment manufacturers for technological developments, appear to spend even less.

Although the U.S. steel industry is one of the world's most profitable, it appears to lag behind foreign steel industries in R&D spending; the Japanese, for example, now spend about 1 percent of sales on R&D. Much of foreign R&D in steel is directly or indirectly supported by governments. At the present time, for example, $36 million is spent annually on steel R&D by the Commission of European Communities, of which $20 million is supplied by governments. In Japan, there also appears to be significant government support of university research in steelmaking.

26 Does the domestic steel industry employ enough technical personnel and use them effectively to enhance its technological competitiveness?

The steel industry has been criticized for its loss of technical leadership, slow adoption of new technologies, and low levels of R&D. It is therefore relevant to consider industry use of technically trained personnel. In comparison to average employment levels of technical personnel by domestic manufacturing industries, the steel industry's use of technical personnel is low. As a percentage of its total employees, steel employs only about one-third the number of scientists and engineers in the petroleum, refinery, and chemical industry, and about half the number in the electrical equipment industry.

Moreover, for the entire steel industry only about 18 percent of all technical personnel are used in R&D. Engineers typically start in R&D and reach higher levels of management by moving to other areas. This practice has the potential disadvantage of driving many of the best technical people out of R&D, because they can achieve higher salaries and greater prestige in other departments. These technical personnel may not have the appropriate expertise for business management and policy work; on the other hand, they have a better understanding of the technological basis of the company and the effective use of technical knowledge for process improvement and market development.

The steel industry draws few technical personnel from high-technology industries. There appears to be a trend toward retired steel personnel going from industry to Government and universities; there appears to be little return flow of midcareer professionals to the industry, however, as is typical of intersectoral mobility and training in West Germany.

There is also some criticism of the industry because training and development of technical staff are geared to managerial and executive development rather than to technical specialties. Most companies have tuition support programs for undergraduate and graduate education, but there is generally much less support for publishing in professional journals or for sabbaticals at domestic and foreign universities. While technical personnel in R&D are given some opportunity to attend meetings and conferences, those in other company areas have fewer such opportunities. This treatment of technical personnel appears consistent with the "mature industry" image accepted by most integrated companies—why upgrade technical skills when steel technology will not change in major ways? (See Topic 24.)

Industry representatives seem satisfied with the availability of new technical personnel, but college recruiters are concerned that more growth-oriented industries may be attracting the best technical talent. Personnel availability may be adequate to present industry needs, given its limited R&D and its current use of technical people: but should the industry choose to change its strategies, it could face difficulty in recruiting the numbers and types of people it will need. Unlike other nations, where steel research is regarded as important and exciting, the U.S. industry could have problems attracting the best technical people away from high-technology, R&D-intensive, high-growth industries.

27 What are the impacts of EPA and OSHA regulations on steel industry modernization?

Social regulations do have an impact on steel industry modernization, and environmental regulations have a greater impact than do occupational regulations, for several reasons. First, environmental regulations have been actively implemented since the late 1960's, but implementation of OSHA regulations has been limited until recently. Second, EPA regulations have an impact on the entire range of production technologies, while those of OSHA have had their greatest impact on cokemaking. Future OSHA regulations may more significantly affect the entire range of operations, but OSHA has a certain degree of administrative flexibility. OSHA compliance deadlines, unlike those of EPA, are not prescribed in authorizing legislation. This gives OSHA greater potential for successfully integrating industry modernization programs with regulatory compliance schedules.

Both sets of regulations have both positive and negative impacts on the steel industry. On the positive side, both EPA and OSHA are forcing the industry to consider technological improvements or substitutes for existing steelmaking processes. An indirect, near-term consequence of regulatory enforcement has been increased use of electric furnaces and an accelerated phaseout of aging and inefficient facilities. An unanticipated, long-range consequence of social regulations may be increased incentive to develop safer and cleaner new processes that are also more cost effective. Continuous casting and DR are among future alternatives showing promise in this regard.

On the negative side, the expenditures (capital and operating) required to comply with environmental regulations divert corporate funds from modernization investments that might otherwise be undertaken. Industry reports suggest that in recent years steel companies have invested about $450 million annually in environmental control facilities. Environmental expenditures are mainly for retrofitting existing equipment and involve gradual improvements in control technology, and to a lesser extent for in-process changes. Because of limited replacement and expansion activity during the past decade, there has been little opportunity to integrate environmental expenditures with new plant construction, and expensive retrofitting has occurred instead. In fact, regulations have been cited as a cause of some capacity reduction, especially in cokemaking, in which import dependence has become a growing concern. The next decade may offer more opportunities.

Available incentives, in and of themselves, have not stimulated industry management to choose technological innovation rather than delay as a cost-effective response to regulations. EPA's incentives are limited to extended compliance schedules and penalty-payment exemptions which allow, to some extent, for new technology development by the steel industry. The Agency does not provide regulatory guarantees or financial support should the innovative approach fail to meet regulatory requirements. OSHA's regulatory incentives are not strongly oriented towards stimulating industrial innovation either. Although OSHA may issue variances in response to operational constraints within the steel industry, stimulating innovation is not a specifically authorized goal in the issuance of these variances. OSHA's only specific authority to stimulate innovation is through its judicially interpreted "technology forcing" policy, which allows it to require the adoption of promising new pollution abatement technologies or practices that have been developed by other industries. Such forced transfers must be limited to the regulation of toxic materials in the workplace, however, and they may not involve new equipment or controls that would necessitate major industry R&D.

A final important consideration is that neither EPA nor OSHA can complement their regulatory requirements with significant economic incentives to encourage the industry to develop more cost-effective technologies. EPA does have a limited environmental technology RD&D program that involves industry cost sharing. Both agencies lack vigorous anticipatory RD&D programs designed to develop greater Government and industry awareness of the environmental implications of emerging steelmaking technologies. This is particularly significant because some new process technologies could be less polluting or hazardous than conventional ones.

28 **How** might labor practices affect the introduction of innovative technology?

The adoption of new steelmaking equipment or technology affects steelworkers in several ways: retraining may be needed, job classifications may need to change to accommodate skill changes; and local practices may need to allow for flexibility in work assignments. On the whole, however, it appears that labor conditions have not been a constraint to the adoption of improved steelmaking equipment. Job classification schedules, periodically updated, are sufficiently flexible to accommodate gradual shifts in skill requirements resulting from technological change. There is some concern, however, particularly among those in the academic community, that apprenticeship and retraining programs do not adequately train people for changing job requirements associated with the adoption of new technologies.

There is a consensus that the work force generally cooperates with management when modern equipment is introduced. The 2-B "local practices" clause in most labor contracts gives management the right to unilaterally change past practices concerning crew size and other staffing agreements when such change is required by "changed conditions, " including technological innovation. However, it appears that the 2-B clause makes it difficult to extend past practices to adjacent production areas not directly involved with the new equipment. Such changes are subject to negotiation with local union affiliates. National union leadership is concerned with technological displacement, but does not resist the introduction of new technology. The industry's view is that—with the possible exception of a few plants—there are no difficulties with steelworkers when new technology is introduced. Thus, it appears that the 2-B contract provision has had no limiting effect on industry adoption of new steelmaking technologies.

Policy Considerations

29 Can the domestic steel industry stay competitive without changes in **Federal policies?**

The need for policy support of the steel industry varies among its three segments. By almost any measure of economic and technological health, the integrated segment is steadily declining. There are trends toward more dependence on steel imports (although they did decline in 1979), less employment, only modest gains in steel demand, aggressive competition from other engineering materials, lower profitability, high debit-to-equity ratios, less investment in R&D, more dependence on foreign technology, a higher proportion of obsolete facilities, smaller domestic steelmaking capacity, and inadequate capital formation for modernization.

Not even large domestic demand and high capacity utilization are likely to reverse the slow decline of the integrated segment. The situation may have already deteriorated to such an extent that profitability cannot be markedly reversed, nor sufficient capital generated, without changes in Federal policies. The only major external factors that might change this pattern are: 1) a large influx of foreign investment and equity capital, and 2) a devaluation of the dollar significant enough to reduce imports and spur substantial domestic expansion.

Current trends might be reversed by changes in Federal policies that permit substantially higher steel prices, fewer unfairly traded imports, and faster capital recovery, or policies that provide more support for R&D and innovation and more direct financial support, such as loan guarantees. (Topics 34 through 40 deal in detail with these policy options.)

The future looks less bleak for the other two segments of the industry. The nonintegrated segment should grow, remain profitable, serve more markets with a greater range of steels, and provide increasing and necessary competition to the larger integrated firms. (Such intra-industry competition will probably have even greater benefits than the competition presently provided by imports.) This segment, too, could gain from changes in Federal policies, particularly those affecting the supply and cost of electricity, but it is likely to prosper even under present policies. There will still be a need for a large domestic ironmaking base to convert iron ore to new iron units.

The alloy/specialty producers are in a period of adjustment to changing Federal policies with regard to imports. It remains to be seen whether the loss of protective import quotas and the enforcement of the new Multilateral Trade Agreement will be adequate to ensure the continuation of this segment's healthy economic condition. Without direct Federal support, however, high-technology steel exports are not likely to increase dramatically.

30 Can the experiences of the steel industry contribute to the formulation of more effective Federal policies for other domestic industries?

The steel industry may be only the first of several domestic industries facing a decline in preeminence and prosperity. As the less industrialized nations begin to lower production costs and to consume more commodities, they become more economically attractive than highly industrialized countries as a location for established industry. Established industries in industrialized countries may also decline if they lose domestic markets through product substitution or replacement, or if they do not produce sufficient technological innovations to reduce production costs or improve products.

These explanations do not appear as valid in today's world economic order as they once were, because government policies have introduced so many imperfections to the free-market and free-trade system that the impact of traditional economic factors on international competitiveness has been fundamentally changed. None of the above factors can adequately explain the decline of the domestic steel industry.

In the first place, no major foreign steel industry has enjoyed a more advantageous combination of labor costs, energy costs, raw material costs, and industrial and technological infrastructure than the United States. At best, foreign steelmaker have had slight advantages in one or two of these factors, but such advantages have generally been short-lived and insufficient in themselves to account for penetration of export markets, particularly the U.S. market.

What has occurred is that foreign governments have adopted policies that provide many direct and indirect benefits to their steel industries, and many of these industries have in fact been built with public funds to serve social and political goals. Even though foreign demand for steel has increased substantially, foreign steel is often exported rather than used to satisfy domestic needs. This has promoted growth, but not necessarily prosperity. The American steel industry, as a private, profit-motivated enterprise, is becoming increasingly unique in the international market (see Topic 32).

Secondly, although steel has faced stiff and increased competition from other materials—notably aluminum, concrete, and plastics—it still possesses a unique combination of properties, forms, and costs that ensure it substantial and growing markets. There has been little technological displacement of steel in the marketplace.

Thirdly, contrary to accepted wisdom, there have been major technological changes in domestic steelmaking and steel products during the past several decades. All signs are that this trend will continue. Some domestic firms have justified their lack of progress on the basis of the "mature industry" image (see Topic 24); others, in the meantime, have moved ahead with boldness and optimism, taking risks, investing in the newest technology, and capturing the profits that are there to be made.

One lesson to be learned from the steel industry's experiences, then, is that domestic industries can find themselves losing price competitiveness because Government policies are not comparable to those of other nations. Foreign government policies have distorted the workings of the marketplace, sometimes in ways unique to a particular industrial sector. The steel experience has shown that Federal policies can improve the profitability of foreign industries while depressing those at home. But in spite of Government policies that have not permitted domestic prices to equal import prices in periods of strong demand, that have limited capital recovery and hence restricted capacity replacement and expansion, and that have not provided R&D assistance comparable to foreign governments, the American steel industry is still the most profitable major steel industry in the world. Surely, more competitive Government policies could help make steel and other "sick" industries well.

High-technology industries have captured much of the public's attention, and basic industries like steel have lost stature. Their critical role in the economy and national security has been overlooked. Government policies must be reexamined to determine whether they allow industries to wither and save only the inept and unprofitable, or whether instead they create a climate in which competent and profitable companies can grow. There is a need to examine, for steel as well as domestic industry in general, the long-term benefits of closing plants that are inefficient, poorly located, or possibly mismanaged. The costs Government incurs in dealing with local, short-term social dislocations may be less in the long run than those of continuing Federal assistance to industrial facilities incapable of technological rejuvenation.

Another lesson to be learned from the past experience of the steel industry—and perhaps the most important lesson—is that sector policies may be needed for major domestic industries if international competitiveness is to be achieved. Foreign governments, particularly the Japanese, have adopted sector policies to build competitive industries. Without a coordinated policy, improvement efforts may be at cross-purposes or fail to address critical issues. For example, the steel industry's emphasis on the need to raise adequate capital for modernization and capacity expansion ignores the need for additional efforts in R&D and innovation. Domestic policies that deal effectively with only one of these areas would not help, in the long run, to ensure a profitable and competitive industry, nor would trade policies that deal effectively with imports but fail to support technology, innovation, and the means of production. The risks of adopting a steel sector policy include: 1) an overemphasis on the welfare of the steel industry, particularly large integrated steelmakers, to the exclusion of other domestic industries and smaller steel producers, and 2) insufficient attention to social goals and impacts, such as environmental protection, pollution control, and worker safety. Such risks must be examined for any industry for which a sector policy is considered.

31 Should the steel industry be singled out for a sector policy?

Some critics contend that the steel industry should not be singled out for Federal help and that legislation affecting all domestic industry should be sufficient. Steel has a unique combination of problems and assets, however, and it has already been uniquely and adversely affected by many Federal policies. For the following reasons, not all of which apply to any other domestic industry, singling out the steel industry for a sector policy presents difficult choices and opportunities for policymakers:

- The industry is essential to the domestic economy and national security, but it is contracting and diversifying out of steelmaking, which can only result in increased imports.
- The current cost-price squeeze and capital shortfall are, to a substantial extent, the results of prices that are too low to provide adequate profits, Government policies that have led to high regulatory costs, and unfairly traded imports that have captured domestic market growth and contributed to artificially low prices.
- There is a nucleus of companies with plants that are extremely competitive in costs and technology, and these could contribute positively to the trade balance by exporting more high-technology steels or impeding imports of commodity steels.
- There are many short- and long-term technological opportunities for strengthening the industry and recapturing the premier status it once possessed.
- The industry has available to it the domestic material resources of iron ore, coal, and ferrous scrap and the human resources of a highly competent labor force, a large national R&D infrastructure, and a reservoir of managerial and entrepreneurial talent.

32 How do foreign government policies affecting their steel industries compare to U.S. policies?

Most foreign governments have placed considerable strategic and economic emphasis on developing and preserving their steel industries, which they view as national assets, essential for industrialization, economic development, and economic stability. In fact, 45 percent of world steelmaking capacity, and more than 50 percent of European capacity, was government-owned in 1979. Foreign governments support their steel industries in a number of other ways, as well, including government planning and financial assistance, favorable tax policies, direct export incentives, tariff and nontariff barriers to steel imports, and the subsidizing and stockpiling of raw materials. American steelmaker see these forms of government support and ownership as trade-disturbing practices that should be met with equivalent U.S. policies.

Foreign governments support their steel industries to such an extent because their industries are not just instruments of production and profits: they also have a role in social, economic, and foreign policy. Their industries are used to:

- sustain employment levels,
- train technical and management personnel for industrialization,
- maintain social stability in certain geographical areas,
- make use of domestic natural resources,
- provide a cheap feedstock for other industries,
- obtain foreign currency through exports,
- gain access to international industrial activities,
- reduce dependence and improve negotiating positions with other nations,
- enhance their national images, and
- improve their military and economic security,

The steel industries in Japan and West Germany are mostly privately owned, as in the United States. Unlike those countries, however, the United States: 1) lacks a national consensus to preserve and modernize its steel industry, 2) enacts laws and regulations that have considerable costs for its steel industry, without providing offsetting direct or indirect benefits, 3) does not use trade laws vigorously to prevent unfairly, or even fairly, traded imports, and 4) provides little support for the development and export of new technology.

Japan makes maximum use of government planning and a coordinated steel sector policy. Through its Ministry of International Trade and Industry, it provides its steel industry with marketing guidance, long-range forecasts, target production goals, plans for domestic and export cartels, support for RD&D, assistance in procuring raw materials, and, most importantly, financial assistance in conjunction with the Japanese banking community. The United States has no comparable programs.

The EEC has been particularly active in providing government financial assistance, some through individual governments and some through regional programs. Such assistance takes the form of: grants-in-aid for antipollution compliance, technical aid, and research: low-interest and preferential-interest loans: and writeoffs of bad debts. Although the United States has used loan guarantees to a small degree, financial assistance here is at a far lower level than in other countries. Domestic producers must rely on direct credit, and they are subject to all the financial tests of the free enterprise system. Moreover, domestic firms argue that U.S. private and public funds, such as Export-Import Bank financing, often go to foreign steel industries at far lower financial costs than domestic companies can obtain.

Direct export incentives used by foreign governments include: export credit and financing, including guarantees to private banks of a favorable interest rate; export insurance with liberal coverage against losses not within the control of the exporter; tax rebates, generally in the range of 10 to 20 percent of the value-added tax in Europe and a like percentage of the export sales price or export value in developing nations; government assistance for trade missions, exhibitions, market research, and export promotion schemes; and assistance to exporters for joint foreign marketing efforts, offices, warehousing, and sales facilities. The United States has been a very attractive export market for foreign steel industries, with markedly fewer and lower tariff and nontariff barriers to imports than most other nations. Although the United States has the Export-Import Bank and appears to be embarking on a more aggressive export incentives program, the domestic steel industry is not particularly experienced in or inclined toward exports. Some domestic companies are attempting to sell technology, particularly in the raw materials area, but direct incentives to export do not match those of many foreign nations.

Foreign governments are also giving more attention to raw materials subsidization and economic stockpiling. European nations have heavily subsidized their coal industries, and most developing nations have state-owned ore and energy resources that provide substantial benefits to steel exporters. Government stockpiling of critical alloying elements, such as nickel, chromium, cobalt, and tungsten, is also widespread. Japan grants bank credits to domestic producers of raw materials, especially coal, under adverse economic conditions. Sweden has a program of tax credits for steel companies that stockpile raw materials and finished steel during periods of declining prices. The United States subsidizes energy resources through controlled energy prices, but this has benefited the domestic steel industry only slightly since over 60 percent of its energy comes from coal, and in any event U.S. energy prices are being gradually decontrolled. The level of assistance provided in energy-rich developing nations with rapidly growing steel industries, such as Mexico, is very great, and energy costs in such nations are far below their market value.

33 What will be the effect of the new Multilateral Trade Agreement on the domestic steel industry?

Vigorous enforcement of the trade agreement is necessary, but not sufficient, to bring about a revitalization of the domestic steel industry. Lax enforcement is sufficient to extend present trends and to ensure the slow but inevitable demise of much of the industry.

Even if the new trade agreement is vigorously enforced by the United States and its trading partners, it could do little to solve the fundamental problems of the domestic steel industry, At best, there would be an uncertain decline in steel imports and an increase in exports. The most important benefit of an effective trade agreement would be to reduce steelmaker' uncertainty about their potential for capturing domestic growth in demand; this could offer them clearer rewards for long-term investments in technology. If the new trade agreement is not vigorously enforced, other steps to aid the industry could be nullified by unpredictable surges in unfairly traded imports or by the industry's fear of such surges.

Policy Options

34 How can increased Federal assistance to the steel industry be justified?

The steel industry is necessary for military and economic security. It is also a major source of employment. Other materials could not even theoretically substitute for most steels; where theoretical substitutions exist, they could not be implemented in any reasonable period of time at manageable cost. And to become dependent on foreign steel is comparable to becoming dependent on foreign food or energy.

There are arguments to be made for providing more Federal assistance to the steel industry, but there is an equally valid case to be made for the industry's fundamental strength. The industry is not, as some argue, composed entirely of inefficient, mismanaged firms using inefficient industrial processes. The industry has an extremely strong infrastructure, an excellent labor pool, access to one of the world's best markets and to abundant domestic resources, a high-quality knowledge base, and a number of highly profitable, well-managed companies upon which to base industry reinvestment, restructuring, and growth. It can thus be argued that the U.S. steel industry has comparative advantages over many foreign steel industries and that these advantages should be used to rejuvenate the industry.

Any Federal policy that helps the steel industry invariably brings objections from other domestic industries or from steel companies that may not benefit equally. The chief objection is that such policies disturb free-market competitive forces either within the steel industry or between steel and competing materials. Other direct Government actions affect various industries unequally, however, and past Government actions have contributed to steel's present problems. The industry can point to market imperfections and uncertainties, resulting from both domestic and foreign policies, that have led to its current low profitability, poor capital formation, and apprehension about high-risk ventures.

A free-market economy for steel has not existed in the United States for some time. There is indirect control of import and domestic steel prices through Government import policies, particularly the trigger-price mechanism used in the past. The Government has used jawboning to keep steel prices within limits that policymakers believe to be non-inflationary. At the same time, rising costs have reduced steelmaker' profits. The loan guarantee program of the Economic Development Administration (EDA) has provided assistance to selected companies that have economic problems, operate in areas of high unemployment, or need assistance with environmental compliance; but stronger and larger steel companies, despite low profitability or inadequate capital, generally have not benefited from this program. They and others have expressed concern that such a program merely postpones the collapse of fundamentally unsound companies.

It can also be argued that, because steel has been so dependent on coal, it has benefited less than some other industries from Federal energy policies that maintain relatively low prices for other energy sources. The aluminum industry, for example, relies extensively on the low-cost Government-controlled hydroelectricity of the Pacific Northwest. Similarly, the plastics industry has benefited from low petroleum feedstock prices.

The social benefits of environmental and occupational safety regulations are inarguable, but the costs of compliance have not been equitably distributed because they have not been fully passed on to the consumer. Limitations on prices, coupled with substantial regulatory costs, have contributed to the steel industry's loss of profitability and capacity. Many other industries also have substantial regulatory costs, but the very nature of the steelmaking process, the industry's large proportion of old facilities, and the lack of Federal support for long-range development of cleaner technologies have all imposed more severe regulatory costs on steel than on most other manufacturing industries.

Other reasons for increasing the Federal Government's support of steel include: 1) neither the low-profitability integrated companies nor the small nonintegrated firms are able to support long-term, risky innovations, even though such innovations may have substantial social and economic benefits; 2) imported steel contributes significantly to a negative trade balance, but steel and technology exports could offset some of this deficit; and 3) the lack of Federal policy support, especially compared to foreign support of their steel industries, reinforces the perception that the United States is losing its leadership in technology and industry, and this contributes to a weakened dollar and a further decline in U.S. influence in the international business community.

A possible long-range negative consequence of more favorable Federal policies toward the steel industry is that they could lead to Federal subsidization or even ownership. Critics argue that such policies led to the nationalization of many foreign steel industries and that, generally, these industries are inefficient and operate at a large loss. This is not a necessary outcome of Federal assistance, however, if policies are designed to help private steelmaker regain sufficient economic health to once again be viable profitmaking enterprises.

35 Is there a need for direct Federal financial assistance to the steel industry?

Clearly, a number of steel industry problems result from inadequate capital for modernization with the newest available technologies and investment in future innovations. The situation has not yet become critical enough to justify broad, direct Federal subsidies to support normal operations and investments, but an argument can be made for selective Government assistance to promote modernization as long as profit levels are low.

Loan guarantees and industrial revenue bonds have become popular forms of Federal assistance because they are not expenditures and bypass the normal budget process. In fact, Government usually shows a profit from the low interest recipients pay. The problem with loan guarantees is that they could disrupt normal competitive forces among individual producers. There are very large differences in costs and profits among companies, as well as among industry segments. Loan guarantees that offer assistance to the least profitable companies act as disincentives to other firms to manage and invest so as to maximize profits. Federal assistance policies also need to provide incentives to companies that are relatively strong, both economically and technologically, and are able to share the risks with Government.

The EDA loan guarantee program, now in its last stages, did not specifically focus on the adoption of new technologies, and it has been criticized by a number of steelmaker for its tendency to help unsuccessful companies. If loan guarantees are to be offered, it would be more efficient to use them to encourage and reward high-risk innovations, increased capacity, better use of domestic resources, products for export, reduced energy consumption, increased overall productivity, and environmentally cleaner processes.

The terms of such a technology-stimulating, limited-term loan guarantee program might require: 1) evidence of the company's inability to raise capital through all conventional means, including selling new stock issues; 2) a degree of risk and innovativeness proportional to the relative level of past profitability, so that successful firms would be stimulated to develop risky, long-range, major innovations, while less profitable firms would still be able to share in Federal assistance; 3) commitments to delay diversification out of steelmaking until companies meet certain objectives, such as achieving mutually agreed-upon steelmaking capacities, productivity improvements, energy-use reductions, or pollution-abatement improvements. This approach, though complex, would least disturb relative competitiveness among domestic companies while still providing a means of regaining domestic capacity and international competitiveness.

Industrial revenue bonds benefit the companies by providing lower interest rates, but they have an indirect cost to the Government in the form of reduced taxes. There are also problems with defining the social benefits of technology-related investments and with allocating such bonds among competing needs.

36 What effect would changes in Federal tax laws have on capital formation?

Insufficient capital to modernize, expand capacity, and innovate is an increasingly critical problem for most of the steel industry, which has long argued that changes in Federal tax policies could help to correct its capital shortfall. There is little doubt, for example, that appropriately designed investment tax credits or reduced depreciation schedules could yield large amounts of additional capital. Furthermore, these methods do not require expenditure of Federal funds and therefore bypass the Federal budget process. Tax credits already exist for energy-saving investments; they could also be directed toward other specific steel-related objectives such as increased scrap use, increased direct use of coal, or plant demonstrations of major innovations.

In the area of the reduced depreciation periods, the Jones-Conable Capital Cost Recovery Act of 1979 (H.R. 4646), if enacted, would allow machinery and equipment to be depreciated over 5 years instead of the present 15. The Department of the Treasury has calculated that, 5 years after its passage, this Act would generate an additional $0.5 billion to $1 billion per year for the steel industry. This amount would probably provide sufficient investment capital over the next decade to achieve the minimum degree of modernization and expansion that is needed to improve profitability and competitiveness.

If tax assistance of any kind were provided to the steel industry, there is no assurance that the additional capital gained thereby would be used for: 1) steelmaking operations of companies already committed to diversification out of steel, or 2) more innovative and risky technologies. While diversification cannot be prevented, it may be blunted by policy changes that the industry perceives to be favorable. Technological innovation could be encouraged by targeting tax assistance for technologies that are likely to result in reduced pollution, lower energy use, greater labor productivity, lower capital costs, or increased use of abundant domestic raw materials and wastes. Critics of legislation that deals directly with technological choices, rather than performance objectives, point to the difficulty and undesirability of having the Federal Government evaluate technology. Those in favor of such legislation point to the risks involved in not requiring the beneficiaries of Federal assistance to emphasize technologies with long-range national and corporate benefits, rather than those that are less risky and more likely to increase the short-term profits of individual companies.

37 Should there be more Federal support for steel R&D and innovation?

The Nation's commitment to the future international competitiveness of the domestic steel industry would be demonstrated most clearly and most effectively by increased Federal support of research. There is a severe lack of basic steel research, especially in universities, and any truly radical innovations in steelmaking will be based on new knowledge. New knowledge might emanate from totally undirected research, but it is much more likely to be produced in basic research programs that focus on the needs of steelmaking.

An attractive approach for improving the level of basic steel research would be to create federally supported research centers, located at universities but with close relationships with industry to ensure eventual use of the research by steelmaker. Financial support for such centers could also be solicited from industry (after clarification of antitrust laws). Because of their low profitabilities and their need for fast paybacks, individual companies are not likely to spend significant sums on basic research; they might, however, contribute to joint efforts. The National Science Foundation has taken a step in this direction by funding a planning grant for a center dealing with research for nonintegrated steelmaking.

Funding is also needed for pilot- and demonstration-plant evaluations of the new process technologies that are vital for the near-term survival of the industry. Policy changes in this area would also require more liberal interpretations of antitrust laws, as well as either assurances of appropriate licensing to all interested companies or provisions to grant proprietary or financial rights to participating firms. Proponents of such funding argue that the lack of sufficient discretionary capital in the industry has limited applied evaluation programs in the past. Risky, large-scale projects generally require many hundreds of millions of dollars for evaluation before commercialization can proceed, and few individual companies can mount such efforts. The cost to the Government could be minimized by using a buyback agreement that allows a company or consortium to purchase the facility upon successful demonstration.

Opponents contend that the Government should not interfere with the private sector's ability to choose, evaluate, and fund projects, and that in any event Government lacks sufficient experience and expertise to make the critical choices. They argue that sufficiently worthwhile projects that offer adequate returns on investment will, regardless of risk, attract venture capital. The determination of risk and return on investment for new steel technology is filled with uncertainty, however, and the present lack of favorable conditions for capacity expansion worsens the risk/reward assessment. Furthermore, biases and attitudes toward the industry can be used to make a promising technology look more risky or less beneficial than it really is. OTA has found that even worthwhile projects are damaged by the generally negative views of those outside the industry and the pessimism of steel executives who do not believe in the feasibility of technological innovations. For these reasons, the arguments against Government assistance are not compelling, although they do identify concerns which should be examined in policy formulation.

An equally important role for Government might be the coordination of steel R&D with other federally sponsored research activities. A good example of such linkage would be with activities in coal gasification and synfuels, which might supply the necessary technology for handling reductants in coal-based DR processes. This linked technology could yield the extremely advantageous combination of a wise, efficient use of abundant domestic resources and a cleaner, low-capital-cost steelmaking process.

Government could also give greater encouragement to innovative efforts by small firms and individual inventors who are outside the basic steel industry and have little access to its resources. It is well known that small firms have a very high rate of successful innovation compared to large corporations. OTA has found a surprising number of such firms and individuals with new steelmaking inventions and processes that are promising, but difficult to assess. Their difficulty is insufficient funding at the pilot and demonstration stage to fully prove or disprove the new technology or to assess accurately its operating and capital costs. The Calderon Ferrocal process, a form of coal-based DR, is an example of a promising invention that is having difficulty obtaining adequate funding for demonstration. It is difficult to envision how means other than direct Federal funding could be used to assist such efforts.

The facilities of the Bureau of Mines, formerly used for research in steelmaking, could be resurrected by the Government with a minimal investment to establish an effective RD&D program with industry, especially the small nonintegrated companies. Both the former Bureau policy (which apparently prevented cooperative research with industry) and the present policy (which prevents research in the materials production area) seem to ignore the needs and opportunities of domestic steelmaking.

38 What regulatory changes could be considered that are simultaneously aimed at improving environmental and occupational protection and at revitalizing the steel industry?

Environmental policy should be reexamined taking into consideration the unique needs, problems, and technological opportunities of the different steel industry segments.

The social goals of environmental and worker safety and health are fundamentally sound. Nevertheless, industry’s concern over the long-term economic effects of such regulations are also legitimate. For instance, industry investment in EPA- and OSHA-mandated technology and facilities is a considerably higher percentage of total capital investment than for other manufacturing industries and may continue to increase during the next several years, Costs of operating these facilities are also very high. In addition, needed improvements in environmental technologies will assume growing importance as toxic pollutant guidelines affecting the steel industry are issued within the next few years.

Possible changes in environmental policy that merit examination and evaluation include:

- Giving industry more flexibility in selecting the most effective means to attain environmental compliance, such as by regulating emissions on a plant rather than an individual process basis.
- Analyzing the regulation of pollutants with the goal of providing tradeoffs be-

tween economic costs and environmental benefits.

- Providing regulatory options for marginal plants with a limited life expectancy, so that environmental goals can be better coordinated with both near-term plant phaseouts and the maintenance of domestic capacity.
- Using EPA and OSHA penalty payments for noncompliance to fund R&D in these areas.
- Clarifying the industry's responsibilities concerning RD&D for improved control technologies that will meet EPA standards.
- Complementing the existing regulatory approach, as embodied in the innovation waivers, with economic incentives to encourage industry RD&D of needed improvements in environmental technology,
- Increasing Federal support of environmental technology R&D, particularly with respect to in-process changes.
- Increasing emphasis by regulatory agencies on innovative steelmaking technologies and process changes that present a number of advantages in addition to improved pollution abatement and worker safety and health.

39 What will be the effects of continuing to export ferrous scrap?

U.S. scrap exports are a positive contribution to the Nation's trade balance, but they are relatively small, in terms of both dollars and tonnage, compared to imports of steel, ore, and coke. For 1979, scrap exports probably equaled about 15 percent of the net steel-related deficit. The scrap industry favors free export of scrap, contending that there is sufficient domestic scrap to export, that more scrap becomes available as prices increase, and that historically the integrated steel producers have not attempted to maximize their use of scrap. To some extent the latter has been true, but that situation appears to be changing (see Topic 21).

By exporting scrap, the United States is exporting a valuable domestic resource. Scrap is a source of both iron and embodied energy (about 19 million Btu/tonne). The more scrap used in domestic steelmaking, the less energy, time, money, and labor are expended to mine and process iron ore and then make iron in blast furnaces.

Some of the exported scrap is used by foreign steelmaker to produce government-subsidized steels, which are then sold back to the United States, with adverse impacts on the domestic steel industry. Scrap exports drive up the domestic price of scrap, but foreign producers can still obtain a net advantage because of the devalued dollar and their inherently greater energy costs. Domestic producers must contend with both high scrap costs and price controls on their output, which put them in a cost-price squeeze.

Continuous casting and other improvements have decreased the amount of home (inplant) scrap being produced; simultaneously, the greater use of electric furnaces and the modification of basic oxygen furnaces have increased the demand for scrap. As a result, steelmaker are becoming more dependent on purchased scrap, which however is declining in quality as "tramp" contaminants build up over numerous recycling. The domestic demand for scrap is so great and growing so rapidly that the scrap industry may have no long-range economic need to export. As nonintegrated electric furnace steelmaker expand in the 1980's, it is even possible that a domestic shortage of ferrous scrap may develop.

Perhaps the most significant long-range consequence of continuing to export scrap is the possible detrimental impact on the nonintegrated steel producers. If formal or informal Government price controls cannot be released quickly enough to offset rapidly rising costs, quickly rising scrap prices (driven by high foreign demand) may put a substantial cost-price squeeze on these firms and even drive them out of the market. This impact is particularly acute now, when coal-based DR has not been developed domestically and when DRI is not yet readily available as an import.

40 Are Federal Government targets for utilization of ferrous scrap and other recovered materials needed, feasible, and the best approach?

The Government has been reluctant to put controls on scrap exports, but two legislative acts have attempted to maximize the use of scrap and other waste sources of iron generated in steel plants. These acts foresaw neither the difficulty of setting meaningful and feasible targets nor the long-range consequences of this approach. For purely economic reasons, scrap use by the steel industry has been increasing. As an alternative to setting targets, the Government could consider direct incentives to the industry, such as an investment credit, to adopt technology that would use more scrap (see Topic 21).

The requirements of the two acts may be summarized as follows:

- Section 461 of the National Energy Conservation Policy Act (Public Law 95-619) of 1978 mandates that the Department of Energy set targets for the use of recovered materials for the entire ferrous industry, including ironmakers and steelmaker, foundries, and ferroalloy producers. Such targets, which have now been set, are voluntary, but steel producers are concerned that they might become mandatory. The target set for 1987 was almost met in 1979.
- Section 6002 of the Resource Conservation and Recovery Act (Public Law 94-580) of 1976 amends the Solid Waste Disposal Act and deals with Government procurement. It sets forth the requirement that Federal procuring agencies shall procure items composed of the highest percentage of recovered materials practicable, and it instructs the EPA Administrator to promulgate guidelines for the use of procuring agencies in carrying out this requirement. It also requires suppliers to the Government to certify the percentge of recovered materials in the total material used in the items sold. As yet, EPA has not set these guidelines, nor has it proposed a schedule.

Although it is in the national interest to maximize the use of recovered materials in order to save energy, the setting of scrap-use targets or guidelines presents a number of problems. It may not be technically or economically feasible in all cases to use recovered materials to the extent suggested or required by the Government. A major problem has been that DOE and EPA do not appear to recognize the different steel industry segments and the unique constraints and opportunities they each have in regard to scrap use. Another problem is that a numerical target rests on many assumptions—about future scrap availability and use, as well as total steel demand and changes in technology—which are themselves highly controversial.

Targets could, in fact, be counterproductive to the original goals of maximizing recovered materials and saving energy. Unrealistic targets could be circumvented, for example, by companies buying and selling one another's home scrap on paper. Should targets and guidelines be effective in increasing demand for purchased scrap, and thereby raise prices, the impact on nonintegrated companies would be much worse than on integrated steelmaker; if this led to a decrease in nonintegrated output, it could ultimately result in lower total scrap use. Technically and economically, it would be extremely difficult for integrated steelmaker to increase substantially their use of recovered materials in existing facilities, and the modification to increase scrap use in basic oxygen furnaces also increases the consumption of oil or natural gas. Credits for scrap-enhancing changes in facilities would thus appear to be more effective than targets, since they ensure that investments would be productive and economically justified.

With the advent of DR and the availability of DRI, electric furnace steelmaker could use less scrap. Hence, targets or guidelines could act as a disincentive to the introduction of DR, a technology that may offer benefits for both the companies and the Nation. Industry cannot totally rely on scrap, so it needs DR, which produces new iron units from ore. Even though the percentage of scrap used per unit of output would decrease in electric furnace shops using DRI, it can be argued that the use of DRI in conjunction with scrap would promote an expansion of electric furnace steelmaking, resulting in a net increase in the use of purchased scrap (see Topic 16).

CHAPTER 4

The Domestic Steel Industry's Competitiveness Problems

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CHAPTER 4

The Domestic Steel Industry's Competitiveness Problems

Summary

Although world steel demand more than doubled during the past two decades, domestic steel production increased by only 20 percent during this time. In this same period, the Japanese steel industry increased production sevenfold, and Common Market steel production went up by 70 percent. The declining role of the U.S. steel industry in the international market is reflected in substantially increased U.S. steel imports and flat export levels. Despite major technological and economic difficulties, domestic steel industry profit levels have been higher than those of foreign steel industries. Nevertheless, steel profits were only about half the U.S. manufacturing average.

Historically, the domestic steel industry's indebtedness levels had been relatively low compared to foreign steel industries. Unlike foreign firms, domestic steelmaker have financed capital investments largely from retained profits or through equity financing. Foreign governments play a more direct role than the U.S. Government in facilitating industrial access to capital markets and public funds.

The U.S. steel industry's market decline may be attributed to a number of factors. Its most recent expansion started earlier and was of a much shorter duration than that experienced by competitor industries, particularly that in Japan. Furthermore, the domestic industry has adopted certain productive new steelmaking technologies at a relatively slow rate. As a result, U.S. plants tend to be older, smaller, and less efficient than the steelmaking equipment of many competing foreign steel industries.

The resource-poor Japanese steel industry, benefiting from post-World War 11 technological, economic, and government policy advantages, has been the world's low-cost producer since the early 1960's. Japan has had a long--lasting steel industry expansion, based largely on new plant construction. As a result, Japan now has superior technological steelmaking capability and a strong competitive position. Some steel-producing less developed countries (LDCs), such as South Korea, are also becoming increasingly cost competitive.

Raw materials, including energy, continue to be the most costly input factors. Foreign steel industries have brought down their raw materials unit costs during the past decade, despite major materials price increases. Domestic raw materials unit costs actually increased. Virtually all steel industries are experiencing declining employment levels. The domestic industry no longer has the highest labor productivity, and U.S. unit labor costs are higher than in Japan but lower than in Europe.

Predictions of future supply and demand of steel products are uncertain, but high steel demand and barely adequate world capacity are possible by the mid-1980's. Under these conditions, if domestic capacity is replaced with modern facilities, increased demand can be met and financed. If limited expansion and modernization do not occur, the United States will become dependent on carbon steel imports at high prices during cyclic periods of high demand.

Decline of the U.S. Position in World Steel Production and Trade

Up to and throughout World War II, the United States maintained an unapproachable lead in steel technology and production. However, the postwar rebuilding and expansion of European and Japanese steel mills provided foreign producers with great competitive leverage. U.S. steel firms did not build enough new plants or expand existing capacity sufficiently to capture a portion of the rapidly rising world demand for steel.

The dramatic decline in the growth rate of the U.S. steel industry, compared to that of other countries, is revealed in world production figures. From 1956 to 1978, the U.S. share of total world output of steel dropped from 37 to 17.5 percent and domestic production increased only 10 percent. During this period, Japan increased its production nearly tenfold (table 16). Japan and the European Economic Community (EEC) experienced a combined growth rate from 1950 to 1976 that was 10 times greater than that of the United States.

That the domestic industry did not capitalize on burgeoning post-World War II international steel demand is shown by the fact that steel exports from the United States have remained constant during the past 30 years, even though worldwide exports increased more than tenfold during that time (figure 8). In 1978, the United States exported only 2.5 percent of its total domestic raw steel production, while West Germany exported 53.7 percent; Japan, 36.8 percent; Italy, 37.6 percent; and the United Kingdom, 21.5 percent (table 17). Clearly the industries in these countries were built with the export market in mind, because their capacities far exceed the volume needed to satisfy their domestic needs.

Not only have domestic steel exports failed to keep pace with growing world steel de-

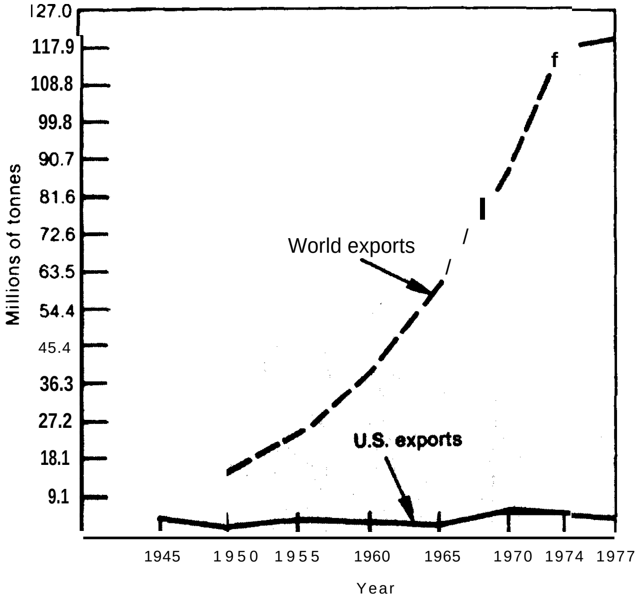
Table 16.—Raw Steel Production: Total World, EEC Countries, Japan, and the United States, 1956-78

	Millions of tonnes				U.S. share of total world production (percent)
Year	Total world	EEC	Japan	United States	
1956	283.8	77.9	12.0	104.5	36.8
1957	291.8	82.0	12.5	102.2	35.0
1958	270.9	78.0	12.1	77.4	28.5
1959	305.8	84.0	16.6	84.7	27.7
1960	346.1	97.9	22.1	90.1	26.0
1961	353.8	96.1	28.3	88.9	25.1
1962	357.4	94.0	27.6	89.2	24,9
1963	382.9	96.5	31.5	99.1	25.9
1964	434.5	109.9	39.8	115.3	26.5
1965	456.3	113.8	41.2	119.3	26.1
1966	470.8	110.2	47.8	121.6	25.8
1967	496.7	114.5	62.1	115.4	23.2
1968	528.3	125.3	66.8	119.3	22.6
1969	573.2	134.7	82.1	128.2	22.4
1970	593.4	137.5	93.3	119.3	20.1
1971	580.4	128.2	88.5	109.2	18.8
1972	629.9	126.2	96.9	120.8	19.2
1973	697.1	150.1	108.2	136.8	19.6
1974	710.0	155.5	117.1	132.1	18.6
1975	645.8	125.3	102.3	105.8	16.4
1976	683.1	134.3	107.4	116.1	17.0
1977	673.9	125.3	102.4	113.1	16.7
1978	711.7	133.1	102.1	124.3	17.5

SOURCE: Compiled from data published by the American Iron and Steel Insitute.

mand, but steel imports into the United States since the late 1950’s have also grown at the rate of 10 percent per year (table 18). * The increasing gap between domestic steel exports and imports has a negative effect on the U.S. trade balance. Steel imports exceeded exports in dollar value for the first time during the late 1940’s and in volume during the late 1950’s (figure 9, table 18). Since that time, imports have captured much of the growth in domestic steel consumption. In 1978, steel exports were only 20 percent of imports, and iron ore exports were a mere 6 percent of imports. These trade patterns have led to a very high annual trade deficit (table 19), second only to petroleum as a source of trade deficit. Although exports of ferrous scrap reduce this deficit by a relatively small amount, imports of coke increase it.

Figure 8.—U.S. Exports—Share of World Steel Trade, 1945-77



SOURCES: American Iron and Steel Institute, Steel *Industry and Federal Income Tax Policy,* June 1975, p 46, U N Secretary of Economic Committee for Europe, Statistics of *World Trade* in *Steel, 1913.59,* Geneva. 1967

Table 17.–Selected Countries’ Steel Exports’ as a Percentage of Their Total Raw Steel Production, 1955-78

						Selected EEC countries		
Year	Total world	EEC	Japan	United States	Rest of world	West Germany	Italy	United Kingdom
1955	13.0	30.3	25.0	4.6	6.8	16.2	8.5	17.1
1956	12.8	30.1	12.9	5.0	6.9	20.4	15.4	16.0
1957	14.1	31.6	9.4	6.3	7.9	26.3	14,7	18.1
1958	14.4	32.9	17.3	4.6	7.4	26.7	17.4	17.4
1959	14.1	36.1	12.0	2.5	7.4	28.2	17.3	18.6
1960	15.0	34.7	13.5	4.0	8.4	30.6	17.6	16.9
1961	14.5	36.3	10.6	2.8	8.0	32.8	12.9	19.0
1962	15.9	36.5	18,4	2.8	10.5	33.1	13.3	20.0
1963	15.8	36.2	22.5	2.7	10.3	33.0	11.6	19.8
1964	16.1	36.1	21.9	3.6	10.4	29.6	18.5	18.7
1965	17.3	39.8	30.8	3.5	9.8	34.5	25.7	19.2
1966	16.6	39.9	26.4	1.7	10.3	36.5	20.7	19.1
1967	16.9	42.3	18.7	1.8	10.7	43.5	16.6	21.3
1968	18.4	42.7	25.5	2.2	11.0	41.4	19.3	22.1
1969	18.7	40.8	25.3	5.0	11.1	37.4	15.5	19.9
1970	19.0	39.0	25.2	7.1	11.3	35.9	13.7	19.9
1971	21.4	46.8	34.9	3.2	11.8	43.7	24.0	27.3
1972	20.7	47.6	28.7	2.9	12.2	42.3	25.7	24.3
1973	20.8	48.2	27.8	3.6	12.0	46.5	22.1	21.4
1974	23.5	53.2	36.6	5.4	11.2	55.7	26.7	19.8
1975	22.5	54.1	37.7	3.4	11.5	53.7	38.2	21.5
1976	NA	NA	44.7	2.8	NA	47.2	43.8	21.6
1977	NA	NA	41.9	2.2	NA	53.2	37.8	21.5
1978	NA	NA	36.8	2.5	NA	53.7	37.6	21.5

NA = Not available

[a] Semifinished and finished steel exports converted t. raw steel equivalent by dividing exports by O.75 Data include intra-EEC exports for EEC and European nations. For EEC in 1978 exports *outside* the member nations amounted to 25 percent of raw steel production, and Imports from outside member nations was 13 percent of exports

SOURCES U S Congress, Senate Committee on Finance, Steel *Imports,* December 1976, American Iron and Steel Institute, *Annual Statistical Reports,* and U.N. Economic Commission for Europe, *The Steel Market.*

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*It is generally recognized that the prolonged steel strike in 1959 played a role in the dramatic shift of the United States from being a net exporter to a large net importer of steel.

Table 18.—U.S. Imports and Exports of Steel Mill Products, 1956-78

Year	Millions of tonnes		Ratio of imports to apparent consumption (percent)
	Imports	Exports	
1956	1.2	3.9	1.7
1957	1.1	4.8	1.5
1958	1.5	2.5	2.9
1959	4.0	1.5	6.1
1960	3.1	2.7	4.7
1961	2.9	1.8	4.7
1962	3.7	1.8	5.6
1963	4.9	2.0	6.9
1964	5.8	3.1	7.3
1965	9.4	2.3	10.3
1966	9.8	1.5	10.9
1967	10.4	1.5	12.2
1968	16.3	2,0	16.7
1969	12.7	4.7	13.7
1970	12.2	6.4	13.8
1971	16.6	2.5	17.9
1972	16.1	2.6	16.6
1973	13.8	3.7	12.4
1974	14.5	5.3	13.4
1975	10.9	2.7	13.5
1976	13.0	2.4	14.1
1977	17.5	1.8	17.8
1978	19.1	2.2	18.1

SOURCE Compiled from official statistics of the US Department of Commerce

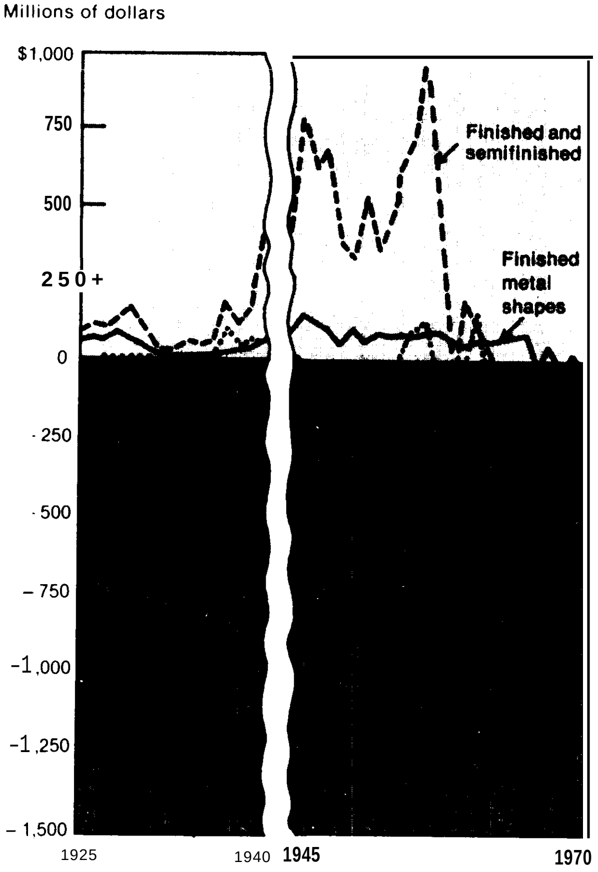
Table 19.—U.S.Iron Ore and Steel Import and Export Levels, 1971-78(millionsofdollars)

Year	Imports		Exports		Combined trade deficit
	Ore	Steel	Ore	Steel	
1971	$ 476,4	$2,636	$36.1	$ 576	$2,500
1972	441.4	2,794	24.9	604	2,607
1973	564.0	2,821	35.7	1,004	2,345
1974	798.3	5,116	38.2	2,118	3,758
1975	1,017.3	4,093	56.3	1,862	3,192
1976	1,078.0	4,025	70.0	1,255	3,778
1977	970.5a	5,531	55.4[a]	1,037	5,409
1978	1,000.0[a]	6,917	60.0[a]	1,329	6,528

[a] Preliminary estimate

SOURCES Ore—Using Import/export tonnage data and average annual prices In U S Bureau of Mines, "Iron Ore, " MCP-13, 1978; steel—U.S. Department of Commerce, *U .S. Industrial Outlook* 1978.

Figure 9.— U.S. Trade Balance in Iron and Steel, 1925-70[a]



[a] Excluding the war years 1941-45

SOURCE: W.H. Branson and H.B. Tunz, *Brookings Papers on Economic Activity,* 2 1971 (based on U S Department of Commerce and U S Bureau of the Census data)

Profitability and Investment in the Steel Industry

Domestic steelmaker' limited exports and the country's growing imports are indicative of the decline in the competitiveness of the U.S. steel industry in the international market. Competitiveness is based on technological capability and its interaction with macroeconomic developments and inputs of labor, raw material, and capital. It is axiomatic that no matter how much technological knowledge exists, it will not be used unless capital is made available to finance applications of that knowledge.

Trends in Domestic Steel Industry Profits

To a significant extent, the problems that the domestic steel industry presently faces can be traced to longstanding low profitability, which according to many people has discouraged equity investment in the industry. Aggregate financial data support this contention. Nevertheless, the domestic steel industry has had a far better financial performance than have many foreign steel producers.* Still, given the prevailing profit status of many domestic steel firms, they will be significantly short of the capital they would need to modernize, solve environmental problems, and no more than maintain current capacity levels, much less expand them.

Conventional comparisons of domestic profitability, measured as aftertax profits as a percentage of stockholder equity, show low steel industry profits compared to other sectors. In only 4 years (1955-57 and 1974) during the past 25 did this measure of steel industry profit exceed the average for all domestic manufacturing firms (table 20). Steel industry profitability has been lower than prime interest rates for 5 of the past 10 years.

Although total revenue for the domestic steel industry has increased steadily, from $9,534.6 million in 1950 to $46,877.3 million in 1978, so have its operating expenses and capital expenditures. Industry net income fluctuated widely during the 1950-78 period (table 21). The real rate of return has declined to very low levels, finally becoming negative during the past few years as inflation rates exceeded steel industry profit margins (figure 10), Dividend payments have been surprisingly stable, however, even in years of very low profitability. In addition, capital expenditures as a percentage of net internally generated cash funds have been relatively high (table 22).

One of the industry's explanations for its shrinking profitability and growing capital problem is the "cost-price'" squeeze, that is, the situation in which steelmaking costs rise more rapidly than do steel prices. The data in table 23 confirm that this has been the case, particularly for all forms of energy and for labor. This trend started in the early 1960's and has continued to the present. Of particular importance has been the inability of the industry to raise prices when it needed to match cost increases and when the world competitive situation would have tolerated higher prices for steel. The industry has always been a prominent target for Government "jawboning" when it announces price increases. During the periods of worldwide steel shortage, the Government directly controlled and held down domestic steel prices. In 1973-74, for example, imported steel reputedly was selling for from $55 to $110/tonne more than domestic steel (at $330/tonne).

Financial Performance of the Steel Industry Segments

The nonintegrated and alloy/specialty steel producers have exhibited much better financial performance than have integrated companies in recent years (table 24). There is wide variation in profitability among integrated companies, however, which seems to reflect major differences in technology, age

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*International profitability comparisons should be made with caution since foreign government ownership and direct and indirect support make measures of profitability used for private U.S. firms difficult to apply to all foreign firms.

Table 20.–Trends in Steel Industry Profits, 1954-78

	Profits after taxes					
	Steel		Percent of stockholder equity[a]			
Year	Millions of dollars	Percent of revenues	Steel	All mfg.	Ratio of steel/mfg.	Prime interest rate (percentage)
1954	$ 637	6.0	9.4	12.4	75.8	3.05
1955	1,099	7.8	15.4	15.0	102.8	3.16
1956	1,113	7.3	14.1	13.9	101.4	3.77
1957	1,132	7.3	13.1	12.9	101.6	4.20
1958	788	6.3	8.3	9.8	84.7	3.83
1959	831	5.8	8.4	11.7	71.8	4.48
1960	811	5.7	7.9	10.6	74.5	4.82
1961	690	5.2	6.5	9.9	65.7	4.50
1962	566	4.1	5.3	10.9	48.6	4.50
1963	782	5.4	7.3	11.6	62.9	4.50
1964	992	6.1	9.0	12.6	71.4	4.50
1965	1,069	5.9	9.4	13.9	67.6	4.54
1966	1,075	5.9	8.9	14.2	62.7	5.63
1967	830	4.9	6.9	12.6	54.8	5.61
1968	992	5.3	8.2	13.3	61.7	6.23
1969	879	4.6	7.0	12.4	56.5	7.96
1970	532	2.8	4.1	10.1	40.6	7.91
1971	563	2.8	4.3	10.8	39.8	5.72
1972	775	3.4	5.8	12.1	47.9	5.25
1973	1,272	4.4	9.3	14.9	62.4	8.03
1974	2,475	6.5	17.1	15.2	112.5	10.81
1975	1,595	4.7	9.8	12.6	77.8	7.86
1976	1,337	3.7	7.8	15.0	52.9	6.84
1977[b]	22	.1	0.1	14.9	0.7	6.83
1978	1,292	2.8	7.3	15.9	45.0	9.06

aBased on equity at beginning of year. [b]Data influenced by Bethlehem Steel's plant closing and large loss.

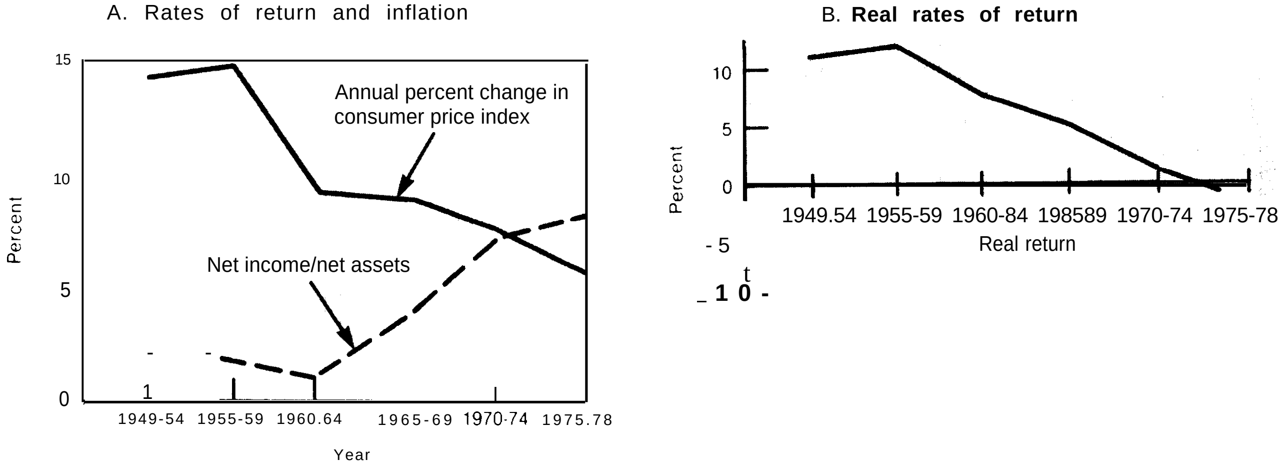
SOURCES: American Iron and Steel Institute; Citibank Corp.

Table 21.—Selected Financial Highlights, Iron and Steel industry, 1950-78 (dollars in millions)

Year	Total revenues	Net income	Net Income as a percentage of revenues	Stock-holders' equity[a]	Net Income as a percentage of stockholders' equity	Working capital ratio	Long-term debt	Captial expenditures
1950,	$ 9,534.6	$ 766.9	8.0	$ 5,458.3	**14.1**	**2.1**	$ **763.1**	$ **505.3**
1951	11,845.0	**682.2**	5.8	6,037.9	**11.3**	**2.0**	**1,029.6**	**1,050.9**
1952	10,858.2	**541.0**	5.0	6,373.0	**9.5**	**1.9**	**1,447.3**	**1,298.3**
1953	13,155.8	**734.9**	5.6	6,780.9	**10.9**	**2.2**	**1,485.7**	**987.8**
1954	10,593.3	**637.3**	6.9	7,139.6	**8.9**	**2.0**	**1,485.7**	**608.9**
1955	14,049.3	**1,098.6**	7.8	7,920.2	**13.9**	**2.0**	**1,546.5**	**713.7**
1956	15)271.8	**1,113.3**	7.3	8,664.7	**12.8**	**2.1**	**1,567,7**	**1,310.6**
1957	15,592.1	**1,131.6**	7.2	9,465.6	**11.4**	**2.3**	**1,801.5**	**1,723.0**
1958	12,551.3	**787.6**	6.3	9,898.2	**8.0**	**1.9**	**2,144.8**	**1,136.9**
1959	14,233.3	**830.6**	5.8	10,248.4	**8.1**	**2.0**	**2,303.2**	**934.3**
1960	14,221.3	**810.8**	5.7	10,545.1	**8.2**	**2.1**	**2,488.2**	**1,520.7**
1961	13,295.4	**689.6**	5.2	10,646.9	**6.5**	**2.7**	**2,968.5**	**959.5**
1962	13,980.6	**566.4**	4.1	10,676.1	**5.3**	**2.9**	**2,853.6**	**911.4**
1963	14,612.6	**782.0**	5.4	11,008.3	**7.1**	**2.7**	**2,694.8**	**1,040.0**
1964	16,357.1	**992.3**	6.1	11,393,4	**8.7**	**2.4**	**2,874.2**	**1,599.5**
1965	17,971.7	**1,069.3**	5.9	12,031.9	**8.9**	**2.4**	**3,120.1**	**1,822.5**
1966	18,288.4	**1,075,3**	5.9	12,045.1	**8.9**	**2.3**	**3,782.3**	**1,952.7**
1967,	16,880.4	**829.8**	4.9	12,168.5	**6.8**	**2,2**	**4,205,3**	**2,145.7**
1968	18,679.6	**992.2**	5.3	12,617,5	**8.2**	**2.0**	**4,6014**	**2,307,3**
1969	19,231.0	**879.4**	4.6	12,836.0	**7.0**	**1.8**	**4,608,2**	**2,046.6**
1970	19,269.5	**531.6**	2.8	12,966.0	**4.1**	**1.9**	**5,1339**	**1,736.2**
1971	20,357.8	**562.8**	2.8	13,281.4	**4.1**	**1.9**	**5,1444**	**1,425.0**
1972	22,555.7	**774.8**	3.4	13,674.5	**5.8**	**1.9**	**5,2296**	**1,174.3**
1973	28,863.2	**1,272,2**	4.4	14,513.5	**9.3**	**1.9**	**4,9629**	**1,399.9**
1974	38,243.6	**2,475.2**	6.5	16,243.2	**17.1**	**1.8**	**4,6512**	**2,114.7**
1975	33,676.3	**1,594.9**	4.7	17,192.2	**9.8**	**2.0**	**5,7053**	**3,179.4**
1976	36,462.4	**1,337.4**	3.7	18,027.3	**7.8**	**1.9**	**6,9665**	**3,252.9**
1977	39,787.4	**23.2**[b]	0.06	17,603.7	**0.1**	**1.8**	**7,9307**	**2,857.6**
1978	46,877.3	**1,291.9**	2.8	18,403.3	**7.3**	**1.7**	**7,7389**	**2,5383**

[a]As of January 1 of each year. [b]Reflects substantial impact of Bethlehem Steel plant closings.

Figure 10.—Steel Industry Annual Average Rates of Return and Annual Average Rates of Inflation, 1949-78



SOURCE American Iron and Steel Institute; U S Bureau of Labor Statistics

Table 22.—Selected Financial Data, U.S. Steel industry, 1954-78 (dollars in millions)

Year	Profits after taxes	Depreciation, depletion, etc.[a]	Gross cash flow	Cash dividends	Net cash flow	Capital expenditures	Captial expenditures as a percent of net internally generated funds
1954 ..., .	$637	$703	$1,340	$343(53.8)[b]	$ 997	$ 609	61.1
1955 ,	1,099	783	1,882	437(39.8)	1,445	714	49.4
1956 ,	1,113	794	1,907	508(45.6)	1,399	1,311	93.7
1957, ...	1,132	816	1,948	566(50.0)	1,382	1,723	124.7
1958 .	788	713	1,501	540(68.5)	961	1,136	118.2
1959 . ,	831	653	1,484	553(66.5)	931	934	100.3
1960 . . . .,	811	840	1,651	564(69.5)	1,087	1,521	139.9
1961 . ,	690	749	1,439	557(80.7)	882	960	108.8
1962	566	958	1,524	508(89.8)	1,016	911	89.7
1963 . . .	782	1,034	1,816	433(56.6)	1,373	1,040	75.7
1964 . . . . .,	992	1,046	2,038	462(46.6)	1,576	1,600	101.5
1965 ,	1,069	1,117	2,186	468(43.8)	1,718	1,823	106.1
1966 .	1,075	1,199	2,274	483(44.9)	1,791	1,953	109.0
1967	830	1,444	2,274	481(58.0)	1,793	2,146	119,7
1968 .	992	1,316	2,308	452(45.6)	1,856	2,307	124.3
1969, ...	879	1,173	2,052	489(55.6)	1,563	2,047	131.0
1970 ,	532	1,128	1,160	488(91.7)	1,172	1,736	148.1
1971	563	1,123	1,686	.390(69.3)	1,296	1,425	110.0
1972 . ,	775	1,196	1,971	402(51.9)	1,569	1,174	74.8
1973	1,272	1,329	2,601	443(34.8)	2,158	1,400	64.9
1974	2,475	1,553	4,028	675(27.2)	3,354	2,115	63.1
1975	1,595	1,591	3,186	658(41.5)	2,528	3,179	125.8
1976 .	1,337	1,614	2,951	637(47.6)	2,314	3,253	140.6
1977 . . ,	22	1,888	1,910	555[c]	1,355	2,850	210.3
1978	1,292	2,010	3,302	533(41.3)	2,769	2,538	91.7

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[a] Includes changes in reserves

[b] Numbers in parentheses are dividends as of percent of after taxcredlts

[c] The industry percent was 104, omitting Bethlehem Steel because of its extraordinary one time loss. **For Bethlehem** itself, dividends represented 146 percent ($65.5 million) of the net loss ($448.2 million)

SOURCE: American Iron and Steel Institute

Table 23.—index of Steel Industry Prices and Costs, 1965-78

Year	Consumer price index	Wholesale price index for industrial commodities	Steel mill products	Metallurgical coal (high volume)	Iron ore (pellets)[a]	Steel scrap	Electrical power	Fuel oil	Wages[b]
	Producer price indexes								
1965	*94.5*	*96.4*	*97.5*	*96.8*	NA	112.6	03.0	*07.7*	94.05
1966	*97.2*	*98.6*	*98.9*	98.4	NA	106.6	99.8	05.0	97.37
1967	100.0	*00.0*	*00.0*	00.0	NA	100.0	00.0	00.0	100.00
1968	104.2	*02.5*	*02.5*	01.8	NA	93.0	00.9	95.7	105.76
1969	109.8	*06.0*	*07.4*	10.2	100.0	110.8	02.2	93.3	112.97
1970	116.3	10.0	14.3	150.9	105.1	138.8	06.6	25.5	119.31
1971	121.3	**13.9**	23.0	185.3	111.1	114.6	15.5	66.0	131.59
1972	125.3	**17.9**	30.4	198.4	111.1	121.8	23.9	58.8	148.70
973	133.1	**27.0**	34.1	216.5	116.4	188.0	32.6	90.4	161.43
974	*147.7*	153.8	170.0	232.8	140.3	353.2	172.3	485.4	190.79
975	161.2	171.5	197.2	622.1	181.2	245.6	193.2	495.5	222.57
976	170.5	182.5	209.7	657.8	201.6	259.0	226.9	451.7	246.82
977	181.6	195.1	229.9	671.3	220.2	233.7	257.2	521.4	273.76
1978	195.4	209.3	254.5	704.9	230.1	278.2	279.7	496.8	300.36

NA = Not available [a] December 1969 base. [b] Including fringe benefits.

SOURCES: U.S. Department of Labor, American Iron and Steel Institute

Table 24.—Steel Company Profitability by Industry Segment, 1977-78

Company	Steel sshipped (thousand net tonnes)		Return on Investment (percent)		Pretax profits from steel only (dollars per tonne shipped)’	
	1977	1978	1977	1978	1977	1978
integrated companies‾						
United States Steel	17,868	18,866	**3.7**	5.3	- 530	– 1. 04[a]
Bethlehem Steel	11,251	11,859	**(11.0)**	9.3	-1048	26.60[a]
LTC . .	4,427	4,881	**(0.4)**	5.8	– 1168	5.26[b]
National Steel . .	6,912	7,438	**5.8**	82	9.45	25.66[a]
Inland Steel .	5,067	5,661	**6.4**	9.7	1538	36.24[a]
Wheellng.Pittsburgh Steel .	2,477	2,655	**(2.0)**	63	– 1327	8.80
Kaiser Steel	1,440	1,443	**0.6**	1.6	- 840	-1225
McLouth Steel	1,286	1,466	**(3.8)**	5.2	– 1873	7 .36[b]
CF&I Steel	1,009	980	**8.8**	6.6	2040	11.64
Interlake	738	787	**5.9**		418	– 31. 64[b]
Average			**1.4**	6.2		
Republic Steel	6,038	6X01	**4.2**	10.4	6.36	23.35[a]
Armco. .,	4,973	5,457	**7.2**	10.4	- 402	12.79[a]
Nonintegrated companies						
Northwestern Steel & Wire	763	1,077	7.2	139	3338	53.33
Nucor . . .	563	718	16.7	250	4169	7004
Florida Steel	418	600	48	138	854	2727
Keystone Consolidated Industries .	461	497	0.2	23	– 14.88	1.35[b]
Laclede Steel. .	397	471	42	94	- 099	1664
Atlantic Steel.	346	430	4,0	96	3.00	2098
Average “.	—	—	6.2	123	—	—
Alloy and specialty steel companies[c]						
Sharon Steel[d]	965	1,055	10.6	153	29.38	5783
Cyclops	776	666	55	103	1614	4111
Allegheny-Ludlum Industries	344	357	52	85	47.75	6330
Copperweld	297	351	111	84	77.41	5413
Washington Steel	42	45	93	116	150.29	190. 29[b]
Carpenter Technology	—	—	168	169	NA	NA
Lukens Steel	—	—	100	9.6	NA	NA
Athlone Industries (Jessop Steel). .,	–	—	7.5	9.9	NA	NA
Eastmet (Eastern Stainless Steel) .,	—	—	6.0	90	NA	NA
Average	—	—	9.1	11.1	—	—

[a] Source: *World Steel Dynamics, Business Week* (Sept. 17, **1979)** has given data on U S Steel Indicating a 1978 loss of $15.00/tonne of steel shipped.

[b] From Steel Form 10-k reports. (U.S. Securities and Exchange Commission.)

[c] Alloy and specialty steels account for more than 10% of the steel shipments of these companies.

[d] Although Sharon Steel is **integrated**, most of its business is in alloy and specialty steels.

SOURCE *Iron Age,* May 7, 1979

and scale of facilities, and management practices. Although the financial performance of many domestic fully integrated steel firms is relatively poor when compared to other domestic manufacturing sectors, their overall performance appears to be far superior to major steel producers in other nations.

Several factors account for the far better financial performance of the nonintegrated and alloy/specialty companies compared to the integrated companies. Importantly, the alloy/specialty mills and many of the nonintegrated mills use advanced and efficient technologies to a greater extent than do integrated plants, and these technologies tend to yield higher profit margins than do older methods. Alloy/specialty mills, since 1973, have been provided with effective quota barriers against competing imports. Furthermore, their comparatively high-priced products have intrinsically greater profit margins than the products the other segments produce. Nonintegrated firms have lower costs than integrated firms because they use ferrous scrap almost exclusively as a raw material, they make a smaller range of simpler products, and they have lower marketing and other overhead costs.

Trends in Steel Industry Investment

The steel companies' net income has been insufficient over time to meet all of their capital needs and the industry has been forced to borrow extensively for investment in new equipment. The industry's long-term debt increased tenfold between 1950 and 1978, from $763.1 million to $7,738.9 million. One of the principal reasons for the increasing debt has been the steady growth in capital expenditures in actual dollars. In real dollars, these expenditures have fluctuated widely (table 25).

In the same 1950-78 time period, stockholders' equity increased only by a factor of three from $6,812,6 million to $17,603.7 million (see table 21). As a result, the debt-to-equity ratio increased from 11.2 percent in 1950 to 44.0 percent in 1978. The debt-to-equity ratio is an important variable, which significantly affects industry's ability to enter equity markets. With a ratio of nearly 45 percent and low profits, most steelmaker cannot issue new stock or increase their debt.

Table 25.—Replacement Rates for Domestic Steel Production Facilities, 1950-78

Year	Capital expenditures on productive steelmaking facilities (millions of 1978 dollars)	Capital expenditures on steelmaking facilities per tonne of finished steel shipped (1978 dollars per net tonne)	Replacement rate[b] (percent)
1950	$1,181	$19.03	1.73
1951	2,268	32.56	2.96
1952	2,749	45.87	4.17
1953	2,055	28.71	2.61
1954	1,258	22.33	2.03
1955	1,447	19.36	1.76
1956	2,484	34.10	3.10
1957	3,094	43.89	3.99
1958	2,045	38.17	3.47
1959	1,647	27.28	2.48
1960	2,675	43.01	3.91
1961	1,698	29.37	2.67
1962	1,600	25.96	2.36
1963	1,811	27.39	2.49
1964	2,760	37.07	3.37
1965	3,107	38.83	3.53
1966	3,405	43.45	3.95
1967	3,367	46.42	4.22
1968	3,576	44.66	4.06
1969	2,869	36.52	3.32
1970	2,214	29.37	2.67
1971	1,705	23.10	2.10
1972	1,265	16.28	1.48
1973	1,630	17.16	1.56
1974	2,163	23.54	2.14
1975	2,684	40.48	3.68
1976	2,599	34.98	3.18
1977	2,054	27.72	2.52
1978	1,706	21.67	1.97
Annual averages			
1950-58. .	2,065	31.57	2.87
1950-78. .	2,245	31.68	2.88
1959-68. .	2,565	36.30	3.30
1969-78. .	2,089	27.06	2.46

aCapital expenditures less environmental expenditures and estimated non steel capital expenditures. Current dollars (adjusted by using the GCP Non-residential Investment Implicit Price Deflator) Capital expenditures shown are for American Iron and Steel Institute reporting companies only

bCapital expenditures (1978 dollars) on productive steelmaking facilities per tonne of shipments divided by replacement cost of facilities per tonne of shipments. Replacement facility cost per tonne of shipments assumed to be $1,100 (1978 dollars)

SOURCE: D.F. Barnett, American Iron and Steel Institute

The relative profitability of the U.S. steel industry compared to foreign steel industries, the large size of the domestic market, and the sizable proportion of imports in domestic steel consumption have made domestic steel mills and steel distributors attractive targets for foreign investment and outright purchase.

The existence of stocks that are undervalued relative to book value and exchange rates favorable to foreigners add to the relative attractiveness of domestic steel mills to foreign investors. As a result, a number of small nonintegrated mills have been purchased or built by foreign interests; these include Chaparral Steel (50-percent interest) and Raritan Steel, by Co-Steel International Ltd. of Canada; Auburn Steel, by Japanese interests; Korf and Georgetown Steel, by West German interests; Atlantic Steel, by Ivaco Ltd. of Canada; Bay Steel by VoestAlpine of Austria; New Jersey Steel and Structural, by Van Roll of Switzerland; Azcon and Knoxville Iron, by Consolidated GoldFields of the United Kingdom; Phoenix Steel (50-percent interest), by Creusot-Loire of France; Judson Steel, by Australian interests; and Schindler Bros. Steel Co. by West German interests. In November 1979, Kaiser Steel Corp. held discussions with Nippon Kokan KK concerning potential takeover. These particular negotiations were discontinued, but further takeovers of domestic steel producers by foreign investors are expected in the future.

Ownership and Financial Performance of Foreign Steel Firms

The financial performance of the domestic steel industry is somewhat difficult to compare with that in other nations because of the significantly different economic settings in which foreign steel firms operate. The principal difference is that many foreign steel firms are at least partly owned and/or controlled by their governments (table 26). Furthermore, in many countries, government support of steel is based on public policy considerations, such as employment stability or growth of other industries, rather than steel industry profitability alone. The same type of socioeconomic considerations in some foreign countries at least partly account for the lower labor productivity in their steel industries compared to the United States (table 27).

The domestic steel industry generally has lower production costs than foreign industries and recently has had higher rates of capacity utilization (table 28). As a result, most foreign steel producers havtl been less profitable during the past decade than domestic steel producers, particularly if the comparison is with the best performing U.S. firms rather than with industry averages (table 29). Only the Canadian steel industry has been consistently more profitable than the U.S. industry but the Canadian industry is much smaller. Data on world rank by size, production, sales, and profitability for a number of foreign steel firms are given in table 30. These data underestimate financial losses, because the most unprofitable companies, often state-owned, generally do not publish their financial results. World Steel Dynamics (1979) has estimated that, for 1978, Western world steel exports represented a loss of $4 billion, suggesting that considerable dumping is occurring and that foreign steel industries are being operated at rates for purposes other than profitmaking.

Summary data on profitability of steel industries in Europe, several foreign nations, and the United States are given in table 31. These data show that the U.S. industry has been much more profitable than Europe’s, which has experienced large losses. Though the technological and cost competitiveness of

Table 26.—Government Ownership of Raw Steel Facilities, Selected Countries
(percent government owned)

Country	1974 production	1978a	1979 capacity
Canada	17	0	13
Brazil	60	75	68
Mexico	47	75	74
Venezuela	86	NA	85
Other Latin America	NA	NA	56
France	0	75	69
West Germany	11	0	9
Italy	57	75	57
United Kingdom	90	75	79
Spain	45	50	39
Netherlands	93	25	NA
Sweden	21	75	59
Belgium	0	50	NA
Austria	100	100	NA
Other Western Europe	NA	NA	60
Republic of South Africa	87	NA	72
Other Africa	NA	NA	70
India	100	75	82
Taiwan	100	NA	12
South Korea	100	75	NA
Other Asia	NA	NA	75
Oceania	NA	NA	30
Total non-Communist countries	19	NA	30
Total Communist countries	100	NA	100
Total world	44	NA	“45

NA = not available
aProductlon or capacity not stated (probably capacity), numbers apparently rounded off to 0, 25, 75, or 100%.

SOURCES 1974 production—D.F. Barnett The Canadian Steel Industry in a Competitlve World Environment Canadian Government. 1977: 1978 production – *The Economlst* Dec. 30, 1978 and 1979 capacity—American Iron and Steel Institute

the Japanese steel industry cannot be refuted, it still has not been very profitable. A number of factors explain this relatively low profitability: low capacity utilization (about 70 percent for the past several years), high financial costs, increasing energy prices and labor costs, and high transportation costs for raw material imports and finished steel exports. With the exception of Canada, * foreign steel industries continue to suffer either large losses or only moderate profits. Nevertheless, as a result of government support, many foreign steel-producing firms have experienced considerably greater expenditures than have domestic steel firms both on a per-tonne basis and as a percentage of the countries' gross national products (GNPs) (figures 11 and 12).

Japanese companies are about 83-percent debt-financed, compared to an average of 44 percent for U.S. steelmaker. Japan's close government/business cooperation, aimed at maintaining a strong, export-oriented steel industry, provides Japanese steelmaker with considerable access to external funds. The Japanese Government, through the Bank of Japan and indirectly through commercial banks, facilitates loans to steel companies to finance modern capacity additions in order to increase production or permit economies of scale. This capital is not a subsidy: the companies pay interest at a rate slightly lower than the prevailing rate. *

The steel industries of developing countries have been given considerable help from international organizations. For example, the U.N. International Development Organization (UNIDO) has considered underwriting the expansion of ironmaking and steelmaking in LDCs, and the World Bank has made available many loans for this purpose. A UNIDO report argues that steel firms in developed countries are planning to build up production of semifinished steel in LDCs. The report states:

> Steel industry projects in developing countries in many parts of the world are being pursued steadily . . . The shift presents the developing countries with an exceptional opportunity. They are able to pursue their own development schemes with technical assistance and deliveries of equipment more readi-

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*For the three largest Canadian (integrated) steel companies, The Steel Co. of Canada, Dominion Foundries & Steel, and Algoma Steel, the average returns on equity for 1974 to 1978 were 11.6 percnt. 12.9 percent, and 10.8 percent respectively. The best performing large U.S. integrated firms for this period were Armco with 11.3 percent and Inland with 11.2 percent return on equity. (‘‘The Steel Industry of America. ” Price Waterhouse & Co., 1 979.)

*The rate paid is about 1/2 to 1 percent lower than the market interest rate in Japan. A subsidy of this magnitude would be less than $0.55/tonne on a $330/tonne product.

Table 27.—Comparison of Productivity and Labor Costs in the U.S. Iron and Steel Industries With Four Other Countries, 1964,1972-77

Measure and year	United States	Japan		West Germany		United Kingdom		France	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Output per hour									
1964	100	46	53	53	60	48	51	48	52
1972	100	85	101	76	84	51	54	62	69
1973	100	94	112	73	80	48	51	59	66
1974	100	95	113	80	88	43	46	61	68
1975	100	103	123	82	91	43	46	61	68
1976	100	108	128	82	91	48	51	63	70
1977	100	104	123	81	89	43	46	64	72
Hourly labor costs									
1964	100	16	16	35	35	29	38	34	35
1972	100	33	34	58	58	33	34	44	44
1973	100	41	42	71	71	33	34	54	54
1974	100	44	46	78	78	35	36	55	65
1975	100	44	46	76	76	37	38	63	63
1976	100	44	45	72	72	33	34	63	63
1977	100	49	51	78	78	33	34	64	64
Unit labor costs									
1964	100	**24**	30	59	67	57	61	66	72
1972	100	32	40	68	75	62	67	64	71
1973	100	37	45	88	97	66	71	83	91
1974	100	39	48	88	97		81	82	98
1975	100	36	44	83	92	80	87	97	107
1976	100	34	42	79	87	65	70	92	101
1977	100	40	40	88	97	72	77	90	99

SOURCE U.S. Bureau of Labor Statistics.

Table 28.—Capacity Utilization in Several Steel Industries (percent of capacity)

Year	United States	Canada	Japan	United Kingdom	West Germany	France	ECSC (six countries)	Total EEC
Annual averages								
1956-65	75.8	86.8	84.2	–	—	—	89.8	
1966-75	86.5	88.7	85.0	–	—	—	81.5	=
1956-75	81.1	87.7	84.7	–	—	—	85.6	–
Annual								
1973	**97.5a**	**—**	**85.8**	**92.5**	**84.2**	90.0	—	86.3
1974	93.5a	—	77.7	80.3	88.1	88.5	—	86.9
1975	76.2	—	67.3	74.2	64.3	64.0	—	66.1
1976	80.9	—	66.6	77.7	64.4	69.7	—	67.9
1977	78.4	—	61.1	70.9	57.6	66.4	—	62.8
1978	86.8	—	67.3	73.6	60.0	68.5	—	65.9

[a] Estimate.

SOURCES: Averages—D.F. Barnett, "The Canadian Steel industry in a Competitive World Environment," Canadian Government, 1977,annualdata—American Iron and Steel Institute, Eurostat, European Coal and Steel Community, and Japan's Ministry of International Trade and Industry.

ly available from developed countries than at any time during the past ten years. As the developing countries make rapid progress with their steel industries, they will reduce their dependence upon imports, improve their balance of payments, and create a sound basis for further industrialization. ’

Table 29.—Steel Industry Net Income as a Percentage of Net Fixed Assets, Five Countries, Averages for 1969-77

Country	Net income/ net fixed assets
United States.	6.7
Japan	1.7
West Germany.	2.9
United Kingdom	– 5.3
France (1972-76)	– 8.3

SOURCE. International Iron and Steel Institute

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[1] U.N. International Development Organization, Progress Report on the World Iron and Steel Industry (draft, no date, Vienna, Austria).

Thus, it is clear that the privately owned and financed U.S. steel industry is largely competing in an international market with foreign steel industries that have significantly better access to capital but that are no more profitable, and in many cases less profitable, than the U.S. industry.

Table 30.— Financial Statistics, Selected Steel Companies, 1978

Company	Country	1978 world rank	1978 production (millions of tonnes)	Sales: 1978 (millions of dollars)	Sales: 1977-78 (percent change)	Profits after taxes: 1978 (millions of dollars)	Profits after taxes: 1978-77 (percent change)	1978 return on book value[a] (percent)
British Steel	United Kingdom	4	16.7	$ 5.882.0	3	-$690.0	NM	-32
Creusot-Loire	France	—	1.5	2,974.8	17	– 85.0	NM	–36
FINSIDER	Italy	6	13.0	—	—	—	—	—
Dalmine	Italy	—	—	630.2	4	– 75.0	NM	–81
Italsider	Italy	—	—	2,941.5	15	-419.6	NM	- 6 6
Thyssen	West Germany	9	11.8	12,086.1	12	66.0	– 18	4
Krupp	West Germany	23	5.1	6,556.3	7	– 10.5	NM	–1
Klockner-Werke	West Germany	28	4.1	1,882.5	13	– 38.6	NM	– 14
Salzgitter	West Germany	29	3.9	3,464.2	5	– 52.0	NM	- 1 6
COCKERILL	Belgium	**20**	5.3	3,294.4	NA	*– 0.2*	NA	NA
ESTEL (Hoogovens and Hoesch)	Netherlands	**21,22**	5.3,5.1	5,571.7	8	*-146.6*	NM	-11
Empresa Nacional Siderurgia	Spain	**25**	4.9	1,390.1	7	*– 174.1*	NM	NA
Nippon Kokan	Japan	**5**	13.4	5,523.8	– 4	*49.3*	98	6
Nippon Steel	Japan	1	31.2	11,526.3	4	*216.1*	185	10
Sumitomo	Japan	**7**	12.0	4,918.3	6	*72.9*	183	10
Kawasaki	Japan	**8**	12.0	4,591.1	3	*83.3*	156	11
Kobe Steel	Japan	**16**	7.1	4,223.9	6	*65.4*	95	11
Stelco	Canada	**24**	5.0	1,496.9	23	101.3	33	12
Dominion Foundries	Canada	**33**	3.3	994.5	22	80.0	39	16
Algoma Steel	Canada	**34**	3.0	728.5	26	58.7	85	13
Broken Hill	Australia	**14**	7.6	2,680.2	11	95.5	62	4
Steel Authority of India	India	**18**	6.3	1,798.8	NA	33.1	NA	NA
Tata Iron & Steel	India	**47**	1.9	426.1	9	9.5	–36	8
South African Iron & Steel	South Africa	**19**	6.1	1,306.1	24	– 84.4	NM	– 7
Comp. Siderurgia Nacionale	Brazil	**43**	2.1	865.8	48	– 2.2	**NM**	– 2

NM = not meaningful, NA = not available

[a] Book value is common equity at end of fiscal year

SOURCES Rank and production—international Iron and Steel Institute, other data–Business Week, July 23, 1979

Table 31.— Average Profitability for Steel Industries in Six Nations and Europe, 1978

Country/area	1978 dollars: Profit per tonne raw steel	1978 dollars: Pretax profit per tonne shipped[a]	1978 profit (percent): Sales	1978 profit (percent): Return on equity
Europe	–21 .19 (1977 = –25.86)b	—	1.6	—
Japan	6.43 (1 977= 2.45)	9	7.6	3.2c
Canada	21.24 (1977= 15.32)	—	—	13.7
France	– 56.67	–48	—	—
West Germany	– 1.41	– 2	—	—
United Kingdom	– 41.32	–50	—	—
United States	10.48 (1977 = 4.81)[d]	31	2.8	7.3

aFrom World Steel Dynamics, September 1979, for commodity carbon steels made m integrated plants only.

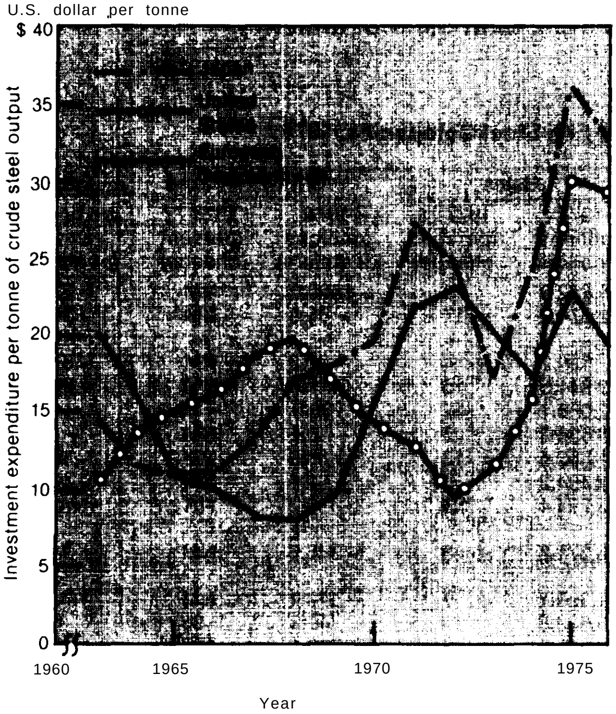
bFrom data in Fortune, Aug. 13, 1979, for 17 European steelmaker representing897 million tonnes of raw steel, 1978 production (only 3 firms showed proflt).

CThe average of 96 percent for the five firms was normalized to 32 percent in order to compensate for the widely different debt-to-equity ratio, assuming that for the United States the ratio is4060 and for Japan it is8020

dExcludes extraordinary losses of Bethlehem Steel and their raw steel production.

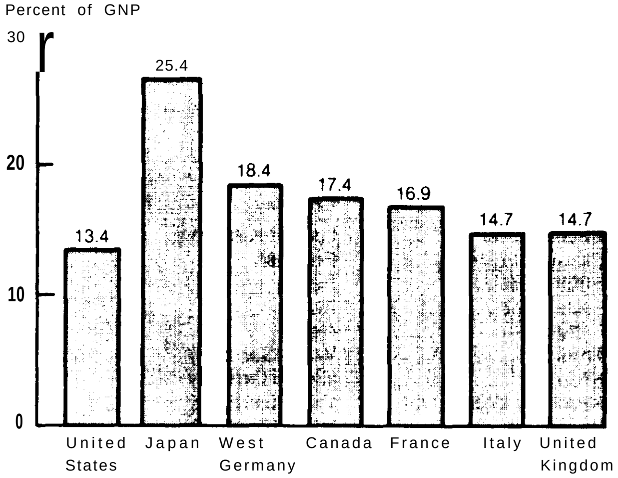
SOURCE American Iron and Steel Institute data. except as noted

Figure 11.— Rates of Investment in Major Steel Industries, 1963-76



SOURCES. Organization for Economic Cooperation and Development, International Iron and Steel Institute

Figure 12.—Capital Expenditures in Steel Manufacturing as Percent of GNP, Selected Steel-Producing Countries, 1960-78



SOURCE U N. International Monetary Fund

Factors in International Competitiveness

The production factors—capital, labor, and raw materials—are combined in various ways, through technology, to produce steel. The productivity of these inputs is partly determined by the technologies in use. Their productivity and prices, in turn, determine production costs, a major element of the profitability needed to attract capital.

Technology

Technology has direct and indirect effects on total steelmaking productivity because investments in up-to-date processing equipment help slow down real production cost increases. * During the 1960's, the domestic steelmaker made major technological gains in hot wide-strip mills, rod and bar mills, and in secondary refining. * The use of low-cost electric furnaces also increased considerably, driven mostly by the construction of domestic nonintegrated plants that take advantage of locally available scrap. The production of raw steel from electric furnaces is comparable to that in Japan, greater than that in West Germany and France, but lower than that in the United Kingdom (table 32).

The Federal Trade Commission (FTC) has concluded that the U.S. steel industry adopted new basic oxygen and continuous casting technology more rapidly than any

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*Adoption of new technology is discussed more thoroughly in ch. 9.

*One of the newest U.S. hot strip mills. computer-controlled from start to finish, requires only 32 workers on each shift compared to about 80 in other facilities. (U.S. Department of Labor. Bulletin No. 1856.)

Table 32.—Comparative Trends in Raw Steel Production in Electric Furnaces, 1964-78 (percent of total production)

Year	United Kingdom	France	West Germany	Japan	United States	Total world (excluding the United States)
1964	—	—	—	—	9.98	—
1965	—	—	—	—	10.50	—
1966	—	—	—	—	11.09	—
1967	—	—	—	18.3	11.86	—
1968	—	—	—	18.2	12.79	—
1969	—	—	—	16.7	14.25	13.7
1970	18.9	—	—	16.7	15.33	14.6
1971	17.5	—	10.0	17.6	17.39	14.7
1972	18.9	—	10.2	18.6	17.80	15.5
1973	19.4	10.7	10.4	17.9	18.40	15.6
1974	22.9	11.5	10.8	17.8	19.67	16.2
1975	26.9	14.2	12.6	16.4	19.44	17.2
1976	29.7	14.2	12.4	18.6	19.23	19.1
1977	30.0	14.5	13.0	19.1	22.25	18.5
1978	34.7	15.0	14.5	21.9	23.53	17.3

SOURCES American Iron and Steel Institute Ministry of Industry and Trade, Japan, Statistlches Bundesamt, West Germany, Iron and Steel Statistics Bureau, United Kingdom

other nation. [2] However, FTC only considered the degree to which new steelmaking capacity used new technologies, not the extent to which total steelmaking used new technologies.

The replacement of still usable and undepreciated facilities by new technology requires ample justification. Domestic steelmaking equipment, largely of the 1950's and earlier vintage, in the industry's view, had not depreciated enough by the late 1960's and early 1970's to warrant replacement. Yet it was inefficient compared to large Japanese integrated plants and some recently acquired European and Third World facilities. Coupled with an alleged unwillingness in the mid-1950's* to adopt advanced, but not widely proven steel production processes, U.S. production capability has not kept pace with constantly modernized Japanese mills and some new production facilities in developing nations. For example, Japanese production increased 5 percent between 1962 and 1978, and capacity increased 50 percent; while U.S. production in this period increased 3 percent, and capacity increased 1 percent.

It appears, in retrospect, that domestic producers did not adequately project the future economic advantages of certain technological options. In particular, they did not fully predict the rising costs of energy, labor, and capital. When these increases did hit, along with environmental control costs, the steel companies were not in a good position financially to adopt available technology. * As of 1978, 26 percent of steel industry plant and equipment was reported to be technologically outmoded, as compared to 12 percent for domestic durable goods industries. [3] A more recent estimate is that 20 percent of steel facilities is obsolete.[4] The age of facilities is particularly high for open hearths, blooming mills, and plate mills, followed by cold strip mills and coke ovens (table 33).

Adams and Dirlan have criticized the U.S. failure to adopt new technology rapidly enough. [5] They argue that since the 1960's domestic steelmaker have lagged behind other

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U.S. Federal Trade Commission, "The U.S. Steel Industry and Its International Rivals, " November 1977.

*This is a highly controversial topic.

* . . . much of the steel industry's apparent unwillingness to invest in energy-conserving equipment can be made to appear completely rational (i. e., consistent with profit maximization) by using constant, rather than steadily increasing energy prices. " F. T. Sparrow, "A Public-Private Sector Interactive Mixed Integer Programming Model for Energy Conservation Policy," Purdue University, 1979.

[3] McGraw-Hill. "How Modern Is American Industry?" November 1978.

[4] "International Iron and Steel Institute, 33 Metal Producing, January 1980, p. 9.

[5] Walter Adams and Joel B. Dirlan, "Big Steel, Invention and Innovation" *Quarterly Journal of Economics (May 1966),* p. 167ff.

Table 33.—Age Distribution of Domestic Steel Production Facilities, 1979

Facility	Average age (years)[a]	Percent older than— 30 years	25 years	20 years
Coke ovens	17.3	14.2	25.6	45.9
Open hearth furnaces	33.2	43.0	78.5	100.0
Basic oxygen furnaces	11.0	0.0	0.0	2.3
Electric furnaces	14.3	6.1	13.8	25.3
Plate mills	25.6	40.8	45.1	53.6
Wire rod mills	13.7	12.6	17.3	17.9
Hot strip mills	19.0	11.6	16.1	31.5
Cold strip mills	21.2	14.7	29.2	54.1
Galvanizing lines	18.8	4.4	8.9	40.1
Aggregate	17.5	12.5	20.4	33.3

[a] As of Jan 1, 1979

SOURCE: American Iron and Steel Institute, *The World Steel Industry Data Handbook, vol. 7.*

major producing nations in the adoption of certain high-performance steelmaking technologies. Basic oxygen steelmaking* was pioneered in Europe, and adopted faster in Europe and Japan than elsewhere from the late 1950's onwards (figure 13). All new U.S. steelmaking facilities built since 1957 have been either basic oxygen or electric furnaces, but the percentage of total steelmaking capacity that uses basic oxygen has not increased as rapidly as in some other countries because the U.S. industry was already so much larger than the others (see table 16). Japan, for example, which was not replacing old facilities but expanding its total industry, was able to advance its use of basic oxygen, as a percentage of all facilities, quicker and easier than was the United States.

Continuous casting did not achieve full commercial success, on a worldwide basis, until the late 1960's, and domestic steelmaker were involved in its development. Again, new steelmaking facilities built since about 1968 have incorporated continuous casters, but few previously existing ingot

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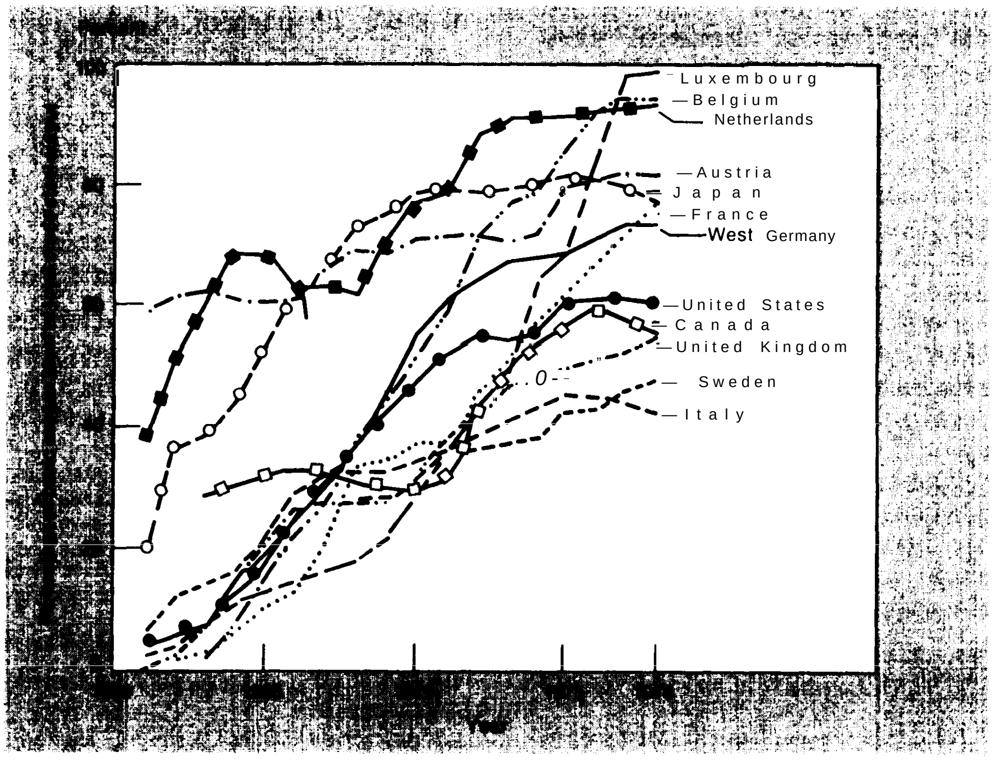
*Basic oxygen steelmaking and continuous casting are discussed fully in ch. 9.

Figure 13.–The Diffusion of Oxygen Steelmaking, 12 Countries, 1961.78



SOURCES" Organ ization for Economic Cooperation and Development; International Iron and Steel Institute casting facilities have been replaced (figure 14). Also by the late 1960's, Japanese and West German rolling mill builders had outpaced domestic engineering design firms specializing in this field, and they have installed this new technology with its higher outputs.

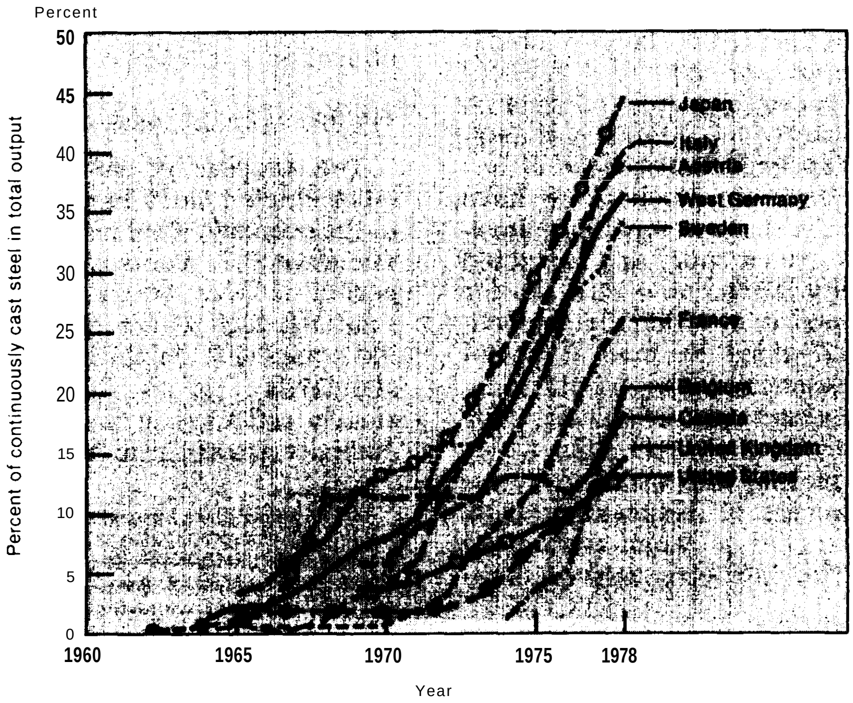
The major innovations during the 1960's were productivity enhancing, so failure to construct plants incorporating any given higher output process cost the United States some of its competitive edge in world markets.[1] Clearly, expansion opportunities, timing of new investments, and the size and cost of new steel plants are among the most important factors affecting technological productivity and competitiveness.

Expansion Opportunities

Steel producers in industrialized nations have on several occasions benefited from periods of rapid demand growth, which have justified capacity expansion. The most recent domestic expansion period took place from 1960 to 1965, when production increased about 20 percent (see table 16). Nevertheless, U.S. steelmaking capacity increased only about 1 percent per year during the 1962-78 period. Domestic steelmaker have emphasized the removal of bottlenecks in existing plants. Such investments do not produce productivity gains as large as does construction of greenfield plants, but they also require less capital.

The most recent European expansion took place during a longer period than that in the United States, lasting from about 1956 to 1975. Japanese post-World War II steelmaking capacity was limited, and capacity in-

Figure 14.—The Diffusion of Continuous Casting, 10 Countries, 1962-78



SOURCE: Organization for Economic Cooperation and Development

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[1] Jonathan Aylen, "Innovation, Plant Size and Performance: A Comparison of the American, British and German Steel Industries," a paper presented at the Atlantic Economics Association Conference, Washington, D. C., Oct. 12, 1979, pp. 34.

creased in subsequent years more than in any other major steel-producing country. During a 15-year timespan between 1962 and 1978, Japanese steelmaker added approximately 50-percent new steelmaking capacity.

In the early 1970's, foreign steel producers planned expansion programs for the decade to follow in such a way as to maintain rapid growth patterns. To a large extent, realizing these plans depended on offers of assistance by governments who shared their industries' desires to break into new markets. This optimism about expansion for the late 1970's, which no doubt stemmed from the 1973-74 steel shortages, was premature. Demand in 1975 fell below the peak demand of the shortage years, creating an overcapacity for production. The events of 1975 and thereafter seem to have daunted most expansion plans in steel-producing nations, including Japan, and the EEC and LDCs. Capital investments have declined since 1975, but generally increasing world steel demand has succeeded in broadening the export market for foreign steel-producing countries, and they expect to hold that market,

Japan's steel industry has been a prominent part of her postwar industrial development. Japan has recognized that the steel industry is critical to the manufacture of capital goods and is an important source of foreign exchange. Japanese steelmaker have benefited more than those in any other steel-producing nation from a rapid and sustained growth in capacity. Based on a strategy for building a large and internationally competitive industry, and aided by their financial structure[7] and economic philosophy, the Japanese have maintained and increased their large capital investment in steel mills. Many large greenfield plants, with excellent infrastructures and access to deep-water ports, have been constructed in Japan during the past 20 years. The infrastructure of these new plants is such that they can be "rounded out" on a cost-effective basis, thereby reducing average unit production costs after capacity increases. Furthermore, Japanese steelmaker with their newer facilities have not had to replace outdated equipment to the extent that U.S. and European producers have. As a result, Japanese investments in large, efficient facilities have more than offset comparatively significant cost increases for input factors.

Efforts in LDCs to attain economies of scale have contributed to the creation of steelmaking capacity in excess of current world demand. * South Korea in particular has an ambitious steel production program and low labor costs. The Central Intelligence Agency has estimated that steelmaking capacity in LDCs will total 112 million tonnes in 1985, as compared with 64 million tonnes in 1978.[8] UNIDO estimates that Brazil, Iran, Argentina, Venezuela, India, and South Korea will collectively contribute 54 million tonnes of additional steelmaking capacity between 1979 and 1985. Steel consumption in LDCs is expected to increase 6.5 percent per year and those industries should reach a capacity utilization level of 85 percent by 1985.

Timing of Investments in New Technology

The process of substituting capital for labor started much earlier and went further in the domestic steel industry than in Europe. The older U.S. plants were designed during a period of labor scarcity and, for that time, relatively high wages, and the industry's capital equipment was highly mechanized by the standards of its day. Now, however, its age is clearly reflected in the declining labor productivity growth rate of the U.S. steel indus-

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[7] See Caves and Masu Uekusa, "Industrial Organization in Japan, " in Asia's New Giant, High Patrick and Henry Rosovsky, eds., The Brookings Institution, 1976; and Bank of Japan, Economic Research Department, The Japanese Financial System, July 1970.

*LDCs benefit from indigenous steel production. For example, the cost of importing steel products to LDCs is from 15 to 30 times greater than the revenues gained from the sale of iron ore, However, many of these countries will remain net importers of steel for the foreseeable future. (Ingo Walter, Trade and Structural Adjustment Aspects of the international Iron and Steel Industry: The Role of the Developing Countries, prepared for the U.N. Trade and Development Board, New York, 1978.)

‘Central Intelligence Agency, "The Burgeoning LDC Steel Industry: More Problems for Major Producers, " 1979.

try. Without new investments in more productive steelmaking technologies, the domestic steel industry may lose its technological and cost competitiveness.

For the time being, domestic steel industry productivity may have reached a plateau, while some other major producing nations have a much higher rate of productivity growth, helped along by improved technology and enlarged plants. Newer plants, embodying newer techniques, are likely eventually to achieve higher output rates than older plants. As “learning” occurs, efficiency should increase at a faster rate with respect to time. Thus, it is expected that the newer foreign plants will have higher trend rates of productivity growth and ultimately achieve higher productivity levels, even though they may initially start up at lower levels of productivity than their more mature, long-commissioned U.S. rivals.’

Size and Cost of Steel Plants

Many U.S. steel plants have smaller capacities than foreign plants, particularly those in Japan (table 34). As of 1979, domestic basic oxygen furnaces had about 20 percent less capacity than those in the United Kingdom and about 25 percent less than those in West Germany, U.S. and West German blast furnaces are of similar capacity, while British furnaces average 5 percent more capacity. U.S. hot wide-strip mills have an average capacity about 25 percent more than British mills, but about 63 percent less than West German mills. ’O Japanese steel plants, on average, have more capacity at all stages of production than either domestic or European steel plants.

Domestic steel plants are generally smaller because they are older. Additional factors have also been thought to encourage small plant size, including high transportation costs, the lower capital intensity of the smaller scale, management policies, and labor relations practices associated with large plants. Because domestic producers, on average, operate smaller plants than some of their foreign counterparts, they are less able to realize economies of scale and have higher operating costs than they would with larger plants.’[1]

In addition to differences in plant size, there are also marked differences among countries in median per tonne capital costs for plants. * This is largely because of differences in construction labor costs and construction efficiency. In 1976, domestic steelmaker had per tonne capital costs for equivalent technology that were about 44 percent higher than in Europe and as much as 41 percent higher than in Japan. ’z These capital cost differences are probably smaller today, but their pattern is similar to that of 1976. In

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[9]Aylen, op. cit., pp. 17 and 21.

[10]Aylen, op. cit., table 1.

[11]Aylen, op. cit.

*Capital costs are discussed more fully inch. 10.

[12]Aylen, op. cit.

Table 34.—Integrated Steel Producers’ Capacities in Selected World Areas, 1976

Area	Number of firms	Plants per firm	Raw steel tonnes of capacity: Approximate total	Average per firm	Average per plant	Average per plant among 10 largest
Canada	4	1.0	13.0	3.3	3.3	NA
United States	20	2.5	115.0	5.8	2.3	5.9
Japan	8	2.5	120.0	15.0	6.0	11.5
European Coal and Steel Community (six countries)	40a	1.8	135.0	3.1	1.8	6.4

‘Estimated
NOTE All numbers are approximate

SOURCES Average for 10 largest plants–H G Mueller, “Structural Change in the International Steel Market, ” 1978, all other data—D F Barnett, ‘The Canadian Steel Industry in a Competitive World Environ merit,” Canadian Government. 1977 contrast to the U.S. capital cost disadvantage, the domestic steel industry has an energy cost advantage—albeit a slowly eroding one—because it is able to use domestic coal.

In conclusion, domestic steelmaker have had less incentive than their international competitors to adopt new technologies to replace open hearth steelmaking, dated-technology blast furnaces, and conventional casting facilities.[13] High capital costs have encouraged the substitution of other factors of production for capital improvements. But with ever-increasing energy and raw materials costs and a rate of productivity improvement insufficient to offset rising employment costs, domestic steel companies cannot expect aging equipment to remain profitable. Investing in new, more efficient, though more expensive equipment may be justified if the new equipment entails sufficiently lower production costs.

Comparative Production Cost Data

Available steel production cost data suffer from two major shortcomings: lack of access to specific confidential industry data and noncomparability among sources. Thus, studies differ in industry cost performance data for similar industry segments and time frames. Even if total cost figures per tonne of steel for materials, labor, and capital are roughly similar, it is not uncommon to find a different breakdown for these inputs in the various studies. The most extensive steel production cost estimates are those prepared by the World Steel Dynamics (WSD) organization.[14] However, that model is based on larger economies of scale for integrated plants than may exist in reality, particularly for U.S. plants. * Thus, total factor productivity may be overestimated somewhat using the WSD data.

In addition to the WSD study, comprehensive steelmaking cost analyses have been made by FTC, the American Iron and Steel Institute (AISI), Mueller and Kawahito, and Thorn.[15] FTC, Thorn, and Mueller and Kawahito took similar approaches by relying on aggregate confidential cost data and/or information supplied by foreign government agencies concerned with steel industries. Only the WSD data are based on models of large integrated plants producing a mix of carbon steel products. The WSD simulation model compares costs in major producing countries (United States, Japan, West Germany, United Kingdom, and France), going back as far as 1969 and projected to 1984.

Available cost studies may differ with respect to both total steelmaking costs and input factors. For instance, the WSD 1974, 1975, and 1976 Japanese cost estimates are higher by 7.6 percent, 10.4 percent, and 13.6 percent, respectively, than those presented by AISI. The WSD data do not include transportation costs, and the same appears to be the case for the AISI data. The AISI estimates also do not include marketing costs, but the WSD data do appear to include them. Both sources deal with average costs for carbon commodity steels only.

The WSD and Thorn data differ in input costs. In comparing 1973 Japanese cost data to those of the United States, the two sources show an almost opposite condition for material and capital costs. There is an even greater dissimilarity between the 1973 West German/U.S. comparisons by WSD and Thorn than between their Japanese/U.S. cost comparisons. The WSD data show an $1 l/tonne West German disadvantage relative to U.S. producers, and the Thorn data show a $33/tonne advantage. Of the major inputs,

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[13] Aylen, op. cit.

[14] World Steel Dynamics, Core Report J, September 1979.

*The WSD U.S. and European cost data are associated with a 3-million- to 4-million-tonne/yr integrated plant and the Japanese data are based on a 5-million- to 6-million-tonne/yr integrated plant.

[15] U.S. Federal Trade Commission, ''U.S. Steel Industry and Its International Rivals,'' November 1977; American Iron and Steel institute, "Economics of International Steel Trade," 1977; Hans Mueller and K. Kawahito, "The international Steel Trade Market: Present Crisis and Outlook for the 1980's,"' conference paper No. 46, Middle Tennessee State University, May 1979: and R. S. Thorn, "Changes in the international Cost competitiveness of American Steel, 1966 -197 S," working paper No. 8, University of Pittsburgh, February 1975.

employment and capital costs contribute most to the discrepancies.

Sets of U.S./Japanese data by WSD, FTC, and Mueller and Kawahito for 1976 also illustrate the limitations of developing comparable steelmaking cost estimates. For the United States, WSD shows the lowest total cost estimates, followed by Mueller and Kawahito, and FTC. The Mueller and Kawahito energy cost estimates are about 25 percent lower than those in the other two sources. And finally, WSD shows a different energy-iron cost balance than do the other two sources (table 35).

The methodologies of the various studies differ in several other respects, as well. The WSD data exclude electric furnace production. Thus, scrap costs tend to be underestimated and energy costs overestimated. ’G The FTC and WSD data are based on market prices for raw materials, while Mueller and Kawahito incorporate company-owned materials prices. Less verifiable differences in the studies include possible differences in industry definitions and adjustments for product mix.

The following discussion is in many instances based on WSD cost data. * It should be kept in mind that the WSD total U.S. cost data appear to be underestimated relative to that of other countries—perhaps by as much as 5 to 10 percent in the cases of Western Europe and Japan, respectively. ’

Labor Costs

A significant portion of the cost of producing steel is labor cost. This cost can rise as a result of increases in hourly wage rates and fall as a result of increases in labor productivity.

Declining Employment and Increased Skill Requirements

Domestic steel industry employment has declined by 21.4 percent during the past two decades, from about 550,000 employees in 1960 to about 450,000 in 1978.** From 1962 to 1966, employment levels rose slowly, about 1 percent annually. Since that time, however,

Table 35.—Estimates of U.S. and Japanese Steel making Costs, 1976 (dollars per tonne)

Study	Country	Iron ore and scrap	Input costs Energy	Labor	Total[a]
FTC	United States	$72.97	$92.80	$157.85	$323.62
	Japan	54.57	68.40	57.98	180.95
WSD	United States	71.84	94.89	115.84	282.57
	Japan	33.51	88.14	59.37	181.03
Mueller	United States	63.10	71.10	155.54	289.74
	Japan	52.92	73.64	61.16	187.73

[a] Totals exclude miscellaneous materials and supplies, and capital costs.

SOURCES U S Federal Trade Commision,'U.S. Steel Industry and Its International Rivals,'November 1977, World Steel Dynamics, Core Report J. 1979, H Mueller and K. Kawahito, "The International Steel Market' Present Crisis and Outlook for the 1980' s," Middle Tennessee State University, conference paper No 46, 1979

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[16] George R. St. Pierre, "Impacts of New Technologies and Energy/Raw Materials Changes on the U.S. Steel industry, " Office of Technology Assessment, contractor report, 1979.

*Transportation costs are not included in the discussion in this section. Unless otherwise noted, all references in this section are to U.S. dollars at actual operating rates.

*This conclusion is based on findings such as:
- The Council on Wage and Price Stability found that 1972-77 WSD U.S. cost data were between 1 and 6 percent lower than comparable industry data (Council on Wage and Price Stability, "Prices and Costs in the United States Steel Industry, " 1977, p. 25):
- WSD Japanese 1974-76 cost estimates were between 7 and 13 percent higher than comparable AISI estimates: and
- WSD has lower 1976 U.S. cost estimates than either Mueller and Kawahito or FTC, even though WSD, unlike Mueller and Kawahito, uses higher market prices for raw materials.

**Based on AISI data. Steel industry employment data are typically about 22 percent lower than U.S. Department of Labor, Bureau of Labor Statistics, data. Unlike BLS, AISI does not include smaller establishments primarily engaged in the finishing of purchased iron and steel.

steel industry employment has dropped steadily, by an average of almost 2 percent per year (table 36). U.S. Bureau of Labor Statistics (BLS) projections for 1985 indicate that steel employment is expected to continue its downward trend, but with **a** somewhat lower rate of decline—about 0.5 percent annually. 1[7]

Declining steel industry employment may be attributed to a number of factors, including growing steel import penetration, increased labor productivity, and product substitution. With the exception of France, steel industry employment in other major producer countries also has decreased to varying degrees, beginning at least in the 1960’ s.* The U.S. decline has been greater than that generally experienced abroad.

Steel industry job content and occupational requirements also have changed considerably in recent years. These changes, brought about mainly by new technologies, are reflected in the relative employment levels of production and nonproduction workers. The number of production workers employed in steel hit a peak in 1965 and since then has declined steadily; nonproduction worker employment increased continuously from 1964 to 1970 and then dropped sharply. From 1966 until 1978, production worker employment declined almost twice as fast as did nonproduction worker employment. For the entire 1960-78 period, employment of production and nonproduction workers fell, on average, 1.36 and 0,58 percent per year, respectively (see table 36).

Among production workers, craft and related workers have remained about the same in number over the past two decades, and skilled workers have increased relative to operators and laborers, whose part in the production process has been slowly diminishing. The increasingly complex machinery and instruments used in steelmaking require craft and maintenance workers who are more highly skilled and trained than those required

Table 36.—U.S. Steel Industry Employment, Productivity, and Compensation, 1960-78

	Average number of employees			Output per employee-hour (annual rate of change)	Compensation per employee-hour (annual rate of change)	
Year	Total	Product ion	Non production		Actual	Inflation adjusted
1960	571,552	449,888	121,664	-5.2	1.1	– 0.1
1961	523,305	405,924	117,381	2.6	3.3	2.5
1962	520,538	402,662	117,876	4.3	3.2	2.6
1963	520,289	405,536	114,753	4.0	1.7	0.6
1964	553,555	434,654	118,901	4.0	0.6	– 0.7
1965	583,851	458,539	125,312	3.9	1.4	– 0.1
1966	575,457	446,712	128,835		3.5	0.8
1967	555,193	424,153	130,990	- 3^{2}2’	3.1	0.4
1968	551,557	420,684	130,873	3.5	4.7	0.5
1969	554,019	415,301	128,718	1.5	7.9	2.1
1970	531,196	403,115	128,081	-2.7	5.4	– 1.1
1971	487,269	403,115	120,287	4.9	10.6	4.5
1972	478,368	364,074	114,294	6.5	16.3	9.6
1973 , ...	508,614	392,851	115,763	10.8	13.8	3.6
1974	512,395	393,212	119,183	0	22.6	3.5
1975	457,162	339,945	117,217	-15.9	28.3	7.3
1976	454,128	339,021	115,107	6.9	19.5	4.4
1977	452,388	337,396	114,992	1.1	18.0	1.7
1978	449,197	339,155	110,042	5.1	30.0	5.8
Average rate of change 1960-78				1.90	10.82	2.62

SOURCES: 1%0-77-American Iron and Steel Institute. Annual Statistical Reports 1969; 1978—Department of Labor, Bureau of Statistics, Steel SIC 331, May 1979, unit labor costs, October 1979 (unpublished)

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[17] BLS Bulletin No. 1856, footnote 22,

* 1978 West Germany: 205,000 employees, down by 4.5 percent since 1960: 1978 France: 135,800 employees, up by 3.12 percent since 1960; 1978 England: 170,000 employees, down by 14.01 percent since 1974; 1978 Japan: 302,487 employees, down by 5.48 percent since 1965. (U. S. Department of Labor, unpublished data.)

for simpler equipment. However, complexity does not necessarily increase the number of workers required, For instance, the more advanced oxygen furnace takes one-fifth as much labor to process heat as is required by the open hearth process.

The proportion of nonproduction (white collar) workers in steel employment also has increased somewhat since 1960, Nonproduction workers now make up nearly 25 percent of the entire steel industry work force. In general, the need for technically trained personnel is growing as more advanced instrumentation, computer controls, and pollution control devices come into use. These personnel include control engineers, programmers, laboratory testers, and R&D specialists, The number of managerial, administrative, and sales personnel also has increased substantially during the past decade.

Productivity

Labor is only one of several input factors of production. Labor productivity, measured by employee hours required to produce a tonne of steel, reflects the joint effects of many influences, including new technology, capital investment, capacity utilization, energy use, managerial skills, and the skills and efforts of the work force. When operating rates are low, labor productivity measures understate the technological capability of steelmaking equipment. Nevertheless, labor productivity at actual operating rates is a reasonable approximation of the technological competitiveness of the domestic steel industry on the international market.

Both BLS and WSD have developed data on international steel labor productivity. * It appears that BLS slightly underestimates U.S. steel industry labor productivity relative to that of foreign steel industries, while Marcus slightly overestimates U.S. productivity levels, The BLS unpublished steel productivity series are based on a 1967 product mix and have not incorporated the U.S. shift toward producing more lightweight and specialty steels since that time. The Marcus data assume larger economies of scale than exist in reality, particularly in the United States.

The domestic steel industry frequently is singled out for its low productivity improvement rate (see table 36), which has been well below that of other U.S. industries since at least the late 1940's. As overall industrial labor productivity and capital investment have declined since the mid-1960's, the gap between steel industry labor productivity improvement rates and those of other industries has narrowed somewhat. During the 1965-70 period, productivity growth rates for manufacturing and for the total private economy both slipped to 2 percent, but that for steel fell more sharply, averaging a minimal 0.2 percent annually. In 1971, when wages began increasing substantially productivity also moved upward. From 1971 to 1978 the average annual increase was 2.4 percent. Benefiting from high operating rates in 1978, U.S. steel labor productivity improved 5 percent.

The wide gap between U.S. and Japanese steel industry productivity improvement rates is of particular significance. During the past two decades, Japanese steelmaking labor productivity has improved faster than that in the United States, and it appears that their productivity level exceeded that of the domestic steel industry for the first time in about 1973. * According to WSD data for integrated plants, U.S. steel labor productivity growth since the early 1960's has been only about half that of the Japanese, although it is still double the West German rate. BLS data, which appear to be valid, show sizable labor productivity improvements for West Germany, as well as Japan, relative to domestic steelmaking (see table 37). The favorable labor productivity improvement rates for Japan and West Germany have substantially reduced or eliminated the output-per-employee-

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*International comparisons are difficult because of the different use of contract labor, level of fixed annual employment, level of capacity use, and product mix.

*BLS data suggest that Japanese steel labor productivity levels exceeded domestic levels in 1973. WSD data indicate that this would not occur until 1984. The 1977 FTC report accepts the BLS findings.

Table 37.—Labor Productivity at Actual operating Rates, Selected Countries, 1969-84
(employee hours required per tonne of carbon steel shipped)

Year	United States	Japan	West Germany	United Kingdom	France
1969	10.53	14.69	12.76	22.73	19.38
1970	10.39	13.67	13.85	21.49	18.03
1971	10.50	13.75	15.05	23.60	18.06
1972	9.76	12.82	12.76	22.82	16.62
1973	9.25	10.13	11.59	20.06	16.20
1974	9.16	9.60	10.82	21.99	15.51
1975	9.57	10.29	12.90	25.62	17.79
1976	9.08	9.91	12.48	21.47	16.27
1977	9.34	10.01	12.88	23.74	15.41
1978	8.63	9.79	11.82	23.21	14.12
1979	8.56	9.20	—	—	—
1980a	8.37	8.54	—	—	—
1985a	7.19	6.48	—	—	—
Average annual change 1969-79	–1.8770	–3.7370	–0.90%	0.23%	–3.010/o

[a] Estimate

SOURCE World Steel Dynamics, Core Report J,1979.

hour advantage long held by U.S. steel producers.

This shift in the U.S./Japanese labor productivity relationship may be attributed in part to continuing U.S. dependence on relatively small, old, and poorly laid-out plants. Such plants do not use labor efficiently.[18] Furthermore, expansion of existing plants (typical among domestic steelmakers) offers lower productivity growth potential than does new plant construction. Relatively old facilities cannot handle the higher workload that a new facility in the same plant can. Thus, bottlenecks develop. Labor-management attitudes about productivity improvement and employment security also can affect growth rates. For instance, occasional delays in setting incentive rates can constrain potential productivity improvements associated with the use of new equipment.

Wages and Unit Labor Costs

Both here and abroad, steel industry wages are often higher than the all-manufacturing average.[19] In the United States, the gap between steel industry and manufacturing industry average wages narrowed during the late 1960's in response to increased import competition and reduced profitability in the steel industry; but in the 1970's and particularly since 1974, the lead held by steel industry wages again increased significantly.[20] Hourly earnings in 1977 in the steel industry were estimated to be 55 percent higher than the all-manufacturing average.[21] U.S. hourly employment costs in the steel industry have increased by 10 to 15 percent since 1960, with higher than average increases during recent years.* The 1979 total yearly increase in steel industry wages appears to have been about 11 percent. [22]

Employment cost data for companies in the three segments of the domestic industry are given in table 38. There is clearly a large employment cost difference among integrated producers, generally about a $55/tonne difference between the high and low labor cost companies. (The very low value for the McLouth Co. is related to its 100-percent use

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[18] Aylen, op. cit., p. 17.

[19] Employees of the major Japanese steel companies receive about 33 percent more in wages than the average for all industrial companies in Japan (WSD, p. J-1-14, 1979).

[20] The substantial increases in the 1974 steel labor settlements were granted in exchange for the union's support of the Experimental Negotiating Agreement (ENA). This agreement was negotiated in an environment of declining U.S. imports, booming demand for U.S. steel products, and sharply escalating world steel prices. In such a situation, management was eager to avoid disruption of production. Cost of living clauses are a part of the Agreement. (Council on Wage and Price Stability, "Prices and Costs in the U.S. Steel Industry," 1977.)

*'Ibid.

*AISI data show a 15-percent annual increase since 1960. BLS data show a 10-percent annual increase since 1960.

"Bradford, op. cit., p. 14.

Table 38.—Employment Costs for Domestic Steel Companies, 1978

Company	**Net income as a** percent of investment	**Employment costs as** a percent of sales	**Employment costs dollars** per tonne shipped	Capacity utilization (percent)
Integrated				
U.S. Steel Corp.	5.3	40.6	$238	76.1
Bethlehem Steel. .,	9.3	41.2	214	84.8
National,	8.2	30.2	152	82.4
Inland.	9.7	**30.0**	**172**	**95.0**
Wheeling-Pittsburgh	6.3	36.5	160	92.4
Kaiser	1.6	49.4	243	65.2
McLouth	5.2	25.0	116	79.3
CF&I.	6.6	44.7	214	82.2
Interlake	3.7	33.1	386	82.0
Republic [a].,	10.4	33.8	180	76.3
Armco [a].	10.4	28.3	226	81.6
Nonintegrated				
Northwestern	13.9	34.2	117	65.5
Nucor.	25.0	18.7	51	96.0
Florida.	13.8	19.7	58	73.5
Keystone.	2.3	42.4	306	90.8
Lacledo.	9.4	39.8	177	91.9
Atlantic ...,	9.6	28.3	114	78.0
Alloy/specialty				
Sharon.	15.3	26.3	122	90.5
Cyclops	10.3	29.4	258	87.1
Allegheny-Ludlum	8.5	33.3	619	73.5
Cooperweld.	8.4	32.3	385	82.6
Washington	11.6	22.1	497	66.0
CarpenterTechnology.	16.9	32.6	NA	NA
Likens	9.6	41.4	NA	81,9

NA = not available
[a] Both of these firms make substantial amounts of alloy/specialty steels.

SOURCES Income. employment. and production data from *Iron Age,* May 1979; capacity data from International Iron and Steel institute Commentary, January-February 1979, data for Nucor from company

of continuous casting.) A considerable spread in employment costs also exists among the nonintegrated steelmaker and, as might be expected because of major product differences, among the alloy/specialty steelmaker. The nonintegrated producers have a lower employment cost than the integrated steelmaker, an average of $144 versus $210, respectively, per tonne of steel shipped.* Although a relationship between profitability and employment costs might be expected, none is found. For the integrated producers, there is also no relationship between employment costs and capacity utilization, although there is a strong correlation (a coefficient of 0.772) between profitability and capacity utilization.

A major reason for the rise in labor costs per tonne of steel is that wage increases have only to a small degree been offset by labor productivity gains or other efficiency improvements in total unit production costs. In the U.S. steel industry, real and nominal compensation increased annually between 1.5 and 5.5 times faster, respectively, than labor productivity (table **36).** Foreign steel industry unit labor costs increased at an even faster rate than in the domestic industry during the 1969-78 period because of currency changes and because of wage increases that exceeded those in the United States. *

From 1969 to 1978, West German and Japanese employment costs increased 345 and 299 percent, respectively, compared with 117 percent in the United States (table 39). Never-

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‘The nonintegrated segment of the steel industry generally does not have contracts with the United Steelworkers of America. Their labor costs are reported to be about one-third less than for unionized companies.

*Foreign producers, particularly the British and French, probably also experienced labor productivity y gains insufficient to offset increased hourly employment costs.

Table 39.—Carbon Steel Production Costs, Five Countries, 1969 and 1978

Country and year	Total	Employment		Financial		Materials	
	Dollars/ tonne	Dollars/ tonne	Percent	Dollars/ tonne	Percent	Dollars/ tonne	Percent
United States							
1969	$169.39	$ 48.33	34.43%	$ 17.46	10.30%	$ 93.60	55.25%
1978	395.65	127.18	32.11	30.91	7.81	237.66	60.06
Percent change, 1969-78	133.57	117.86		77.03		153.91	
Japan							
1969	$124.95	$ 25.41	20.41	$ 18.93	15.21	$ 80.11	64.37
1978	410.51	101.60	24.74	81.87	19.94	227.03	55.30
Percent change 1969-78	229.85	229.84		332.48		183.39	
West Germany							
1969	$126.48	$ 30.10	23.79	$ 21.37	16.89	$ 75.01	59.30
1978	438.12	134.23	30.63	60.02	13.09	243.87	55.66
Percent change, 1969-78	246.38	245.94		180.86		225.11	
United Kingdom							
1969	$146.37	$ 37.87	25.87	$ 21.42	14.63	$ 87.09	59.49
1978	460.64	135.28	29.36	58.36	12.66	267.00	57.96
Percent change, 1969-78	214.70	257.22		172.45		206.57	
France							
1969	$152.22	$ 42.45	27.88	$ 25.86	16.98	$ 83.91	55.12
1978	456.33	143.10	31.35	71.77	15.72	241.47	52.92
Percent change, 1969-78	199.78	237.10		177.53		187.77	

SOURCE World Steel Dynamics,Core Report J. 1979

theless, in 1978, U.S. hourly costs were still 30 percent higher than West German costs and 40 percent higher than Japanese costs (table 40), but it can be seen that annual employment cost increases in local currencies were much lower than in dollars. Thus, the rapid foreign labor cost increases of the past decade have not yet eliminated the unit cost advantage held by foreign steelmaker (see table 27). Only 1978 was unexceptional year, with relatively low U.S. unit labor costs because of very favorable operating rates.

Raw Materials and Energy

Key raw materials for steelmaking are: iron ore, scrap, coal and other sources of energy, limestone and other fluxes, alloy additives, refractories, and oxygen. Raw materials comprise more than half of all input costs for steelmaking (table 39). During the past decade, the cost per tonne of raw materials for domestic steel has increased by 5 percent annually and now represents 60 percent of all input costs.

Within the materials component, direct energy costs have risen most (275 percent) and now account for almost 40 percent of raw materials costs (table 41) or 24 percent of total steelmaking costs for integrated operations. About two-thirds of the energy used to make steel from ore comes from coal. Of the major producing countries, Japan has made

Table 40.—Steel Industry Hourly Employment Costs, Five Countries, 1969 and 1978

Country	1969		1978		Average annual percent increase	
	Dollars	Local currencies	Dollars	Local currencies	Dollars	Local currencies
United States	$5.54	$5.54	$14.73	$14.73	18.43%	18.43%
Japan	1.73	625.00 yen	10.42	2,169.00 yen	55.81	27.44
West Germany	2.36	9.25 DM	11.34	22.73 DM	42.27	16.19
United Kingdom	1.66	LO.70	5.83	L3.04	27.91	33.71
France	2.18	fr11.32	10.09	fr45.44	40.31	33.49

SOURCE World Steel Dynamlcs, Core Report J. September 1979

Table 41 .—Unit Costs for Inputs, United States and Japan, 1956-76 (dollars per tonne of steel produced)

Year	Total		Iron ore		Scrap		Coking coal	
	United States	Japan	United States	Japan	'United States	Japan	United States	Japan
1956	$110.84	$119.83	$17.51	$25.78		$35.15	$12.15	$20.01
1957	110.00	133.21	18.17	31.55	10.95	37.98	12.73	23.03
1958	122.18	98.65	19.75	21.20	9.94	19.37	13.09	16.75
1959	113.98	90.04	17.25	18.08	10.87	24.59	10.93	13.03
1960	120.18	85,08	19.47	17.91	8.24	23.16	11.48	11.50
1961	122.50	91.59	20.58	18.54	9.45	30.09	10.21	11.85
1962	118.74	81.56	19.93	18.97	6.83	17,43	10.17	12.33
1963	116,01	79,03	19.60	17.80	7.39	18.12	9.16	10.99
1964	114.97	75.20	20.41	16.73	8.25	19.27	9.74	10.05
1965	112.99	76.38	19,92	18.63	9.56	16.75	9.78	10.94
1966	113.21	71.86	19.95	18.14	7.72	14.88	9.99	10.84
1967	117.70	69.53	20.10	16.68	6.73	15.73	10.83	10.27
1968	119.40	67.78	20.65	16.99	6,71	12.16	10.69	10,91
1969	125.25	69.93	20.34	16.66	8.60	14.00	10.29	11.72
1970	137.23	78.05	21.54	17.47	10.05	16.05	12.80	14.65
1971	145.98	81.28	22.85	19.43	8,53	9.06	15.15	16.76
1972	155.11	83.56	23.84	16.97	11.26	12.04	16.08	14.65
1973	161.21	100.97	24.42	17.62	17.08	23,38	17,44	15.18
1974	215.55	147.30	29.66	21.65	34.10	33.65	29.20	29.84
1975	270.27	159.26	37.58	27.85	18.98	17.23	52.40	43.18
1976	294.65	161.93	44.51	26.87	21.82	22.72	53.73	41.38

Year	Fuel oil		Electric power		Noncoking coal		Natural gas
	United States	Japan	United States	Japan	United States	Japan	United States
1956	$2.26	$2.85	$4.15	$6.07	$0.74	$3.31	$1.58
1957	1,97	4.27	3.73	6.29	0.75	3.31	1.46
1958	1.99	2.54	3.96	6.72	1.07	1.94	2.28
1959	1.78	2.09	3.47	6.61	0.80	0.61	2.19
1960	1.80	2.30	3.92	6.44	0.85	0.75	2.59
1961	1.74	2.04	4.27	6.50	0.89	0.63	2.99
1962	1.59	1.92	4.71	6.28	0.83	0.54	3.29
1963	1.58	2.04	4.73	5.87	0.73	0.45	3.19
1964	1,41	1,92	4.48	5.88	0.63	0.37	3.01
1965	1.28	1.93	4.64	5.70	0.63	0.31	3.09
1966	1.14	1.75	4.90	5.33	0.63	0.24	2.93
1967	1,05	1,87	5.30	4.92	0.63	0.13	3.16
1968	1.09	1.74	5.74	5.02	0.61	0.10	3.56
1969	0.94	1.44	5.83	4.80	0.51	0.10	3.54
1970	1,23	1,81	6.49	4.74	0.56	0.11	3.74
1971	1.54	2.73	7.70	5.31	0.62	0.00	4.55
1972	1.60	2.47	7.60	5.45	0.54	0.00	4.64
1973	1.91	3.43	8.09	6.04	0.54	0,00	4.40
1974	5.02	9.01	10.21	10.54	0.76	0.00	5.67
1975	4.95	8.66	14.03	12.41	0.85	0.00	8.60
1976	5.05	6.84	15.84	14.47	0.85	0.00	9.31

SOURCE US Federal Trade Commission Staff Report on the United States Steel industry and its Internatlonal Rivals," 1977.p 113

the greatest improvements in energy-efficient steelmaking. Coke rates in Japan are presently 25 percent more efficient than those in the United States'[1] (table 42)

The cost of iron ore and scrap metal went up by about 120 percent during the past decade and is now 26 percent of raw materials costs, according to WSD.[24] Ore costs, since 1974, have been pushed up at an annual rate of nearly 10 percent as a result of large increases in energy and labor costs in mining, a decline in the quality of ore obtained, and

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[1] In Japan the average coke rate is now about 420 kg/tonne of pig iron, with only about 40 liters of oil injected. In the United States, the coke rate was 585 kg'tonne last year, with only slightly less oil used. Only the Bethlehem Steel "L" blast furnace at Sparrows Point has achieved a coke rate similar to that in Japan. (Bradford, op. cit., p. 17.)

*WSD,op.cit.,p.J-l-49,

Table 42.–Coke Consumption per Tonne of Pig Iron Produced, 11 Countries, Selected Years, 1958-78
(kilograms/tonne)

Year	West Germany	France	Italy	The Nether-lands	Belgium	Luxem-bourg	United Kingdom	Japan	United States	Canada	Sweden
1958	922	1,023	750	839	890	1,100	880	667	780	—	675
1960	834	980	680	787	852	1,092	820	619	720	—	650
1965	672	780	633	559	658	860	680	507	650	585	555
1970	559	629	524	484	586	730	610	478	636	544	545
1971	521	595	526	475	569	683	604	451	629	495	550
1972	487	563	509	456	559	645	590	442	610	486	540
1973	494	558	518	475	557	601	576	432	599	486	550
1974	517	551	500	465	564	538	597	442	608	484	—
1975	497	531	479	467	545	525	609	443	610	491	
1976	482	—	—	—	—	—	—	432	592	475	—
1977	484	—	—	—	—	—	—	434	595	451	
1978	486	—	—	—	—	—	—	429	597	432	

SOURCES: Statistical Office of the European Community, *Iron and Steel Yearbook,* 1976, for the six original EEC countries for all years and the United Kingdom for 1973-75; data for United States and Canada, for 1958-70 forward, were calculated from data available in various issues of the *Annual Statistical Report* of the American Iron and Steel Institute; for Japan, Japan Iron and Steel Federation, Tekko *Tokei Yoran,* various issues; Bo Carlsson, "Scale and Performance of Blast Furnaces in Five Countries—A Study of Best Practice Technology," Stockholm mimeo, March 1975; Statistiches Bundesamt, West Germany, U.S. Bureau of Mines

sharply higher costs for ore-processing capital equipment. Increased steel demand and limited coking capacity encouraged producers during the 1970's to substitute scrap for virgin metallics. Following the elimination of general price controls in 1974, scrap prices increased rapidly as domestic producers competed with potential foreign scrap buyers in a strong worldwide market.[25]

During the past decade, the United States was the only major steel-producing country in which raw materials price increases exceeded the average increase in total production costs. As a result, it was also the only major producing country where raw materials costs became a larger proportion, by 5 percentage points between 1969 and 1978, of total production costs. In other countries, raw materials became a smaller element of production costs by 2 to 9 percent (see table 39). It is noteworthy that the materials cost differential between the United States and Japan widened sharply from 1975 to 1977, when very large increases in the costs of coking coal and iron ore were recorded.

Capital Investment and Financing Costs

A number of factors influence steel industry investment decisions; some are quantifiable and others more speculative. Market size and rates of growth; the relative costs of capital, labor, and fuel; the absolute cost of capital; and Government taxation and subsidy policies all influence the potential profitability of investment projects. Other factors, such as attitudes towards risk, time horizons, and time preferences, also influence investment in less conspicuous ways.

There are considerable differences between the capital-attracting abilities of the U.S. steel industry and foreign industries. Domestic steel companies rely heavily on internal sources, namely aftertax profits, for investment funds and can only attract outside capital if they are reasonably profitable. Foreign companies, often with the assistance of their governments, have easier access to external capital sources.

The U.S. industry's aftertax profits depend in part on the depreciation rate the Internal Revenue Service (IRS) allows on capital expenditures. The faster capital assets can be depreciated, the greater the deduction from the gross profits, the lower the tax burden, and hence the higher the level of aftertax profits. The IRS has, for many years, required that capital investment in steel be depreciated over 18 or more years, although most other U.S. industries are allowed to write off their capital investments much faster, e.g.,

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[25] Council on Wage and Price Stability, op. cit.

plastics in 9 years and aerospace in 7 years. By comparison, the Canadian steel industry is able to write off capital investments in 3 years. This puts the U.S. industry at a disadvantage in attracting capital on the basis of profitability.

During the 1970's, real capital spending by the U.S. steel industry was 20 percent lower than during the preceding decade (table 25). * On a per tonne basis, U.S. capital expenditures also lagged behind that of foreign producers. From 1972 to 1977, domestic steel industry capital spending was, according to industry estimates, about 73 and 79 percent, respectively, of Japanese and West German steel industry investment levels (table 43).

Table 43.—Capital Expenditures per Net Tonne of Raw Steel Production, Five Countries, 1972-77 (dollars)

Country	Expenditures
United States	$19
Japan	26
West Germany	24
United Kingdom	35
France (1972-76)	28

SOURCE International Iron and Steel Institute

The reliance of the U.S. steel industry on internal financing does leave it with a lower financial cost burden than some foreign industries have. As a percentage of total production costs, the U.S. industry's direct financial costs were about 9 percent during most of the decade. In Europe, they hovered between 13 and 17 percent of total production costs. Japan had a higher financial cost component than any of its international competitors, at 20 percent of total production costs. It was the only major producing country with faster rates of increase in financial costs than either employment or raw material costs (see table 38). These higher Japanese financial costs are the result of higher debt-equity ratios and higher investment levels than are found elsewhere.

Though financial expenditures are generally a low fraction of direct production costs, the capital expenditures they represent have important effects on improving equipment, labor, and energy productivity. Improved total productivity plays an important role in determining total steel production costs per tonne of output. Thus, though financial costs may directly increase total costs, they may indirectly reduce unit costs, so their influence is much greater than their share of total production costs would indicate.

Macroeconomic Changes

Two major external factors influence steel industry production costs considerably—changes in operating rates and changes in currency values. Operating rates tend to change cyclically, but often currency values change abruptly. Both are strongly affected by general economic conditions such as GNP growth rates and inflation.

Operating Rates.—High operating rates increase the efficiency of steelmaking equipment with respect to raw materials and labor, particularly in integrated plants. U.S. steelmaker have enjoyed higher capacity utilization rates than their international competitors during recent years. During 6 of the past 10 years, U.S. operating rates were more than 85 percent—a high level.[26] Depressed operating rates for integrated plants have been a severe handicap for Japanese and other foreign producers, whose operating rates have been below U.S. levels for 7 of the past 10 years.[27]

Even at comparable operating rates, domestic producers have one advantage not enjoyed by most foreign producers—that is, more flexibility in employment levels. European unit labor costs increase significantly during periods of low demand because of their industries' limited ability to lay off

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*Required environmental capital expenditures (10 to 16 percent of total U.S. steel industry capital investment during the past few years) have had a downward effect on the productivity-improving potential of new capital investment. Other major producing nations have had similar experiences.

[26] WSD, op. cit.

[27] Ibid. For example, in 1977 when the Japanese rate was 69 percent and the U.S. rate 78 percent, U.S. production costs were 12 percent greater than the Japanese; but in 1978, with the Japanese rate at 66 percent and the U.S. rate at 86 percent, U.S. costs were 3 percent less than the Japanese.

workers during those times. * The Japanese steel industry is relying more and more on contractors. However, the Japanese lifetime employment system does have an upward effect on unit labor costs at low operating rates because of the difficulty of laying off workers during a slowdown.

Currency Values.—Recent dollar devaluations have had a favorable effect on the international competitiveness of the domestic steel industry. Monetary changes have made most foreign steel production costs more expensive than domestic costs. For instance, during the past decade, U.S. steelmaking costs increased at a higher rate than Japanese and West German costs in home currencies, but at a much lower rate in dollars (table 44).

Table 44.—Production Costs per Tonne of Carbon Steel Shipped: Percentage Increase 1969-78

Country	Home currencies	U.S. dollar
United States	133%	133%
Japan	92	229
West Germany	72	246
United Kingdom	291	214
France	160	199

SOURCE World Steel Dynamics, Core Report J 1979

Shifts in Cost Competitiveness

From 1946 to 1959, the international steel market was dominated by U.S. exports. In the 1960's, however, several European countries and Japan became lower cost producers of steel.[28] Two additional competitive shifts have taken place since about 1973. The Japanese have lost some of their cost advantage relative to the United States, * and European producers lost their advantage altogether. Compared to other major steelmaking nations, U.S. raw material and employment costs per tonne of steel are somewhat high and capital costs somewhat low (see table 38).

U.S. steelmaking costs increased by 133 percent between 1969 and 1978, largely as a result of rapidly rising purchased energy costs and wage rates.[29] Japanese steelmaking costs increased by as much as 230 percent during this period as a result of dollar-priced raw materials, devaluations of the U.S. dollar, and the greater impact of rising energy prices on Japanese producers. Nevertheless, WSD data show that major Japanese producers have had a cost advantage of about 15 percent over U.S. steel firms for a decade or more. The Japanese cost advantage decreased from about 27 to 12 percent between 1969 and 1977 (see table 38). For the U.S. steelmaker, 1978 was a unique year: total production costs were roughly similar to those in Japan because of the unusually favorable U.S. operating rate compared to Japan. In 1979, U.S. steel production declined by about 10 percent because of reduced demand for steel plates and structural steel products,[30] and by the first quarter of 1979, Japanese steelmaker again had lower costs. Although their operating rate was still far below that of the United States, Japanese producers benefited from a weakening of the yen combined with a lower inflation rate than the United States.[31]

At the present time, the EEC steel industry is characterized by far greater diversity in structure and performance than those of Japan and the United States. The West German industry does well, on average, with respect to technology and productivity; but newer, larger, and better located steelworks can be found in Italy, France, and England. Most of the individual EEC steel industries have pock-

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*The European disadvantage has been offset somewhat during the past few years because of government transfer payments.

[28] Mueller and Kawahito, op. cit., p. 4.

*only Mueller and Kawahito suggest that Japan recently has been able to increase its cost advantage over the United States to pre-1973 levels.

[29] Bradford, op. cit., p. 14.

[30] Bradford, op. cit., p. 6

[31] WSD, op. cit., p. J-l-5.

ets of less-than-average efficiency, and these affect adversely the average performance of those industries and of the EEC steel industry as a whole.[32] From 1969 to 1972, U.S. production costs were generally 5 to 15 percent higher than European costs, but the European advantage evaporated in about 1973-74 because of currency changes, increased labor costs, and insufficient offsetting improvements in labor productivity. From 1972 to 1977, U.S. costs were about 5 to 15 percent lower than European costs, and they were about 9 to 22 percent lower during the early part of 1979. West German steelmaker are among the most efficient European producers. In 1978, their costs were 1 to 7 percent higher than U.S. costs, while French costs were 10 to 15 percent higher (see table 38).

On the international market, raw materials, labor, and capital costs only partly determine competitiveness. The costs of exporting, including transportation costs, warehousing, sales, and marketing, are also relevant. Japanese steelmaker have made impressive efficiency gains in transportation costs. Nevertheless, ocean freight costs increased during 1978 by as much as 55 percent because of skyrocketing oil prices. Total export cost for 1979 added about 25 percent to the cost of Japanese steel products—up by 5 percentage points from 1978.

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[32] Mueller and Kawahito, op. cit., p. 34.

[33] WSD, report A, p. A-3-8, 1979.

Future Trends in Competitiveness, Supply-Demand, and Trade

The cost factors that favored domestic producers in the 1970's, along with changes in demand and investment activity, will continue to affect future steelmaking costs, but in uncertain ways. High operating rates throughout the world are likely by the mid-1980's, and Japan is expected to continue as the world's lowest cost producer of steel, The United States has a potential for the selective export of high-technology domestic steels, but its cyclical import dependence may grow in importance.

Steel Shortages in the Mid-1980's

There are major problems in forecasting both future steel demand and future capacity. Rates of economic growth, actual new plant construction, and capacity utilization rates are major uncertainties. A low-demand-growth scenario could create a favorable U.S. cost position, because fixed-cost obligations affect domestic steelmaker less than they affect foreign competitors. Rapid demand growth and the associated high operating rates could benefit foreign steelmaker more than U.S. firms. In the immediate future, from 1980 to 1983, there probably will be excess steel-producing capacity in most countries of the world and for the United States, even assuming improved economic conditions and the continued closing (rationalization) of older European facilities. But after 1983, there could be a worldwide shortage of steel products. By shortage is meant a very close matching of supply to demand in major areas of the world that causes substantial increases in export prices.

The domestic industry is aware that a shortage could occur, and that its comparative cost position would be vulnerable in that case. According to George Stinson, Chairman of National Steel:

> We are not crying wolf, nor are these scare tactics to gain public or government support . . . Our analysis concludes that there is a good possibility that the world will face a steel shortage beginning in the mid-1980's . . .

The industry view has also been supported by a majority of steel experts in Government and financial communities, who have been noting the steady decline in U.S. capacity as older plants are closed. * However, some experts claim that a steel shortage is not likely. David G. Tarr, senior economist of FTC, for example, states that:

> The imminent (steel) shortage has been predicted by industry spokesmen for at least five years. Every year or two the onset of the shortage is pushed back by a year or two. The projections of shortage are wrong, I believe. The industry is cyclical, and if a simultaneous worldwide boom occurs there will be a shortage. But it will be temporary not secular .34

Most forecasts indicate that by the mid-1980's capacity utilization would have to reach 85 percent to satisfy demand, and this would represent the production level at which pricing reflects a shortage condition. Table 45 summarizes some of the major demand-supply forecasts.

Potential for Exports

If worldwide steel shortages do develop there may be opportunities for the U.S. producers to export steel. However, this possibility raises a number of issues. The United States does not possess a clear production cost advantage in commodity carbon steels; additional shipping costs also will constrain successful competition in foreign markets with commodity carbon steels. Domestic producers may be able to expand their exports of high-technology steels in which the United States is clearly cost and technologically competitive. However, several factors are likely to mitigate against this expansion. Among these are a lack of international trade experience among many domestic producers,

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*Almost all steel specialists in the financial community see the possibility of worldwide steel shortages after 1982. See, e.g., any of the current industry analyses by Peter F. Marcus from Paine, Webber, Mitchell, and Hutchins, Inc.; Joseph C. Wyman of Shearson Hayden Stone, inc.: and Father Hogan of Fordham University.

“Correspondence between David G. Tarr and Bernard L. Weinstein, Special Study on Economic Change, U.S. Congress, Joint Economic Committee, July 30,1979.

Table 45.—World Raw Steel Supply-Demand Forecasts, 1980-2000 (millions of tonnes)

		Capacity		Demand	
Source of data	Year	Western	Total	Western	Total
Chase[a]	1977	**625**	—	**430**	—
Marcus[b]	1977	**637**	—	—	—
Hogan[c]	1977	—	815	—	—
Marcus	1979	**652**	—	—	—
Ilsl[d]	1979	—	—	484	755
IISl.	1980	—	—	480	760
AISI[e]	1980	613	926	608	—
Marcus	1983	698	—	—	—
Chase	1985	715	—	**588**	—
IISl.	1985	675	—	—	—
AISI	1985	696	**926**	**691**	—
Hogan.	1985	—	**890**	—	**900**[f]
Bureau of Mines[g].	1985	730	—	—	**840**
Chase	1986	730	—	**614**	—
Chase	1990	794	—	—	—
AISI	1990	781	**1,200**	**776**	—
Marcus	2000	791[h]	—	—	—
Bureau of Mines	2000	—	—	—	**1,350**

aMichael F Elliott-Jones (Chase Econometrics), “Iron and Steel in the 1980's: The Crucial Decade,” speech at George Washington University Steel Seminar, Apr. 19, 1979.
bWorld Steel Dynamics, Apr. 25, 1979.
cW.T. Hogan, "Steel Supply and Demand in the Mid-1980's, " *Center Lines,* May 1979.
dInternational Iron and Steel Institute, 33 *Metal Producing,* December 1979, p. 38.
eAmerican Iron and Steel Institute, “Steel at the Crossroads: The American Steel Industry in the 1980' s,” 1980: assuming operating rate = 0.85.
fHogan has given the following summary for total world steel demand in 1985:

	Date of forecast	*Millions of tonnes*
AMAX	3178	919
Citibank	6178	890
Cleveland Cliffs	7/78	920
Metals Society (United Kingdom).	5178	1,015
Stanford Research .,	4179	970
Wharton. . .	10/77	896

9Bureau of Mines, *Iron and Steel,* MCP-15, 1978
hExtrapolated fro_m 1983 using given growth rate of 1.8 Percent Per Year

and tariff and nontariff trade restrictions by many countries.

There is a growing shift of strategy among steel companies in industrialized nations, which may result in a growing cyclical dependence on steel imports. Industrialized nations appear to be aiming at higher average capacity utilization by scaling capacity to meet normal steel demand rather than cyclical peak demands and to supply domestic rather than export demand. Future exports may emphasize technology rather than steel, including the export of high-price, technology-intensive steels, rather than commodity carbon steels. The net result of these changes could be that in future periods of high domestic demand, domestic capacity would be inadequate and the United States would be more dependent than at present on steel from LDCs, which have distinct energy and labor cost advantages,

The role of LDCs in the world steel supply and demand situation is critical. Their rates of growth in steel consumption are very high (figure 15). Depending on their rates of economic growth and of new steel plant construction, their impact on world exports could be substantial (table 46). Specific LDCs are likely to develop increasing capability to export semifinished steel and direct reduced iron to industrialized nations if these industrialized nations make major capital investments in LDCs. For the United States, energy- and iron-ore-rich Latin America presents singular uncertainties.

Future Costs and Productivity*

In home currencies and at high operating rates, U. S., French, and British steelmaking costs are expected to increase by about 8 percent, while Japanese and West German costs may increase by less than 4 percent, from 1980 to 1984.[35] Depending on operating rates, Japanese steelmaking costs may be about 14 to 17 percent lower, and West German costs may be 2 to 6 percent higher than domestic steelmaking costs.

During the mid-1980's, West German and especially Japanese steelmaker are expected to continue as leaders in making further improvements in the efficient use of raw materials, and their costs would then increase at only about half the U.S. rate. Furthermore, materials costs in these countries are expected to remain a smaller proportion of total steelmaking costs than those in the United States. It is expected that by 1985 the cost to domestic steelmaker of oil and coking coal will reach world market levels. The combined U.S. unit cost for oil and coal is expected to be $3/tonne higher than in Japan but about the same as in the EEC. Higher American unit costs for iron-bearing materials would be approximately offset by lower electricity costs.[36]

It appears that U.S. producers did not experience any improvements in labor productivity during 1979 because of increased repair and maintenance requirements caused by bringing old equipment back into the production stream. As a result of anticipated reductions in the work force, gains in U.S. productivity into the mid-1980's should be around 2.5 percent annually. This is higher than recent domestic labor productivity growth rates but lower than those expected for major producers abroad. As a result of major cost reduction efforts, the largest labor productivity gains are projected for Europe [4.5 percent annually), followed by Japan (3.5 percent). Thus, barring major technological improvements in the United States, Japan will increase its lead over the domestic industry in having lower man-hour requirements during the mid-1980's. Of the major European producers, only West Germany is likely to approach U.S. labor productivity levels.

It is projected that unit labor cost differences will widen, and by the mid-1980's domestic cost levels may be 8 to 10 percent higher than Japanese unit labor costs.[37] This

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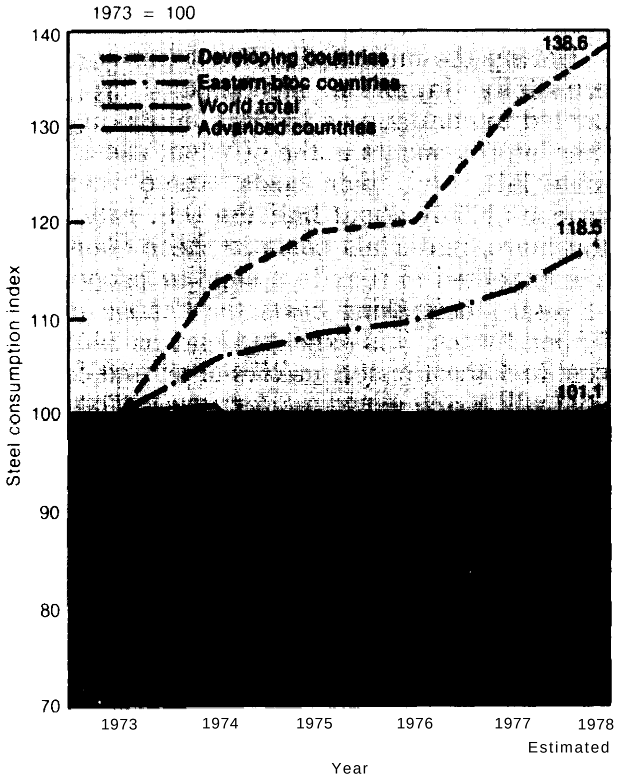
*Cost projections in this section are based on WSD cost data, adjusted by 5 to 10 percent for methodological reasons. They are limited to raw material, labor, and capital costs, and should be viewed as indicators of trends rather than specific developments.

[35] WSD, op. cit., p. J-l-25

[36] Mueller and Kawahito, op. cit., pp. 29-30.

[37] WSD, 1979.

Figure 15.—Apparent Steel Consumption Indexes by Region, 1973”-8



NOTE. Eastern-bloc countries include North Korea and China.

SOURCE International Iron and Steel Institute

deterioration in the U.S. unit labor cost position is expected for several reasons, including declining U.S. productivity growth rates and increasing hourly employment costs. At the same time, anticipated increases in the operating rates of Japanese and European steel producers will increase their labor productivity and restrain upward pressures on unit employment costs. The U.S. industry, operating at close to full capacity now, has already exhausted these economies.[38]

Whereas the U.S. steel industry’s present capacity is almost the same as it was in 1967, one-third of steelmaking capacity in the EEC and two-thirds of that in Japan has been put in place since that year. Thus, a considerably larger portion of steelmaking capacity in the United States will need to be replaced by 1985 or soon thereafter than in Japan or in the EEC. Maintenance costs can also be expected to be higher in the United States than in the EEC or Japan because of the difference in average age of plant and equipment.

Domestic steelmaker are expected to add a number of continuous casting facilities and new electric furnaces, thus bringing onstream new and efficient capacity. * In general, the scrap-based producers have modern, highly automated facilities and use continuous casting extensively. These factors should enable the scrap-based producers to cope with rising labor and energy costs more effectively than can the integrated producers.[39] However, limited scrap availability could reduce the growth potential of this low-

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[38] Mueller and Kawahito, op. cit.. pp. 28-29: Bradford, op. cit., p. 16.

*These and other components of modernization are discussed in ch. 10.

[39] Bradford, op. cit., p. 5.

Table 46.—Potential Impact on World Steel Supply by Less Developed Countries (in crude steel equivalents)

	Steel capacity	Steel production		Net Imports		Apparent consumption	Degree of self-sufficiency
Year and growth assumption	(million tonnes)	(million tonnes)	(percent of consumption)	(million tonnes)	(percent of consumption)	(million tonnes)	(percent)
1960	100	8.7	414	12,3	58.6	21.0	41.4
1965	200	16.1	50.2	16.0	49.8	32.1	50.2
1970 : : :	28.0	21,6	53.2	19.0	46,8	40.6	53.2
1977	58.0	41 7	609	26.8	39.1	68.5	60.9
1985 projected at:							
30% GNP growth	110-115	92	92	8	8	100	92
4% GNP growth	110-115	93	86	15	14	108	86
5% GNP growth.	110-115	95	79	25	21	120	79
6% GNP growth,	110-115	95	73	35	27	130	73
7% GNP growth	110-115	98	68	47	32	145	68

SOURCE: Central Intelligence Agency. "The Burgeonlng LDC Steel Industry More Problems for Major Steel Producers 1979 cost segment of the U.S. steel industry, unless direct reduced iron becomes available. This cannot happen before 1983 at the earliest. Partly as a result of the shift to electric furnace steelmaking, integrated producers are expected to reduce costs by consuming 15 percent less coke in 1980 than in 1979.[40]

Japanese producers are likely to derive long-term benefits from their decision to put most of their investment funds into the construction of modern greenfield plants. These benefits include low-cost production and stabilizing capital costs in the 1980's for replacement and pollution control.[41] Japanese and to some extent European steel companies now have sufficient modern infrastructure to add 9 million to 14 million tonnes of capacity at a relatively moderate cost. Nevertheless, Japan is expected to continue its current strategy of slowing down its steel industry plant construction program while continuing to introduce more energy-saving equipment.[42]

The Japanese steel industry is very dependent on raw material and energy imports (table 47), which has caused many of the raw material and energy prices in Japan to be somewhat higher than in the United States. The only raw material the U.S. steel industry imports in substantial amounts is iron ore—about one-third of iron ore is imported. Nevertheless, unit costs per tonne of steel produced in Japan have been markedly lower than those for most plants in the United States (see table 41). This is a consequence of the newer facilities and more modern technology in Japan,

During the next several years, Japan is expected to continue as the world's lowest cost steel producer. Some developing nations with lower labor cost and modern plants are now becoming almost as competitive as the Japanese. Indeed, they now pose a threat to the Japanese market; this is especially true of South Korea.

The largest European production cost improvements will result from programs designed to make the industry more efficient. Apparently West Germany will be most likely to succeed in cutting back its share of the 27-million-tonne capacity reduction planned for Common Market producers. Capacity reduction may be accelerated if foreign governments adopt implementing legislation for the Multilateral Trade Agreement subsidy code, which limits governmental aid to ailing producers and boosts payments to terminated workers.[43]

World Steel Trade

The domestic steel industry periodically states that the U.S. competitive position in home markets is eroded by the below-cost pricing of exports by Japan, as well as by European countries.[44] However, steel industry

Table 47.—import Dependence of the Japanese Steel Industry, Selected Years, 1955.78 (percent imported)

Industry	1955	1960	1965	1970	1974	1976	1977
Iron ore	**84.7**	**92.0**	**97.1**	**99.2**	**99.4**	**98.7**	**98.8**
Coking coal	**22.0**	**35.9**	**55.1**	**79.2**	**86.1**	**88.6**	**89.7**
Iron and steel scrap	**19.5**	**28.6**	**15.5**	**13,4**	**12.9**	**4.4**	**3.9**

SOURCE: Japan's *Iron and Steel Industry,* Tokyo, Kawata Publicity, Inc. 1973 Edition, pp. 249, 250, 1975 Edition, p. 35: and 1978 Edition. p 48

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[40] Ibid., p. 18.

[41] Mueller and Kawahito, op. cit., pp. 30-31.

[42] Ibid., pp. 34-35, Moreover, it is predictable that at some point in the future the Japanese steel industry will face many of the same difficulties as those currently confronting the U.S. steel industry. At some future time (probably beyond 1990-2000), Japan will face substantial capital replacement. These replacement needs will place a considerable burden on Japanese steel producers, especially because some of the important advantages the Japanese presently enjoy will no longer be operative.

[43] WSD.

[44] Putnam, Hayes and Bartlett, Inc., The *Economic Implications of* Foreign *Steel* Pricing Practices in the U.S. Market, prepared for American Iron and Steel Institute. Newton, Mass., 1978.

findings of below-cost pricing have been disputed by many analysts, including FTC.[45]

There is a consensus that at the present time most U.S. steel companies are price competitive for comparable steel qualities in the domestic market. Nevertheless, Japanese steel producers have been able to secure a significant share of the U.S. steel market. Some analysts claim that Japanese steel producers rely on agressive, even countercyclical, export programs to stabilize their highly leveraged positions. Others correctly dispute this allegation.[46] Some analysts and consumers believe that Japanese steel—made in more modern plants—is of high quality and is for this reason more competitive than other steels in the domestic market. There may have been times at which some Japanese steel was sold in the United States at below-cost prices, but most available data support the basic cost advantage of the Japanese. Although Japanese producers' profits may be small and their financial structure difficult to comprehend, the dumping of Japanese steel does not appear to be a valid issue.

As the amount of Japanese imports in the U.S. market declined in 1978 and early 1979, EEC and LDC exports to the United States increased. European producers have lost their cost competitiveness during the past several years. WSD cost data suggest that many European producers may have been selling in the American market below cost, because their costs are higher than U.S. costs but their prices are equal to or below U.S. prices.

LDC finished products have also, to some extent, replaced Japanese steel imports. EEC countries, exceptionally sensitive to imports, established a policy in 1977 to cut imports from developing countries like Mexico, South Africa, and South Korea. Japan traditionally has resisted significant imports of steel products. Thus, the United States provides the most accessible market for steel exports from all foreign countries. Exports of semifinished steel and direct reduced iron to the United States also could become significant in the future.

The trigger-price mechanism has been the Government's method of monitoring unfairly traded imports. According to the Treasury Department, the trigger-price mechanism has achieved its twin objectives of reducing steel imports and preventing dumping. * It has also led to price increases. However, the domestic iron and steel industry and some Government analysts do not share the Treasury Department's enthusiasm. The net effect of the system has been 1) to allow the least profitable, highest cost foreign steelmaker, especially the Europeans, to obtain higher export prices and to reduce, but not eliminate, their losses; and 2) to give the Japanese greater profits. At the same time, any benefits the United States realizes from low import prices have been largely eliminated, because the mechanism acts to set price levels. For example, during 1978, every tonne of finished steel imported from Europe that could have been produced in the United States would have generated a domestic profit of more than $22/tonne. Instead, European exports to the United States under the trigger-price mechanism reduced European losses by $3/tonne.

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[45] FTC criticized a major AISI-sponsored study as follows: "Thus (Putnam, Hayes and Bartlett) have estimated the costs of making all steel and compared these costs with the price of carbon steel alone. Ignoring special steels in the price series results in a series bias in favor of finding below-cost pricing. Since PHB have not removed this bias from their data and estimates, one cannot conclude from their estimates that below-cost pricing has occurred. " (FTC, "Staff Report on the United States Steel Industry and Its International Rivals: Trends and Factors Determining Competitiveness, " 1977, p. 244.)

[46] A study undertaken by the Council on Wage and Price Stability, "Prices and Costs in the United States Steel Industry," October 1977, states: "We conclude that a major reason for the success of the Japanese steel industry cannot be found in a countercyclical dual-pricing approach to domestic and world markets. Japanese exports have grown at phenomenal rates during good times and bad for the home economy." (p. 90).

*For example, steel imports were discussed extensively in the 2 days of steel talks on Feb. 7 and 8, 1979, which opened with Treasury Undersecretary Anthony Solomon's report to the Senate steel group on improved industry performance since the inception of the trigger-price mechanism. Import penetration dropped from 20 to 17 percent in the final 8 months of 1978, when the plan was in effect, and in December it dropped to 14 percent.

The situation has been summed up by Roger E. Alcaly, senior economist with the Council on Wage and Price Stability:

> In short, the major impact . . . was on import prices, with most of the gain accruing to foreign producers, while the effects on the domestic steel industry were too small to reverse the long-term trends.[47]

Over the 2 years of the trigger-price mechanism, carbon steel import prices rose 39 percent, while the domestic producer price index for steel mill products rose 21 percent.[48]

Because of the industry's skepticism about the trigger-price mechanism, it has made a considerable effort to have the new Multilateral Trade Agreement vigorously enforced, particularly its provisions against direct export subsidies. The domestic steel industry also feels that the Government's handling of the existing trade laws has been "less than vigorous" and that enforcement powers should be transferred to another Government agency.* Further, the domestic industry would like to have the burden of initiating unfair trade practice agreements lifted from industry and handled by the responsible Federal agency.

The steel industry feels that Government decisions regarding the enforcement of trade laws should allow for more trade association and labor union input. Also of importance to the industry is a new definition of injury to an industry that would extend and codify the limits within which dumping can be prohibited. Given active foreign government participation in their steel industries, effective implementation of the subsidy code will also grow in importance.

The new Multilateral Trade Agreement includes many of the industry's objectives, but the details and specifics of the agreement remain to be implemented. Its actual impact on the domestic iron and steel industry cannot be precisely determined at this time, A definite possibility exists that selected, high-technology U.S. steels would be more easily exported under a well-enforced Multilateral Trade Agreement and some domestic alloy/specialty steel producers might be able to capitalize on this opportunity.* It is clear, therefore, that Government policies within the context of the Multilateral Trade Agreement are of paramount importance to the domestic iron and steel industry, both for preventing unfairly priced imports and for obtaining fair trade in export markets.

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[47] *American Metal Market,* Dec. 24, 1979.

[48] C. A. Bradford, "Steel Industry Quarterly Review,"' Merrill, Lynch, Pierce, Fenner & Smith, Inc., February 1980.

*In July 1978 the Treasury Department was stripped of most of its international trade responsibilities. The Undersecretary for Trade at the Commerce Department now administers international trade programs such as the trigger-price mechanism.

*Discussed more fully in ch. 8.

Chapter 5

Past and Future Domestic Use of Steel

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CHAPTER 5

Past and Future Domestic Use of Steel

Summary

Steel is the most important engineering material in American society. There is literally no aspect of private or public life that is not in some way dependent on steel. Nevertheless, steel is taken largely for granted. Steel is not generally considered to be technology intensive, changing in character, or especially critical for economic or military security, Yet, steel is all these things. It plays such a pervasive and vital role in all primary manufacturing and construction that it will remain a strategic material for the Nation. With regard to military security, the strategic role of steel is increasing. In 1967 President Lyndon B. Johnson commented that "steel . . . is basic to our economy and essential to our national security;[1] that statement is still valid today.

Domestic consumption of steel continues to increase, although at a slower rate than during the early phases of U.S. industrialization when there were large increases in per capita income. Although the use of aluminum and plastics has greatly increased in the past several decades, the per capita consumption of these materials is only about 60 to 140 lb, respectively, compared to approximately 1,000 lb per capita consumption of steel, Steel competitiveness may improve as a result of future energy and raw material cost changes, which will have stronger adverse impacts on aluminum and plastics than on steel.

Although it may appear, according to some measures, that the use and role of steel are declining, it must be recognized that for many applications there are no cost-competitive performance substitutes for steel. One frequently mentioned exception is the use of steel in automobiles. Driven by the need to reduce vehicle weight, automobile manufacturers are reducing the amount of steel used in each automobile. Steady or decreased demand for steel in this market is likely. To the extent that foreign automobile companies produce more of their automobiles in the United States and use domestic steel, the decline in steel use per car may be partially offset by an increase in the number of cars produced. Some observers believe there will be a surge in steel demand for capital reconstruction of physical structures such as bridges, buildings, railroads, and primary manufacturing facilities, as those built during the past 50 years wear out.

Inadequate domestic steel capacity in the future is a distinct possibility. The modernization and expansion program for the 1979-88 period proposed by the industry, through the American Iron and Steel Institute (AISI), assumes a very low rate of increasing domestic demand for steel (1.5 percent per year). Should that projection be too low, the capacity planned for would be inadequate, and, according to other, higher demand growth forecasts, imports could rise to 20 percent of domestic consumption, or 27 million tonne/yr. This would be about 50 percent greater than any previous import tonnage. Without the modernization and expansion program the industry deems necessary, low domestic capacity might require the import of more than 44 percent of U.S. steel by the end of the 1980's. The current overcapacity in the world steel market is likely to disappear soon and that degree of import dependence could expose the United States to economic and national security problems not unlike those the Nation has encountered with petroleum.

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[1] Presidential Proclamation 3778, Apr. 8, 1967.

The Importance of Steel

Steel has generally been considered a basic industry. There is good reason for this. Virtually every sector of the economy and all aspects of human activity depend on steel in some direct or indirect way. When steel is not used directly, it invariably has been used in the equipment that made the nonsteel materials being used and that transported them from original source to final application. Steel is the backbone of any industrialized society. From rails, to machines, to girders in buildings, to beverage containers, to eating utensils, steel is ubiquitous. Yet, steel is no longer thought of as a critical material in society. Overshadowed by high-technology products and industries, steelmaking is generally taken for granted and considered to be a simple and unchanging technology.

In fact, steelmaking has undergone great changes and continues to do so. Steel products have also changed dramatically as new alloys and coatings for steel have greatly enlarged its range of properties and applications. Other engineering materials, notably aluminum and plastics, have given stiff competition to steel, but by and large steel has held its own and remains the most important engineering material in society.

Steel is particularly important from a national security viewpoint. It is irreplaceable in military hardware like tanks and guns, but military needs for steel go far beyond the actual steel in weapons. Like the economy itself, the military establishment depends totally on steel for the manufacture and transportation of all its supplies. The Federal Emergency Management Agency estimated in 1979 that in a 3-year non-nuclear war, 26 percent of steel industry output would be required for direct military purposes.[2] This assumes that such an effort would be preceded by mobilization of both military and industrial resources. Another 56 percent of domestic steel would be needed for essential purposes in support of the military effort, leaving 18 percent for civilian purposes, The corresponding estimates in 1969 were 6 percent, 66 percent, and 28 percent respectively, an indication that the strategic role of steel has increased during the past decade.

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[2] Communication from P. Kruger of the Federal Emergency Management Agency, Jan. 15, 1980.

Steel Compared to Aluminum, Plastics, Cement, and Wood

For one material to be used in place of another, the substitute must perform adequately in a specific application. If it does, then economic considerations—both cost and price factors—play an important role in the competition between the materials. Finally, trends in technological innovation will influence the materials selection. *

Comparative Properties of Materials

To some extent, a particular steel may have unique properties that determine its selection, but more often it competes on the basis of cost with other materials capable of satisfying the requirements of the application. The two properties chosen for comparison here are strength and stiffness, but many other properties may be important in a given use. Although those properties have the same units (MPa), they represent quite different characteristics of a material. Strength represents material's resistance to breakage (breaking or tensile strength) or to permanent deformation (yield strength). Stiffness on the other hand represents a material's resistance to temporary deformation while a load or stress is being imposed on it—such deforma-

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● More detail on steel innovation is provided in other chapters, particularly ch. 6.

tion as the deflection of a stairtread when stepped upon or the coiling of a spring. Using absolute values, steel can have a wide range of strengths, but all steels have approximately the same stiffness. However, the stiffness of one class of materials is generally quite different than another class; for example, steels are about three times as stiff as are aluminum alloys—even though, contrary to the general impression, some aluminum alloys are stronger than some steels.

The stiffness of material should be appropriate to its design application. For example, if an automobile were made of some flexible material, its doors might fit very snugly when empty but very poorly when loaded with passengers. Most plastics would be unsuitable for such an application because of their low stiffness. However, when very low stiffness plastics are combined with a very stiff material, such as graphite or glass fibers, then the reinforced plastic may have a composite stiffness as good as or better than steel.

Strength is important in materials applications, either in terms of yield strength (for ductile material) or breaking strength (for a brittle material). A ductile material has a yield strength below its breaking strength. A brittle material's yield strength is the same as its breaking strength, Once the strength is known, a material can be chosen for an application so that only some fraction of either the yield or breaking strength is realized in service. When the service condition involves an applied stress level greater than the design stress (an overload), then the material may fail, causing loss of function. Failure may be permanent (plastic) deformation, such as in a bent wheel, or actual breakage, such as in broken glass. The ability to deform prior to fracture is normally an asset; for example, some autos are designed to deform rather than break under low-speed impacts so that little or no damage occurs to the critical parts of the auto or to the passenger. The metal deformation absorbs some of the energy of the impacts.

As a general rule, materials with much stiffness, such as graphite fibers, are also brittle. An auto made of graphite would break into pieces upon overload. When the stiff graphite fibers are mixed with the more flexible plastics, the composite material is more likely to stay in one piece on overloading. The advantage that most metals have is that they combine reasonable stiffness with reasonable ductility. An auto made of steel will permanently bend when overloaded but usually will not break into pieces.

The properties of yield strength and stiffness can be given on an absolute and on a specific basis. The specific strength or specific stiffness shows the "strength-to-weight" or "stiffness-to-weight" ratio of each material. These ratios provide a means of comparing the size, volume, or mass of materials with different properties required to perform in an equivalent manner. For example, a large piece of a weak material may respond in the same way to the same load as a smaller piece of a stronger material.

Tables **48** and **49** present comparisons of the stiffness and strength, respectively, of steel, aluminum, cement, plastics, lumber, and composite materials. Table 50 provides data on temperature and chemical environment limitations to the use of these materials. Breakeven price indexes were also calculated for these materials. The indexes indicate the amount paid for alternative materials to steel, on a weight basis, for equivalent stiffness or strength. At prices below the index prices (determined by multiplying the index by the cost of steel), the alternative materials cost less than steel for equivalent stiffness or strength. Note that this index measures only one cost; comparisons among materials require consideration of a multitude of factors, including the practical means of obtaining the desired form and shape of the material.

Table 51 presents actual breakeven stiffness and breakeven strength prices for the various materials competitive with steel in 1976, and compares these prices with actual prices. From this limited type of consideration, it is found that certain plastics and cement could be more competitive than steel.

Table 48.—Comparison of Material Properties (I): Stiffness

Material	Elastic modulus (MPa x 10^3)	Specific gravity	Specific modulus[a]	Equivalent stiffness (steel = 1.000) Thickness ratio[b]	Weight ratio[c]	Breakeven price index[d]
Steel	207.0	7.870	26.30	1.000	1.000	1.000
Aluminum	69.0	2.699	25.60	1.442	0.495	2.020
Plastics						
Thermoplasts						
6/6 nylon	**2.83**	1.100	2.57	4.182	0.585	1.709
HDPE	**0.83**	**0.950**	0.87	6.295	0.760	1.316
ABS	**2.10**	**1.060**	1.98	4.619	0.622	1.608
Thermoses						
Epoxies	**6.90**	**1.100**	6.27	3.107	0.434	2.304
Wood (clearwood)						
Softwood						
Douglas fir (green)	8.14	**0.400**	20.40	2.941	0.149	6.711
Douglas fir (12% H_2O)	9.66	**0.430**	22.47	2.778	0.152	6.579
Hardwood						
White oak (green)	10.42	**0.640**	16.28	2.708	0.220	4.545
White oak (12°\0 H, O)	15.73	**0.720**	21.85	2.361	0.216	4.630
Composites						
Portland Cement concrete (reinforced)	**34.50**	2.410	**14.30**	**1.817**	**0.556**	**1.799**
Fiber-reinforced plastics						
S-glass/Epoxy (60% fiber, filament wound)	31.70	**1.990**	15.93	1.869	0.473	2.114
Graphite fiber/Epoxy						
Thornel 300 (resin-impregnated strand)	227.50	**1.740**	**130.40**	**0.969**	**0.214**	**4.673**

[a] Specific modulus = modulus ÷ specific gravity

[b] Thickness ratio = (steel modulus + alternative material's modulus) one.third power, derived from deflection of simple cantilever beams

For attainment of a desired stiffness with an alternative material, multiply thickness of steel by the thickness ratio, e,g., aluminum must be 1 442 times thicker than steel to provide stiffness equivalent to steel

[c] Weight ratio = thickness ratio X (specific gravity of alternate material + specific gravity of steel)

Determines the weight of an alternative material which wiIl give stiffness equivalent to steel, e g , for aluminum need O 495 of the weight of steel

[d] Breakeven price index = reciprocal of the weight ratio

The multiplier of the steel price which is used to calculate the upper limit of how much may be paid for an alternative material to achieve same stiffness as steel, e.g., if steel costs $0.20/lb then aluminum must sell for $0 404/lb, or less, to compete with steel strictly on the basis of stiffness, Average 1976 prices used.

NOTE: S.I. metric units of Mega Pascals (M Pa) may be converted to customary English units (pounds per square inch, lb/in^2) by the following factor: 1 MPa = 145 lb/in', e.g., the elastic modulus of steel at 207 x 10^3 MPa con. verts to 207,000 MPa x 145 lb/in^2/MPa = 30 x 10^6 lb/in^2.

SOURCE: Office of Technology Assessment

Table 52 presents actual breakeven prices for engineering properties by material in the year 2000, assuming real rates of inflation in steel prices of 1, 3, and – 1 percent per year from 1976 to 2000. The inflation rates (in real terms) that will lead to parity pricing (for engineering properties of steel) of other materials—given the steel inflation rates assumed in table 52—are presented in table 53. Only some plastics and cement could undergo larger cost increases than steel and still remain competitive for the properties considered.

Comparative Economic Trends

Because the competitiveness of steel is normally related to price, as well as to engineering properties, it is useful to review the past pricing of steel and its competitor materials. Figure 16 presents price indexes in real terms for five engineering materials. From 1956 through 1972, steel prices in real terms were relatively constant. Cement and aluminum prices in real terms were, in general, declining, but plastic prices were plummeting. Lumber prices were quite level through the second half of the 1960's, after which their volatility increased. Since 1972, steel has exhibited relatively small price increases,

Capital costs, energy costs, the rate of technological change, and Federal and State regulations are all important elements in the cost of engineering materials, although lumber is to a considerable extent an exception.

Table 49.—Comparison of Material Properties (II): Strength

Material	Tensile strength (M Pa)	Specific gravity	Specific tensile strength[a]	Equivalent strength (HSLA steel = 1.000)		
				Thickness ratio[b]	Weight ratio[c]	Breakeven price index[d]
Steel (wrought)						
Plain carbon (1010)	365.44	7.870	46.43	**1.150**	**1.150**	0.870
HLSA (970X).	483.00	7.870	61.37	**1.000**	**1.000**	1.000
Stainless (301)	1,275.58	7.870	162.08	**0.615**	**0.615**	1.626
Aluminum (wrought)						
Commercial purity (1060-H18)	131.0	**2.699**	48.54	1.920	**0.659**	1.519
Alloy						
Single-phase (5052-H38)	289.59	**2.699**	**107.30**	1.291	**0.443**	2.258
Multiphase (7178-T6).	606.76	**2.699**	**224.81**	0.892	**0.306**	3.268
Plastics						
Thermoplastics						
6/6 nylon. ., ...	81.36	1.100	73.96	2.437	**0.341**	2.936
HDPE	27.58	**0.950**	29.03	4.185	**0.505**	1.980
ABS	48.27	**1.060**	45.53	3.163	**0.426**	2.347
Thermoses						
Epoxies.	68.95	1.100	62.68	2.647	**0.370**	2.703
Wood (clearwood)						
Softwood						
Douglas fir (green).	24.82	0.400	**62.05**	4.411	0.224	4.460
Douglas fir (12% $H^{2}O$).	43.44	0.430	**101.02**	3.334	0.182	5.489
Hardwood						
White oak (green).	31.72	0,640	49.56	**3.902**	**0.317**	3.151
White oak (12% $H^{2}O$).	45.51	0.720	63.21	**3.258**	**0.298**	3.355
Composites						
Portland Cement concrete (reinforced).	34.50	**2.410**	14.32	3.742	1.146	0.873
Fiber-reinforced plastics						
S-glass/Epoxy (60% fiber, filament wound).	877.00	1.990	**440.71**	0.742	**0.188**	5.329
Graphite fiber/Epoxy Thornel 300	2,654.00	1.740	**1,521.20**	0.427	**0.094**	10.602

[a] Specific tensile strength = tensile strength - specific gravity.

[b] Thickness ratio = (HSLA strength – strength of alternative material), one-half power, as derived from formula for maximum surface stress in a cantilever beam

For attainment of a desired strength (load.bearing capacity) with a material other than HSLA steel by the thickness ratio, e g , a 1010 plain carbon steel must be 1.15 times thicker than HSLA while a 301 stainless steel need be only 0.615 times as thick as the HSLA.

[c] Weight ratio = thickness ratio X (specific gravity of alternate material + specific gravity of HSLA)

Determines the weight of a given material which wiIl provide the load. bearing capability of a piece of HSLA steel, e.g., for 7178-76 aluminum only *0.306* kg of that material would be needed to replace 10 kg of HSLA

[d] Breakeven price index = reciprocal of the weight ratio

The multiplier of the HSLA steel price which determines the upper limit that should be paid for an alternate material in order to gain the same load bearing capacity as the HSLA steel, e.g., if HSLA steel costs $0 50/lb then 7178-76 aluminum must cost less than $1.634/lb to be competitive Average 1976 prices used

NOTE S I metric units of Mega Pascals (M Pa) may be converted to customary English units (pounds per square inch, lb/in^2) by the following factor: 1 M Pa = 145 lb/in^2, e g the elastic modulus of steel at 207 x 10^3 MPa converts to 207,000 MPa x 145 lb/in^2/MPa = 30 x 10^6 lb/in^2.

SOURCE Off Ice of Technology Assessment

Steel

The steel industry is the Nation's largest industrial consumer of energy. However, rising oil prices will affect steel less than they will most other energy-intensive industries. Most of the energy used in steelmaking is in the form of coal in coking operations, and domestic coal is abundant. World prices for coking, or metallurgical-grade, coal are likely to remain low relative to other energy sources for several reasons. First, consumption of coke per tonne of iron produced has been dropping steadily, and promises to continue to do so. Second, low-grade coal is coming into use for coking. The Japanese in particular have been using lower quality coals for coking, the United States is beginning to explore actively the use of formcoke technology that will permit the use of abundant low-grade coals, and the Soviet Union's development of dry quenching may also provide a technology for using lower quality coals. Coal-based direct reduction (DR) may also become commercialized (see ch. 6). Finally, the recent opening of Australian mines has made major additions to world supply of coking coal. Problems with inadequate domestic coke capacity, discussed in chapter 7, appear to be only of a short-term nature.

Electric power costs are also important to steel industry costs. Electric power is increasingly being used to melt scrap and make steel in electric furnaces, to produce oxygen, and to operate high-horsepower rolling mills and other equipment. Thus, the apparent trend toward closing the gap between industrial and residential power rates in the United States has important implications for U.S. steelmaking costs.

Capital costs for steel are very high for integrated greenfield (new plant) capacity, but increased electric furnace capacity costs a great deal less than new integrated plants, as do expansions at existing plants. One way of obtaining steel capacity is to improve the mill yield on raw steel. Continuous casting (discussed in ch. 9) is clearly the most important route to such improvements. Computer control and new high-temperature sensor technology will also improve yields and provide savings both in raw steel and in labor costs as well. Future changes in steelmaking are fully analyzed in chapter 6. In the long term, these are promising developments that could offer substantial production and capital cost savings.

Table 50.–Comparison of Material Properties (III): Environmental Behavior

Material	Range of service temperature (°C)[a]	Resistance to chemical environment
Steel (wrought)		
Plain carbon (1010)	430 / – 20	F / P
HSLA (970X)	500[c] / -50	G / P
Stainless (301)	540/ None	VG/VG
Aluminum (wrought)		
Commercial purity (1060)	105/ None	VG/VG
Alloy		
Single-phase (5052)	105/ None	VG/VG
Multiphase(7178)	200[c]/ None	G / G
Plastics		
Thermoplastics		
6/6 nylon	150 / 20	G / E
HDPE	60125	G / E
ADS	100[c]/25[c]	G / E
Thermoses		
Epoxies	180/ N.A.	VG/I E
Wood		
Softwood		
Douglas fir	200[d]/N.A.	G[e]
Hardwood		
White oak	200[d]/N.A.	VG[e]
Composites		
Portland Cement concrete (reinforced)	1,170/ None	F / VG[f]
Fiber-reinforced plastics		
S-glass/epoxy	100/ N.A.	F[g]
Graphite fiber/epoxy		
Thornel 300	100[c]/N.A.	F[g]

[a] Service temperature limits due to (elevated temperature creep/low temperature brittle failure)

[b] Chemical environment resistance for (acidic/baste) environments; ratlng scale P = Poor; F = Fair; G = Good; VG = Very good; E = Excellent,

[c] EstImated

[d] Upper seervice temperature limit for wood defined as ignition temperature

[e] Wood measured in terms of decay resistance

[f] Poor in contact with alkali cations, reinforcing bar attacked by chlorides

[g] Susceptible to moisture or ozone or ironlzing radiation damage at fiber.resin interface; otherwise the acid/base resistance IS as stated for epoxies

SOURCE: Office of Technology Assessment.

Table 51 .—Equivalent Prices for Engineering Properties by Material, 1976 (in cents per pound)

		Breakeven stiffness price relative to carbon steel		Breakeven strength price relative to carbon steel	
Material	**Actual 1976 price**	**Hot-rolled sheet**	**Cold-rolled sheet**	**Hot-rolled sheet**	**Cold-rolled sheet**
Carbon steel					
Hot-rolled sheet	**13.2¢**	**N.R.**	**N.R.**	**N.R.**	**N.R.**
Cold-rolled sheet	**15.2**	N.R.	N.R.	N.R.	N.R.
Aluminum mill product	65.0	26.7¢	30.7¢	23.0¢	26.5¢
Plastics					
HDPE	28.0	17,4	20.0	30.0	34.6
ABS	46.0	21.2	24.4	35.6	41.0
Portland Cement	1.8	23.7	27.3	13.2	15.3

N R. = not relevant.

SOURCE: Office of Technology Assessment

Table 52.—Equivalent Prices for Engineering Properties by Material, Year 2000 (in 1976 cents per pound)

				Forecast year 2000 prices			
				Breakeven stiffness price relative to carbon steel		Breakeven strength price relative to carbon steel	
	Assumed steel product price inflation (percent per year)	Actual 1976 price	Forecast year 2000 price	Hot-rolled sheet	Cold-rolled sheet	Hot-rolled sheet	Cold-rolled sheet
Carbon steel							
Hot-rolled sheet	1%	13.2¢	16.8¢	N.R.	N.R.	N.R.	N.R.
Cold-rolled sheet	1	15.2	19.3	N.R.	N.R.	N.R.	N.R.
Aluminum mill product	1	65.0	N.R.	33.9¢	39.0¢	29.3¢	33.7¢
Plastics							
HDPE	1	28.0	N.R.	22.1	25.4	38.2	43.9
ABS	1	46.0	N.R.	27.0	31.0	38.2	52.1
Portland Cement	1	1.8	N.R.	21.3	34.7	16.9	19.4
Carbon steel							
Hot-rolled sheet	3	13.2	26.8	N.R.	N.R.	N.R.	N.R.
Cold-rolled sheet	3	15.2	30.9	N.R.	N.R.	N.R.	N.R.
Aluminum mill product	3	65.0	N.R.	54.1	62.4	46.8	54.0
Plastics							
HDPE	3	28.0	N.R.	**35.3**	**40.7**	61.0	70.3
ABS	3	46.0	N.R.	**43.1**	**49.7**	72.3	83.4
Portland Cement	3	1.8	N.R.	**48.2**	**55.6**	26.9	31.0
Carbon steel							
Hot-rolled sheet	–1	13.2	10.4	N.R.	N.R.	N.R.	N.R.
Cold-rolled sheet	– 1	15.2	11.9	N.R.	N.R.	N.R.	N.R.
Aluminum mill product	- 1	65.0	N.R.	21.0	24.0	18.2	20.8
Plastics							
HDPE	–1	28.0	N.R.	13.7	15.7	23.7	27.1
ABS	–1	46.0	N.R.	16.7	19.1	28.1	32.1
Portland Cement	–1	1.8	N.R.	18.7	21.4	10.4	11.9

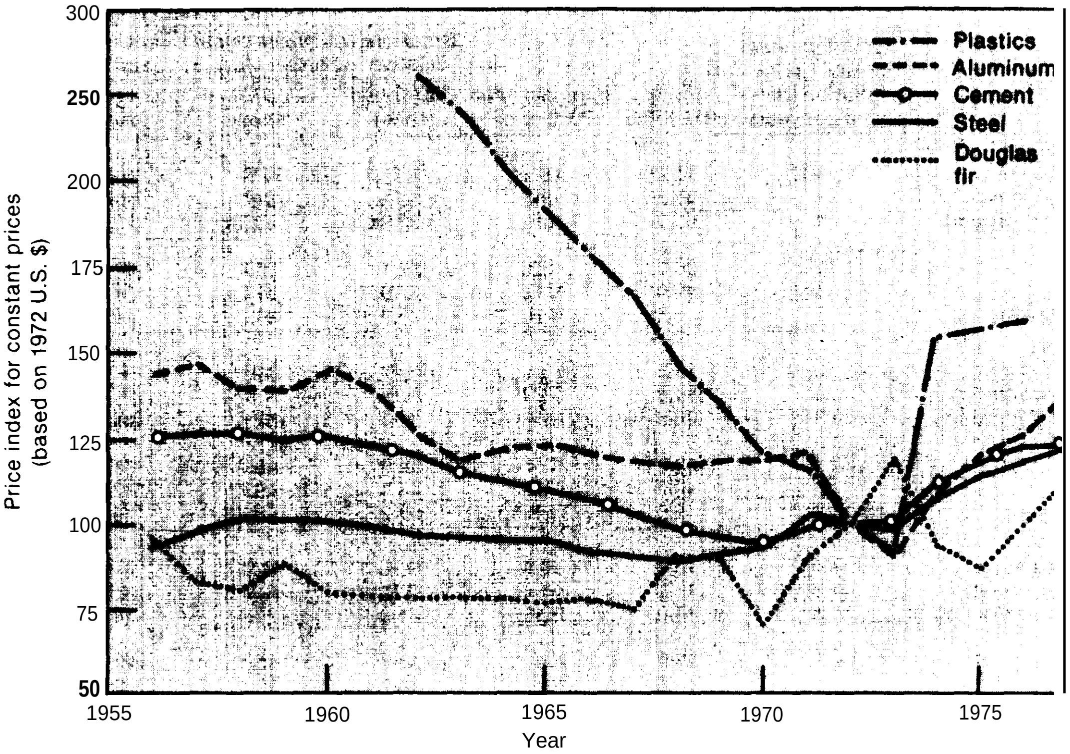
N R = not relevant SOURCE: Office of Technology Assessment.

Table 53.—inflation and Parity Pricing of Engineering Properties by Material, Year 2000 (in percent per year or average annual compound growth rate)

		Inflation rates for other materials that yield parity pricing with steel in 2000			
		Stiffness		Strength	
Material	Assumed steel product price inflation (percent per year)	Hot-rolled sheet	Cold-rolled sheet	Hot-rolled sheet	Cold-rolled sheet
Carbon steel	1%	N.R.	N.R.	**N.R.**	**N.R.**
Aluminum mill product	1	– 2.7%	– 2.1 %	**–3.3%**	**–2.7%**
Plastics					
HDPE	1	– 1.0	-0.4	**1.3**	**1.9**
ABS	1	– 2.2	-1.6	– 0.1	0.5
Portland Cement	1	10.8	13.1	9.8	10.4
Carbon steel	3	N.R.	N.R.	N.R.	N.R.
Aluminum mill product	3	– 0.8	– 0.2	– 1.4	– 0.8
Plastics					
HDPE	3	1.0	1.6	3.3	3.9
ABS	3	-0.3	0.3	1.9	2.5
Portland Cement	3	14.7	15.4	11.9	12.6
Carbon steel	–1	N.R.	N.R.	N.R.	N.R.
Aluminum mill product	–1	– 4.6	– 4.1	– 5.2	– 4.6
Plastics					
HDPE	–1	– 2.9	– 2.4	-0.7	– 0.1
ABS	–1	– 4.1	3.6	-2.0	– 1.5
Portland Cement	–1	10.2	10.9	7.6	8.2

N R = not relevant SOURCE Office of Technology Assessment

Figure 16.—Real Price Trends in Engineering Materials



SOURCE: Office of Technology Assessment.

Aluminum

Like steel, aluminum suffers from very high investment costs for new capacity relative to historical costs. Unlike steel, no major technological alternatives exist or appear likely in the future for producing primary aluminum. The aluminum industry is and will continue to be almost totally dependent on imports of ore (bauxite) or down-line products. The cheapest form of additional aluminum capacity will be increased recycling and growth in the secondary smelting industry.

The most likely source of scrap is the two-piece beverage can. In 1978, of the 1.1 million tonnes of aluminum sheet that went into cans, some 270,000 tonnes, or 25 percent, were recycled. The price paid for scrap was one-third of that for ingot. The ceiling on the recycle rate is probably 75 to 80 percent, judging from the experience of the Adolf Coors Co., which requires distributors to recycle cans and reports recycle rates of 75 percent. A recycle rate of 75 percent in two-piece beverage cans in 1978 would have supplied on the order of 10 percent of total apparent aluminum consumption.

Electric power costs are at least 20 percent of the manufacturing costs of aluminum ingot, and they increased by a factor of three from 1950 to 1977, from 16.6 to 51.3 cent/lb. Although smelters now use considerably less electric power per pound of aluminum than formerly (see the section on comparative innovation trends), the rate of change is slow. A new Alcoa process promises lower power consumption, but commercialization is at least a decade away, judging from public pronouncements. About one-third of the primary smelting capacity in the United States is located in the Pacific Northwest and uses electric power from the Bonneville Power Administration's hydroelectric plants. Supply contracts between Bonneville and these smelters will begin to expire in the early 1980's. The industry clearly will not be able to renew the contracts at rates based on hydroelectric generating costs. * At best, the smelters in the area will pay a weighted average cost of electric power from hydroelectric, coal, and/or nuclear rates. However, the rates are structured in such a way that one-third of the aluminum industry's smelting capacity will suffer a severalfold increase in the cost per kilowatthour.

A conservative estimate is that these increases alone will double the average cost of electric power for the entire U.S. aluminum industry. As a result, aluminum prices are expected to rise very sharply in the future. Indeed, in the past year, prices have already begun to increase sharply.

Plastics

Capital costs are important in plastics production, but with feedstock prices set by the alternative-use values for liquid and gaseous hydrocarbon fuels, plastics prices are very sensitive to imported oil prices. Technological change in resin and monomer production is more rapid for plastics than for more traditional materials and provides some cushion for these materials. U.S. natural gas pricing policy will set the prices for the feedstocks of the most important monomer, ethylene. U.S. gasoline demand and Government policies on octane additives will be critically important to the other major class of derivatives, the aromatics. It is reasonable to expect that the prices of the thermoplastics, which have remained relatively stable in the past (for some types of plastics, i.e., high-density polyethylene and polypropylene), will increase significantly in the future.

Cement

The cement industry is capital intensive and new capacity is likely to set prices in most regions. Although capital costs are an undeniably strong upward cost pressure on cement prices, several favorable cost influences are also at work on future prices. After World War II, cement producers switched from coal to fuel oil to provide the required process heat. They are now in the process of switching back and will benefit from the ability to use high-sulfur coals, which will be a relatively low-priced and available fuel during the next two decades.

Even though raw materials for cement are ubiquitous, and their cost is equal only to on-site extraction costs, an even cheaper raw material may be available. Pollution control of coal-fired electric power generation produces a cementitious material on which utilities can "make" money by giving it away to avoid disposal costs. It is unlikely to be free, but it will no doubt be inexpensive. Not all grades of cement can be produced from this material, but it is an important cost factor nevertheless.

In spite of these factors, cement prices, which increased less than steel in the last three decades, are expected to rise, principally because of increasing capital costs.

Lumber

The most important factors in lumber prices are U.S. Government forestland management strategy and homebuilding trends. Recent forestland practices have tended to remove more land from active forest management, reducing the supply of lumber and pressuring prices upward. These practices are currently going through a major policy review. As other factors drive new home costs up, pressure increases to free more timber in order to keep building costs down.

Prices have increased in the last two decades by a factor of three for Ponderosa pine and slightly less for Douglas fir and Southern pine. They can be expected to increase more rapidly in the future unless economic condi-

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*The total price per kilowatthour paid for hydroelectric power does not even pay for the fuel required to generate a kilowatthour with coal.

tions significantly dampen housing construction.

Comparative Innovation Trends

Opportunities for technological gains may be found in the way materials are processed, in the quality of their performance, and in the forms in which they are marketed. Advances in material processing can play a major role in reducing production costs; modification or better control of the composition, structure, and properties of materials can make them easier to form, stronger, more resistant to corrosion, and the like; and new methods of fabrication can open up new markets or widen old ones.

Material Processing

Electric power consumption per pound of aluminum ingot and coke consumption per tonne of iron have decreased gradually over the past decades. Average data like these reflect a mix of new state-of-the-art plants and older plants with varying degrees of efficiency. As an industry matures, the rate of capacity replacement slows and with it the rate at which technological improvements, other than those that can be accomplished through retrofit, can be implemented on an industrywide basis. This has been a particularly acute problem for domestic steel.

In the post-World War II period the basic oxygen process effected steel production economies. By using oxygen and reducing the time required per heat (batch), the basic oxygen furnace made continuous casting feasible on the scale required for commercial development, The main advantage of continuous casting is that it improves yield by about 10 percentage points. This improvement in yield reduces unit energy, capital, labor, and pollution control costs. *

Electric arc furnace capacity can be added in much smaller increments than can oxygen furnaces. Their smaller scale and lower capital costs per annual tonne reduce the risk in building a mill. Rolling mills too have become more efficient with the installation of multistand continuous mills. The continued evolution of process-control computers, coupled with better gauge-detection technology, will improve yields significantly.

In aluminum production, electric power consumption rates have improved, and there have been substantial gains in labor productivity in rolling and drawing operations—about 5.5 percent per year during the last two decades. Continuous casting has also found its niche in the aluminum industry, one that is likely to widen. Scale gains have been impressive: for continuous casters, the production rate has grown from 1 tonne/hour in 1960, to 1.7 in 1970, to 4 in new units. These gains followed increases in the diameter of casting rolls and the width of slabs.

The main reason continuous casting has higher yields than the ingot pouring method (for both aluminum and steel) is quite simple. The ends of ingots must be cropped for proper performance in finishing operations; metal is lost on each end of each ingot. In processing a slab, metal is lost only at the beginning and the end of a long, continuous strand of metal. The slab ends are squared off properly when they are severed from the continuous strand. Future process innovations are possible for aluminum, but a broader range of major steelmaking changes may be commercialized during the next decade,

For plastics, technological change has been rapid, as is to be expected for a new industry. From the early 1950's through the early 1970's, the real decline in plastics prices was substantial. Lower prices were the result of several factors:

- product standardization made it much easier for new producers to enter the market, which widened competition;
- accumulated experience lowered the manufacturing costs in a dramatic way, and
- market growth permitted plant-scale economies that brought substantial sav-

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*The adoption of these two major technological changes in steelmaking is reviewed in ch. 9, and future changes are discussed fully in ch. 6.

ings in capital costs per annual pound of product.

The final two factors are technological in nature, but market growth and size were essential to both. The experience curve is a well-documented phenomenon repeated in industry after industry. Mathematically, value added in real terms for a particular product or group of products is stated as a function of cumulative experience; the relationship is usually stated in terms of the percent decline in real value added for each doubling of production. Typical for average industries are experience curves of 15 to 20 percent; petrochemicals, in particular the commodity thermoplastics, have achieved declines in real value added of 20 to 30 percent, with some monomers and polymers boasting gains over decade-long periods of 40 to 50 percent.

Scale gains are particularly important in plastics production, Sharing of infrastructure is an important element in these gains. In some industries, rules of thumb have been worked out to estimate the relationship of scale to total capital costs, The capital cost of a plant double the size of another plant will be only about 1.5 times the capital cost of the smaller plant. Each pound of product from the larger plant will therefore have to bear only three-fourths of the capital costs—profit, interest, and depreciation—carried by the product from the smaller plant.

Probably the most significant future process innovation for plastics will be the use of nonpetroleum feedstocks. Although this can remove a dependency problem, it may not lead to actual cost savings for quite some time.

For lumber, the most important technological gains have come in land management practices and the development of faster growing species, In the cement industry, the regional nature of markets limits the scale of plants, and no great scale economies are available, anyway. The development of suspension preheating has lowered costs, and flash calcining is expected in the coming decades, but no major technological changes that profoundly affect costs are likely for cement,

Materials Performance

Technological innovations in production techniques or in alloys and additives that modify material properties can have major market impacts by influencing the choice of material and by changing the amount of material required for a particular application.

In steel, perhaps the most talked about new material is high-strength low-alloy steel, which is not really new. The use of these steels in automobiles to reduce weight offsets part of the decline in steel use per vehicle in the United States. Their effect on total steel demand is important in this one market alone.

The ever-increasing awareness of the massive cost of corrosion has major implications for national materials policy. One steel industry response to this problem was the development of one-sided galvanized steel. Galvanized steel has been available for years, but only with the costly coating on both sides. Galvanizing only one side has lowered the cost of corrosion resistance. (This is discussed more fully in ch. 9.) More new steels are on the horizon. Dual-phase steels, which are strengthened as they are formed, offer users a material easier to form than other steels but just as strong when finished. This product, which is just coming onto the market, might account for significant tonnages of steel in the coming decades. Another major steel product innovation just evolving from much basic research is amorphous or glassy (noncrystalline) steels. They may offer a host of new properties, but major commercial use is probably several decades off.

In aluminum, one of the most interesting lines of development is the search for an alloy usable for both body and end stock. The effort would have the major benefit of enabling aluminum cans to be recycled into high-value aluminum can sheet. This would not only lower the cost of can sheet, it could also raise the price for used aluminum cans, thereby increasing the recycle rate. This could have a very positive effect on U.S. aluminum supply.

In the early years of its commercial use, a major problem in using polyvinyl chloride

(PVC) for residential siding was the heat expansion of extruded PVC. Because of this problem, only light colors of siding could be produced. Now, recently introduced additives permit the use of a broad range of colors, which greatly enhances the marketability of PVC siding.

A particularly attractive market to high-density polyethylene producers is the 55-gal drum market, now held primarily by steel. One method of producing plastic drums is rotational casting. This process has very low tooling costs and is appropriate for short production runs of specially designed containers. To be able to take advantage of this competitive edge, though, a more expensive grade of cross-linked polymer is required. Plastics processors believe that in time they may learn enough about rotational casting to use the regular grade of polymer, which is considerably less expensive than that now used.

An enormous number of examples of plastics innovation could be cited. Two particularly important ones for high-strength applications are fiber reinforcements and fabrication techniques, like reaction injection molding with faster curing times. These developments prove that gains in technology will be the result of progress both in material properties and in fabricating practices.

Fabrication of End-Use Products

Innovations in this area affect materials demand through materials substitution and through changes in material consumption per product. Metal cans are an example of how new forms affected the choice of materials. Before the advent of the two-piece aluminum can for beverage packaging, the three-piece, tin-plated steel can held that segment of the market. When the aluminum can hit the market, the use of metal cans for beverage packaging grew, and aluminum took most of that growth and some of the existing market away from steel. But steel producers began to experiment. They produced a steel two-piece can, but they could not match the operating efficiencies achieved in aluminum can production. The difference is now minimal, and steel is making a comeback in the beverage can market. The steel two-piece can is first replacing the steel three-piece can, then aluminum. Most can plants now include several lines for aluminum cans and several lines for steel. This dual tooling approach is being adopted in other industries as well; some auto plants have tools designed to work with either steel or aluminum.

The auto industry offers the most conspicuous example of how fabrication affects materials demand, but there are many others. For example, until recently the standard 55-gal drum sported sides of 20-gauge steel and a top of 18-gauge steel. By making both the top and bottom out of X)-gauge steel, producers saved 4 lb of steel per drum (thickness decreases as gauge rating increases), Although impact of that change on total steel demand is relatively minor, the cumulative effect of all such changes is quite substantial, and they play an important, if unquantified, role in the decline in per capita consumption of steel in developed economies.

Impacts of Changes in Energy Costs on Steel and Other Engineering Materials

OTA has estimated the effects of some projected fuel price changes on the costs of producing steel in: 1) U.S. integrated plants, 2) U.S. nonintegrated plants, and 3) plants in Japan, Europe, and Brazil. Transportation energy costs have been estimated and added in for imported steel. In addition, the energy costs involved in the domestic production of aluminum, engineering plastics, and reinforced concrete are compared with the energy costs of domestically produced steel. In all cases, technology **was** assumed not to change and all electrical energy is user plantsite energy.

Four Energy Price Scenarios

Many possible combinations of high and low price-growth rates for five fuels are listed in table 54. From these combinations, four scenarios were selected for comparison of future energy costs; these are shown in table 55.

These scenarios appear to be logical choices to show relative changes in energy costs in 2000. Scenario A reflects a scarcity of natural gas, which results in a substantially higher price-growth rate for it than for other fuels. Scenarios B and C reflect a scarcity of both natural gas and oil, but in scenario B, electricity prices are independent of oil and natural gas, implying coal and nuclear generation of power. Scenario C has a high electric price-growth rate too, which could result from the high capital costs of constructing nuclear and environmentally acceptable coal-burning powerplants. Scenario D reflects a shortage of coking coal.

Other possibilities were not selected for a variety of reasons. In a situation where coal and coke have high price-growth rates, the other rates would be high also, so there would be no relative change in prices among the various fuels. A price scenario with a low price-growth rate for steam coal, but high rates for coke and electricity, would closely approximate an all-high growth-rate scenario because little steam coal is used *directly* to produce engineering materials.

Table 54.—0TA Data on Future Energy Costs (in 1976 dollars)

	Annual cost growth rates			1976	1980		1985		1990		2000		3rd-quarter actual
Energy source	Low	High	Item	Base	Low	High	Low	High	Low	High	Low	High	1979[a]
Electricity	10/0	4.7%	¢/kWh	1.9	2.0	2.3	2.1	2.9	2.2	3.6	2.4	5.7	2.37
			$/MBtu	5.57	5.86	6.74	6.15	8.50	6.44	10.55	7.03	16.70	6.94
Natural gas	4%	5%	**$/10^3 ft^3**	**1.31**	1.53	1.59	1.86	2.03	2.26	2.59	3.35	4.22	1.81
			$/MBtu	1.27	1.48	1.54	1.80	1.96	2.19	2.51	3.24	4,09	1.76
Oil	1,70/0	4.80/.	@US gal	28.6	30.5	34.4	33.2	43.6	36.2	55.1	42.8	88.1	35.7
			$/MBtu	1.66	1.77	2.00	1.93	2.53	2.10	3.19	2.48	5.11	2.07
Steam coal. . .	1 %	5%	$/tonne	32.6	33.9	39.6	35.6	50.5	37.4	64.5	41.4	105.0	36.0
			$/MBtu	1.31	1.36	1.59	1.43	2.03	1.50	2.59	1.66	4,22	1.45
Coke.	1 %	5%	$/tonne	74.3	77.3	90.3	81.2	115.2	85.4	147.0	94.3	239.5	82.05
			$/MBtu	2.60	2.70	3.16	2.84	4.03	2.98	5.14	3.30	8.38	2.87

[a] From Energy Information Agency, monthly energy report for all *Industry,* January 1980. Steel Industry costs for natural gas and electricity are likely somewhat less than average prices paid by al I domestic Industry

NOTE The original projections were made in early 1979 before very large Increases in 011 prices occurred The actual 1979 third.quarter data show that 011 prices have risen much faster than originally anticipated but the results of the analysis are not affected qualitatively

SOURCE Off Ice of Technology Assessment

Table 55.—Four Energy Cost-Growth Scenarios (percent annual increase)

	Scenario			
Energy source	A: all low growth rates	B: low rate only for electricity	c: all high growth rates	D: high rate only for coke
Electricity.	1.0%	1.0%	4.7%	1.0%
Natural gas.	4.0	5.0	5.0	4.0
Oil	1.7	4.8	4.8	1.7
Steam coal	1.0	5.0	5.0	1.0
Coke	1.0	5.0	5.0	5.0

SOURCE Off Ice of Technology Assessment

Energy Use Factors

Energy Used to Produce Domestic and Imported Steel

The quantities of the various energies used to produce steel are shown in table 56. The U.S. integrated plant assumed here is a large multimillion-tonne-per-year type. Energy data for a nonintegrated, scrap/electric arc furnace plant were obtained by adding finishing energies to the energy needed to produce liquid steel. The nonintegrated plant is assumed to produce 0,9 million tonne/yr.

All the foreign data were taken in aggregate form. The European data listed in table 56 represent an average for the United Kingdom, France, and West Germany. Data from Brazil are incomplete: no natural gas data were available; it is not certain whether the electricity is total or purchased; and the value per tonne of steel of the biomass energy that Brazil uses was unavailable. The United States, Japan, Europe, and Brazil all have different production yields, mostly because each country has a different product mix and various adoption rates of continuous casting. Therefore, all energy values have been norrealized to a common yield of 0.64 tonne shipped per tome produced. A common yield statement corresponds somewhat to a common shipped product, such as cold-rolled sheet.

Table 56.—Energies Used to Calculate Energy Costs to Produce Domestic and Imported Steel and Domestically Produced Aluminum, Plastics, and Concrete[a]

	Steel					Other engineering materials (U. S.)		
	United States[b]					Aluminum	Plastics[d]	Concrete
Energy source	Integrated	Non integrated (scrap/EAF)	Japan	Europe[c]	Brazil	(ingots)	(poly-ethylene)	(reinforced)
Electricity (10^6 Btu/tonne) (buss bar) .	1.61	4.05	1.93	1.82	3.02[e]	64.1	N/A	0.274
Natural gas (10^6 Btu/tonne)	6.43	5.53	—	3.24	N/A	12.98	N/A	1.11
Oil (10^6 Btu/tonne).	3.46	2.55	4.79	6.03	6.69	40.3	95.5	0.466
Coal (10^6 Btu/tonne)	1.01	—	—	N/A	—	0.57	N/A	0.476
Coke[f] (10^6 Btu/tonne) . . .	19.16	0	15.62	18.36	11.1[g]	14.04	N/A	1.386

[a] Energy per tonne of steel shipped is for common 70% yield from liquid steel
[b] From World Steel Dynamics
[c] Average of United Kingdom, West Germany, and France
[d] Based on yield of oil feedstock to produce polyethylene processing energy not available
[e] Whether this is total or purchased electricity is unknown
[f] Does not include energy to make coke
[g] Brazil uses fair amount of biomass, amount unknown

SOURCE Off Ice of Technology Assessment

Transportation Costs to Ship Steel to the United States

The transportation costs of shipping steel from Japan, Europe, and Brazil were estimated from daily operating costs reported by Gilman.[3] Gilman's data include daily fuel, capital, labor, and maintenance costs at sea and in port for various freighters. He also provides freight dock-handling charges for Japan, England, the Third World, and the United States. Using Gilman's data, it is estimated that fuel costs in 1976 dollars are about $0.64/tonne/1,000 statute miles. Fixed costs, which include maintenance, depreciation, and crew, are about $2.12/tonne/l,000 statute miles. All fuel for transportation was assumed to be oil.

Table 57 shows the average shipping distance and oil cost to ship steel products and various steelmaking materials to the United States. The distances from Japan, Europe, and Brazil are an average for shipping to the U.S. east coast and west coast. Shipping costs for ore were also considered. For Japan, the distance used is the average of South America to Japan, and Australia to Japan. A factor of **1.45** tomes of ore per tonne of steel shipped was used. One-half of Europe's ore is assumed to be imported from a shipping distance that is the average for South Africa and

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[3] S, Gilman, *Journal of* Transport Economics and Policy, vol.II, No. 1 (1977).

Table 57.—Estimated Energy Costs for Shipment of Materials Involved in the Production of U.S. Consumed Steel[a] (per tonne of steel delivered)

	Production country							
	U.S. integrated		Japan		Europe		Brazil	
Item of shipment	Distance (1,000 miles)	Cost ($)	Distance (1,000 miles)	Cost ($)	Distance (1,000 miles)	Cost ($)	Distance (1,000 miles)	Cost ($)
Product to United States[b]	—		9.5	$ 5.04	6.8	$3.58	8.0	$4.12
Ore to production site[c]	1.0	$1.00	14.0	11.80	4,8	2.00[d]	0	0
Coking coal to production site	—	—	6.0	2.75	0	0	—	—
Oil to production site	0	0	12.0	1.00	0	0	—	—
Total costs		$1.00		$20.59		$5.58		$4.12

[a] In 1976 dollars

[b] Average distance used from production site to east and west coasts of the United States Estimated shipping cost was $0.58/tonne/1,000 mile

[c] Last figure includes correction for amount of item per tonne steel shipped

[d] Assume one half of European ore is Imported

SOURCE Off Ice of Technology Assessment

South America to Europe. The shipping distance for the United States is for Great Lakes shipping. Japan's coking coal is assumed to be imported from Canada and Australia, and her oil from the Middle East. Domestic supplies or relatively short shipping distances were assumed for the rest of the fuels. An estimate of the total shipping costs was made for dock-to-dock imported steel product. An in-port rate of $0.73/tonne/d is used for an assumed total in-port time of 9 days. Freight-handling charges per tonne of steel are estimated from Gilman at $0.73, $1.82, and $1.21 between the United States and Europe, Japan, and Brazil, respectively.

Figure 17 shows the effect of rising fuel costs on the cost of shipping steel both to Los Angeles and to New York City. Two fuel cost curves are shown for each port-of-entry city in accordance with a 1.7- and 4,8-percent annual increase in fuel oil prices. The relative shipping distances are readily apparent in the shipping rates, with Japan to New York City being the longest and Europe to New York City, the shortest. These costs compare favorably with U.S. Federal Trade Commission (FTC)-reported shipping costs from Japan to New York City of $48/tonne.[1] However, estimated shipping rates of $33 to $40/tonne from South America appear to be slightly lower than FTC values. Fuel costs appear to be relatively a small fraction of the total shipping costs of imported steel, from 10 to 15 percent of the totals in 1976 for the six shipping routes shown. Depreciation is the highest single cost, ranging from 45 to 50 percent. Freight handling is about 20 percent of the total cost.

The import (or export) of iron ore has lower dock-to-dock shipping rates because of automated loading and unloading equipment. With reduced in-port time and handling costs, the fuel cost of shipping ore becomes a larger fraction of the total shipping costs than it is for finished steel products.

Energy Used to Produce Aluminum, Plastics, and Concrete

Table 58 shows the energies needed in the domestic production of aluminum, plastics, and reinforced concrete. The aluminum data are for ingot production. The production of aluminum alloys from ingots requires an additional 25 percent of energy of unknown type for milling and heat treating; these processes mostly use electrical and oil-based energies, and additional use of electrical and oil energies will have little influence on the comparisons among materials.

Industrywide energy consumption data for plastics production is difficult to find because

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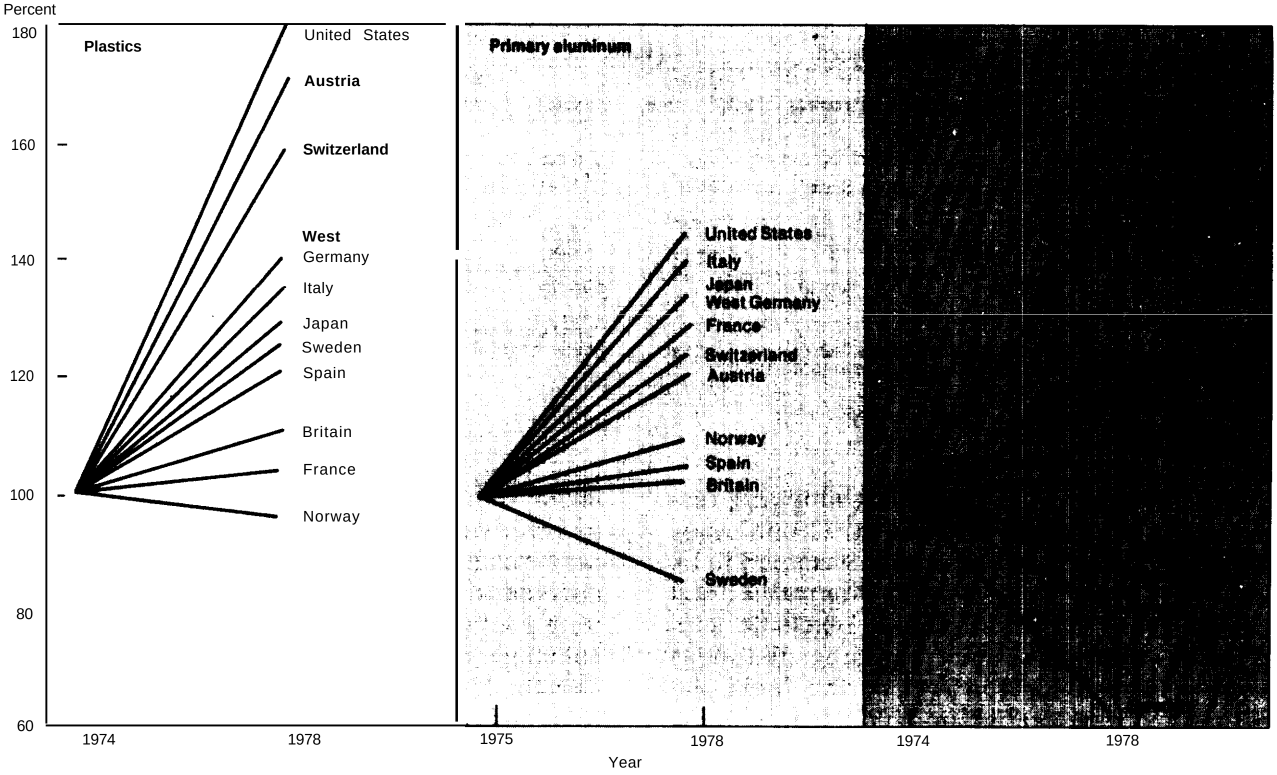
[1] U.S. Federal Trade Commission, "The U.S. Steel Industry and Its International Rivals," November 1977.

Figure 17.— Percent Growth in Per Capita Consumption of Plastics, Aluminum, and Steel in Selected Countries, 1974-78



SOURCE: *Economist* Intelligence Unit.

Table 58.—Projected Year 2000 Energy Cost for Domestic and Imported Steel and for Domestic Aluminum, Plastics, and Concrete, Using Four Price Scenarios (in 1976 dollars per tonne)

		Scenario A		Scenario B		Scenario C		Scenario D	
		Low: all		High: gas, oil		High: gas, oil, electricity		High: coke	
Item	1976 cost	2000 cost	Total energy growth rate[a]	2000 cost	Total energy growth rate	2000 cost	Total energy growth rate	2000 cost	Total energy growth rate
Steel; U.S. integrated (BF-BOF).	$ 74.7	**$107.0**	**1 .5%**	**$120.0**	**2.00/0**	**$ 135.0**	**2.5%**	**$204.0**	4.3%
Steel; U.S. non integrated (scrap-EAF) . .	33.7	54.5	2.0	65.9	2.8	**104.0**	**4.8**	54.5	2.0
Steel; Japan	79.9	108.0	1.3	123.0	1.8	**142.0**	**2.4**	187.0	3.6
Steel; Europe.	77.6	107.0	1.3	135.0	2.3	**152.0**	**2.8**	200.0	4.0
Steel; Brazil	60.9	80.8	1.2	104,9	2.3	**134.0**	**3.3**	137.0	3.4
Aluminum (ingot). . . .	506.0	682.0	1.2	806.0	2.0	**1,470.0**	**4.5**	758.0	1.7
Plastic (polyethylene) . .	168.0	252.0	1.7	518.0	4.8	**518.0**	**4.8**	152,0	1.7
Reinforced concrete.	8.4	12.9	1.8	15.5	2.6	**18.1**	**3.2**	20.4	3.8

aGrowth rates are average annual growth rates for 19762000

SOURCE Office of Technology Assessment

of the multiproduct integration, the variety of production processes, and the product mix that characterize the petrochemical industry. The most common engineering plastic is nylon, and the most common reinforced structural plastic is thermosetting polyester. The starting monomer for polyester is p-xylene. Overall, the most used polymer is polyethylene, with ethylene as the monomer. Over the past few years, the cost of benzene, p-xylene, and ethylene has been steadily rising. Because these monomers are byproducts of crude oil refineries, their prices for the most part are controlled by crude oil prices. The limited data found for polyethylene production was used for purposes of comparison with other materials, even though bulk polyethylene is only about 40 cent/lb and bulk engineering polymers are generally twice as expensive. The yield of ethylene from oil was determined from published data for the C. E. Lummus process, which produces half of the world's ethylene. No statement could be found for other process production energies. The yield of polyethylene from ethylene is essentially 100 percent on a weight basis. The amount of electrical energy used in polymerization is minimal compared to the energy content of the polymer. The assumption can be made that no coal or coke is used in plastic production.

The energies required to make reinforced concrete were determined by using a typical composition of a structural concrete found in the Concrete Construction Handbook. Table 59 presents this composition and the relative amounts of each energy used to produce each component. The largest single energy item in concrete is the coke required to produce the steel reinforcing rods.

Projected Energy Costs

The energies listed in table 56 and energy costs in tables 54 and 57 were used to estimate total energy costs in 2000 according to the four price scenarios. Table 58 presents these estimates and also lists effective annual energy cost-growth rates.

In the steel projections, the deficiencies in the Brazilian data make it difficult to compare the Brazilian results with those for the United States, Japan, and Europe. All four price scenarios show little relative change in energy costs in 2000 for Japan, Europe, and the United States (integrated plant). In price scenarios with high oil price-growth rates (B and C), European and Japanese energy costs are the highest of any in 2000 because of added shipping costs. Japan's high coke efficiency is reflected in scenario D with an energy cost saving of about $16/tonne by 2000. Because the reductant energy for iron ore is not included in the U.S. nonintegrated (scrap/electric furnace) plant data, those energy costs are substantially lower than the other estimates.

Table 59.—Production Energies for Reinforced Concrete

Item	Volume percent	Weight percent	Electricity (buss bar)	Natural gas	Oil	Coal	Coke	Total energy
Steel (rod) . . .	2.9%	9%	0.195	0.619	0.283	0.098	1.386	2.58
Cement	12.0	15	0.066	0.487	0.183	0.378	0	1.11
Water.	16.8	7	—	—	—	—	—	—
Gravel	43.8	45	0.010	0	0	0	0	0.01
Sand . . .	23.5	24	0.003	0	0	0	0	0.003
Air	1.0	0	—	—	—	—	—	—
Totals	100.0	100	0.274	1.106	0.466	0.476	1.386	3.70
Percent			7.4	30	13	13	37	100.4

SOURCE Off Ice of Technology Assessment.

Comparing absolute energy cost values for steel, aluminum, plastics, and concrete is much more risky than comparing values within the steel industry. Because of the wide variety of common applications for these engineering materials, the amounts of energy and material required to manufacture a specific product can vary immensely from material to material. As a result, the price per unit of weight or volume is not as significant as the rate of energy cost increases. Using scenario A, there is little difference in relative energy costs between 1976 and 2000. The annual energy cost-growth rates vary between 1.2 percent for aluminum and 2.0 percent for steel from a nonintegrated plant. Plastic (polyethylene) is clearly at an economic disadvantage in the high oil cost-growth rate scenarios, as is steel from an integrated blast furnace plant in the high coke rate scenario. Because the most energy-intensive component of reinforced concrete is steel rod, the cost-growth rates for concrete parallel the cost rates of steel. Scenario C is probably a good estimate of how aluminum is likely to lose competitiveness relative to steel made in integrated plants.

Conclusion

When a static technology for engineering materials is assumed, U.S.-produced steel will have the most energy cost advantage over imported steel if the prices of oil and natural gas increase worldwide at a higher rate than those of coal or coke (scenarios B and C). Steel will have the most energy cost advantage over aluminum and plastics if the prices of electricity, gas, and oil increase at a greater rate than coal and coke. Conversely, the worst situation for U.S. (integrated) steel will be if the price of coke is high, relative to all other energies (scenario D). This could be the situation if domestic coke capacity continues to decline and imports increase (see ch. 7).

Trends in Domestic Consumption of Steel and Competing Materials

General Trends

All sectors of the economy use steel and will continue to do so in the future. Further, because of technological developments in the production of alloy and specialty steels, applications of these products are increasing. Nevertheless, as shown in figure 18, steel consumption in some industrialized countries is declining relative to consumption of aluminum and plastics. In large measure, the effort to reduce automobile weights and, in some cases, lower prices for other materials are behind the deceleration in steel consumption.

Trends in per capita steel consumption in the United States (figure 19) show a very slight increase from 0.420 to 0.450 tonnes between 1950 and 1977. Measured in terms of tonnes consumed per $1,000 of real gross national product (GNP) (figure 19), however, steel consumption has declined slightly from 0.120 to about 0.074 tonnes per $1,000 of real GNP between 1950 and 1977. Comparable data for aluminum and plastics consumption are shown in figures 20 and 21. In absolute terms, the growth rate of steel consumption during the last several decades in the United States has averaged about 2 percent per year as compared to 6 percent for aluminum and 8 percent for plastics.

This slow-growth trend in steel consumption will probably continue. A recent, conservative analysis projects a growth rate of about 1.6 percent per year from 1977 to 2000.[5] (Future supply-demand forecasts are considered in detail in the next section.) It is

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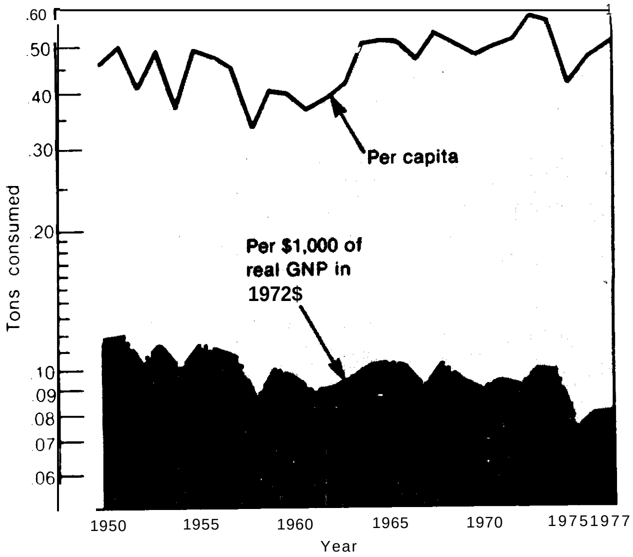
[5] Robert K. Sharkey, et al., "Long-Term Trends in U.S. Steel Consumption: Implications for Domestic Capacity," Industrial Economics Review, U.S. Department of Commerce, vol. I, May 1979, pp. 11-24.

Figure 18.—Trends in U.S. Apparent Consumption of Steel, 1950-77



Fiqure 19.—Trends in U.S. Apparent Consumption of Aluminum, 1960-77

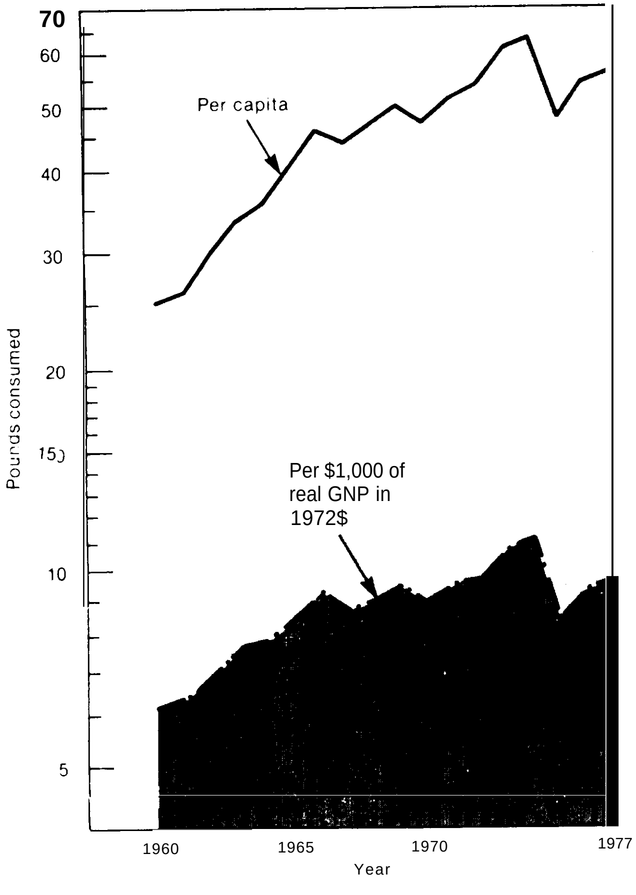
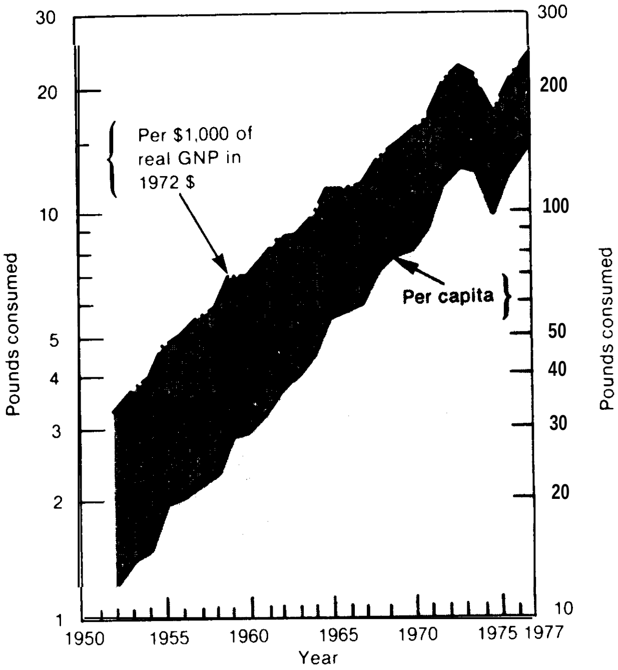


Figure 20.—Trends in U.S. Apparent Consumption of Plastics, 1952-77



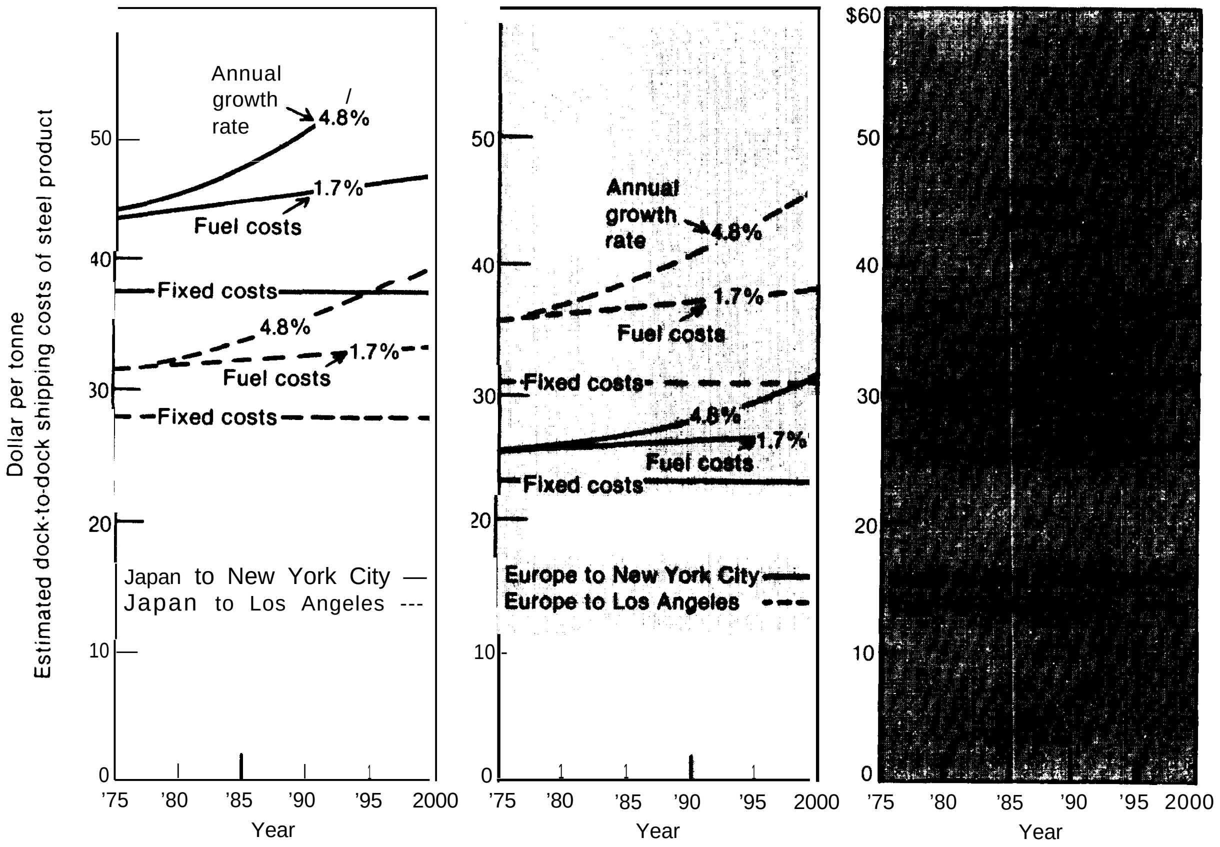
SOURCE: Figures 18, 19, and 20—Office of Technology Assessment.

expected that plastics will continue to capture some steel markets in the future, but aluminum could lose competitiveness in some markets. However, neither material, nor any other, can to a significant degree replace steel as the principal engineering material in any of the major steel-using sectors of the economy, and the demand for steel is likely to increase over time (see the next section).

Domestic Markets

The "service centers and distributors, " which serve a multitude of users, are the largest market for steel. The next largest is the automobile industry, which consumed 21.7 percent of domestic steel shipments in 1978, and then building construction, which consumed 13.7 percent. Other important markets for steel mill products are equipment and machinery manufacturers, with 10.9 percent of total shipments in 1978, and container and packaging manufacturers, with 6.7 percent (see table 60). It is generally accepted that about 60 percent of steel consumption is related to capital expenditures.

Figure 21.—Effects of Rising Fuel Costs on the Shippinq Costs of Steel Products From Japan, Europe, and Brazil to Los Angeles and New York



NOTE. Due to the actual Increases in petroleum prices m 1979, shipping costs are shifted along the same axis to the right

SOURCE Off Ice of Technology Assessment

Table 60.—Steel Shipments by Selected Market, 1967-78 (in thousands of tonnes)

	Steel service centers		Automotive		Construction		Containers		Machinery		Rails		Total ship-ments
	Tonnes	Percent	Tonnes	Percent	Tonnes	Percent	Tonnes	Percent	Tonnes	Percent	Tonnes	Percent	Tonnes
1967	12,127	15.9	14,955	19.7	12,234	16.1	6,580	8.6	8,534	11.0	2,925	3.8	76,095
1968	12,797	15.4	17,477	21.0	12,902	15.5	7,167	8.6	8,858	10.6	2,765	3.3	83,313
1969	14,315	16.8	16,576	19.5	12,649	14.9	6,481	7.6	8,771	10.3	3,033	3.6	85,146
1970	14,535	17.7	13,129	15.9	12,111	14.7	7,052	8.5	8,153	9.9	2,810	3.5	82,354
1971	13,083	16.6	15,857	20.1	12,346	15.6	6,541	8.3	7,824	9.9	2,725	3.4	78,943
1972	15,235	18.3	16,523	19.8	12,375	14.9	6,001	7.2	8,761	10.5	2,476	2.9	83,267
1973	18,487	18.3	21,058	20.8	15,591	15.4	7,085	7.0	10,404	10.3	2,928	2.9	101,067
1974	18,503	18.6	17,168	17.3	15,971	16.1	7,454	7.5	10,468	10.5	3,099	3.1	99,291
1975	11,519	15.9	13,799	19.0	10,926	15.1	5,490	7.6	7,959	11.0	2,859	3.9	72,521
1976	13,298	16.4	19,365	23.9	10,893	13.4	6,271	7,7	8,739	10.8	2,772	3.4	81,128
1977	13,909	16.8	19,493	23.6	10,886	13.2	6,092	7.4	8,964	10.8	2,936	3.6	82,906
1978	15,760	17.8	19,277	21.7	12,127	13.7	5,497	6.7	9,667	10.9	3,224	3.6	88,827

ancludes agricultural and electrical

SOURCE American Iron and Steel Institute

The automobile market for steel is growing at a rate of 1.5 percent per year, the building construction market at 2.1 percent, the equipment and machinery market at 1.7 percent, and the container and packaging market at 0.8 percent (table 61). Major declines in steel consumption are occurring in transportation, oil and gas, military goods, and export markets. Steel imports have grown spectacularly, but there are no statistics on how that steel is used. Commonly used data on steel consumption also do not take into account the steel embodied in other imported products, such as automobiles.

Automotive Industry

The automobile industry is an important steel market not only for the amount it consumes but also for the form of its consumption. The type of steel demanded has an important bearing on the technologies used in steel production. Automotive applications account for more than 40 percent of sheet and strip shipments and the auto industry is clearly the key segment in future sheet demand. Thus, it will play a major role in determining the kind of raw steel capacity the steel industry needs to add. This is an especially pertinent point because the requirements for steel by domestic motor vehicle producers will continue to grow, albeit at a more modest rate than in the past.

The fundamental reason for the slowdown in future steel demand by the automobile industry is the need to manufacture lighter cars that will meet Government fuel-efficiency regulations. Although there has been little change in average steel consumption for vans and light trucks in the past few years, they too will be affected by increasing fuel costs and energy-conservation measures that will make steel substitutes attractive. There is a continuing effort to find appropriate lighter-than-steel substitutes like graphite-reinforced plastics, glass-reinforced polypropylene, and aluminum. In 1960, the average automobile incorporated 25 lb of plastics, and in 1979, approximately 200 lb; the forecast is that in 2000a car will contain 750 to 1,000 lb of plastics.

A number of factors may mitigate the rapid rate of substitution for steel in cars, Other usable materials have higher production costs and lower rates of production per unit of time than steel. Potential supply shortages of aluminum and the dependence of plastics on petroleum feedstocks are also significant factors. The cycle of automobile model changes and tool design also make any shift to new materials a gradual process. Table 62 presents a recent General Motors forecast of average material consumption per passenger car from 1978 to 1987. Such forecasts tend to change frequently, but this one shows declining steel consumption to be a function of down-sizing, not of major materials substitution, Steel's share of the vehicle net material weight remains relatively constant, even though the amount of steel used decreases substantially.

New technologies in steel materials for automotive applications also make steel more competitive with aluminum and fiber-reinforced plastics. The longstanding emphasis of the domestic steel industry on product could have substantial future payoffs in this market. Substitution for steel by other materials is, and will continue to be, offset by the availability of new types of alloy steel, such as high-strength low-alloy and dual-phase steels, and eventually perhaps by superplastic steels and amorphous alloys.

New fabrication techniques being considered also will sustain the use of steel in automobiles. These combine steel, aluminum, and plastics in relatively low-cost composites. Steel/plastic sandwich constructions, all-steel honeycomb constructions, and steel channel sections filled with polyurethane plastic foam all provide suitable combinations of strength and stiffness with reduced

Table 61.—Historical Growth Rates for Steel Product Shipments by Markets, Imports, Exports, and Apparent Consumption, 1951-77 (percent per year)

	Average annual compound growth rate	
Market segment	Trendline[a]	Compound analysis[a]
Building construction	1.9%	2.1%
Automobile	1.6	
Air, sea, and rail transportation	– 0.5	– 0.8
Equipment and machinery (industrial and electrical)	1.8	1.7
Agriculture and mining	1.4	1.2
Oil and gas industry	– 1.8[b]	– 1.8[b]
Containers and packaging	0.8	0.8
Consumer and commercial products	0.6	0.4
Military	-1.1	– 3.6
Service centers and distributors	1.7	1.6
Steel converters	0.7	0.9
Other shipments	4.1	4.4
Total domestic shipments	1.4	1.3
Steel mill product exports[c]	-0.1	– 0.3
Total U.S. mill shipments	1.4	1.2
Total exports[d]	0.6	0.6
Total imports	8.6	13.1
Apparent U.S. consumption	2.1	**2.0**

[a] Both methods are based on annual average consumption during 5-year periods from 1951.75 The compound analysis is simply the average annual rate of change required to Increase (or decrease) average annual consumption from the level prevalent in 1951.55 to that in 1971.75 The trendline growth rate is derived from regression analysis of 5-year annual average shipment data, trend. line analysis of annual data yields almost Identical results

[b] Inaccurate due to the importance of imported products and service centers in supplying this market segment

[c] As reported by the American Iron and Steel Institute

[d] Includes steel mill product exports

SOURCE Office of Technology Assessment

weight. Because of such developments in fabrication techniques and the developments in new materials, steel will likely continue to dominate the automobile market, even though the use of aluminum and plastics will grow. One forecast indicates 1985 steel use in the automobile sector at about the same level as in 1978.[6]

The projected growth of automobile industry consumption of steel to 2000 is shown in table 63. The projections were calculated by assuming growth rates for passenger cars and light trucks. Future steel consumption for these vehicles is then compared to 1978 consumption (determined by the same method) to derive the implied growth rate for steel. The present economic instability and various exogenous factors, such as future oil prices and import penetrations, subject any projection to considerable uncertainty, and this one should be regarded with suitable caution.

A more general belief is that total steel consumption will decrease. One recent forecast, for example, indicated a decrease by 1985 of 1,185 lb in the conventional iron and steel

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[6] J. J. Tribendis and J. P. Clark, "An Analysis of the Demand for Steel in the U. S.: 1978-1985," *Materials* and Society, vol. 3, No. 4, 1979.

Table 62.–Material Consumption in Passenger Cars as Percentage of Total Weight, 1978-87 (net materials consumption as percentage of net weight)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Steel	59.5%	60.00/0	60.2%	60.0%	60.2%	61.3%	60.4%	60.50/o	60.60/0	59.90/0
Cast iron	17.9	17.1	16.2	16.0	15.1	12.9	12.2	10.7	10.5	10.4
Aluminum	**2.9**	**3.2**	**3.6**	**3.9**	**4.2**	**4.8**	**5.5**	**6.1**	**6.3**	**6.4**
Plastics	**5.4**	**5.6**	**5.7**	**5.9**	**6.6**	**6.7**	**7.6**	**8.3**	**8.5**	**9.0**
Glass	**2.7**	**2.3**	**2.7**	**2.7**	**2.6**	**2.7**	**2.8**	**2.8**	**2.8**	**2.8**
Other	**11.6**	**11.9**	**11.5**	**11.6**	**11.2**	**11.6**	**11.5**	**11.7**	**11.4**	**11.5**
Total	**100.0**	**100.1**	**99.9**	**100.1**	**99.9**	**100.0**	**100.0**	**100.1**	**100.1**	**100.0**
Steel weight (lb/unit)										
Gross[a]	**2,871[b]**	**2,831**	**2,763**	**2,734**	**2,715**	**2,666**	**2,526**	**2,385**	**2,364**	**2,316**
Net	**2,083**	**2,057**	**2,004**	**1,986**	**1,958**	**1,936**	**1,825**	**1,736**	**1,721**	**1,688**

[a] Gross weight = amount of steel purchased Net weight = amount of steel in automobile

[b] 1978 steel usage for pickups and vans was.

	Pickups	Vans
Gross	3,525	3,428
Net	2,580	2,596

SOURCE General Motors Corp , administrative services engineering staff, Apr. 2, 1979

Table 63.—Steel Usage in Passenger Cars and Light Trucks, 1978,1985,2000

	Passenger cars	Pickups	Vans	Total	Implied steel growth
1978 **base**					
Unit production (1 ,000)	9,153	2,791	698	N.R.	N.R.
Gross steel consumption per unit (kg)	1,302	1,599	1,555	N.R.	N.R.
Gross steel consumption (1 ,000 tonnes).	11.917	4,462	1,085	17,708	N.R.
1978-85					
***Case* A—cars: 2.5% growth** **trucks and vans: 3.0% growth**					
Unit production (1 ,000)	**11,152**	**3,536**	**884**	N.R.	N.R.
Gross steel consumption per unit (kg)	**1,082**	1,599	1,555	N.R.	N.R,
Gross steel consumption (1 ,000 tonnes).	**12,062**	5,652	1,374	19,099	1.1 %
Case B—cars: 1.5% growth **trucks and vans: 3.0°A growth**					
Unit production .,	**10,311**	**3,270**	**818**	N.R.	N.R.
Gross steel consumption per unit (kg)	**1,082**	1,599	1,555	N.R.	N.R.
Gross steel consumption (1 ,000 tonnes).	**11,152**	5,227	1,272	17,651	0.1 0/0
Case C—cars: 2.5% ***growth*** ***trucks and vans: 3.0% growth*** ***—700/.* steel *reduction in* vans** **and *trucks***					
Unit production	**11,152**	**3,536**	**884**	N.R.	N.R.
Gross steel consumption per unit (kg)	1,082	1,559	1,555	N.R.	N.R.
Gross steel consumption (1 ,000 tonnes).	12,062	5,088	1,237	18,388	0.6%
1978-2000					
Case A—cars: 1.5% growth **trucks and vans: 2.0% growth**					
Unit production (1 ,000)	13,943	4,749	1,190	**N.R.**	**N.R.**
Gross steel consumption per unit (kg)	974	**1,295**	**1,260**	**N.R.**	N.R.
Gross steel consumption (1 ,000 tonnes).	13,576	6,164	1,498	21,238	1 .0%
Case B—cars: 1.O% growth **trucks and *vans:* 1.5% growth**					
Unit production (1 ,000)	**12,947**	**4,421**	**1,105**	**N.R.**	**N.R.**
Gross steel consumption per unit (kg)	**974**	**1,295**	**1,260**	**N.R.**	**N.R.**
Gross steel consumption (1 ,000 tonnes).	**12.606**	**5,726**	**1,391**	**19,724**	**0.50/0**

Growth rates are average annual compound rates
N R = not relevant

SOURCE Off Ice of Technology Assessment

materials that go into an average automobile. The loss would be partially offset by an increase of 450 lb in high-strength low-alloy steel.[7] A factor which most forecasts have not taken into account is the possible growth in domestic production of automobiles now made in other countries. This could lead to a net increase in purchases of domestic steel, especially for foreign-owned plants in inland locations in the United States. However, one study foresees no growth in automobile steel use in the 1980's even if Japanese plants in the United States buy one-half their steel domystically.[8]

Building Construction

Materials competition in the construction sector is considerable. The amount of steel consumed in building and construction is understated because some is purchased by service centers and distributors, and then sold to builders. Service center steel shipments to construction markets are not reported directly, but various sources which include estimates for these shipments, indicate the actual amount of steel used in construction is very large (see table 64). The proportion of shipments to this sector as a percentage of total steel shipments has remained relatively stable over the last three decades, and available information suggests that the volume consumed in construction activity will continue at the historical rate. However, if major

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[7] *Iron Age*, Jan. 8, 1979, p. 25. Another forecast, by Arthur Anderson & Co., leads to the same level of steel use per auto, 1,400 lb, but by 1990; American *Metal* Market, Dec. 24, 1979.

[8] C. A. Bradford, "Steel Industry Quarterly Review," February 1980, Merrill. Lynch, Pierce, Fenner & Smith, Inc.

Table 64.—Estimated Usage of Iron and Steel Construction Materials (1,000 tonnes)

	1974	1975	1976	1977
Concrete reinforcing bars	4,624	3,325	3,516	3,790
Galvanized sheets	5,537	3,374	4,698	5,131
Cast iron pipe				
Pressure	1,776	1,138	1,210	1,456
Soil	702	539	597	619
Fabricated steel products	4,141	3,932	3,372	3,162
Plates and structural shapes	16,507	15,901	16,354	10,793
Piling	600	385	299	318
Total	33,887	28,594	30,046	27,856

SOURCES "Iron and Steel, " MCP-15 Mineral Commodity Profiles, Bureau of Mines, U S Department of the Interior, July 1978
"Iron and Steel, " a chapter from *Mineral Facts and Problems,* 1975 edition, Bureau of Mines reprint from Bulletin 667, U S Department of the interior
"Steel Mill Products, " Current Industrial Reports, MA-33B (76).1, issued September 1977. Bureau of the Census, U S Department of Commerce
"Iron and Steel Products Shipments, Bookings and Backlog," Bureau of Mines, U S Department of the Interior, January/February 1978

capital spending for the U.S. industrial base occurs during the next decade, then this market could consume increased amounts of steel. Much steel for construction is used as a component of concrete in the form of reinforcing bar. Three basic types of commercial construction use steel in different amounts:

- standard steel construction, in which a floor deck is concrete and strong enough to span the high-strength steel beams on which it rests;
- composite construction, in which steel shear connectors are welded through the concrete deck to the steel beams below; and
- concrete construction, in which a great many steel reinforcing bars are used to take care of tensile stress.

Table 65 shows the variation in the amount of steel, energy, and labor used in these three types of construction. In spite of these differences, an analyst notes that "assuming a large project with many repetitive sections, the dollar costs of the three systems are approximately the same.'[9] In general, the choice of system is made for other reasons, including material availability, labor availability, and scheduling needs.

Table 65.—Summary of Materials, Energy, and Labor Used in Comparative Floor Bay Construction

	Labor	Energy	Materials	
Commercial building bays	Man-hours/ft^2	Btu x **10^3/ft^2**	Steel **lb/ft^2**	Concrete **ft^3/ft^2**
Standard steel	**0.49**	**284**	**10.3**	**0.33**
Composite steel	**0.44**	**250**	**8.9**	**0.33**
Concrete	**0.36**	**172**	**5.7**	**0.80**

SOURCE B. Hannon, "Materials, Energy, and Labor Impacts in Typical Building Floor Bay Assembles, " University of Illinois, August 1978

Containers and Packaging

This segment of the steel market has consumed a constant share of steel shipments. Nevertheless, steel's share of the total packaging market has declined in the last quarter century. From 1972 to 1975, aluminum's share of the can market increased from 13 to 25 percent.[10] The growth of both aluminum and plastics has relied heavily on this market. For instance, containers and packaging accounted for 10 percent of total aluminum shipments in 1960 and 20 percent in the mid-1970's; packaging accounts for 25 percent of total plastics use, The growth of aluminum and plastics in packaging has come in part from new products and from products not appropriate for steel, but both materials have also penetrated steel markets.

Because aluminum prices may escalate sharply, it may not continue to displace steel in the container market at the historical level; thinner steels are being used to retain the market share on a unit basis. One study has forecast a 1985 consumption level of steel for

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[9] B. Hannon, "Materials, Energy and Labor Impacts in Typical Building Floor Bay Assemblies, " University of Illinois, August 1978.

[10] U.S. Bureau of the Census,

this market at about 10.4 million tonnes, a 30-percent increase over 1978.[11]

Equipment and Machinery

For most equipment and machinery applications, steel has no major competitors. This market has become somewhat less steel intensive over time, though. In large part, this is because of the rapid growth of computer-aided machinery, which uses less steel per unit of output than machinery relying on mechanical components. Also, the United States has lost some of its export market in machinery, and domestic industrial capital spending has been at relatively low levels. No significant growth is expected in this sector through 1985 unless there is a turnaround in capital spending.[12]

Other Consumers of Steel

Agriculture and Mining.—Steel has almost no substitutes for agricultural and mining equipment. Nevertheless, that market has only retained its share of total steel product shipments.

Air, Sea, and Rail Transportation.—The transportation market segment has declined in relation to total steel demand. Little new rail mileage has been laid in the United States in recent years, and railroad expenditures for maintenance have been severely depressed by that industry's economic malaise. This trend appears to be changing now, and rails could represent a growing steel market in the next decade.

Because of weight restrictions, use of titanium and aluminum is more important than steel in aircraft manufacture.

Although the worldwide shipbuilding industry has enjoyed intermittent booms in tanker construction, particularly growth in tanker size, the U.S. industry has not captured much of this market. The Japanese steel industry reaped major benefits from the Japanese shipbuilding industry's role in tanker construction. In fact, demand for steelplate served as a "base load" for new steel capacity during the 1960's and 1970's. However, the future trends in domestic steel demand for this use are expected to continue at the historical rate.

Consumer and Commercial Products.—The rate of household formation directly affects demand for steel because it governs the course of appliance sales. Plastics, however, have provided steel with competition in some major appliance components, such as refrigerator door liners and washing machine tubs. The best estimate of future demand for steel by the consumer sector indicates a continuation of past trends, with relatively little growth.

Domestic Supply-Demand Forecasts for Steel

There are many uncertainties in supply-demand forecasting for a commodity such as steel, which is very sensitive to general domestic economic conditions and world supply factors. Nevertheless, relatively good agreement exists among various steel demand forecasts. Table 66 shows forecasts from several sources and, with the exception of Wyman's forecast,[13] the range is not wide. For 1985, the demand forecasts vary from a low figure of 114,7 million tonnes, representing the opinion of industry itself,[14] to a high of almost 133.4 million tonnes projected by Tribendis and Clark[15] on the basis of a high-economic-growth scenario. For 1990, the industry projects steel demand in the United States at 125.0 million tonnes and Chase Econome-

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[11] Tribendis and Clark, op. cit.

[12] Ibid.

[13] Shearson Hayden Stone and J. C. Wyman, "Gold, Technology and Steel," February 1979.

[14] American Iron and Steel Institute, "Steel at the Crossroads: The American Steel Industry in the 1980s," 1980: U.S. Steel Corp., *Steelweek*, Feb. 11, 1980.

[15] Tribendis and Clark, op. cit.

Table 66.—U.S. Steel Demand and Capacity, Comparison of Various Forecasts, 1980-2000 (millions of tonnes)

	Demand (total consumption = domestic shipments – exports + imports)								Capacity			
Year	Bureau Mines[a]	Chase[b]	DRI[c]	Commerce[d]	Shearson Hayden Stone’s	Industry analysts[f]	AISI[g]	MIT[h]	Chase[b]	World Steel Dynamics’	AISI[g]	MIT[h]
1980. . . .			110.5T 111.7C	111.0	141.3	105.2	107.1			105.5	94.1	
1981					145.9							
1982. . . .					150.7							
1983. . . .					155.6					106.6		
1984. . . .					160.6							
1985. . . .	119.3		124.7T 124.1 C	119.4	165.9	117.9	114.7	133.4 High 121.7 Base 112.0 Low			111.8	115.8
1986. . . .		126.8							117.8			
1990. . . .		137.3	137.1T 129.4C	129.3		131.5	125.0		129.6		121.8	
1995. . . .												
2000. . . .	151.1											

[a] *Bureau of Mines, Iron and Steel,* MCP-15, JuIY 1978, *p.* 25.

[b] Michael F Elliot-Jones, “Iron and Steel in the 1980’s The Crucial Decade,” Chase Econometric Associates, Inc. Apr. 19, 1979 (assumes yields from raw: 1977 = 72, 1986 = 74, 1990 = 77)

[c] DRI Long Range Forecasting Model cited in (d), T = trend, C = cycle.

[d] Robert K. Sharkey, et al, “Long Term Trends in U.S. Steel consumption: Imlications for Domestic Capacity, ” *Industrial Economics Review,* U S Department of Commerce, vol. 1, May 1979, pp. 11-24

[e] Shearson Hayden Stone and J C Wyman, “Gold, Technology and Steel, ” Feb. ruary 1979 (Includes Indirect steel Imports and steel used in foreign industries to construct factories producing exports to the United States

‘Cited in (d)

[g] American Iron and Steel Institute, ***Steel*** at ***the*** *Crossroads The* ***American Steel Industry in*** *1980’s, 1980,* assuming raw yields of 1960 = 72, 1985 = 74, 1990 = 77 and an operating rate of 90%

[h] J J Tlbendls and J p Clark, “An Analysis of Demand for Steel in the US 1978.1985,” ***Materials*** *and* ***Society***, vol *3, No 4, 1979* Demand based on three economic scenarios with Imports a variable Capacity calculated from maxi. mum domestic shipments (min imports of 140/.) assuming 90% operating rate

[i] World Steel Dynamics, Apr 25, 1979 (assuming raw yields of 1980 = 72, 1983 = 73)

tries” at 137.3 million. Only one steel demand projection, that of the U.S. Bureau of Mines,[17] is available for the period beyond 1990. This forecasts steel demand in the United States for 2000 at 151.1 million tonnes.

The low projections of AISI and the U.S. Department of Commerce[18] are based on low growth rates in steel demand, 1.5 percent and 1.6 percent annually, respectively. The Tribendis and Clark low-growth-rate scenario calls for a 1.9-percent annual increase in steel demand, their high-growth scenario has a growth rate of 3.7 percent annually.

The methodologies used in these projections vary. For example, the Bureau of Mines used the following methodology:

> In a mature economy, such as that of the United States, it is believed that iron and steel demand closely follows population. The demand forecasts were therefore based on a curvilinear regression of steel demand (steel mill shipments plus imports) on population. The relatively rapid rise in steel usage at the beginning of the 20th century, caused by the advent of the automobile, was eliminated by beginning the regression line with 1915 data, establishing a 62-year trend. The demand projections for 2000 were based on Bureau of the Census population projections Series I-111, Although the demand data used in the regression included exports, the projections were made on the basis of domestic consumption excluding exports, Exports were assumed to remain at the average of 3 percent of steel demand (including exports) established over the past few years.[19]

Apparently the Bureau of Mines did not take into account any surges in capital spending.

The Department of commerce forecast methodology was as follows:

> The forecast model for apparent steel consumption for 1980, 1985 and 1990, developed by the Office of Industrial Economics (OIE) for this study, is a partial adjustment multiple linear regression model with three explanatory variables: (1) residential fixed investment, (2) non-residential fixed investment, and (3) motor vehicles and parts,
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> One advantage of using major components of GNP as as explanatory variables is that

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“Michael F. Elliot-Jones, “Iron and Steel in the 1980s: The Crucial Decade,” Chase Econometric Associates, Inc., Washington, D. C., Apr. 19, 1979.

[17] U.S. Bureau of Mines, Iron and Steel, MCP-15, July 1978, p. 25,

[18] R. K. Sharkey, et al., op. cit.

[19] U.S. Bureau of Mines, op. cit., p. 23.

> they have been projected through 1990 using the Data Resources, Inc., (DRI) long-term macroeconomic model. The DRI model provides alternative growth paths for the economy. The higher growth rate scenario is termed “trend,” which is a stable growth long-run simulation of the DRI quarterly model of the U.S. economy, and a lower growth rate is termed “cycle,” which is a less optimistic view of long-term growth embodying periods of recession and strong growth.’”

The reason for the high-demand forecast of Wyman can be found in several unusual, but perhaps ultimately correct, underlying assumptions:

> In assessing the real amount of steel usage associated with the U.S. economy, one must count both the indirect imports of steel and the steel used to construct the factories in which the foreign cars used in the U.S. were built. Similarly, steel used for overseas plants that exported steel directly to the U.S. must be included, as well as the shipyards which were “exported” from the U.S. In short, we end up noting that since 1955, i.e., since capital spending of the industrial world began to outpace that of the U. S., domestic steel consumption statistics became progressively understated.
>
> . . . whereas it typically is assumed that steel consumption has grown by 2.39 percent annually since 1955, we think it, in fact, has grown by more, and perhaps by as much as 3.26 percent. The latter figure still would be well below the actual 5.15 percent annual growth for the Free World . . . Thus, our calculations indicate that U.S. steel consumption grew 36.7 percent less quickly than that of the Free World (instead of 53.6 percent). Steel consumption of the U.S. should have grown at a slower rate than that of the Free World because the U.S. is the more mature economy and because substitution of steel by other materials is probably much more advanced in the U.S. than in other areas. However, a U.S. consumption growth rate of less than half that of the Free World, as the traditional statistics show, is much harder to understand than a growth rate of somewhat less than two-thirds of the Free World’s. Therefore, we think our estimated growth rate is more plausible than the traditionally assumed growth rate for steel consumption in the U.S.[21]

There are few domestic steel production capacity projections. Such projections involve major uncertainties: the extent of import penetration and of investment, modernization, and expansion in domestic capacity. World Steel Dynamics[22] has projected domestic steel industry capacity at 106.6 million tonnes in 1985. Chase Econometric Associates[23] estimates capacity will be 117.8 million tonnes in 1986 and 129.6 million tonnes in 1990, and industry” itself forecasts 100.7 million tonnes in 1985 and 109.7 million tonnes in 1990. The industry forecast assumes that a substantial modernization and expansion program takes place (see ch. 10).

To compare the capacity and demand projections, it is necessary to assume an operating rate; a 90-percent operating rate assumption yields a realistic production level. The demand projections exceed those for domestic production, and the difference is made up by imports. Most forecasters assume some level of imports, but Tribendis and Clark used their modeling technique to generate imports.[25] Their model predicted an import level of 18.1 million tonnes for 1979, when the actual value was 15.9 million.[26] In their moderate-growth case and without import controls other than the trigger-price mechanism, imports capture 26 percent of the domestic market in 1985, a very high fraction; domestic steel shipments would then be 90.1 million tonnes. If they assume a lower level of imports, 141 percent, domestic shipments would be 104.2 million tonnes in 1985. AISI forecasts assume a 15-percent import level, which results in domestic shipments of 102 million tonnes in 1985.

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[20] R. K. Sharkey, et al., op. cit.

[21] Wyman, op. cit. Wyman arrived at his U.S. steel demand projections by extrapolating 1956-76 data by use of “best fit” curves.

[22] World Steel Dynamics, Apr. 25, 1979.

[23] M. F. Elliot-Jones, op. cit.

[24] American Iron and Steel Institute, op. cit.

[25] Tribendis and Clark, op. cit.

[26] *American Metal* Market, Jan. 31, 1980.

The various supply-demand projections suggest two alternate possibilities for the next 10 years.

1. The AISI low-demand-growth (1.5 percent) forecast with current levels of imports (15 percent), if incorrect, could lead to inadequate domestic steel capacity—if demand is higher because of a substantial capital-spending period or faster economic growth, for example. With 1990 steel consumption of 137 million tonnes (forecast by Chase Econometrics and DRI) and capacity of 122 million tons (by AISI), imports would be 20 percent, or 27 million tonnes; this would be about 50 percent more than the maximum of actual imports to date. If the world steel oversupply of the past few years does not persist, and this is quite likely, then imports would be both costly and difficult to obtain, Operating rates and profitability for the domestic industry would be high, particularly if Government policies allow domestic prices to rise to meet high import prices. The AISI forecast presumes a substantial modernization and expansion program for the next 10 years. Without such a program domestic capacity would be only 85 million tonnes in 1988 (AISI). With a high demand of 137 million tonnes, this would lead to a more than 44-percent level of imports in 1990.

2. Alternatively, the domestic capacity in 1990 might be greater than the AISI forecast. This could result from aggressive nonintegrated plant construction and possibly from an influx of foreign capital into steelmaking. If the Chase Econometrics capacity forecast of 130 million tonnes is coupled with the low-demand forecast of AISI, then either imports would drop to 7 percent with a domestic operating rate of 90 percent or operating rates would decrease to 82 percent while imports are maintained at 15 percent, If the Chase capacity forecast is coupled with their high-demand forecast of 137 million tonnes, the 15-percent import level is compatible with a domestic operating rate of 90 percent.

CHAPTER 6

New Technologies for the Steel Industry

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CHAPTER 6

New Technologies for the Steel Industry

Summary

Steel technology has entered a period of particular vitality, Whether new processes are being stimulated by raw material and energy changes or whether they are creating opportunities to use new raw materials and energy sources is not important: the technology of the industry is not static. Relatively small integrated systems based on coal reductants and electrical energy are feasible now, and the opportunity to add capacity in small increments, where it is needed, can lower the industry's capital intensity. Large existing integrated systems can adopt new technologies that will increase efficiency, productivity, and product quality. The roots of the steel industry have also spread; the diversity and wide geographical distribution of steel plants in the United States are strengths with which the industry can face the changing conditions of the coming decades.

It is expected that changes in the availability and cost of raw materials, fuels, and energy sources will provide impetus for building new steel plants and modifying existing ones. Integrated companies face some difficult decisions about replacing or drastically altering operating systems; about using new raw materials, fuels, and energy sources; and about how to fulfill often noncomplementary objectives. But for the industry has a whole, the rich variety in plant size, location, and character will ease the industry's adjustment to new raw materials and energy sources and its adoption of new technologies.

Technological developments that offer flexibility in the choice of inputs are more attractive than those that depend on single sources. Also, new technologies that can be adopted rapidly in efficient-sized modules, that can be constructed in a variety of locations, and that can fulfill regional market requirements, will receive more attention than larger, less flexible systems.

The following technological developments appear to offer particular promise for the steel industry:

- alternatives to metallurgical coke as a blast furnace feed material;
- continuing improvement in coal-based direct reduction (DR) systems, including those that utilize coal gasification and those that use coal directly:
- continuing development of DR systems that allow for the use of alternate fuels and energy sources, including biomass, hydrogen, and nuclear sources;
- improved methods of increasing scrap and sponge iron use;
- increased availability of direct reduced iron (DRI) as a substitute for scrap;
- increased availability of suitable iron oxide/carbon composites (pellets, briquettes) as "self-reducing" materials;
- continuing development of systems for solid-state processing (the direct conversion of metallic powders into structural forms);
- alternate electric furnaces such as plasma systems;
- continuing development of high-speed melting, refining, processing, and transfer equipment;
- secondary or ladle steelmaking processes that allow separation of melting and/or primary refining from final composition control;
- improved instrumentation and control procedures;
- continuous casting and direct rolling; and
- improved methods for using waste materials and heat.

Several of these technologies are explored in this chapter to illustrate the range of opportunities available to the steel industry.

Introduction and Background

Steel Industry Technology

"The steel industry" is composed of those companies that produce steel products from ferrous raw materials including ore, pellets, sinter, sponge iron and other DRI, pig iron, * recycled iron and steel scrap, and a variety of waste products. Conventionally, the iron and steel foundry industry is considered separate from the steel industry, although substantial overlap occurs in many technical areas. Differences in scale and product make it possible to distinguish the two industries clearly. In 1978, the steel industry had approximately 156.9 million tonnes of annual capacity, and the foundry industry 18.1 million tonnes.[1] The foundry industry produces only about 1.8 million tonnes of steel castings per year, about 2 percent of the total national steel production; its remaining capacity is used to produce iron castings.[2]

In 1978, the steel industry was composed of 93 companies operating 158 individual plants.[3] The industry may be divided into three categories, based on the type of primary operations, products, and marketing approach of the individual companies: integrated companies, alloy/specialty companies, and nonintegrated companies.

Integrated companies have primary raw material and ironmaking facilities (blast furnaces), ** steelmaking units, and finishing mills. Alloy/specialty companies produce alloys and special products from steelmaking units; usually they do not deal with primary raw material or engage in ironmaking activities. Nonintegrated companies operate melting and casting units and fabrication mills, and produce a limited range of products for a regional market. The term "minimill" is used to describe some of these nonintegrated activities, although it is now conventional to restrict that term to plants with capacities less than 544,200 tonne/yr.

Table 67 shows that the majority of integrated plants are in the size range of 0.9 million to 8.2 million tonne/yr; most nonintegrated plants are in the 90,700- to 907,000-tonne range; and most of the specialty plants in the range of 9,070 to 108,840 tonne/yr. The final column of the table lists the total number of plants in each size range operated by all three categories of companies.[4] The United States does not have a single steel plant with a capacity of 9.1 million tonne/yr, although two are between 7.3 million and 8.2 million tonnes. In contrast, Japan has eight post-World War II steel plants with capacities of about 9.1 million tonne/yr.[5] The heaviest concentrations of U.S. steel mills are in the Pittsburgh and Chicago areas; only three fully integrated plants are in the Western States.

Although plants vary widely in character and size, it is helpful to use current integrated plants to describe steelmaking technology. Figure 22 shows a flow line of steelmaking. All of the major material inputs and operations are indicated, but many of the secondary operations, materials-handling operations, and environmental control operations are not, nor are any of the inspection and quality control operations. An integrated

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*DRI designates the metallized products that come under the general heading of direct reduced iron. The term "sponge iron" describes a common type of DRI, DRI is formed from iron oxide without fusion. Frequently, such iron is porous and appears spongelike under the microscope. Pig iron is solidified blast furnace iron: the term originates from the appearance when cast from a common feeder of liquid iron and one or more rows of small castings result.

[1] Institute for Iron and Steel Studies. "Plant Locations and Capacities. " 1978: D. H. Desy, "Iron and Steel."' Mineral Commodity Profiles. MCP-15, U.S. Bureau of Mines, July 1978; American Iron and Steel Institute, "Annual Statistical Report,"' 1978.

[2] Institute for Iron and Steel Studies, op. cit.; American Iron and Steel Institute, op. cit.

[3] Institute for Iron and Steel Studies, op. cit.

**A new class of integrated plant is emerging based on direct reduction. as discussed later.

[4] Additional discussion of the characteristics and distribution of steel plants is contained in a report prepared for OTA in July 1979: G. R. St. Pierre, C. E. Mobley, C. B. Shumaker, and D. W. Gunsching. "Impacts of New Technologies and Energy/Raw Material Changes on the Steel Industry," July 17, 1979.

[5] K. L. Fetters, "Innovation-The Future of the Iron and Steel Industry,'' Journal of Metals, June 1979, pp. 7-13.

Table 67.–Capacities of Steel Plants in the United States, 1978

Size range raw steel capacity tonnes/yr	**Number** of plants operated by the— 17 integrated companies	33 specialty companies	43 scrap/DRI companies	Total number of plants in size range
7,256,000-8,162,999	2	0	0	2
6,349,000-7,255,999	1	0	0	1
5,442,000-6,348,999	1	0	0	1
4,535,000-5,441,999	3	0	0	3
3,628,000-4,534,999	4	0	0	4
2,721,000-3,627,999	9	0	0	9
1,814,000-2,720,999	11	0	1	12
907,000-1,813,999	15	3	0	18
816,300- 906,999		0	0	1
725,600- 816,299	1	1	1	2
634,900- 725,599	0	0	1	1
544,200- 634,899	1	3	3	7
453,500- 544,199	1	1	3	5
362,800- 453,499	1	1	4	6
272,100- 362,799	2	1	5	8
181,400- 272,099	2	2	14	18
144,190- 181,399	1	2	6	9
126,980- 144,189	0	2	4	6
90,700- 126,979	0	10	9	19
68,025- 90,699	0	3	2	5
45,350- 68,024	2	10	9	19
22,675- 45,349	0	5	0	5
0- 22,674	0	3	0	3
Total number	57	47	54	158

SOURCE Institute for Iron and Steel Studies

plant would have many of the indicated operations; a nonintegrated plant would have only a few. A nonintegrated steel plant might have electric furnaces for melting scrap, continuous casting units to produce slabs or billets, and rolling mills. A specialty steel plant might have only electric furnaces with some secondary steel-refining equipment such as vacuum degassing units, electroslag remelting equipment, argon-oxygen decarburization (AOD) units, in addition to special forming and rolling facilities. Most of the various operations can be performed on a widely varying scale, but several are inefficient and costly on a small scale. Blast furnaces and sheet-rolling mills are examples of units that cannot be scaled down economically. Where product demand or capital availability is too low to justify constructing a blast furnace, scrap-based electric furnace steelmaking or DR ironmaking can be used.

Steelmaking, even in the simplest form, consists of a number of processes. Iron from the mine may go through more than 20 processing steps and transfers before it becomes a finished product. Ore is ground, beneficiated, reconsolidated into pellets, indurated, reduced, desulfurized, refined, cast, and finally subjected to a series of forming and heat-treating steps. Technological developments that can eliminate these operating steps or establish a more continuous flow clearly have the greatest potential benefits.

Technological Change in the Industry

Major developments in ironmaking and steelmaking include:

1. pneumatic steelmaking—first the Bessemer process, and more recently the basic oxygen converters;*
2. hot-blast techniques that permit "continuous" production of liquid iron in the blast furnace;
3. the electric arc furnace (EAF);
4. continuous casting; and

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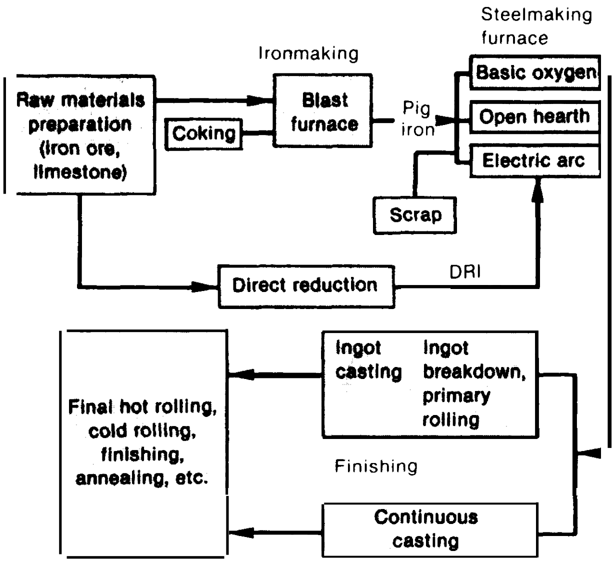
*These processes are discussed inch. 9.

Figure 22.—Schematic Flow Chart for Integrated and Nonintegrated Steelmaking



Possible major routes:

Integrated:	coking-blast furnace-basic oxygen-ingot casting-finlshlng.
Non integrated:	scrap-electric furnace-continuous casting finishing,
Semi.integrated:	direct reduction + scrap-electric furnace-continuous casting-finishing.

SOURCE Off Ice of Technology Assessment

5. continuous rolling facilities to produce a wide range of flat and structural products.

Very recently, DR processes have also taken on importance.

The 20th century has seen many lesser developments in steelmaking as well: coking procedures, low-cost systems for producing oxygen, ore beneficiation and pelletizing procedures, rapid analytical and control techniques, and a host of others. Along with these process developments came a multitude of product developments based on a fuller understanding of the relationships between composition, microstructure, and properties of steel. Of necessity, steelmaking also became more sophisticated in the areas of composition and structure control.

A review of technological change in the steel industry during the period 1963-76 reveals the adoption of more than a hundred different developments during a 10- to 15-year period.’ Although this information must be interpreted carefully, two conclusions are evident:

- information on technological developments in the steel industry is transmitted very rapidly; and
- each new technology has characteristics that provide opportunities in markedly varying degrees to individual companies.

Impacts of Changes in Raw Materials, Energy Sources, Environmental Requirements, and Capital Requirements

The overall conversion or dissociation of iron ore (hematite, Fe_2O_3), to metallic iron (Fe) may be represented as, Fe_2O^3- 2Fe + 3/2O_2. The minimum theoretical energy requirement to convert $Fe_20_3$to Fe is about 7 million Btu per tonne Fe. Expressed in another way, the conversion of $Fe_2O_3$to Fe represents the formation of a new “fuel” by a matching consumption of another fuel or energy source. The replaced fuel might be coal, oil, natural gas, hydrogen, combustible biomass, combustible wastes, another metal (e.g., aluminum in the thermite process), or combinations and derivatives of all of these. Potential energy sources include electrical energy introduced by a variety of techniques (electric arc, plasma, high-frequency induction, etc.) and obtained from a variety of sources (fossil fuels, hydro systems, wind, solar, nuclear, etc.).

The conversion of $Fe_2O_3$to Fe cannot be accomplished with energy alone—the thermodynamic stability of iron oxide is too great. A temperature of several thousand degrees Celsius is required to bring about spontaneous dissociation to form metallic iron. Material reactants must be used to drive the dissociation at moderate or practically attainable temperatures. All of the common fossil fuels and their derivates can act as suitable reduc-

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“R. K. Pitler,"Worldwide Technological Developments and Their Adoption by the Steel Industry in the United States, ” American Iron and Steel Institute, Apr. 13, 1977.

ing agents; however, there are strict thermodynamic requirements that limit the efficiency with which C, CO, and H_2 can be used. For example, the value of CO as a reducing agent is practically exhausted when the CO_2/CO ratio is about three to one. * The minimum material requirement of CO corresponds to an equivalent carbon requirement of about 0.43 tonne of carbon per tonne of Fe.**

One common procedure for assessing the combined requirements is called “thermochemical balancing.”’ For any particular system, thermochemical balancing can be used to find optimal operating modes for the lowest possible energy and material consumption.

Changing conditions stimulate the development of new processes and the adoption of new technologies, Examples may be found among changes in raw materials, energy sources, environmental requirements, and capital availability.

Raw Materials.— Iron ore and scrap are the two major sources of iron units for steelmaking, As scrap availability increases, incentives are created for adopting technologies that use more scrap. The replacement of open hearth with basic oxygen furnaces permitted an expansion of scrap-based electric furnace steelmaking. On the other hand, a limited supply of high-quality scrap may lead a scrap-based steel company to seek sources of DRI of known quality or to construct new DR facilities of its own. Future developments in the area of amorphous materials may create situations in which entirely new steelmaking and casting sequences will be needed.

Coal, coke, and natural gas are the principal reductants available for the conversion of iron ore. If coking coal is not readily available and natural gas is, there is clear incentive to adopt gas-based DR processes in place of blast furnace ironmaking. Current blast furnaces also depend in part on injected oil to achieve high production rates and low coke-consumption rates. If oil is in limited supply or very expensive, alternatives must be considered.

Energy Sources.— If the availability of conventional fuels is limited, development of new processes such as those using plasma and magnetohydrodynamics (MHD), which make direct use of electrical energy, becomes important.

Environmental Requirements.—As pressure to meet stringent environmental constraints increases, processes are needed that are more amenable to physical enclosure and require lower volumes of waste discharge. For example, dry methods can replace aqueous methods, as they have in coke quenching, and countercurrent flow processes like cascade rinsing become attractive. The need to produce low-sulfur steel can foster changes in the mode of operation of an integrated steel plant, External desulfurizers can be installed, secondary steelmaking units can be added, and blast furnace practices can be altered drastically.

Capital Requirements.—For a new technology to be adopted it must represent a sound use of limited financial resources. Processes that have high throughputs per unit volume and that depend on a minimum of auxiliary support equipment may meet such requirements.

International Comparisons of Production and Energy Consumption

Tables 68 through 71 contain information on raw material, energy, and labor consumption in the international steel industry. The data in these tables represent a composite for integrated plants and do not reflect the wide differences in process configurations, age of plant, available raw materials, and product requirements of individual plants. Table 68 presents unit inputs per tonne of U.S. steel shipped in 1977. Table 69 compares product

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*To fix the precise value, one must consider the individual reduction steps (Fe_2O_3 - Fe, O_4, FeO - Fe) and the effective temperature of each.

* *This is surprisingly close to recent record coke consumptions in ironmaking: however, those records are achieved through the injection of otherr reductants (tar, oil, etc.).

mixes for major steel-producing countries,* table 70 provides country comparisons on a wide range of operating parameters for several types of steelmaking units, and table 71 deals with energy consumption per tonne of steel shipped. All these data point to technological opportunities for the domestic steel industry, but without full investigation of capital requirements and return-on-investment factors for both replacement and expansion, information of this type can be badly misinterpreted. A clear distinction must be made between technological opportunity and feasibility.

Table 68.—Unit Material and Energy Inputs per Tonne of Steel Shipped, United States, 1977[a]

Unit input (tonnes or as noted)	Data source AISI[b]	 WSD[b]
Iron ore	1.33	1.68
Coking coal	0.7666	1.01
Noncoking coal	0.033	0.033
Coke[c]	0.538	0.643
Scrap	0.292	0.14
Natural gas (10^3ft^3)	6.96	6.17
Fuel oil (U.S. gallons)	20.50	21.13
Electricity (kWh)	537.00	452.00
Oxygen (10^3ft$_3$	3.04	NA
Fluxes and alloys	0.304	NA

NA = not available.

[a] 113,939,091 tonnes raw steel produced; 82,860,909 tonnes raw steel shipped, yield (shipments/production) = 72.7%.

[b] American iron and steel Institute, actual operating data for entire US. industry, World Steel Dynamics idealized model based on 10° tonne/yr integrated plain carbon steel plant

[c] Coke is produced from coking coal, and thus represents a double counting of inputs in this table Coke usage is included for comparison with data in subsequent tables

SOURCE: G. St. Pierre for OTA.

Table 69.—Steel Product Mixes for Various Countries, 1976 (percentage of total shipments)

Product type	Country United States	 Japan	 United Kingdom	 West Germany	 France
Hot-rolled sheet, under 3mm thick	51.9	43.1	28.6	22.3	34.9
Light sections	15.9	19.1	19.4	14.0	16.0
Heavy plate	8.0	15.5	11.0	11.0	8.7
Strip	6.5	2.1	7.4	7.6	6.9
Wire rods	4.9	8.2	9.0	10.3	11.6
Heavy sections	4.7	7.1	11.2	6.3	6.1
Semis for sale		—	5.3[a]	9.2	6.2
Medium plates	(b)	1.7[c]	2.2	11.1	3.7
Percent total production	94.6	96.8	94.1	91.8	94.1
Sheets (< 3mm) and strip	58.4	45.2	36.0	29.9	41.8

[a] Deliveries [b] Included in heavy plates. [c] From 3 to 6 mm.

SOURCE: Annual Bulletin of Sfeel *Statistics for Europe, vol.* V, 1977, U.N. Economic Commission for Europe

Table 70.—Comparison of Operating Parameters, 1976

	Country United States	 Japan	 United Kingdom	 West Germany	 France	 Brazil
Raw steel produced, million tonnes	116.4	107.4	22.3	42.4	23.2	9.2
Apparent yield[a]	69.9%	84.%	76.80/o	80.7%	83.8%	81 .8%
Average blast furnace Coke rate $\left(\frac{\text{tonne coke}}{\text{tonne pig iron}}\right)$[b]	0.60	0.43	0.60	0.48	0.52	NA
Steelmaking process[c]						
BOF	62.50/o	80.9%	51.47%	73.3%[e]	80.1%	NA
OH	18.2	0.5	18.1	14.3	5.6	NA
EF	19.2	18.6	30.3	12.4	14.2	NA
Continuous casting of raw steel	10.5	35.1	9.4	28.3	18.0	12.1

NA = not available.

[a] **Apparent yield is the ratio** of steel shipments to raw Steel production. This ratio is dependent on the range and type of final products shipped, The relatively low apparent yield value for the United States is associated, in part, with its relatively large fraction of thin products and limited use of continuous casting.

[b] This coke rate (tonnes coke/tonnes pig iron) reflects only the actual coke charged to the blast furnaces and is not the blast furnace fuel rate (i.e., tonne fuel/tonne pig iron). It is estimated that the fuel rates for the non-U.S. countries are about 0.05 units greater than the coke rates cited

[c] 1975 world steel production by process was 51 1 percent by BOF, 17.1 percent by EF, 305 percent by OH, balance (1 3 percent) by Thomas and other processes

[d] 0.1 percent of steel made by "other" unspecified Processes

[e] Includes 14 percent steel production by Thomas (airblown) converter process.

[f] Includes 11.8 percent steel production by Thomas (airblown) converter process.

SOURCE: G. St Pierre for OTA.

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*Product mix for any nation varies with time. For the United States, there is a trend toward making fewer flat products, which are very energy and capital intensive.

Table 71 .—Aggregated Industry Apparent Energy Consumption for Steel making by Country, 1976
(million Btu/tonne steel shipped)

Fuel	United States	Japan	United Kingdom	West German y	France	Brazil
Coking coal.	24.62	20.02	23.85[a]	22.22’	23.22[a]	21.91
Steam coal	1.01	—	—	—	—	0.98
Natural gas....	6.64	—	2.57	4.00	1.92	6.96
Fuel oil	2.71	3.99	6.63	4.07	5.13	3.08
Electricity	1.86	1.61	1.95	1.14	1.67	1.83
Total	36.84	25.62	35.00	31.44	31.94	34.76
Total[b].	25.75	21.52	26.88	25.37	26.77	25.27
Relative energy consumption.	100	84	104	98.5	104	98

United States, 1976 = 100

[a] Coking coal consumption is estimated from known coke consumption. Typically 1.45 tonne of coking coal is used to produce 1 tonne of coke.

[b] The total energy per tonne of steel produced is the product of the total energy per tonne steel shipped and the apparent yield for each country

SOURCE: G. St. Pierre for OTA.

Energy Consumption in the Domestic Steel Industry

Tables 72 through 74 summarize energy consumption in the U.S. steel industry. Although the industry consumes about 4 percent of the total U.S. domestic energy, most is in the form of coal. Steel processing accounts for only about 0.6 percent of total domestic petroleum consumption and about 3.2 percent of domestic natural gas consumption. However, the trend is toward increasing the use of petroleum (from 6.2 percent of steelmaking energy in 1972 to 11 percent in 1979) and decreasing the use of coal (from 69 percent in 1972 to 63 percent in 1979). After adjusting for the decrease of 8 percent in total energy use, the petroleum energy used in steel production increased by 63 percent during this period while coal energy use decreased by 16 percent.

Table 72.—The American Steel Industry and the Nation’s Energy Consumption

Year	Consumption (quadrillion Btu)		Steel industry as percentage of total domestic economy
	Steel industry	Total domestic	
1972	3.13	71.63	4.4%
1973	3.45	74.61	4.6
1974	3.42	72.76	4.7
1975	2.94	70.71	4.2
1976	3.05	74.51	4.1
1977	2.91	76.54	3.8
1978	2.98	78.15	**3.8**
1979	2.88	NA	NA

NA = not available

SOURCES. American Iron and Steel Institute, *Annual Statistical Report* Department of Energy, “Monthly Energy Review “

Table 73.—Steel Industry Energy Consumption by Source

Source of en erg y	Percent from each source							
	1972	1973	1974	1975	1976	1977	1978	1979
Coking coal.	64.0%	64.50/.	62.1 %	66.8%	65.7%	62.4°10	56.30/o	NA
Other coal.	3.5	3.4	2.9	2.6	2.4	2.9	2.4	NA
Outside coal	1.3	1.7	2.8	(1 .5)	(0.9)	0.9	5.8	NA
Subtotal from coal.	68.8	69.6	67.8	67.9	67.2	66.2	64.5	63.0
Natural gas.	**20.7**	**19.0**	**20:0**	**20.0**	**19.9**	**19.9**	**20.5**	**21.0**
Petroleum	**6.2**	**6.9**	**7.6**	**7.3**	**7.8**	**8.6**	**9.4**	**11.0**
Liquid petroleum gas.	**—**	**—**	**—**	**0.1**	**0.1**	**0.1**	**0.1**	**NA**
Purchased electricity	**4.3**	**4.5**	**4.6**	**4.7**	**5.0**	**5.2**	**5.5**	**5.0**
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

NA = not available

SOURCE American Iron and Steel Institute, *Annual Statistical Report.*

Table 74.—The Mix of Energy Sources

Energy source	Total domestic 1978	Steel industry 1972-78 average	
		Direct	Adjusted
Coal	18.20/o	67.5%	69.6%
Natural gas	25.3	20.0	20.8
Petroleum	48.6	7.7	8.5
Nuclear	3.8	—	0.4
Hydro and other		—	
Electricity	(a)	4.8	(a)
Total	100.0	100.0	100.0

[a] Included in sources above. The adjusted mix for the steel Industry distributes the 48 percent purchased electricity to the primary fuels in proportion to primary fuels consumed by the electric utility industry during the 1972.78 period.

SOURCES. American Iron and Steel Institute, Annual *Statistical Report,* Department of Energy, “Monthly Energy Review.“

Characterization of New Technologies

Definitions

Developments in the steel industry can be divided into four broad groups:

- radical and major technologies;
- incremental technology developments;
- regulatory technology developments; and
- developments from other industries.

The term “radical” is used to describe a process modification that eliminates or replaces one or more of the current steelmaking processes or creates an entirely novel option for ironmaking and steelmaking.[7] DR is thus a radical ironmaking change because it is an alternative to the traditional coke oven-blast furnace sequence. Direct steelmaking processes are radical changes because they combine several processes into a single reactor. Continuous casting is radical because it replaces ingot casting and shipping, reheating, and blooming mill operations. Rolling of powders to strip is also radical.

“Incremental” technology developments include process modifications that improve efficiency, increase production, improve product quality, or lower operating costs. Energy conservation measures and the recycling of waste materials fall into this category. So too does external desulfurization of blast furnace iron, although it involves adding a new operating unit. Secondary steelmaking processes including AOD also are incremental technologies. * The economic impact and technological significance of incremental developments may be great.

Developments in environmental technology include add-on systems that do not alter the steelmaking process. Examples are biological treatment of waste waters, pipeline charging of coke ovens, and fugitive particulate collectors.

Developments from other industries can be used in many ways. Analytical and control techniques are transferred to the steel industry on a broad basis. The adoption of coal gasification processes in conjunction with DR might represent a type of technology transfer, although the steel industry has had long experience with generating, cleaning, and using fuel gases in coke oven operations, in the recycling of blast furnace top gas, and more recently in the collecting of carbon monoxide from steel convertors.

Pitler, op. cit.: J. Szekely, “Toward Radical Changes in Steelmaking. Technology Review, Massachusetts Institute of Technology, February 1979, pp. 23-29.

*AOD is a case study in ch. 9.

Potential Technological Changes and Opportunities

Table 75 lists potential technological changes to steelmaking identified in OTA workshops, seminars, and reports and in the current technical and commercial literature.[8] The entries in the table represent different process designs such as DR. The adoption projections in the table should be interpreted

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[8] St. Pierre, et al., op. cit.; OTA workshop on "Radically Innovative Steelmaking Technologies. Massachusetts Institute of Technology, (J. Szekely, chairman), Apr. 24-25, 1978: OTA seminar on "New Technologies in Steelmaking, " Washington, D. C., (J. Hirschhorn, chairman), May 2-3, 1979; S. Eketorp and M. Mathiesen, "Direct Steelmaking—A Review of Processes Under Development. " report to OTA, 1979: J, T. Strauss and T. W, Heckel, "Future Potential of Ferrous Powder Metallurgy." report to OTA, August 1979.

Table 75.—Potential Technological Changes in the Steel Industry

Technological process[a]	Category	Significant adoption possible within: 5 yr	10 yr	20 yr	Pricipal features
Plasma arc steelmaking[a]	1	—	—	?	Fast reactions, small units.
Direct steelmaking[a]	1	—	?	7	Eliminates cokemaking.
Liquid steel filtration	2	?	?	?	Improves product quality.
Continuous steelmaking[a]	1	—	?	?	Conserves energy and reduces number of reactor units.
Secondary refining systems[a]	2	x	x	x	Improves product quality.
Hydrometallurgy production of iron	1	—	?	x	Low-temperature processes.
Nuclear steelmaking[a]	1	—	—	?	Alternative energy source for steel making.
Hydrogen systems[a]	1	—	?	x	Alternate fuel/energy source.
Direct reduction processes	1	x	X	X	Low-temperature solid-state reduction of iron ore to iron.
Coal gasification	4	‘?	x	x	Alternate fuel/energy source.
Preheating of coking coal/ pipeline charging	2,3	x	x	x	Reduces pollution and conserves energy in cokemaking operation.
Dry quenching of coke	2,3	x	x	x	Reduces pollution and conserves energy in cokemaking operation.
BOF/Q-BOP off gas utilization	2,3	x	x	x	Energy conservation measure.
High top pressure BF electricity generation	2	?	?	x	Energy conservation measure.
Evaporative cooling	2,3	x	x	x	Improved cooling system, saves water usage.
External desulfurization[a]	2	x	x	x	Allows improved product quality and increased blast furnace productivity.
Induction heating of slabs/coils	2	x	x	x	Reduces scale formation, increases yield, and conserves energy.
Catalytic reduction process	2	—	?	x	Used with coal-based reduction processes to increase reaction rate.
Blast furnace fuel injection	2	x	x	x	Use of alternative fuels to replace coke (possible energy conservation).
Direct casting of steel	1	—	?	x	Eliminates mechanical forming and heating.
Continuous casting	1	x	x	x	Direct conversion of liquid steel to solid slabs and squares. Major energy conservation measures and increased yield.
Formed coke	1	—	7	x	Replaces metallurgical coal/coke.
Biomass energy systems	2	—	?	x	Alternate fuel source.
Self-reducing pellets and briquettes	2	—	?	x	Iron ore/carbon flux is intimately mixed to allow reduction in the pellet.
Powder metallurgy steel sheet	1	?	x	x	No melting or reheating required, mini mill concept.
Direct/inline rolling	2	7	x	x	Eliminates holding and reheating steps.
Computer modeling/control	2,4	x	X	x	Applies to any unit/process operation.
High-temperature sensors	2,4	x	x	x	Units to measure and control high-temperature iron making and steel making process variables.

Categories I-radical, 2-incremental 3-environmental, 4-transfer ?-significant adoption possible if pilot efforts show promise. X-significant adoption possibl.
[a]Includes a variety of processes

SOURCE: G. St. Pierre for OTA.

with care: a question mark indicates that a significant adoption is possible within that time period if current pilot efforts show promise; an X-entry, that the technology should be significantly adopted within the time period; a dash, that adoption within the time period is improbable. A number of the technologies are currently adopted or near adoption.

Radical and Major Technologies

Four major new technologies-direct reduction, direct steelmaking, plasma steelmaking, and direct casting—are described and assessed in this section. * These technologies are in markedly different stages of research, development, demonstration, and adoption. The first process is in use throughout the world; the last three have not advanced beyond the R&D stage.

Direct Reduction

Description.— DR processes convert iron ore (fines, pellets, sinter, etc.) into sponge iron at temperatures well below the melting point of iron.** These processes distinctly differ from the conventional blast furnace process in two major respects: solid metallized product is produced, rather than molten iron;*** and a wide variety of reductants may be used in place of metallurgical-grade coke. DRI is normally porous, or in some cases has a filamentary form, and must be processed in steelmaking units that convert it into a usable product. If the starting oxide material is finely divided, the resulting DRI does not have the characteristic spongelike structure but consists instead of finely divided particles of iron. Subsequent processing involves consolidating the reduced or metallized powders by either compression and sintering into finished forms, as in the powder metallurgy industry, or direct rolling of these powders into sheet products.

Another type of DR process is based on combining the reducing agent with the iron oxide as a charge material. For example, it may use a self-reducing pellet or briquette in which finely divided iron ore or mill scale is mixed with a carbonaceous reductant material and fluxes. This pelletized or compacted mixture contains all of the reactants for DR, and it is only necessary to provide the heat for metallization. If the particles are very finely divided and well mixed in the pellet or briquette, reactions can be very fast; for example, a number of reports indicate that under favorable heat transfer conditions 95-percent metallization can occur within 4 to 5 minutes at temperatures of about **1,3000** C.

The fuel requirements in the DR processes are very different from those in conventional blast furnace ironmaking. Current blast furnace practices require high-grade metallurgical coke, which is produced in coke ovens from selected blends of coal. Current DR processes use a variety of fuels and reductants, including coal without prior coking, natural gas, oil, or gases produced from any of these fossil fuels. DR processes also maybe of many mechanical designs: there are batch-type processes in which preheated, preformed reducing gases are passed over a static bed of iron oxide material; other designs are based on concurrent or countercurrent flows of gases and solids in a shaft. Fluidized beds have also been used for DR, as have rotary kilns with countercurrent or concurrent flows of gases and solids. Figure 23 is a schematic diagram of several of the principal DR systems.

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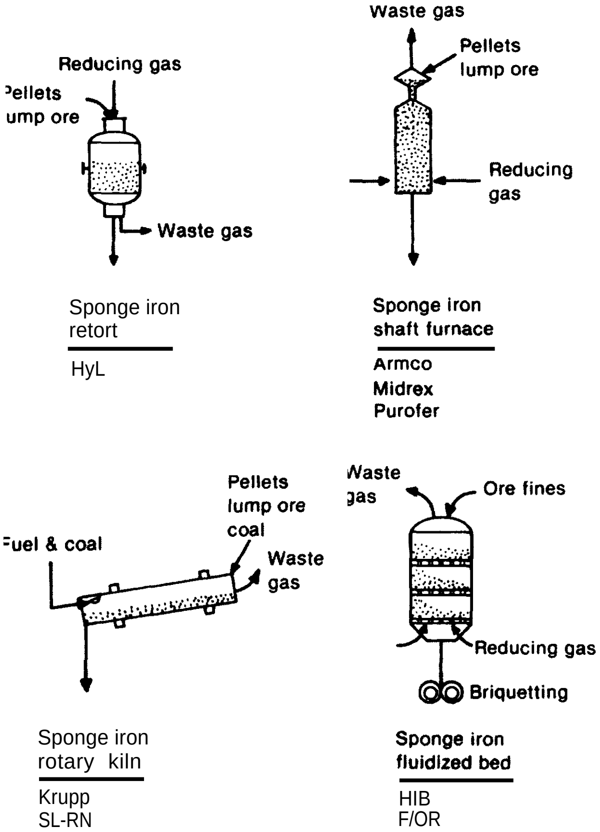
*TWO other major changes, formcoke and continuous casting, are fully described and discussed in ch. 9.

**The principal concepts of DR were presented by William Siemans in 1869; however, elementary direct reduction using char was practiced by ancient ironmakers,

***The degree of metallization describes the fraction of the iron content of the ore which is converted to metallic iron.

Figure 23.—Schematic Diagram of Direct Reduction Processes



SOURCE: K.H. Ulrich, "Direct Reduction by Comparison With Classical Method of Steel Product Ion," *Mefallurgical Plant and Technology, No.* 1, 1979.

In all of these systems, the operating temperatures must be controlled so that the material moves uniformly through the system without sticking, agglomerating, or clinkering; the gases and solids must have adequate contact for fast reactions and heat and mass transfer; and the design must allow the materials to be discharged and cooled properly.

About 20 different DR processes are in use throughout the world.[9] (See table 76.) Most of the processes have not spread widely: only three processes have been adopted in more than four plants. The most prevalent process, the Midrex, was first built at Oregon Steel Mills in 1969; the remaining 16 Midrex plants are widely scattered and include several 2.3-million-tonne/yr plants in the U.S.S.R. The 14 HyL plants are also widely dispersed. All of the Midrex and HyL plants use natural gas as a reductant. The coal-based SL-RN process has been adopted at six plants. Additional information on the distribution of operating DR plants is given in table 77. A number of U.S. steel companies are showing substantial interest in adopting DR: at least six plants have been constructed, and at least another four are planned.

Tables 76 and 78 show that most of the current DR systems, whether based on coal or gas, have been built in units of less than 362,800 tonnes nominal capacity; however, several larger units are being planned and modules of 1.2 million tonne/yr are probable in the next decade. Several DR plants have individual capacities in excess of 907,000 tonne/yr.[10] Some representative characteristics of major DR processes are shown in table 79.

Energy consumption figures for the four major natural gas DR processes vary significantly, as table 80 shows. The lower energy processes are the more prevalent ones.

Table 78 presents general information on three categories of operating coal-based DR processes: direct use of coal, coke breeze, and gasified coal. The third category is really a separate breed, because the coal gasification processes can, in principle, be coupled with any of the gas-based processes.[11] Such a

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[9] J. R. Miller, "Use of Direct Reduced Iron Ore and Balanced Integrated Iron and Steel Operations,"' *Ironmaking and Steelmaking*, 1977, No. 5, pp. 257-264; "The Inevitable Magnitudes of Metallized Iron Ore,'" iron and *Steel* Engineer, December 1972.

[10] "Saudi Resources and Korf Technology Combine to Create a Dessert Steel Mill,"" 33 *Metal* Producing, May 1979. pp. 54-57: W. Loewe, "DR Unit Construction Due in Six Months," *Washington Post*, May 31, 1979.

[11] J.W. Clark, "Integrated Steelmaking Based on Coal Gasification and Direct Ore Reduction," Westinghouse R&D Center. Pittsburgh, Pa., Dec. 8, 1979; OTA seminar. May 2-3, 1979.

Table 76.—Direct Reduction Plants Constructed or Scheduled for Completion by 1980

Process	Number of plants	Year of original plant	Year of last plant	Countries	Reductant	Capacity, 10^3 tonnes	Type[b]
Hoganas	3	1954	1954	1,2	Coke breeze	63-154	—
Wiberg	4	1954	1964	1,3	Coke breeze	9-82	—
Rotary kiln	1	1957	1957	3	Coal	22	R.K.
HyL	14	1957	1980	4, num.	Natural gas	91-1,905	St. B[c]
Highveld kiln	2	1968	1977	5	Coal	272-907	R.K.
Midrex	17	1969	1980	2, num.	Natural gas	272-2,268	S.F.
Kawasaki	3	1969	1977	3	Coke breeze	65-227	R.K.
SL-RN	6	1970	1978	6, num.	Coal	54-327	R.K.
Purofer	4	1970	1980	7, num.	Natural gas, CO	136-726	S.F.
Koho	1	1971	1971	3	Coke breeze	44	—
Armco	1	1972	1972	2	Natural gas	300	S.F.
Krupp	1	1973	1973	5	Coal	136	R.K.
HI	1	1973	1973	8	Natural gas	590	FI. B.
Sumitomo	1	1975	1975	3	Coal	218	—
Kubota	1	1975	1975	3	Coal	190	—
ACCAR	2	1975	1976	9	Coal, oil, gas	45-218	R.K.
FIORD	1	1976	1976	8	Natural gas	363	FI. B.
NSC	2	1976	1977	3	Oil	136-218	—
Kinglor-Metor	1	1976	1976	10	Coal	36	
Azcon[c]	1	1978	1978	2	Coal	91	R'K.

a1-Sweden, 2-united States, 3-Japan, 4-Mexico, 5-South Africa, 6-New Zealand, 7-West Germany, 6-Venezuela, 9-Canada, 10-Italy.
bR, K, = rotary kiln, St.B. = static bed, S F = shaft furnace, FI. B. = fluidized bed (See text)
cNow known as Direct Reduction Corp. (DRC).

SOURCE: G. St. Pierre for OTA.

Table 77.—Distribution of World Direct Reduction Capacity, 1980

By process	
Midrex	38.5%
HyL	38.1
SL-RN	5.6
Purofer	4.2
Others	13.6

By reductant source	
Natural gas	87.40/~
Coal	11.1
Gas/fuel oil	1.5

By process type	
Shaft furnace	44.6%
Static bed	38.9
Rotary kiln	12.6
Fluidized bed	3.9

By country	
Venezuela	24.8%
Iran	14.2
Mexico	10.7
Canada	8.7
United States	6.1
Japan	6.1
Others	29.4

SOURCE: R.J. Goodman, "Direct Reduction Processing—State. of-the. Art," *Skillings Mining Review, vol. 68, No* 10, March 1979

coupling would involve producing clean fuel and reducing gas by pressurized gasification of nonpremium, high-sulfur coal; using the gas as a reductant in the chemical reduction of iron ore; using the offgas from ore reduction either as a fuel for combined-cycle power generation or as an auxiliary energy source for gasification and reduction plants; and then melting and refining the DRI in an electric furnace with electricity from the combined-cycle powerplant. Several coal gasification processes might complement other steel processes.[12]

Table **81** summarizes energy consumption in coal DR kilns. There is a wide range in the energy consumption figures for coal-based rotary kiln DR because of the flexibility in the operation of rotary kilns. In particular, coals of varying ash and moisture content and ores of varying quality can be processed. The low consumption figures are for coals of low moisture and ash content with ores [pellet, lump, fines) of low gangue and moisture and high iron content. Energy consumption in shaft units is about the same as in rotary kilns.[13] The consumption in static beds is almost 50 percent greater, and in fluidized beds may be 75 percent greater, than in kiln and shaft systems.

Total consumption of energy in coal gasification processes might be as low as 12.1 mil-

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[12] E. J. Smith and K. P. Hass, "Present and Future Position of Coal in Steel Technology,"' *Ironmaking and Steelmaking*, 1979, No. 1, pp. 10-20,

[13] D. S. Thornton and D. I. T. Williams. "Effects of Raw Materials for Steelmaking on Energy Requirements, *Ironmaking and Steelmaking*, No. 4, 1975, pp. 241-247.

Table 78.—Operating Direct Reduction Plants Based on Coal or Coke Breeze

Process	Location	Company and country	Capacity (tonnes)	Startup	Product use[a]
Plants-using-coal **directly**					
SL-RN.	N.W. Ontario	Steel Co. of Canada	362,800	1975	A
SL-RN.	Arizona	Hecla Mining, United States	54,420	1975	c
SL-RN.	Rio Grande	Aces Fines Pir., Brazil	58,955	1973	A
SL-RN.	Fukuyama	Nipon Kokan, Japan	317,450	1974	B
SL-RN	Glenbrook	New Zealand Steel	108,840	1970	A
SL-RN/Krupp.	Benoni	Dunswart, South Africa	90,700	1973	A
Azcon–DRC, ...	Tennessee	Azcon Corp., United States	90,700	1978	A
Kinglor-Metor	Cremona	Danieli, Italy	36,280	1976	A
Kinglor-Metor ...	Monfalcone	Danieli, Italy	9,070	NA	A
Sumitoma	Kashima	Sumitoma, Japan	195,912	1975	B
Highveld .	Witbank	Anglo-Am. Corp., South Africa	907,000	1968	B
ACCAR.	Ontario	Sudbury, Canada	226,750	1976	NA
Plants **using coke** breeze					
Hoganas	Hoganas	Hoganas AB, Sweden	136,050	1954	c
Hoganas	Oxelosund	Granges AB, Sweden	32,652	1954	c
Wiberg	Sandriken	Sandrik AB, Sweden	21,768	1954	c
Kawasaki	Chiba	Kawasaki, Japan	54,420	1969	B
Kawasaki.	Chiba	Kawasaki, Japan	54,420	NA	B
Sumitomo	Wakayama	Sumitomo, Japan	217,680	1975	B
Rotary kiln.	Muroran	Nippon, Japan	43,536	NA	B
Plants using gasified coal					
NSC	Hirohata	Nippon, Japan	136,050	1977	B

NA = not avaflable
aProduct use: A = steel making feed B = ironmaklng feed C = specialty product

SOURCE Department of Commerce ‘Production of Iron by Direct Reduction,’ May 1979

Table 79.—Characteristics of Direct Reduction Processes and Electric Furnace Consumption

	SL-RN	Armco	Midrex	Purofer	HyL	HIB	FIOR-ESSO
Furnace ., . .	Kiln	Shaft	Shaft	Shaft	Retort	Fluid bed	Fluid bed
Reductant source .	Coal	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas or oil
Energy, 10^6 Btu/ tonne DRI. . .	13.1	13.1	11.9	13.1	15.5	17.9 -19.9	15.1
Feed, type . .	Coarse ore, pellets	Pellets	Pellets	Coarse ore, pellets	Coarse ore, pellets	Ore fines	Ore fines
Product metallization.	900/o	90%	92-960/0	95°/0	85-900/0	90%.	920/o
Elect ric-f urn ace consumption charge							
Sponge . . .	75%	200/0	700/0	500/o	600/0	—	75%
Scrap	25	30	30	50	40	—	25
Hot metal.	0	50	0	0	0	—	0
Power, kWh/tonne.	555	272	550	583	625	—	535
Yield . .	91 %	84%	93°/0	—	92.40/.	—	—

SOURCE: E.J. Smith and K.P. Hass, Present and Future Position of Coal in Steel Technology.” *Ironmaking and Steelmaking,* 1976, No 1, pp. 10-20

lion Btu/tonne of DRI. The most favorable energy consumption figures for blast furnaces are about 14.3 million Btu/tonne of iron. The high efficiency of modern blast furnaces is undisputed, and it is unlikely that any DR system will consume less energy when proper account is taken of all inputs and outputs.[14] Waste heat losses are **0.5** million to 5.0 million Btu/tonne for steel production by the coke

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“Clark, op. cit.; R. S. Barnes, “The Current State of Iron and Steel Technology. ” *Ironmaking and Steelmaking,* 1975, No. 2, pp. 82-88: Thornton and Williams, op. cit.

Table 80.—Energy Consumption in Gas Direct Reduction Processes

Type	Reductant energy 10^6 Btu/tonne	Electricity consumption kWh/tonne	Total 10^6 Btu/tonne
Shaft	10-12	33-135	11.1 -12.8
Retort.	12.5	20	136
Kiln.	13-20	35-45	13-20
Fluidized bed .	15-18	40	14.7

SOURCE G St Pierre for OTA

Table 81 .—Energy Consumption of Direct Reduction Rotary Kilns

Item	Consumption	
	Low	High
Coal, Btu/tonne	14.3 x 1 o’	22.0 x 10’
Electricity, kWh/tonne.	38.5	49.5
Total energy, Btu/tonne. . . .	14.4 x 10’	22.2 x 10’

SOURCE: G St Pierre for OTA

oven-blast furnace-basic oxygen furnace (CO-BF-BOF) sequence and **11.8** million Btu/tonne for the direct reduction-electric arc furnace (DR - EAF) sequence using **20** percent scrap.[15] The latter figure is likely to improve as technological advances occur, but for energy consumption from ore to metal it will be difficult to better the performance of a modern blast furnace system; however, capital and operating costs may be improved with DR systems.

A comparison of coal-based DR system energy costs with other types of DR systems has been prepared using OTA energy prices and projected rate of increase, (See ch. 5.) The results are presented in table 82 by specific process and in figure **24** by type of process. A favorable situation is predicted for coal-based DR systems in the United States.

New DR Processes.— A number of new DR processes are under development. In the United States, the Midrex Corp., originator of one of the two leading natural gas DR processes, has also developed a direct coal DR process. It is fundamentally different from the coal kiln processes in use for some years. The principle of the electrothermal process is electrical resistance heating of the iron ore and coal mixture; this is shown in figure 25A. This process is now in the pilot stage and is expected to be marketed for plant sizes of 181,400 tonne/yr within the next 5 years. Because of its relatively simple design, the process appears to offer good process control and reliability, with a relatively low capital cost.

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[15] Barnes, op. cit.

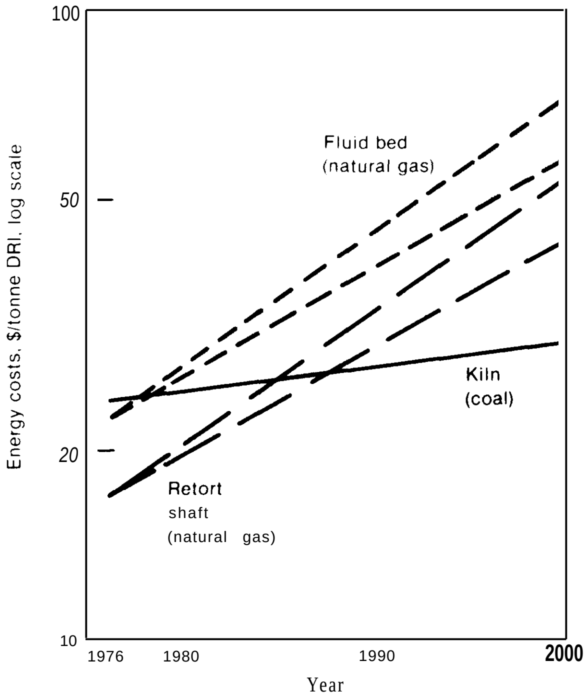
Table 82.—Energy Costs for Direct Reduction Processes Based on OTA Energy Costs

Energy source[a]	OTA energy cost and annual cost increase	Allis-Chalmers kiln	Armco shaft	FIOR fluid	HIB fluid	HvL retort	Krupp kiln	Midrex shaft	Purofer shaft	SL-RN kiln	Cost averages: Fluid bed	Cost averages: Retort shaft	Cost averages: Kiln
Electricity 10° Btu/tonne ., ...	—	0.17	‘0.12	0.15	(d)	0.08	0,15	0.51	0.38	(d)			
$ in 1976	$5.57	0.95	0.67	0.84	(d)	0.45	0.84	2.84	2.12	(d)	–	–	–
Low $ in 2000	1.0%	1.22	0.84	1.04	(d)	0.57	1.04	3.60	2.71	(d)			
High $ in 20()().	4.7%	2.88	2.01	2.49	(d)	1.38	2.49	8.55	6.39	(d)			
Natural gas 10^6 Btu/tonne			12.65	16.06	19.86	13.75		11,90	1320	(d)			
$ in 1976	$1.27	(b)	16,07	2040	25.15	17.46	—	15.11	16.76	(d)			
Low $ in 2000”	4.0%		41.18	52.58	64.46	4476		37.87	42.97	(d)			
High $ in 2000. .	5.0°10		51.81	65.78	81.10	56.32		48.73	54.07	(d)			
Coal 10° Btu/tonne.		18.O[c]					18.O[c]			18.O[c]			
$ in 1976 ... .,	$1 31	23.8	–	–	–	–	238	–	–	23.8	–	—	
Low $ in 2000	1.0%	30.2					30.2			30.2			
High $ in 2000. .	5.0%	76.7					76.7			76,7			
Total energy costs per tonne													
1976. , ...	($)	24.8	16.7	21.2	25.2	17.9	24.6	18.0	15.3	25.8	23.2	16.7	24.4
2000; all low increases, ...	($)	31.4	42.0	53.6	645	45.3	31.2	41.5	45,7	30.2	59.1	43.1	30.9
2000; low electricity, high natural gas, low coal.	($)	314	52.7	66.8	81.1	56.9	31.2	52,3	56.7	30.2	74.0	53.9	30.9

a1976 dollars, no coke or 011 used; energy consumptions from R.J. Goodman, “Direct Reduction –State-of-the-Art, ” Skillings Mining Review, Mar. 10-17, 1979
bAllis-Chalmers unit can use natural gas, oil, and coal. Coal used here
cAn average value of 18 10^6 Btu/tonne was used to represent a readily available coal Typical of kiln processes and assumed to be used in each Process
‘Data not available

SOURCE: G St Pierre for OTA (see tables 54 and 55)

Figure 24.—Projected Energy Costs to Produce a Tonne of Direct Reduced Iron



Key,

High-curve: 5 percent Increase natural gas costs, 1 percent coal, 1 percent electricity

Low-curve 4 percent Increase natural gas costs. 1 percent coal, 1 percent electricity

Reactor type

Fluid bed: average of FIOR & HIB process data

Kiln average of All Is-Chalmers, Krupp, and SL-RN data

Shaft furnace and retort: average of Armco, HyL, Midrex, and Purofer.

SOURCE G St Pierre for OTA

A rather ingeniously designed coal-based DR process has recently been described by its American inventor. ” (See figure 25 B.) Although pilot testing has not yet been carried out, the proposed process uses well-accepted chemical reactions, simple design, and already proven technologies and materials for its components. It is a good example of designing a new technology to suit contemporary concerns, constraints, and opportunities. The basic features of the Calderon Ferrocal ironmaking process are:

- any grade of coal is mixed with any type of iron ore, including domestic low iron content taconite ores;
- the mixture is put through a heating-reduction vessel consisting of a vertical tower made up of several cells, each insulated from the others and tapered downward;
- the inside of the cells are made of alloy steel which serves as a susceptor for induction heating, with the induction coils surrounding the outside of the tower;
- induction heating of the cells leads to a temperature at which there is combined coal gasification and solid-state reduction of the iron ore; the hot gases rise through the tower and preheat the next batch of the ore-coal mixture before being collected, processed, and used for heating, electrical generation, or sale;
- a portion of the solid metallic iron is periodically pushed out of the bottom of the tower into an induction-heated holding vessel of liquid iron, in which slag is formed and removed and desulfurization is accomplished; and
- molten iron is periodically removed and delivered to either a basic oxygen or electric arc steelmaking furnace in the same way that pig iron is delivered in a conventional integrated plant.

This process has several advantages that make it highly attractive, It could be adopted by present scrap-based nonintegrated plants, but it can also use the raw material and steelmaking facilities in existing integrated plants, It uses low-cost iron ores and coals, but unlike conventional DR processes it produces hot liquid iron which can be used in existing integrated facilities. It is a closed system with minimal environmental problems. It has high thermal efficiency, and, because it produces enough medium-Btu gases to generate electricity in considerable excess of the demands of its induction units, it is adaptable to the cogeneration of electricity. Present cost estimates also indicate considerable savings:

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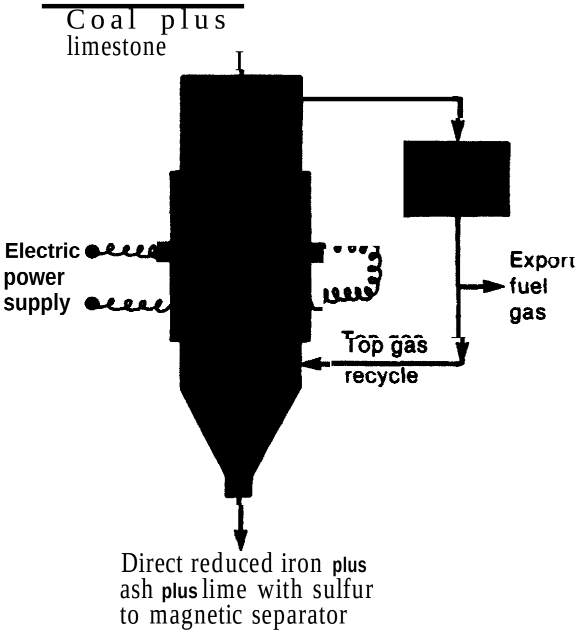
[11] A. Calderon, “Program for Reconstruction of U.S. Steel Industry,” Calderon Automation, Inc., Cleveland, Ohio, February 1980. (Patents applied for.)

capital costs (exclusive of electricity cogenerating facilities) may be only one-half those of coke ovens and blast furnaces; the modular design allows higher utilization rates at lower capacity levels; and there might also be savings in both construction time and maintenance costs. Return on investment could be as high as 25 percent.

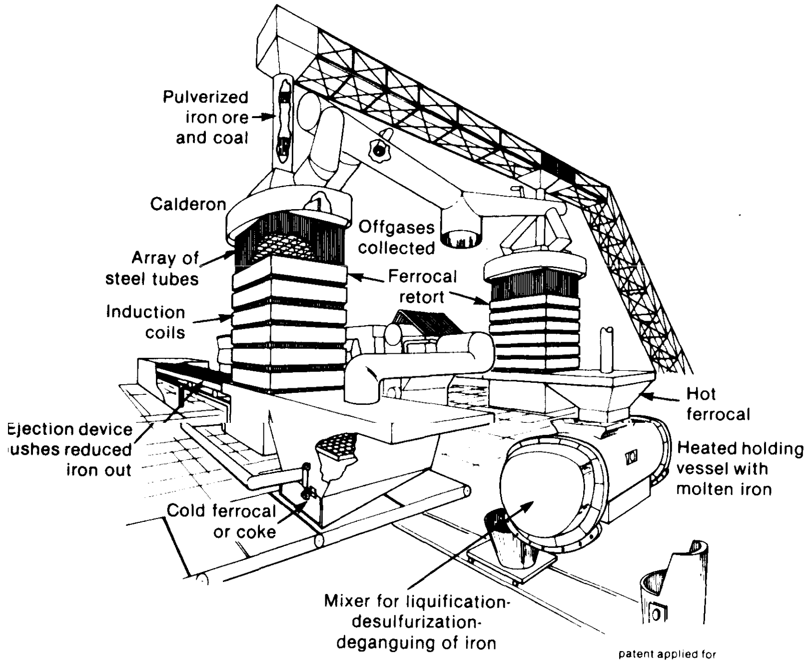
A pilot plant has been designed to produce 4.5 tonne/hour. It would cost approximately $5 million to construct and operate for at least several months. Since the process has been invented by someone outside of a steel company, although with considerable experience with the industry as a designer and builder of steelmaking facilities, pilot evaluation which requires a steelmaking plant may prove to be difficult. At this stage the technology provides an excellent example of the problems facing the introduction of major innovations into the steel industry. This American invention or something similar to it could become the most important innovation for domestic integrated steelmaking in the coming decades.

Figure 25.—Two New Coal Direct Reduction Processes



SOURCE: Midrex Corp.

B. Calderon Ferrocal Ironmaking Process



SOURCE: Calderon Automation, Inc.

A number of new ironmaking processes are also being developed in Sweden, All are based on the concept of using partial (low degree of metallization) DR followed by a smelting operation that melts and further refines the material to produce the equivalent of the pig iron. Descriptive information on three of these processes is given in table 83. Some of them appear to offer a potential for considerable energy savings, both in energy units and in costs. This results from the use of low-grade coals rather than coke. All produce less environmental pollution because of their relatively simple design (figure 26). Several processes and plants based on the same approach of prereduction and smelting were developed in the United States; but for many reasons, including the difficulty and expense of testing new steelmaking technology in pilot and demonstration plants by firms that are not steelmaker themselves, they were not successful. 17

Apparently the Hofors plasma process is related to a recently announced, more traditional DR process producing DRI rather than pig iron. The DR process, called Plasmared, uses plasma heating and can burn oil, gas, or coal as the energy source.[18] A small plant is now under construction in Sweden.

Costs.—An important aspect of evaluating new DR processes is their capital costs. Reported capital costs for a number of DR processes are given in table **84.** The cost for presently used natural gas processes is relatively low, generally about $110 per annual tonne of DRI capacity. This compares to two to three times that cost for coke ovens and blast furnaces to produce pig iron. The capital costs of using coal gasification, direct coal, or coke oven gas are higher than those for natural gas, but they are still quite competitive with the conventional coke oven-blast furnace route. The capital costs for the new Swedish processes that produce pig iron are also quite competitive with the conventional route (see table 83).

More detailed data for a particular direct coal, kiln DR process and a typical gas-based process as a function of plant size are shown in figure **27.** This illustrates the savings re-

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[17] See, e.g., T. E. Ban. "Effective Energy Utilization Through Direct Electric Smelting of Hot Prereduced Iron Ore," Skillings Mining Review, Sept. 14, 1974.

[18] *American Metal Market*, Sept. 21.1979, and Aug. 8, 1979.

Table 83.—Three New Swedish Steelmaking Processes

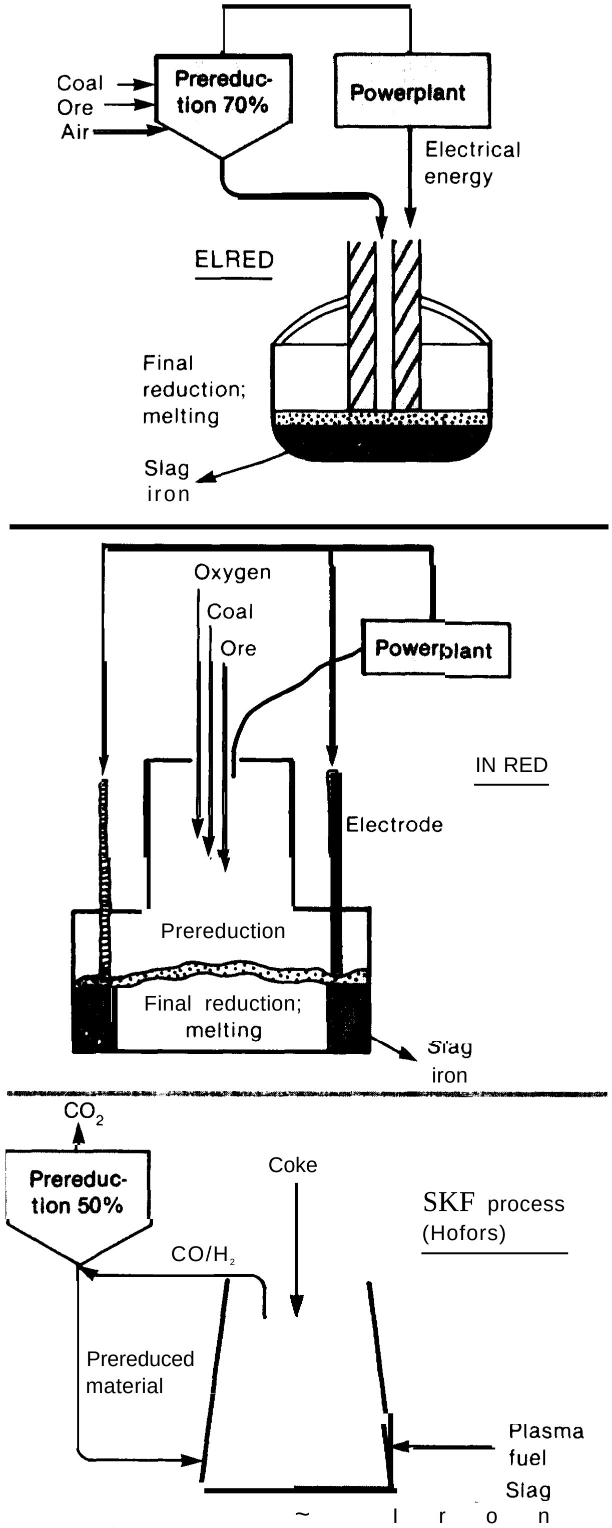
Process	Capital costs ($1979)/tonne annual capacity	Production costs ($ 1979)/ tonne pig iron	Energy use 10^6 Btu/tonne pig iron[a]
ELRED.—Reduction stage uses coal in a fluidized bed. Final smelting-reduction stage is in an electric arc furnace. Flue gases from both stages generate electricity.	NA	NA	15
Hofors. —Reduction in fluidized beds followed by smelting reduction in a plasma-heated shaft furnace. Gas for first-stage reduction from smelting operation using coke. Outlet gas from first stage used for drying and preheating of materials. The plasma-heating requirement can be reduced by injection of oxygen or oxygen-hydrocarbon mixture in second stage.	$140	$116	
Low- and high-electricity versions within about 3 percent of each other.			10
INRED. -First-stage reduction-smelting using coal which is partially burned, the remainder forming coke. Second-stage uses coke from first-stage and prereduced iron in an induction-heated furnace. Electricity is produced from steam formed by cooling of first stage furnace. Coal is sole energy source.	178	125	16

NA = not available

[a] For comparison purposes the energy for a blast furnace ranges from 11.8 10^6 Btu/tonne of pig iron for a new blast furnace to 15.4 10^6 Btu/tonne for an existing one.

SOURCES: ELRED from P. Collin and H Stickler. "EL RED-A New Process for the Cheaper Production of Liquid Iron," provided by ASEA Corp. Others from S Eketorp, et al "The Future Steel Plant—A Study of Energy Consumption," Nat tonal Swedish Board for Technical Development, 1979

Figure 26.—Three New Swedish Ironmaking Processes



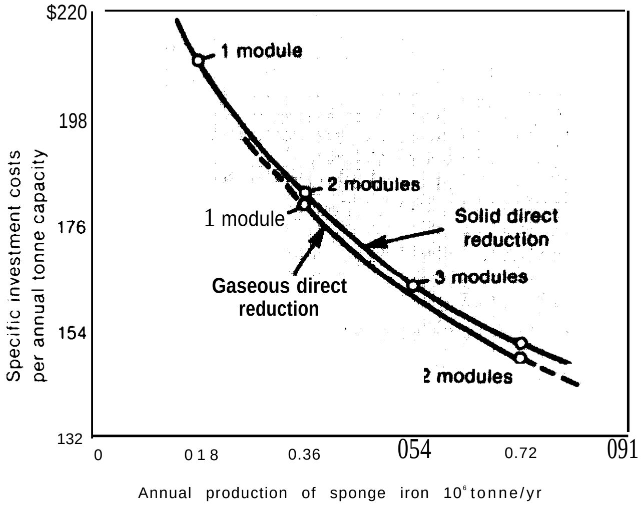
SOURCE S Eketorp for OTA

Table 84.—Capital Costs of Direct Reduction Processes (1979 dollars per tonne of DRI)

Process	cost
Natural gas plants	
Typical gas process in the United States[a]	$120
Typical gas process in the United States[b]	100
HyL process[c]	100
Midrex process in Venezuela[d]	110
Unstated in Italy[e]	200
Coal oven gas (existing coke plant)[f]	190
Coal gasification	
Midrex process with either Lurgi or Texaco gasifiers[f]	300
Unstated DR process with Koppers-Totzek gasifier in Brazil[g]	200
Direct coal	
Midrex electrothermal[f]	200
Tata iron and steel process in India[h]	182
Accar process in India[i]	167
Swedish Plasmared process[j]	135
Azcon—DRC in South Africa[k]	150

[a] H. W. Lownie, Jr., "Cost of Making Direct Reduced Iron," 1978 SME-AIME Fall Meeting, 1978.
[b] J. W. Brown and R. L. Reddy, "Electric Arc Furnace Steelmaking With Sponge Iron," *Ironmaking and Steelmaking*, No. 1, 1979, pp. 24-31
[c] *33 Metal Producing*, July 1979, p. 27.
[d] *The Washington Star*, Oct. 1, 1979.
[e] *American Metal Market*, Nov. 13, 1979.
[f] From Midrex Corp.
[g] *American Metal Market*, Oct. 19, 1979.
[h] *American Metal Market*, Oct. 30, 1979.
[i] *American Metal Market*, Sept. 26, 1979.
[j] *American Metal Market*, Sept. 21, 1979.
[k] *American Metal Market*, June 12, 1980.

Figure 27.—Specific Investment Costs per Tonne of Direct Reduced Iron (Krupp coal process, price basis, 1978)



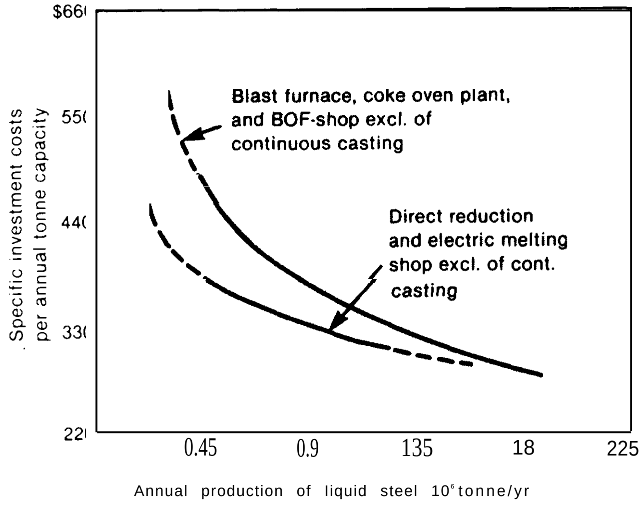
SOURCE: K.H. Ulrich, "Direct Reduction by Comparison With Classical Method of Steel Production," *Metallurgical Plant and Technology, No 1, 1979* suiting from scaling up DR processes, which is just now beginning.

Another way of examining the potential economic advantages of new processes is to consider the costs to produce steel rather than DRI, Capital costs as a function of annual capacity for a direct coal, kiln DR process and conventional blast furnace based on steelmaking are shown in figure 28. For capacities less than 907,000 tonne/yr, DR appears to have a distinct capital cost advantage. A similar result holds for production costs, as shown in figure 29.

A comparison of both capital and production costs for conventional steelmaking with several variations of a coal gasification steelmaking process, shown in figure 30, shows considerable savings possible.

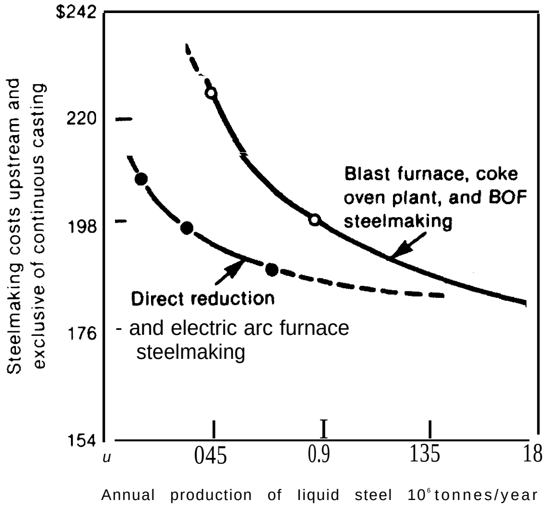
A comparison of the Swedish ELRED process production costs with both conventional blast furnace steelmaking and a typical natural gas DR system is shown in table 85. The comparison with the conventional route is valid, and it shows a saving with the ELRED process at this relatively low annual capacity, but the comparison with the gas DR plant

Fiqure 28.—Specific Investment Costs for Different 'Routes of Steelmaking per Tonne of Raw Steel Capacity (price basis, 1978)



SOURCE K H Ulrich, "Direct Reduction by Comparison With Classical Method of Steel Production," Metallurgical *Plant and Technology, No* 1, 1979

Figure 29.—Steelmaking Costs Upstream and Exclusive of Continuous Casting for Different Production Routes per Tonne of Raw Steel
(price basis, 1978)



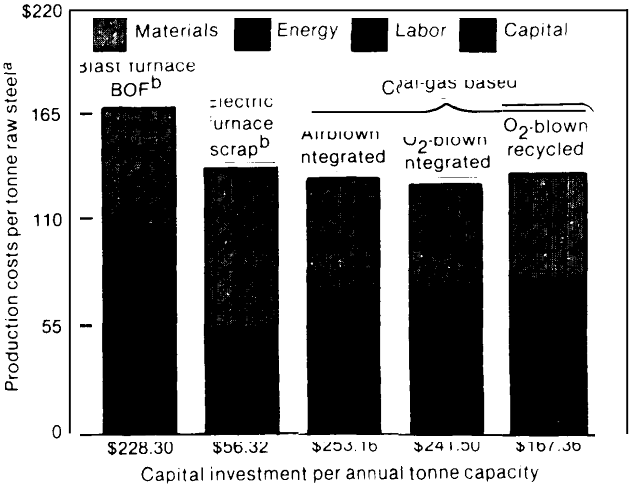
Coking coal: $72/tonne
(respective coke price depending on size of coke oven plant)

DR-coal: $33/tonne
Oil: $72/tonne
Electric power. $0.02/kWh

SOURCE K H Ulrich. '"Direct Reduction by Comparison With Classical Method of Steel Product Ion," *Mefallurgical Plant and Technology No* 1, 1979.

Figure 30.—Comparison of Coal Gasification Direct 'Reduction Steelmaking to Conventional Blast Furnace and Nonintegrated Steelmaking

Coal-gas processes yield steel at $128to$134/tonne



[a] Costs in 1978 dollars.

[b] Scrap at $81.68/tonne.

SOURCE: Westinghouse Research and Development Center.

Table 85.—Total Steelmaking Costs in 1978 Dollars per Tonne of Raw Steel (for 050,000 tonne/yr of raw steel)

	Blast furnace (sinter) + BOF	ELRED + BOF	Shaft furnace (sponge iron) + arc furnace
Iron raw material[a]	$51.6	$33.5	$60.0
Energy[b]	54.4	16.8	47.6
Processing	37.5	38.0	51.6
Capital costs[d]	39.0	45.7	44.3
Unforeseen costs	—	11.0	—
Total steel making costs	$182.5	$145.0	$203.5
Relative total costs as a percentage	100%	80%	112%

aConcentrates and pellets, respectively, alloying element, cooling pellets,

bCoke, coal, oil, minus energy credit plus electricity in steel mill ($181 tonne)

CLabor operation, repairs, and maintenance), electricity, electrodes, lime, oxygen. refractories, desulfurizing (for ELRED)

dFor the ironmaking and steelmaking plants Plants assumed to be in Europe.

SOURCE P. Collin and H. Stickler, “EL RED-A New Process for the Cheaper Product Ion of Liquid Iron, ” ASEA Corp.

Table 86.—Capital Costs for Different Steelmaking Routes (1979 dollars per annual tonne steel product capacity)

Process route	cost
Conventional new plant (greenfield)	$1,320
Integrated blast furnace[a]	275
Nonintegrated scrap-electric furnace[a]	275
Combined scrap non integrated with coal DR[b]	
Direct coal	385
Coal gasification	418
Integrated gas DR[c]	
0.45 million tonne/yr, Midrex process Argentina	660
1 million tonne/yr, unstated process and location[e]	550
0.85 million tonne/yr, Midrex process, Saudi Arabia[f]	814
0.6 million tonne/yr, unstated process, Egypt[g]	725
Coal gasification-DR integrated	
Unstated DR with Koppers-Totzek gasifier in Brazil[h]	1,011

aFrom ch. 10 Value for nonintegrated plant is for a broader product mix than is currently true for most such plants

bAssumes 50-percentt use of DR plant to produce 1 tonne of steel Less then 50 percent of DRI would be used with scrap, but because of Incomplete metallization of the ore and yield uncertainties extra DR capacity is accounted for The unit cost for direct coal DR is $220/tonne and for coal gasification $3301 tonne The value for the base steelmaking plant is $2751 tonne

CAssumes a product mix corresponding to a domestic nonintegrated producer

dAmerican *Metal Market, Aug 281979*

eAmerican Metal Market, Aug. 21, 1979 (by French Society of Steel Studies)

f33 Metal *Producing,* May 1979

gArnerican Metal Market, June 11 1980.

hAmerican Metal *Market,* Aug. 19, 1979.

is not quite so meaningful because the cost of gas purchased in Europe would be high.

To help put the potential capital cost advantages of DR in better perspective, cost data for steelmaking capacity for a number of different process routes, including conventional steelmaking, are given in table 86. Although steelmaking based entirely on natural gas is not likely to be practicable for the United States, it is being adopted by foreign nations with domestic sources of gas and without large supplies of scrap. The costs are less than for blast furnace technology. The two more likely cases for the United States are the use of a combination of coal DR and scrap-based steelmaking and the use of coal gasification DR ironmaking. Because coal gasification is just now being commercialized, there are no reliable cost data for the United States. However, the data for a Brazilian plant based totally on coal gasification, and the data shown in figure 30, suggest that this is a viable option for future domestic steelmaking. The most intriguing possibility for the near term (within 5 to **10** years) is the combination of scrap-based steelmaking with either direct coal or coal gasification. A greenfield plant using a combination of scrap and DRI (discussed more fully in ch. 8) would cost much less than expanding an existing integrated plant or constructing a new integrated plant. Costs for the latter are discussed in chapter **10.**

Labor requirements for DR systems range from 0.4 to **0.6** employee-hours per tonne.[19] For DR with EAF, the range is **1.6 to 1.9** employee-hours per tonne.[20] In contrast, the CO-BF-BOF sequence uses around 2.6 employee-hours per tonne.

Product Use.— In the steel industry DRI has three major uses:

- feed to ironmaking units (BF, cupola, electric smelting);
- feed to steelmaking units (BOF, EAF); and
- feed to metal powder processes.

In addition, DRI may be used for a variety of special applications such as the recovery of copper from water streams. DR processes may be used to recover other constituents in

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[19] H. W. Lownie, Jr., “Cost of Making Direct Reduced Iron,”’ SME-AIME Fall Meeting. Florida, Sept. 11.1978,

[20] Clark, op. cit.

an ore feed, and in the extreme case DRI may be a lesser value byproduct.

The composition of DRI determines its suitability for various applications. Some DRI products have relatively low degrees of metallization (less than 90 percent, and even 80 percent in a few cases); these are suitable only for ironmaking. Other DRI products have a relatively high carbon content. Frequently, DRI is marketed on the basis of its carbon-tin oxygen ratio, which—depending on the particular steelmaking operations—is a very important factor in the selection among available DRI products.

One advantage of DRI is that it is free of the so-called "tramp" elements that often appear in recycled scrap. Recycled scrap contains a variety of alloying elements, including copper from copper-bearing alloys, tin and zinc from coated products, and many others, all of which can pose problems in steelmaking. On the other hand, DRI can have the disadvantage of a high sulfur content.

Desirable composition specifications of DRI are given in table **87.** It must be recognized, however, that off-specification material may be used in blending batches of DRI. DRI is normally used in conjunction with scrap, and an optimal ratio of DRI to scrap can be established for any particular situation.[21] In one estimate of EAF energy consumption, it was found that energy consumption decreased linearly from about 770 kWh/tonne at 80-percent metallization to 500 kWh/tonne at 96-percent metallization.[22] Most studies have shown that EAF productivity peaks at an optimal ratio of DRI to scrap corresponding to about 45 percent DRI.[23]

Table 87.—Typical Specifications for Direct Reduced Iron Used in Steelmaking

Item	Specification (by weight)
Metallization	More than 95%
Total iron	More than 93%0
Metallic iron.	More than 88%
Gangue [a]	Less than 6%
Sulfur	Less than 0.03°/0
Phosphorus	Less than 0.05%
Carbon	Between 0.8 and 1.7°A
Size [b]	Variable
Strength and density.	Variable

aThe gangue specification would take into account the balance of basic oxides (CaO, MgO, etc) over acidic oxides (SiO^2, Al^2O_3. etc). The former are desirable, while the latter are undesirable from the standpoint of slag formation and refractory lining life in steelmaking

bFor example, for Midrex processes. 100 percent less than 0.75 inch and no more than 5 percent less than 0.13 inch

SOURCE G St Pierre for OTA

Siting.—The selection of optimal sites within the United States for coal-based DR plants is a complex problem. Site selection depends on whether the plant is to operate in association with contiguous ironmaking and steelmaking operations or is to transport and market DRI. In the former case, it is important to consider:

- distance from ore and coal sources;
- availability and price of scrap;
- site, labor, and environmental constraints;
- cost of electricity; and
- distance to steel product market centers.

In the latter case, important factors include:

- distance from ore and coal sources;
- labor, environmental, and climatic constraints; and
- distance from iron and steelmaking centers.

There is almost no region within the continental United States that would be entirely unsuitable for a DR operation in some form. Particularly attractive opportunities appear to exist in the Southwest and Gulf States, the Appalachian States, the Northern Great Lakes region, and the Canadian border States.

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[21] "Ironmaking by Direct Reduction-A Review of the Detroit Meeting,"' *Iron and Steelmaking*, May 1979, pp. 44-45; D. H. Houseman, "Direct Ironmaking Processes, " *Steel Times*, April 1978; B. Rollinger, "Steel Via Direct Reduction, " *Iron and Steelmaking*, January 1975, pp. 8-16: J. W. Brown and R. L. Reddv. "Electric Arc Furnace Steelmaking With Sponge Iron,"' *Ironmaking and Steelmaking*, No. 1, 1979, pp. 24-31: F. Fitzgerald, "Alternative Iron Units for Arc Furnaces, " *Ironmaking and Steelmaking*, No, 6, 1976, pp. 337-442: K. Shermer, "Improved Technology for Processing Sponge Iron in the Electric Arc Furance,' '" *Ironmaking and Steelmaking*, No. 3, 1975, pp. 1 18-92; J. D. 1)' Entremont, Armco Steel Corp., paper presented a I 1979 conference.

[22] Brown and Reddv, op. cit.

[23] Rollinger, op. cit.

Alternate Energy Sources.—In addition to coal, other inexpensive solid reactants may be used for DR systems. These include biomass, peat, lignite, wood and paper wastes, and municipal and industrial wastes. Biomass, which embraces a large variety of vegetable and animal wastes, and the other materials have similar advantages and drawbacks as reactants. They cost little, are generally available, and are regenerable. They also contain little inorganic matter, such as ash, and few of the elements, such as sulfur and phosphorus, that are undesirable in steel. In addition, these materials frequently provide very reactive sources of carbon; biomass, for example, may consist of cornstalks, nutshells, and perhaps pulp and skin from a variety of food-processing operations.

The chief disadvantages of these materials are their high moisture content and low bulk density. The direct charging of wet, low-density materials into iron production units, such as rotary kilns, causes a substantial loss of productivity, which translates into higher energy, labor, and capital costs per tonne of product. Both problems can be overcome by pretreating (drying, carboning, etc.) and compacting the materials, although this too takes energy. Ironmaking operations present an attractive site for processing these materials. Most large steelmaking plants have low-temperature waste heat available. Transferring that heat is not very efficient, however, and the bulky equipment is costly.

If inexpensive methods can be found to convert all of these materials into a product roughly equivalent to sub-bituminous coal in moisture, density, and transportability, then their use by DR plants within a reasonable distance might follow. The pretreatment technologies are broadly recognized and are under intensive investigation throughout the country; significant advances should occur during the next decade.

Advantages of DR Systems.—DR systems offer an advantageous alternative to the blast furnace process for the production of iron from iron ore and recycled iron oxide, and to scrap in the manufacture of steel products in the electric furnace. Not all of the potential advantages of using DR would apply to every economic or regional enterprise. Further, it is apparent that there is a wide variety of DR processes from which to choose, and each has its particular advantages and disadvantages. The following advantages, then, should be treated as opportunities presented by the development of DR systems:

- DR units can be built on a variety of scales, to use a variety of charge oxides and reductants, and in a variety of locations;
- scrap-based companies can manufacture high-grade steels from DRI, which, unlike scrap, has a known, uniform composition;
- DRI can be transported and handled easily and can be charged to furnaces on a continuous basis;
- DRI can be used as a feed material for blast furnaces and basic oxygen steelmaking units;
- DR processes do not require metallurgical-grade coke;
- DR systems do not pose environmental problems as severe as those of coke oven-blast furnace systems;[24]
- DR processes can be coupled with several energy-generation systems (nuclear, MHD, etc.);
- DR processes can be coupled with coal gasification systems;
- DR systems can be constructed with comparatively low capital costs; and
- DR systems have competitive operating costs.

The DR processes provide attractive opportunities for all three segments of the steel industry. The integrated segment could increase ironmaking capacity in increments much smaller than is economical for the blast furnace, and could do so without the need to build additional coke capacity or purchase coke. Both integrated and particularly scrap-

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[24] L. G. Twidwell, “Direct Reduction: A Review of Commercial Processes,”’ Environmental Protection Agency, 1979.

based producers would benefit from having DRI as an alternative to purchased scrap. * Nonintegrated plants using DRI could produce higher grade steels and control their operations more readily. In addition, DR facilities would allow this segment to integrate operations from ore to steel product. The alloy / specialty steel companies, too, would benefit to some extent by the opportunity to substitute high-grade DRI for scrap.

In general, the substitution of DRI for scrap lowers residual element (“tramp”) levels, facilitates material handling and charging, and enhances product quality. In addition, DRI enables steelmaker to write tighter specifications for iron units than is usually possible with scrap. Although DRI use does not require special arc furnaces, many developments are likely in electric furnace design for adaptation to DRI.

Difficulties With DR Systems.—Like DR's advantages, not all of its disadvantages apply to each DR system or economic region:

- DR processes have higher energy and material requirements than blast furnaces;
- DR processes cannot be built on a scale equivalent to a large modern blast furnace;
- DRI is a solid product that cannot substitute significantly for “hot metal” as a feed to BOFs;
- DRI must be handled, stored, and charged in a different manner from scrap;
- in coal-based DR processes, special provision must be made for sulfur control;
- solid waste materials (lime, ash) from coal-based DR processes must be disposed of in a different manner than slag from a blast furnace;
- the variety of DR options, many not yet proven on a commercial scale, makes it difficult to select an optimum process for a given set of conditions;
- off-specification DRI (high-oxygen, alkali, silica contents, fines) can damage electric furnaces;
- without special provisions, DRI use might increase the generation of fugitive particulate emissions around electric furnaces; and
- some coals are not suitable for direct use in coal-based DR systems and must be gasified in separate units.

Forecast.—The capacity of DR plants throughout the world has grown at a rate of about 30 percent per year since 1965; however, this growth rate has been achieved in a relatively early stage in the technology's development and adoption, when DR capacity is still less than 5 percent of total world steel production. Nevertheless, forecasts of future growth in DR plant capacity have used rates as high as 13 percent per year for the period 1980-85 and 4.7 percent per year for the period 1990-2005.[25] The latter may still be too low, in view of expected steel production growth rates of 7.5 percent in the developing countries and 3.2 percent in the developed countries for the same period.

Worldwide, it is estimated that about 40 new DR units are planned for operation between 1981 and 1985. About one-half will use natural gas, one-quarter will use coal directly, and the remainder will use liquefied natural gas, gasified oil, gasified coal, or byproduct gas.

The figures shown in table 88 are conservative estimates for the growth of DR capacity. All of these projections might be influenced markedly by shifting practices in the United States and Japan or by industrial activity in China. The table also shows data on actual production of DR plants and it can be seen that production has been far below capacity. This has resulted from a depressed world steel market, startup problems in developing nations, and a combination of high natural gas costs and low scrap prices in the industrialized nations.

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*Also discussed in chs. 7 and 8.

[25] H. W. Lownie, Jr., “Prospects for the Future, ” draft of ch. 13 for forthcoming book on direct reduction edited by J. R. Miller: Lownie's estimate agrees closely with the median estimate established by the Hamersley Delphi study.

Table 88.—Projections for Direct Reduction Growth (millions of tonnes)

	Capacity[a]							Production	
Year	Rate*	North America	Japan	EEC	Third World	Mid East	Free world	Free world[b]	Free world[c]
1975	27.8	2.0	1.2	0.7	4.0	0.0	8.0	2.7	2.7
1979	NA	NA	NA	NA	NA	NA	NA	7.2	9.0
1980	13.1	2.9	4.1	3.6	11.2	4.4	27.3	10.1	14.4
1985	9.3	5.3	6.3	6.6	21.2	9.6	50.6	19.0	NA
1990	5.7	9.5	7.7	9.4	33.9	15.3	78.9	NA	NA
1995	2.4	13.3	9.0	11.9	45.2	20.3	104.1	NA	NA
2000	–	15.3	9.7	13.2	51.2	22.9	117.2	NA	NA

“Annual compound growth rate (%) projected for succeeding 5 years

SOURCES [a]G. St. Pierre for OTA
[b]A.B. Jensen, “New Alternates for Charge Metal lie,” Ferrous Scrap Consumers Coalition Symposium, February 1980
[c]Department of Commerce, “Production of Iron by Direct Reduction, ” May 1979

Direct Steel making

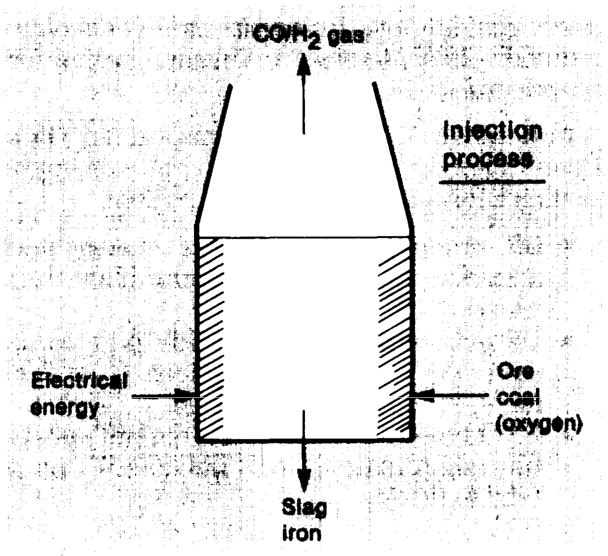
Description.— Direct steelmaking is the conversion of iron ore to steel in a single reactor system. This would represent a radical or major technological advance, because it would replace several operations in either the CO-BF-BOF or DR-EAF sequences.[26] Included in this class of technology are continuous steelmaking systems and plasma steelmaking systems The latter are described separately in a later section of this chapter.

In essence, direct steelmaking allows the reduction, melting, and refining functions to occur and be controlled in a single (perhaps divided) reactor. Figure 31 is a schematic diagram of a proposed system, which has not advanced beyond pilot-plant exploratory work. Furthermore, none of the proposed systems represents the application of new basic principles.

Advantages of Direct Steelmaking.—The advantages of direct steelmaking may be summarized as follows:

- ore is converted to steel in a single reactor, rather than first making iron and then making steel;

Figure 31 .—Schematic Diagram of Direct Steelmaking System



SOURCE S. Eketorp for OTA

- consolidation of fumes, transfer of liquid products, and environmental problems are reduced;
- less land area, equipment, and capital are required; and
- a variety of raw materials (iron oxide and reductant) may be used.

Suitability for Industry Segments.—Direct steelmaking processes provide an opportunity for integrated steel plants; however, it is unlikely that significant adoption by alloy/ specialty or scrap-based companies would occur rapidly.

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[26] S. Eketorp, ''Decisive Factors for the Planning of Future Steel Mills, ” *Iron and* Steelmaker, December 1978, pp. 37-4 1; D. H. Houseman, “Continuous Steelmaking Processes,”' *Steel* Times, May 1978, pp. 457-462; A. K. Syska, “The S-Process,”' OTA seminar, May 2-3.1979.

Disadvantages of Direct Systems.—None of the pilot-plant efforts on direct steelmaking has yet been successful. Specific technical problems exist that require major research, development, and demonstration efforts, such as:

- wall refractories are needed that can withstand severe chemical and mechanical erosion;
- procedures are needed for controlling steep chemical potential gradients (e.g., simultaneous injection of reductant and oxygen);
- injection refractories that can operate continuously must be developed;
- uniformity of product must be maintained over a significant period; and
- steel output per unit of reactor volume must be increased to compete with alternative routes to steel.

Forecast.—The idea of going from oxide concentrate directly to steel in a continuous, smooth operation has excited imaginations for many years. Europeans, Americans, and many others have spent a great deal of money on small pilot efforts, but none of these efforts, has been particularly successful from a research standpoint, and none has been carried to commercial scale. The problem has been that the different functions cannot be isolated properly: all the equipment must be tied up in a single strand, and the system has little flexibility with respect to either process variables or product requirements.

The major recent gains in improving the speed, efficiency, and productivity of steelmaking systems have been accomplished by separating rather than combining the different parts of ironmaking and steelmaking. In integrated systems, for example, substitution of a desulfurization station between the blast furnace and the steelmaking units can result in the increased productivity of each at a relatively low capital cost. In the development of the AOD system, adding another unit to separate the melting function from the refining function has markedly increased the productivity of stainless steel and high-alloy production systems.

Although major advances in the rates of reduction, melting, and refining and in the throughput per unit volume of equipment must be made, it is very unlikely that any direct, continuous single-reactor process will assume commercial significance in the next decade.

Plasma Steelmaking

Description.— Plasmas are already used commercially for steel melting and refining, but they can also be used for reduction reactions.[27] A plasma is generated in a steelmaking reactor either from "inert" gases like argon or nitrogen or from reactive gases like hydrogen or methane, and fine iron oxide particles and solid reductant are then fed into the plasma. While most plasma smelting systems use the plasma as an intense and efficient source of energy, some experts now think that the plasma also participates in unique reactions with the oxide undergoing reduction. Figure 32 is a schematic diagram of a plasma smelting (reduction) system for steel production. Bench-scale and small pilot systems have been operated, and several are reported in the literature. These systems include:

- the extended arc flasher at the University of Toronto;
- the falling film reactor at Bethlehem Steel Corp.;
- the SKF Hofors plasma reduction process;
- the rotating plasma process; and
- the expanded precessive plasma furnace.

Advantages of Plasma Steelmaking.—The advantages of the plasma steelmaking systems are similar to those of the direct steelmaking processes, but with several additional advantages:

- the plasma provides an intense, concen-

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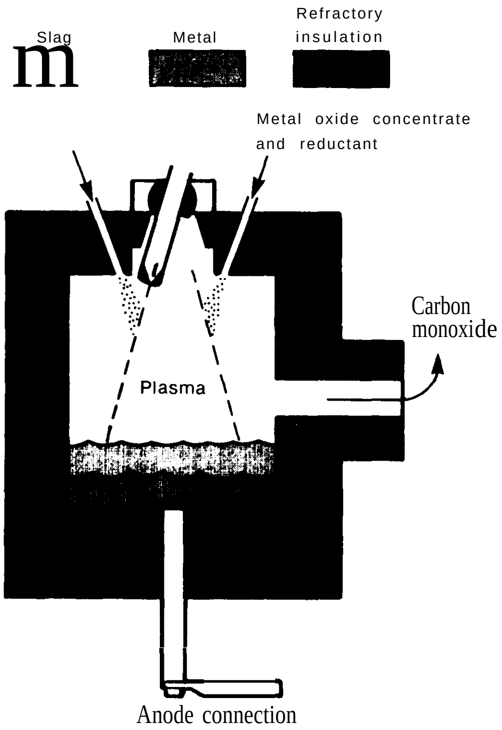
[27] L. Gulliver and P. J. F. Gladman, "Plasma Furnace Processing," OTA seminar, May 2-3, 1979; D. R. McRae, "Plasma Reduction of Iron Ores to Raw Steel," OTA seminar, May 2-3, 1979, paper No. 15; K. J. Reid, "Direct Steelmaking Based on Solid-Plasma Interactions," OTA seminar, May 2-3, 1979, paper No. 16.

Figure 32.-Plasma Steelmaking System

Expanded precessive plasma process
using closed-bottom reactor



SOURCE. Tetronlcs Research & Development Co., Ltd, United Kingdom and foreign patents pending.

trated source of energy for endothermic reactions;

- the plasma system is ideally suited for the conversion of finely divided solids;
- plasma processes may involve some unique gas-solid-liquid reactions that are not encountered during conventional processing; and
- plasma "reactions" may be very fast.

Suitability for Industry Segments.—If successful development of the plasma steelmaking processes occurs, they could provide major opportunities for all three segments of the industry. Alloy/specialty companies might benefit in a most significant manner by being able to produce highly alloyed steels directly from oxide charge materials rather than from ferroalloys.

Disadvantages.— All of the disadvantages of the direct steelmaking processes apply to some degree to the plasma systems. An additional difficulty is that the engineering developments and control procedures for plasma systems are still in an early stage. Also, the reported power requirements and of fgas volumes are very high.

Forecast.—Some commercial development of plasma steelmaking systems is likely to occur by 2000. The first adoptions are likely to be for the manufacture of alloy steels.

Direct Casting

Description.— Direct casting is the pouring of liquid steel directly into thin solidified sections suitable for conversion into strip products. While continuous casting produces slabs that must be hot and cold rolled into thin-gauge products, direct casting would produce a thin product ready for final rolling into suitable gauges.

Advantages of Direct Casting.—Direct casting would eliminate the necessity to produce slabs for hot rolling. Some unique properties might be developed, particularly if an amorphous material can be produced in the casting step.

Suitability for Industry Segments.—All three segments of the industry would benefit from the development of this technological opportunity.

Disadvantages.— Flexibility in the control of properties and gauges of sheet products might be lost.

Forecast.—The need for development and demonstration is so extensive and costly that it will take many years to bring such a technique to the point of adoption on a significant scale.

Incremental Technologies

From literally thousands of advanced incremental technological opportunities that are or will be available to the steel industry, a few have been selected for illustrative purposes, These have particularly wide applicability during the next 10 years.

External Desulfurization

External desulfurization refers to all processes that lower the sulfur content of hot iron after it leaves the blast furnace and before it enters a steelmaking unit. It may be accomplished in torpedo cars or in ladles by introducing a sulfur-capturing reagent through plunging or lance injection. Many reagents have been used, including calcium oxides, calcium carbides, soda ash, and magnesium-impregnated coke (mag-coke). Special handling, injection, or plunging equipment must be used to provide a fast, efficient reaction. In addition, pollution abatement equipment is usually required.

The principal advantages of external desulfurization are that:

- the blast furnaces can be operated with less basic slags and at higher production rates;
- lower sulfur-content hot metal can produce low-sulfur steels in BOF processes; and
- capital requirements are modest compared to the alternatives.

External desulfurization is a proven technology available to the steel industry in a variety of engineering "packages. " It benefits integrated and alloy/specialty steel companies that use the CO-BF-BOF sequence. Continuing adoption by integrated steel companies is expected through the early 1980's.

Self= Reducing Pellets

Self-reducing pellets are prepared from a finely divided iron oxide concentrate, a solid reductant such as char, and lime (for sulfur absorption).[28] They contain all required reactants for iron production. The pellets may be cold- or hot-bonded, but heat is required for the endothermic reduction reaction. In addition, porosity is required to eliminate gaseous reduction products (Co, Co_2).

The principal advantage of self-reducing pellets is that no gaseous reactant is required. It is only necessary to establish suitable heat transfer in a reactor to produce sponge iron. In addition, the pellets could be used as supplemental feed to a BF system. The principal disadvantages are that the production, handling, and conversion techniques are unproven commercially, although some limited tests appear promising. Abrasion and impact resistance is important from both a handling and a processing standpoint. Another disadvantage is that the sponge iron quite readily absorbs sulfur from the carbonaceous reductant.

The development of self-reducing pellets could benefit all segments of the industry, and it is likely that development will proceed as an adjunct to DR developments during the next decade.

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[28] E. M. Van Dornick, "Furnace Reduction of Pelletized Ferriferous Materials,"' U.S. patent No. 3,340,044, Sept. 5, 1967; G. D. McAdam, D. J. O'Brien, and T. Marshall, "Rapid Reduction of New Zealand Ironsands. " *Ironmaking and Steelmaking*, No. 1, 1977, pp. 1-9; K. Schermer, "Improved Technology for Processing Sponge Iron in the Electric Arc Furnace, " *Ironmaking and Steelmaking*, No. 3. 1975, pp. 118-92.

Energy Recovery

Energy recovery technologies in the steel industry have advanced significantly during the past 10 years.[29] The pressures of rapidly rising energy prices and declining availability have served as major incentives. Energy now represents nearly 20 percent of the cost of producing steel; 10 years ago it was 10 percent. There are a number of energy recovery opportunities available to the steel industry, and some new ones may be on the way. Nippon Steel Co. of Japan has demonstrated the effectiveness of energy recovery and conservation. In 5 years (1974-78) they achieved a total energy savings of 11.4 percent. Of this total, 3 percent resulted from energy-saving equipment installation, 6 percent from changes in operation, and 2.4 percent from modernization of facilities such as the use of continuous casting.[30]

Various estimates have been made of the potential for energy conservation in the steel industry. A North Atlantic Treaty Organization study indicated a potential for energy savings of up to 40 percent.[31] A study in the United Kingdom concluded that a savings of 30 percent was possible.[32] This would be somewhat applicable to the United States. Another study indicated that 15 to 20 percent of present energy consumption could be saved within the next decade. That study noted that two-thirds of the heat input to an integrated plant is wasted: 13 percent in waste gases, 16 percent in cooling water, 13 percent in sensible heat in residual matter such as slag and coke, and 24 percent lost to the ambient atmosphere.

Electric power could be generated by gas-expansion turbine generators operating on high-pressure top gas from BFs. The technology has been demonstrated in Japan, but adoption is difficult and economically questionable for most older BFs. Similarly, hot offgases from coal-based DR kilns are being used to produce steam for electrical generation.[34]

Another demonstrated technological opportunity is in BOF offgas collection.[35] Carbon monoxide is released intermittently from steelmaking units, and its collection and use for fuel purposes have been adopted by some European, Japanese, and American operators. Hood design is the most critical parameter in modification for this purpose.

Adoptions of this nature are likely to continue through the 1980's along with the development and demonstration of new concepts for recovery of sensible heat from process materials (coke, slag, sinter, and steel),

Continuous Rolling

If slabs from continuous casting units could be rolled directly without the necessity of reheating, a considerable amount of energy could be saved. However, the technology is difficult to develop and the capital costs could be high. In addition, the effect on cold-rolling operations and the ability to control final steel properties with such processing are unproven. Until research efforts show the feasibility of this technology, and until the composition and cleanliness of liquid steel fed to continuous casters are controlled more tightly, any major development effort is unlikely. With continued developments in secondary refining[36] and perhaps filtration, direct rolling may become an attractive technological opportunity.

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[29] Morley, "Industry is Making Its Energy Work Harder," *Iron* Age, Aug. 27, 1979.

[30] *Nippon Steel News*, December 1979.

[31] E. G. Kovach (ed.), *Technology of* Efficient Energy Utilization, Pergamon Press, 1974.

[32] G. Leach, "A Low Energy Strategy for the United Kingdom,'" *International Institute for the* Environment *and* Development, 1979.

[33] H. G. Pottken, et al., *Metallurgical Plant and* Technology, vol. 4, 1978, p. 47.

[34] Metal Producing, February 1980.

[35] " Potential for Energy Conservation in the Steel Industry to Federal Energy Administration, " Battelle, Columbus Laboratories, May 30, 1975; U. K. Sinha, "Recent Developments in the Iron and Steel Industry in the Light of Energy Conservation," *Steel* Times, January 1978. pp. 61-71.

[36] J. C. C. Leach, "Secondary Refining for Electric Steelmaking," *Ironmaking and Steelmaking*, No. 2, 1977, pp. 58-65.

[37] R. L. Reddy, "Some Factors Affecting the Value of Direct Reduced Iron to the Steelmaker," 38th AIME Ironmaking Conference, Detroit, Mich., 1979.

High= Temperature Sensors

It is difficult to determine the composition, cleanliness, and temperature of liquid iron and steel on a continuous, reliable basis. Although immersion thermocouples and oxygen-potential probes have been developed for intermittent measurements, no instruments are available for long-term continuous control.[38] The difficulty lies not in the primary instruments but in the severe conditions under which they must operate. Under reactive conditions at 1,550° C, “protective” materials fail rapidly. Hence, developments in this area depend on the development of immersion materials and/or major innovations in remote sensors.

If continuous control measurements of temperature, composition, and cleanliness can be developed, significant increases in productivity and overall quality could be achieved. As is always the case, improvements of this nature lead to decreased energy and raw material consumption per tonne of steel product shipped. Contact and remote sensors for hot solid products in process are available and under continuing improvement. The major research problem is in the liquid steel processing area. All sectors of the industry would benefit, and the impact would be significant. Breakthroughs on a selective basis are expected during the next two decades.

Computer Control

This subject is very broad and complex. From a “black box” point of view, the steel industry appears no more complex than other basic industries. The complexities arise when the inputs must be fully characterized and the process mechanism (reaction and transformation rates, heat and mass transfer, electrical and electromechanical characteristics, and process variables) must be fully described. Despite major effort, the surface has only been scratched.[39]

Processing of Iron Powders

The potential advantages of avoiding the very high temperatures associated with liquid steel processing and the potential opportunities for making difficult alloy components with iron powders have provided incentives for many ventures in iron powder processing. The powdered metal industry has developed proven technology for converting iron oxide to metallic products through powder processing,[40] but powder processing has not competed with liquid processing for major steel markets. Efforts to roll quality iron powder directly into thin-gauge steel sheet continue,[41] The technology must advance to the point where wide strip with a uniform thickness and structural quality can be produced before significant demonstration can occur. Cost competitiveness might be achieved through major energy and fuel savings in the 1990’s.

Plasma Arc Melting

In the Soviet Union and East Germany, plasma melting of steel scrap has become an industrialized process.[42] Plasma arc furnaces with capacities of 27.2 to 90.7 tonnes are in operation there, replacing conventional EAFs used to melt and refine steel scrap. The furnaces may also be used for melting DRI.

In the conventional EAF, electric arcs are ignited between carbon electrodes and the furnace charge. Heat is transmitted by convection and radiation. Plasma arc furnaces

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[38] J. P. Ryan and R. R. Burt. “Oxygen-Sensor Based Deoxidation Control,” *Iron and Steelmaking*, February 1978, p. 28.

[39] C. L. Kusik, M. R. Mournier, and G. J. Kucinkas, “State-of-the-Art Review of Computer Control in the Steel Industry, ” A. D. Little, Inc., contractor report for the Department of Energy, June 1979; Central Intelligence Agency, “Foreign Development and Application of Automated Controls for the Steel Industry, ” S.K. 79-10010, January 1979; Iron Age, Feb. 4, 1980: H. Okada, “Background to ‘technological Advance in the Japanese Steel Industry, ” Workshop on Innovation Policy and Firm Strategy, Dec. 4-6, 1979.

[40] Strauss and Heckel, op. cit.

[41] M. Ayers, “New Technology for Steel Strip Production, ” OTA seminar, May 2-3, 1979, paper No. 11: P. Witte, “An Energy Efficient, Pollution Free Process for the Production of Steel Sheet from Iron Concentrates,” OTA seminar. May 2-3, 1979. paper No. 12.

[42] Eketorp and Mathiesen, op. cit.: A. S. Borodachev, G. N. Okorokov, N. P. Pozdev, N. A. Tulin, H. Fiedler, F. Muller, and G. Scharf, “Melting Steel in Plasma Electric Furnaces, ” *Stal*, 1979, pp. 115-17.

have bottom electrodes under the charge. The plasma arc is generated by forcing a stream of argon or nitrogen gas through an electric arc, which ionizes the gas and raises its temperature. The gas may reach temperatures as high as 13,7000 C. The arcs of injected gas throw plasma streams through ports in the furnace walls into the charge.

The advantage of the plasma arc furnace is that the plasma process transfers heat much more rapidly to the metal being melted and refined. Radiation and convection are much more efficient. According to reports, the power coefficient is 96 percent, which is considerably higher than in the EAF, where typical values are on the order of 75 percent.

Long-Range Opportunities

Perhaps the two most significant opportunities on the horizon for the steel industry are:

- complete elimination of the need for fossil fuels through the production of hydrogen by water hydrolysis; and
- adaptation of steelmaking to the potentials afforded by advanced nuclear reactors, high-temperature gas-cooled reactors, and, further off, fusion or MHD reactors .43

For the first opportunity to become a reality, energy from nuclear reactors must be available at costs well below those for fossil fuels. Hydrogen can then be used as a substitute for other gaseous reductants in most of the DR processes. For the second opportunity to emerge, the steel industry must work closely with the nuclear industry and take advantage of related developments in plasmas and MHD.”[44] Although the Japanese have made the first major move, * a U.S. energy-chemical-steel consortium is underway. [45]By the turn of the century, experts expect a demonstration plant to be operating. By combining the best features of available technology, it might be possible to achieve very fast oxide reduction and melting in DR and melting units.

Changes in Steel Products

Perhaps the major factor affecting the development of steel mill products is the energy shortage. Steel products play a large role in energy production (e.g., in tubing for petroleum production and transport and in materials for fossil fuel processing equipment and for electricity generation), and the increased needs of the energy sector will place greater demands on steel products. At the same time, the role of steel in the transportation industry will be one of helping to conserve energy (e.g., by decreasing vehicle weights to save fuel or by increasing the efficiency of electrical equipment such as motors and transformers). In these energy-related areas, steel products will have to achieve higher levels of performance in such characteristics as strength, toughness, corrosion resistance, fabricability, weldability, and formability. (See ch. 5 for a discussion of these properties.)

Such characteristics have always been considered in the development of steel alloy composition and processing. Except for the specialty steels (such as high-alloy steels, stainless steels, and tool steels), production costs, when weighed against properties, have generally led to the use of carbon as the ma-

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“J. Cushman, “Nuclear Steel: Long Wait for the Birth of an Industry,” *Steel Week*, Nov. 26, 1979.

“R. W. Anderson, “Application of MHD Power and MHD Exhaust Gas Sensible Heat,<’ OTA seminar, May 2-3, 1979,

*See ch. 9 for discussion of the Japanese nuclear steel making program.

[45] Cushman, op. cit.

jor modifier of properties. That is, it has been possible to satisfy most markets by using the range of properties attainable from carbon steels in either the hot-rolled, cold-rolled, or heat-treated condition.

The combinations of characteristics that will be needed to meet future performance requirements are not readily attainable with the plain carbon steels. Consequently, steel metallurgists have been using a combination of strengthening mechanisms to develop materials with greater strength and toughness—a difficult combination. A number of new products have already been marketed to a limited degree or are in advanced stages of development. In some cases, barriers in processing technology are affecting or are likely to affect the product developments.

Incremental Product Developments

High-strength low-alloy (HSLA) steels are already marketed for energy production and automotive applications. In these steels, alloying elements such as titanium, vanadium, columbium, molybdenum, manganese, nickel, or cobalt are added. Carbon content is reduced in order to achieve high strength along with good toughness, better weldability, and better corrosion resistance. The precipitation of fine alloy carbides, which are smaller and better distributed than the carbide in commodity steels, improves the properties of the steel. This alloying effect and controlled rolling and heat treatment, which create small gains in strength and toughness, are the basis of the HSLA steels.

Dual-phase steels are on the market on a limited basis in automotive applications. These steels take advantage of the strength of a high-hardness crystalline form of iron (martensite) but use it in a mixture of very fine grains of relatively soft, virtually carbon-free iron. The combination of grain hardness and fine grain size, which can control the deformation pattern of the mixture, makes the dual-phase steels especially useful in sheet metal applications. The original material for sheet metal is relatively soft and easily shaped, but as it is being formed into shape, it attains the high strength needed for final service. This strengthening during the deformation process, or work-hardening, of a fine grain size material is a major alternative to the heat-treatment process for HSLA steels. The lack of carbide precipitates in the dual-phase steels generally gives them better weldability, formability, and corrosion resistance than conventional HSLA steels.

Superplastic ferrous alloys are less developed than superplastic nonferrous alloys, but there are some mainly small-scale test applications, primarily for the automotive and packaging industries. These ferrous alloys extend the concept that very fine-grained solids are both stronger and tougher than conventional steels by using ultrafine grains. The grains in these alloys are extremely fine (0.lμ to 5.0μ) mixtures of two crystalline phases, one iron (austenite) and the other a ceramic iron carbide (cementite). When this material is deformed at a moderately elevated temperature, it can be shaped, like a typical organic polymer plastic, into intricate patterns with very little applied force. The potential savings in design of dies and operation of presses for forming of sheet metal could be substantial. Moreover, by using such alloys in bulk form, such items as gears might be formed in a small number of simple extrusion steps with significant savings of energy and material compared to current machining practices.

One-side galvanized steel is described and discussed in chapter 9.

Major Product Developments

Amorphous ferrous alloys are under development in some small-scale test applications, primarily in electromagnetic devices. The amorphous ferrous alloys demonstrate the reduction of grain size taken to the limit, so that the aggregates of atoms no longer have any of the ordered characteristics of crystalline solids; they are amorphous solids like glass. Such materials have very useful properties, such as high strength, corrosion resistance (higher than ferrous alloys such as stainless steels), and easy magnetization (equal or better than materials such as permalloy).[46] The ferrous metallic glasses, as they are commonly called, can be obtained only by an extremely rapid cooling from the liquid to the solid state (10^{60} C/see). They do not have compositions typical of steels, although they have iron contents ranging from 3 to 93 percent. The greatest potential for these materials seems to be in transformer cores or in electric motors. The ease of magnetization would greatly increase transformer and motor efficiency.

According to a recent description of the potentially large impact of metallic glass:

> The random structure gives metallic glass unique magnetic properties that translate into vastly improved transformer efficiency, And, if scientists can learn to use this substance in the transformer's moving counterpart—the electric motor—Americans eventually could save up to $2 billion annually in energy costs.
>
> According to the U.S. Department of Energy, metallic glass will begin to tap enormous quantities of wasted electric energy before the decade ends.[47]

The National Academy of Sciences has noted that commercial exploitation of these materials will stimulate much R&D during the next 5 to 10 years.

Development Problems

These steel products or potential products face some common problems in further development and use, problems which reflect the higher quality level of those products. Two are general problem areas: control of melt chemistry; and ability to carry out complex and/or tight-specification thermomechanical processing.

The melt chemistry problem involves the control of both impurities and alloy additions. The role of impurities, such as sulfur, oxygen, nitrogen, hydrogen, and in some cases even carbon, in affecting the properties of further processing of steel is well known. Control of those impurities requires more extensive processing such as vacuum remelting, or degassing, as well as better process monitoring and control procedures [e.g., the use of solid-state oxygen detectors for rapid chemical analysis). The control of alloy additions requires similar attention. It is noteworthy that the newer low-alloy steels are called "microalloyed" steels, which reflects the low levels of alloy addition as well as the need to control those levels within narrow ranges.

The problem of thermomechanical processing is central to all the materials that have been discussed. Facilities to carry out such processing, or the lack thereof, will significantly affect the marketing of the new steel products. These facilities will affect the product costs in two ways: the more complex and more closely controlled processing that these materials require will raise operating costs; and the equipment and facilities for producing the higher quality products will not be part of the existing plant of most steel mills, so production will require investment in new facilities. It is reasonable to assume that those mills with the more sophisticated thermomechanical processing capability will be in the most competitive position to participate in the market for these products.

The new products also have some individual disadvantages:

- Both HSLA and dual-phase steels pose some problems in die design if they are to be properly formed. For HSLA, the major problem is that its great strength causes "spring-back;" that is, the steel deforms elastically, but then springs back after the die pressure is removed. For dual-phase steels, the problem is to have the die contour control strain distribution so that sufficient hardening occurs. In both dual-phase and HSLA steels, corrosion resulting from the use of thinner gauges of steel is of some concern. The use of more extensive corro-

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[46] J. J. Gilman, "Ferrous Metallic Glasses. " *Metals* Progress, July 1979, pp. 42-47.

[47] Freeman, "Science and Technology—A Five Year Outlook. " National Academy of Sciences, 1979.

sion protection methods will probably compensate for that potential disadvantage.

- Superplastic ferrous alloys are as easy to form as plastics, but like plastics they also have a low forming rate: it takes longer to form one piece of the superplastic alloy than to form an ordinary steel sheet. Additionally, the fine grain size of the superplastic alloys is likely to lower their corrosion resistance.
- The amorphous ferrous alloys suffer from two significant disadvantages with respect to structural applications. They are relatively brittle (have very low ductility), and they are currently only available in very limited shapes and sizes. Perhaps the biggest potential problem in applying the amorphous alloys is that they are extremely susceptible to crystallization or devitrification if service is at elevated temperatures.

Summary

There are a number of steel mill product developments that indicate a continued competitiveness for steel products. Although product development continues to improve the applicability of the materials, there are needs to be met in the processing technology at the mills before full advantage of the potential markets can be realized, Of special note are the need to gain greater control over chemical composition and metallurgical structure in order to produce uniformly high-performance materials, and the need to develop the procedures and facilities to carry out the more complex processing needed to obtain the desired metallurgical structures. Mills that have the financial and technical resources to meet these needs should be at an advantage in developing the markets.

The steel industry has played the dominant role in the development of HSLA, dual-phase, and superplastic steels; but chemical companies, universities, electrical equipment firms, and commercial research organizations have been very active in innovating in the glassy steels. There is a high probability that new companies will become the dominant producers of glassy steels.

CHAPTER 7

Technology and Raw Materials Problems

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CHAPTER 7

Technology and Raw Materials Problems

Summary

Coke and scrap are essential raw materials for the steel industry: coke is the basis for reducing iron oxide to metallic iron in blast furnaces; scrap is the major input to electric steelmaking furnaces. The adequacy of future supplies of both is uncertain.

A shortage of cokemaking facilities, not of metallurgical coal from which to make coke, is the problem. Coke, used by the integrated steel companies as a feedstock in ironmaking, is mostly produced in byproduct ovens from high-grade metallurgical coals. About one-third of all domestic coke ovens are considered old by industry standards. These older ovens are less efficient than newer ones and tend to produce a poorer quality coke. The domestic steel industry has a much higher coke oven obsolescence rate than do other major steel-producing countries, and the actual productive capability of U.S. coke ovens has declined by almost one-fifth since 1973. The major reasons for this capacity decline are growing capital costs and regulatory requirements, both of which discourage new coke oven construction.

As cokemaking capacity declines, coke imports are growing and employment is falling off in this phase of steelmaking. Domestic coke consumption has been higher than production during 3 of the past 6 years. In 1978, domestic consumption was 5.4 million tonnes, an amount 16 percent higher than domestic production. One estimate is that by 1985, the coke shortage will increase to about 9 million tonnes, or 20 percent of domestic production, as capacity declines further and demand grows. However, a different study indicates that ample domestic cokemaking capacity exists,

Several options, with varying degrees of effectiveness, could help stabilize or reduce current coke shortages. These include: importing more coke, using more direct reduced iron (DRI), importing more semifinished or finished steel products, increasing the use of electric arc steelmaking (which would also require more scrap), and improving the coke-use rate in blast furnaces.

The steel industry is also a major consumer of commodity ferrous scrap. Although scrap prices have doubled since 1969, in real terms scrap remains an economical source of iron input for steelmaking. However, the future physical availability of high-quality scrap and its price are matters of some concern. Scrap industry processing capability and the availability and cost of transportation may affect scrap supply; however, the problems that exist in these areas are being remedied to some extent.

Scrap supply projections range from adequate, though at higher prices, to inadequate, even at higher prices. Because the substitution opportunities for scrap are limited, demand does not decline significantly when supplies diminish and prices increase. Most near-term technological changes will tend to increase the use of scrap; these changes include the growing use of electric furnaces and continuous casting and the modification of basic oxygen furnaces to increase the proportion of scrap used. At the same time, demand is growing for high-performance specialty steels, which incorporate a higher proportion of alloy and other materials that make scrap recovery difficult.

The growing demand for scrap places the steel industry in an increasingly difficult position. The energy-efficient, nonintegrated producers will be affected most severely by scrap price increases and supply problems. There are statutory resource conservation targets that apply to scrap, but these do not distinguish scrap-use problems by industry segment. Furthermore, for economic or technical reasons, these targets are not always feasible on a plant basis.

Options that might be used to offset scrap supply problems and to maintain existing scrap inventories include expanding the use of DRI and imposing scrap export controls. Scrap exports have been relatively stable so far, but they are expected to increase because of worldwide increases in electric furnace use. U.S. scrap is attractive to many foreign buyers because of favorable currency exchange rates. The bleak outlook for scrap has prompted steel industry interest in export controls, but the scrap industry opposes such measures.

Iron ore supplies do not appear to pose a substantial problem that calls for, or affects, new technology. Although about one-third of iron ore is imported, the United States has substantial domestic ore resources and modern, efficient ore mines and processing facilities. Nevertheless, industry economics are such that imports will continue, ' Observations by World Steel Dynamics confirm this outlook:

> The North American iron ore business has a unique industrial structure, resulting from the combination of economics (huge capital and economy of scale requirements), traditional factors, and the longer-term strategic perceptions of the various players.
>
> Until the 1960's there was always a major advantage for the steel producer to operate its own iron ore mines. And these mines were developed jointly in view of the huge capital requirements, economy-of-scale factors, and long lead times, The self-producers' advantage eroded during the 1960's as numerous foreign ore properties were developed and technological changes brought down transportation expenses. However, the nationalization of iron ore properties was important for long-term economic survival. There are not many iron ore properties in North America whose output is sold on a year-to-year basis to the highest bidder. The mentality of steel producers is that they have preferred long-term arrangements,
>
> Today, with steel production at high levels in the United States and inventories depleted by the iron ore strikes, demand is strong for the output of North American iron ore properties. Should the Western World economy be stagnant in the years ahead, economic forces will push down the profit margins of North American iron ore producers—as was the case during the 1960's and early 1970's. Conversely, if Western World economy is strong, Rotterdam iron ore "spot" prices will rise sharply within the next few years.[2]

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[1] Iron Ore, Bureau of Mines, MCP-13, May 1978.

[2] World Steel Dynamics, Core Report A, ch. 12, 1979.

Coke Supply and Demand

A recent study for the Government concludes that the United States faces a shortage of metallurgical coke that is expected to worsen in the next 3 to 5 years.[3] Coke is an essential, coal-based industrial material used primarily in the steel industry's blast furnaces to reduce iron ore to iron, which is subsequently refined into steel. The United States holds the most favorable world position in terms of the size and quality of its coking-coal reserves and the technological capability for their commercial development. Nevertheless, as a result of coke oven obsolescence and declining capacity, the Nation's metallurgical coal reserves are being underutilized. Domestic coke producers are unable to satisfy consumer demand and substantial quantities of coke are being imported to supply the domestic deficit. Under current conditions, it is possible that this situation will not improve and that dependence on imported coke will increase, in which case domestic iron and steel production may eventually be

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[3] Most of the material on coke presented in this chapter was obtained from William T. Hogan, S. J., and Frank T. Koelbe, Analysis *of* the U.S. Metallurgical Coke Industry, prepared for the Economic Development Administration and Lehigh University, October 1979.

curtailed. Alternatively, the use of steelmaking technologies not based on coke will increase and improvements in the technology will result in ample domestic cokemaking capacity.’

U.S. Metallurgical Coke Industry: Process and Age Distribution

The U.S. coke industry consists of 34 companies with 59 plants in 21 States. The current annual capacity of these plants is about 57.5 million tonnes (table 89). Forty-six of these plants are “furnace” plants, operated by iron and steel companies that produce coke primarily for use in their own blast furnaces; the other 13 are “merchant” plants that generally sell their coke on the open market to foundries and other consumers. Furnace plants produce 93 percent of the Nation’s coke output (table 90).

Ninety-nine percent of all domestic “oven” coke is produced in byproduct ovens. * Byproduct ovens use a distillation process that heats metallurgical coals to high temperatures to drive off their gaseous content. The resulting coke is hard, porous material, high in fixed carbon and low in ash and sulfur, which is used as a reductant in the blast furnace for the ironmaking phase of steelmaking. A major advantage of byproduct coke ovens is that they permit the recovery of salable, petroleum-type products, whose value is rapidly increasing.

About one-third of total coke oven capacity is 25 or more years old, and nearly one-fifth is in the 20- to 25-year age category (see table 90). Domestic coke oven obsolescence rates are high compared to those in other major steel-producing countries. About two-thirds of all coke ovens in the European Economic Community (EEC) countries are less than 20 years old, and in Japan nearly 70 percent of the coking capacity is less than 10 years old and none of it is more than 25 years old.[5]

The generally accepted standard for the normal, effective lifespan of a coke oven is 25 to 30 years. Compared to newer coke ovens, those installed 25 to 30 years ago are less efficient, generate more pollution, require greater maintenance, produce lower quality coke, and contribute less to the overall productivity of the blast furnaces using that coke. Based on this standard, facility obsolescence is an acute problem for the domestic coke industry.’

‘C. A. Bradford, “The Phantom Coke Shortage, ” Merrill Lynch Pierce Fenner & Smith, 1980.

*An alternative coking method, the beehive process, is used by only two plants. They produce relatively minor quantities of “beehive” coke, most of which is marketed for blast furnace use and classified separately for statistical reporting purposes.

‘International Iron and Steel Institute Survey, 33 *Metal* Producing, December 1979.

[6] Hogan and Koelbe, op. cit., p. ix.

Table 89.—Geographic Distribution of U.S. Coke Oven Capacity

States	Number of plants	Number of batteries	Number of ovens	Capacity in existence	Percent of total
Alabama	7	25	1,215	5,182,338	9.02
California, Colorado, Utah	3	14	710	3,273,472	5.70
Connecticut, Maryland, Massachusetts, New Jersey, New York	4	18	1,074	4,987,013	8.68
Illinois	4	7	326	1,807,560	3.14
Indiana	6	25	1,076	9,926,684	17.27
Kentucky, Missouri, Tennessee, Texas	5	10	415	2,094,916	3.64
Michigan	3	8	508	3,338,690	5.81
Minnesota, Wisconsin	1	2	100	163,210	0.28
Ohio	12	35	1,878	8,619,017	14.99
Pennsylvania	12	46	2,962	14,679,309	25.54
West Virginia	2	9	519	3,411,191	5.93
Total	59	199	11,413	57,483,400[b]	100.00

aTonnes of Potential maximum annual capacity in existence on JuIy 31.1979, as determined by Fordham University survey.
b51.8 million tonnes are in operation, while actual p[roductive capacity has been estimated at 476 million tonnes (see table 98)

SOURCE William T Hogan, *Analysis of the U.S. Metallurgical Coal Industry, 1979*

Table 90.—Age Distribution of U.S. Coke Oven Capacity

Age in years[a]	Number of batteries	Number of ovens	Capacity[b]	Percent of total
Furnace plants				
0-5	24	1,437	12,028,221	22.66
5-10	7	526	4,687,077	8.83
10-15	6	330	1,583,767	2.98
15-20	20	1,225	5,737,183	10.81
20-25	40	2,383	10,746,376	20.24
25-30	37	2,216	9,793,931	18.45
30-35	17	1,071	5,072,425	9.56
35-40	12	650	2,728,886	5.14
Over 40	6	238	705,809	1.33
Total	169	10,076	58,083,675	100.00
Merchant plants				
0-5	4	242	901,132	20.48
5-10	2	95	419,778	9.54
10-15	4	201	827,638	18.81
15-20	1	60	217,834	4.95
20-25	0	0	0	0.00
25-30	7	298	947,810	21.54
30-35	1	47	86,074	1.96
35-40	3	100	256,899	5.84
Over 40	8	294	742,556	16.88
Total	30	1,337	4,399,721	100.00

[a] Age dates from first entry into operation or from last date of rebuilding.

[b] Tonnes of potential maximum annual capacity in existence on July 31, 1979, as determined by Fordham University survey.

SOURCE William T. Hogan, *Analysis of the U.S. Metallurgical Coke Industry, 1979*

Most of the coking equipment being retired is 25 to 30 years old. Many ovens in this critical age category cannot be upgraded to meet pending environmental regulations and have been earmarked for abandonment.’ Pennsylvania, Indiana, and Ohio are the sites of 57 percent of total in-place coking capacity (see table 89) and would be affected most by future plant closings.

Actual Productive Capability and Declining Capacity

When discussing coke oven capacity, it is important to differentiate between several measures of available or effective capacity. First, 5 to 10 percent of all ovens are offline at any point in time for rehabilitation or major repairs. Second, coke ovens will seldom, if ever, sustain a 100-percent operating rate over an extended period of time; periodically, they must be shut down for maintenance and minor repairs. Thus, some additional percentage of ovens will be temporarily out of service at any time. In recent years, pollution control has required a number of output-reducing modifications in coking practice. As a consequence, the maximum annual operating rate attainable by active coke plants throughout the industry is currently about 92 percent of their aggregate capacity.’

Coke oven capacity may be measured in three ways, according to operating conditions:

- capacity in existence (gross capacity, includes ovens out of order for rebuilding and major repairs, used to measure historical trends and age of equipment);
- capacity in operation (potential maximum productive capacity, excludes facilities that are offline for rebuilding and major repairs); and
- actual productive capability (excludes ovens shut down for minor repairs and maintenance, in addition to those out for rebuilding and major repair).

‘Ibid., p. 48,

‘Ibid., p. 43.

Existing capacity has declined by 15 percent since 1973 and is now 57.5 million tonnes. A decrease of similar magnitude has taken place in operating capacity, which is now 51.8 million tonnes. Actual productive capability has fallen since 1973 by an even greater amount—17 percent. This may be attributed to the aging of cokemaking facilities and to the expansion of regulatory requirements affecting cokemaking. During the past 6 years, 10 million tonnes of capability have been lost, and current actual productive capability is no more than 47.6 million tonne/yr (see table 91).

U.S. Production and Consumption: A Growing Shortage

Total coke production has declined considerably since 1950—and dramatically since 1976. Production decreased by 20 percent between 1950 and 1976, and by 33 percent between 1976 and 1978. * Coke consumption also declined during this time, but at a much slower rate: 23 percent between 1950 and 1978. More importantly, consumption has been higher than production during the past few years. During 1978, for the first time in nearly 40 years, the coke industry produced less than 44 million tonnes of coke, thus falling almost 15 percent below the Nation's consumption of 51.3 million tonnes (table 92).

The loss of coking capacity has resulted from a number of interrelated economic, technical, and regulatory causes, the most significant of which are:*

- long-term limitations on market growth and producer profits, which restrict the flow of investment capital into coke oven replacement and modernization;
- the consequent problems of coke oven age and obsolescence, reduced operat-

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*Earlier production decreases were largely the results of improved blast furnace efficiency; more recent decreases are also the result of capacity reduction.

*These causes are listed without regard to ranking or degree of importance.

Table 91 .—Estimated Decline in Actual Productive Capability of Coke Oven Plants in the United States: 1973 v. 1979[a] (millions of tonnes)

	Capability			Capability change			
				1973-79		1979-85 est.	
	1973	1979	1985 est.	Tonnes	Percent	Tonnes	Percent
Capacity in existence. .	68.0	57.5	52.7	10.5	15.5	4.8	8.3
Capacity in operation.	61.2	51.8	—	9.4	15.4	—	—
Actual productive capability	57.6	47.6	42,6	10.0	17.3	5.0	10.4

[a]Comparison of estimated average levels for 1973 and levels on July 31, 1979, as determined by Ford ham University survey

SOURCE William T Hogan, *Analysis of the U..S Metallurgical Coke Industry, 1979*

Table 92.—U.S. Coke Consumption (thousands of tonnes)

Year	Total production	Imports	Exports	Net stock change	Domestic consumption
1950	65,955	397	361	– 598	66,589
1955	68,299	114	482	– 1,132	69,063
1960 ., ...	51,907	114	320	+ 51	51,650
1965	60,637	82	756	+ 663	59,300
1970	60,338	139	2,248	+ 901	57,328
1971	52,094	158	1,369	-506	51,389
1972	54,880	168	1,117	– 532	54,463
1973	58,343	978	1,265	– 1,594	59,650
1974	55,854	3,210	1,159	– 226	58,132
1975	51,887	1,652	1,155	+ 3,688	48,694
1976	52,908	1,189	1,193	+ 1,356	51,548
1977	48,533	1,658	1,126	–43	49,109
1978	44,074	5,189	629	-2,674	51,309

NOTE Totals may not add due to rounding

SOURCE U S Departments of the Interior Commerce, and Energy ing efficiency, and increased oven emissions;

- the fluid state of cokemaking technology and the uncertainty of investing in unfamiliar equipment that may soon become obsolete;
- the escalating capital costs of coke oven facilities, attributable to inflation and the need to install complex pollution control and occupational safety equipment;
- additional obstacles to investment that derive from regulatory uncertainty as to future rules governing coke oven facilities;
- environmental control regulations which have contributed to the closing of older coke plants and to the curtailment of operating rates and output levels in remaining plants; and
- environmental restrictions on the construction of new and replacement coke ovens in certain geographic areas.

Capital Investment Requirements.—Coke oven costs have increased considerably during the past few years. These sharp cost increases have contributed to the shortage of coke ovens and coke. In 1969, the cost of installing a tonne of annual coke oven capacity was $82 to $94, or a total of $82 million to $94 million for a million-tonne battery of coke ovens. Installing a tonne of coke capacity now costs between $198 and $220, or between $198 million and $220 million for a million-tonne battery. This represents almost a 150-percent increase in 10 years, which partly results from the inflation that has driven up all capital costs.

Regulatory Requirements.—About one-fourth of the total capital investment in coke facilities is for environmental and occupational safety equipment. A recent estimate suggests that the capital cost for regulatory equipment may be as high as 30 percent.[9] The impact of regulations has been dramatic in certain elements of the cokemaking process, for example, on the quenching cars that receive the coke as it is pushed from the oven. A new car with gas-cleaning equipment involves an investment of $6.5 million, compared with $150,000 for a conventional quenching car purchased 10 years ago. The Environmental Protection Agency (EPA) maintains that environmental regulations have played a secondary role to economic and other causes in the loss of coke capacity; however, there is at least a similarity of timing between environmental regulations and capacity shutdowns.

Most of the Nation’s coke oven batteries are located at steel plants that are in poor air quality, nonattainment areas. EPA has developed strict requirements for these areas. The most stringent requirements apply to new or rehabilitated coke oven batteries, but old facilities also have to be retrofitted with costly controls. In a number of cases, companies have decided that it would be more economical to shut down an operation and procure coke from outside sources because the remaining life of a battery was too short.

A considerable percentage of existing coke ovens is either in compliance with environmental standards or moving toward that goal. Batteries that have a number of years of life remaining have been or are being retrofitted with pollution control devices. The installation of pollution control equipment often requires increased energy consumption. The equipment may also require changes in operating practices, and these have slowed down the coking process considerably.

Environmental regulations have also contributed to limiting plans for cokemaking capacity expansion. Current industry plans call for less than a complete replacement of those ovens scheduled to be abandoned, and there are no announced plans to add capacity.

To install new coke oven capacity or replace existing ovens* in poor air quality regions, the following conditions must be met:

- high-performance environmental tech-

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[9] 33 Metal Producing, May 1979, p. 69.

*If a battery that has been in operation is torn down to be replaced by the same capacity, this is considered a new source of pollution that will have to meet the most stringent requirements.

nology, providing the least attainable emission rates, must be used;

- a company desiring to add a new installation must have all of its facilities within a State in compliance with EPA standards, or be under agreement to bring them into compliance; and
- the company must demonstrate continuing progress in reducing particulate matter so as to attain applicable air quality requirement levels.

In addition to these requirements, a company planning to expand cokemaking capacity in a nonattainment area must offset the additional pollution with pollution reductions in that area. This condition poses a serious problem for a new company moving into an area in which it has no other facilities for which pollution can be reduced. Even if a company has the necessary funds to build a coke oven battery in a nonattainment area, it may be difficult to make arrangements for a pollution tradeoff. * The increasing value of coke byproducts, however, is making such new ventures more attractive.

Coke Imports and Declining Employment

As a result of declining coke oven capacity and coke shortages, virtually every major steel producer has had to resort to imports—particularly since 1973. Coke imports, in turn, have contributed to reduced employment opportunities in the steel industry. Coke imports are expected to continue as present coke oven capacity is reduced.

Imports of MetaHurgical Coke.—Annual coke imports averaged about 16,326 tonnes between 1950 and 1972 and nearly 1,814,000 tonnes between 1973 and 1977. In 1978 they jumped to 5.2 million tonnes (table 92) or 10 percent of U.S. requirements, with almost 70 percent coming from West Germany. The balance came in relatively small amounts ranging from 12,000 to 300,000 tonnes from several other countries, including The Netherlands, Japan, the United Kingdom, Argentina, and Italy (table 93). * This marked the sixth consecutive year that imports were near or above the million-tonne level. Despite recent, temporary improvements in domestic availability and the current slowdown in steel activity, 1979 also saw a high level of imports.

The need for the United States, with the largest and best coking-coal reserves in the industrial world, to import substantial quantities of coke on a regular basis is an anomaly. It represents an example of the Nation's growing dependence on foreign suppliers for an industrial source of energy. This dependence on foreign coke may also present supply and price problems when steel industries in exporting countries are operating at a high rate. During the 1973-74 worldwide steel boom, U.S. companies imported a substantial amount of coke for $138/tonne, which was over $55/tonne more than it cost to produce coke domestically at that time. At the height of the 1974 boom, prices for spot sales were $143 to $154/tonne, and in one instance rose as high as $180/tonne. Should an increase in steel operations develop abroad, there is a real question as to whether the United States could count on obtaining coke from foreign sources. However, the present closing of much European steelmaking capacity and the Third World's ever-increasing use of direct reduction (DR) could make more coke available.

Trade and Employment Effects.—The 5.2 million tonnes of coke imported in 1978, including freight and insurance charges, cost close to $500 million. These imports contributed about 10 percent to the steel-related balance-of-payments deficit. Importing coke produced in part from foreign coal also carried a high price in the loss of job opportunities. If the 5.2 million tonnes of imported coke had been produced in this country from domestically mined coal, there would have been an additional 3,400 jobs at the coke ovens, plus as many as 6,000 jobs in the Nation's coal mines. It can also be argued that the loss of coke

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*For additional comments, see ch. 11.

*Steel plants in Western Europe and Japan did not operate at maximum levels in 1978 as did domestic producers. As a consequence, they had excess coke capacity available.

Table 93.—U.S. Imports of Coke by Country of Origin, 1972-78 (thousands of tonnes)

Country of origin	1978	1977	1976	1975	1974	1973	1972
West Germany	3,604	1,108	808	1,259	2,505	664	—
The Netherlands	304	67	15	91	57	—	—
Japan	259	8	10	8	—	—	—
United Kingdom	213	17	—	44	347	8	—
Argentina	211	27	19	—	—	—	—
Italy	191	158	—	39	7	29	—
Canada	119	109	122	134	177	263	155
France	84	138	102	—	2	—	—
Australia	54	—	—	—	—	—	—
Norway	45	—	—	—	51	—	—
Belgium-Luxembourg	36	16	102	4	—	—	—
South Africa	33	—	11	54	31	—	—
Sweden	24	10	—	4	—	—	—
Austria	12	—	—	—	—	—	—
U.S.S.R.	–	—	—	—	26	—	—
Czechoslovakia	—	—	—	—	—	11	—
NewZealand	—	—	—	—	7	—	—
Hungary	—	—	—	—	—	3	—
Others	—	—	—	15	—	—	13
Total	5,189	1,658	1,189	1,652	3,210	978	168

SOURCE:US Departments of Commerce and the Interior

oven byproducts caused the use of more imported energy and an additional loss of jobs in the petrochemical industry.

Future Coke Shortages

Anticipated reductions in domestic coke oven capacity will force the domestic steel industry to depend on imported coke whenever steel demand is high. It has been estimated that coke imports are indispensable whenever the steel industry has an operating rate of 83 percent or more—as is expected to be the case often during the next several years. The current supply-demand imbalance is expected by some to lead to an annual shortage of 7 million to 11 million tonnes in domestically produced coke by 1985. Given likely increases in world steel demand, coke imports might not be readily available, or available only at high prices, unless additional coke oven capacity is constructed in the meantime.

Decline in Capacity.—Based on the excess of scheduled domestic coke oven abandonments over installations, it is expected that an additional 4.8 million tonnes of annual capacity (8.3 percent) will be lost by the end of 1985, thereby reducing total existing capacity to 52.7 million tonnes (see table 91), Ninety percent of this scheduled capacity loss is expected to occur by the end of 1982, when environmental control deadlines must be met. Of more immediate concern is the fact that 2 million of the 4.8-million-tonne loss is expected to occur by the end of 1980. Given the present decline in domestic steel consumption, however, this much reduction in cokemaking is not necessarily critical in the near term.

Actual productive capability is expected to decline even more than total existing capacity. When production losses from facilities scheduled to be rebuilt or repaired, from maintenance operations, and from environmental constraints are taken into account, it is estimated that the industry's actual productive capability will decline by 10.4 percent by 1985, to a maximum level of approximately 42.6 million tonnes.

Increased Demand.—Assuming a 2-percent-per-year growth rate in domestic steel output and the need for 0.56 tonne of coke to make 1 tonne of pig iron, approximately 53.5 million tonnes of coke would be needed to meet demand in 1985. The domestic coke shortfall would be about 11 million tonnes. Barring coke importation, a shortage of that magnitude would result in a 15.4-million-tonne decline in the amount of blast furnace iron available for steelmaking; raw steel output would then be short of demand by some 26.3 million tonnes, the equivalent of 19.5 million tonnes of finished steel products. * A l-percent-per-year increase in domestic demand for steel would require 49.9 million tonnes of coke in 1985, leaving a shortfall of 7.3 million tonnes of coke from domestic sources, enough to have a significant negative effect on pig iron and steel production. Without coke imports and without an increase in domestic capacity, the steel industry could have finishing facilities that are standing idle while the country imports the steel it needs.

Changing Technology.—A recent analysis[10] concludes that even with a steel boom in 1985 domestic demand would only be 41.7 million tonnes of coke, which implies that adequate capacity would exist. The critical difference between this analysis and others is its optimism about future reductions in the amount of coke needed to produce a tonne of pig iron in blast furnaces: it forecasts a usage rate of 0.50 tonne of coke per tonne of pig iron for the United States in 1985. Modernization of existing blast furnaces appears likely, and this forecast may thus be correct. Other factors which lead to the conclusion of ample coke capacity include the increasing replacement of open hearths with electric furnaces, and continued improvements in existing cokemaking facilities to provide greater capacity.

Although OTA has not performed its own detailed analysis of future cokemaking capacity and demand, the above conclusions are consistent with other OTA findings: the increasing use of electric furnace steelmaking (especially by nonintegrated steelmaker), and a modernization and expansion program for the coming decade aimed at improving the performance of existing integrated facilities (see ch. 10). Hence, although there is uncertainty about future coke shortages, only the combination of very low capital spending and high domestic steel demand would likely lead to a severe coke shortage in the coming decade.

Potential Solutions to Coke Shortages

Domestic coke shortages, should they occur, could be remedied in part by purchasing coke elsewhere. An active worldwide steel market, however, could significantly reduce the likelihood that imported coke would be available, and whatever coke did become available would be at very high prices. Another alternative would be for steel consumers to import up to 19.5 million tonnes of finished steel products. Occurring at a time when steel demand is expected to be high all over the world, this would also mean exorbitant prices for steel imports. * A third alternative would be to increase domestic coke oven capacity. This course would make the steel industry more self-sufficient by reducing coke imports, would improve the Nation's balance of payments, and would increase domestic job opportunities. The ever-increasing price of petroleum may also provide ample motivation for expanding coking capacity, because the coke byproducts that can substitute for petroleum products in some uses will have more value. Byproduct sales would help to reduce the real cost of coke for blast furnace use.

Additional solutions to the coke shortage are available, but each presents problems of its own:

- The use of electric furnace steelmaking based on scrap iron could be increased. The limitations to this option are that it does not use virgin ore and thus does not add to the available iron supply; a shortage of scrap iron may occur, or markedly higher prices may reduce the competitiveness of this steelmaking technology; ** and there may be inadequate domestic supplies of electricity.

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*This projection for 1985 is based on the following assumptions: growing emphasis on scrap-based electric furnace steelmaking: no major use of direct reduction; 0.580 of iron output for each tonne of steel output.

[10] Bradford, op. cit.

*Whenever steel imports enter the United States under domestic shortage conditions, rather than in competition with domestic steel, prices reflect what the market will bear. This was borne out in 1974, when import prices for steel were between $55 and $110/tonne higher than domestic production prices.

**See following section on scrap.

- DR could supplant or complement blast furnace technology based on coke. Available projections suggest that the use of DR will increase. However, construction of domestic DR facilities will depend on additional coal-based DR technology becoming available for large integrated plants or small nonintegrated plants, or both. The availability of imported DRI depends on developments in a number of less developed countries and is still somewhat speculative. (See ch. 6.)
- Semifinished steels could be imported to bypass the need for domestic blast furnace operations. It would be better to import semifinished rather than finished steel, because domestic capital investment for primary ironmaking and steelmaking would be greatly reduced while profitable secondary steel processing and finishing would be done domestically. Nevertheless, imports of semifinished steel would still add to already sizable balance-of-trade deficits.
- Blast furnace-based plants could change processes to reduce the amount of coke they use. Such changes might have a major impact because of the large number of old and small domestic blast furnaces currently in use.
- Formcoke technology could be adopted to promote the use of cheaper, nonmetallurgical-grade coals. This technology may offer environmental advantages, but it has not yet been demonstrated on a large scale. Furthermore, there are indications that capital costs and energy use may be high. *

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*See case study of formcoke in ch. 9.

Ferrous Scrap Supply and Demand

Recent testimony by the chairman of the Ferrous Scrap Consumers' Coalition provides an introduction to the issues that currently confront the domestic steel industry with regard to the demand and supply of ferrous scrap:

> The recent rate of United States ferrous scrap exports has reached record levels. Current exports parallel those experienced in 1973 and 1974, a period in which Commerce imposed export restraints, During 1978, domestic consumption of ferrous scrap approached the 100-million-ton level, 54 percent greater than in 1977. Japan accounted for almost all of the increase in the United States exports. Between 1977 and 1978 domestic exports of ferrous scrap to Japan increased by 208 percent to more than 3 million tons. Scrap exports to Canada, Italy, Mexico, Taiwan, South Korea and Spain also increased. During the last six months of 1978, as domestic demand rose and exports skyrocketed, inventory stocks of industrial ferrous scrap purchased on the open market declined by 6 percent.[11]

Ferrous scrap is an important raw material in steelmaking, and the demand for it is growing rapidly, partly as a result of increasing worldwide use of the electric furnace. Scrap can be viewed as embodied energy; as such, it is a valuable domestic resource, and there are advantages to maximizing its domestic use. However, to produce high-quality steels with minimum impurities, it is necessary to have the domestic steel industry convert ore into new iron units, some portion of which will eventually become available as ferrous scrap. There are also limits to increased domestic steel production unless new iron units are produced from ore.

The availability and quality of scrap will also affect the development and adoption of

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[11] W, J. Meinhard, testimony before International Finance Subcommittee of Senate Banking Committee, Mar. 12, 1979.

new steelmaking technologies. DRI, for instance, could partially substitute for scrap, and the possible development of domestic coal-based DR technology and the availability of foreign DRI may reduce the future demand for scrap. Scrap availability and price, in turn, will determine to some extent how viable DR will be.

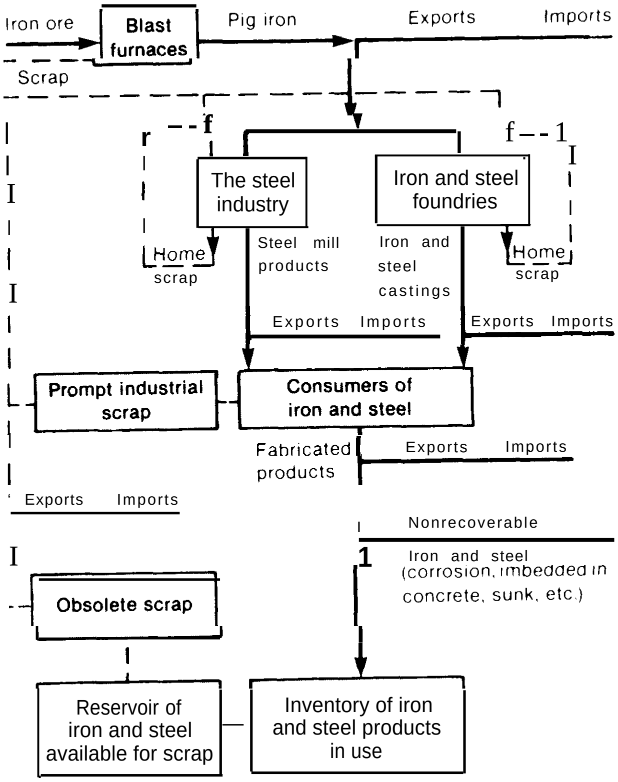
U.S. Ferrous Scrap Industry

Ferrous scrap is often defined as the portion of ferrous material that can be economically recycled. This economic definition is significant because scrap is not a homogeneous commodity. Ferrous scrap normally originates from three sources:

- Home or revert scrap is discarded material generated in the iron and steel industry itself during the primary and secondary steelmaking operations.
- Obsolete or capital scrap is wornout or discarded material from diverse sources such as industry, consumers, or municipal dumps. This scrap is often mixed and contaminated with other materials. Several of these materials, such as copper, are difficult to remove and are deleterious to the steelmaking process or the final steel products.
- Prompt industrial or process scrap is discarded material generated in manufacturing operations using steel, which cannot be recycled in the same plant.

Home and prompt industrial scrap generally represents higher quality iron than obsolete scrap. It is estimated that about 45 percent of all scrap in North America is home or prompt industrial, and 55 percent is obsolete. Because it is such a heterogeneous commodity, scrap is classified according to a complex set of specifications based on such factors as physical-chemical properties, origin, and consumer requirements. * Scrap that requires a great deal of treatment to improve its physical or chemical characteristics may be an uneconomic source of iron units.

Figure 33.— Flow Chart of Ferrous Metallics



SOURCE U S Department of Commerce

The scrap industry is noted for its involved, integrated market structure (figure 33). The industry can be divided into four discrete functions—collection, dealing, brokerage, and processing. These functions may be completely segregated in different firms or combined in firms with some degree of vertical integration. A collector gathers the scrap and sorts it into useful and nonuseful material; most collection is now carried out by dealers who classify the scrap before processing it to meet customer's requirements. A broker generally acts as the middleman between dealer and customer, making arrangements on be-

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*More than 10 different grades of scrap are widely used. These grades have various characteristics with respect to bulk density, size coating, and chemical impurities.

half of a customer for the purchase of specified grades of scrap on a contractual basis. Scrap processors are usually fully integrated companies that process material, such as autos and appliances, into acceptable grades for use in steel production. Scrap processing is a major business, often involving high investment in such processing equipment as shears, slabbers, crushers, and shredders.

Supply, Demand, and Price

The steel industry is the major consumer of ferrous scrap, although other consumers such as foundries offer competition for scrap supplies in many areas. Total scrap consumption has gradually increased over the years, while home scrap production has declined somewhat. Scrap prices fluctuate considerably with demand and availability, although the general trend has been upward, with a more than twofold increase in price from 1969 to 1978 (table 94).

Not all types of scrap are equally important when considering availability, Home scrap is not a primary concern. It is completely internal to the steel mill and bears no relationship to the price of scrap, except that a reduction in home scrap could lead to greater demand for purchased scrap. Purchased scrap is a mixture of obsolete and prompt industrial scrap. The availability of obsolete scrap, particularly, is at the core of the question of whether the U. S. steel industry has adequate supplies of domestic scrap. The major and contradicting views on this question have been presented in the Nathan study for the research arm of the Institute for Scrap Iron and Steel[12] and the Fordham University study for the American Iron and Steel Institute (AISI).[13] The Nathan study was conducted for scrap suppliers and the Fordham study for scrap users.

The main thrust of the Nathan study is that adequate domestic supplies of obsolete scrap exist and that a shortage is unlikely, although prices could increase substantially. Nathan started with a 1955 estimate of the total pool of domestic obsolete scrap[14] and added to it his estimates of subsequent annual iron and

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[12] Robert R. Nathan Associates, Inc., *Price-Volume Relationship for the Supply of Scrap Iron and Steel:* A Study of the Price Elasticity of Supply, for the Scrap Metal Research and Education Foundation, Washington, D. C., Jan. 8, 1979.

“William T. Hogan, S. J., and Frank T. Koelbe, Purchased Ferrous Scrap: United States Demand and Supply Outlook, for AISI by Industrial Economics Research Institute, Fordham University, New York, June 1977.

[14] Battelle Memorial Institute, “Identification of Opportunities for Increased Recycling of Ferrous Solid Waste, ” for Scrap Metal Research and Education Foundation, Washington, D, C., 1972.

Table 94.—Measures of U.S. Ferrous Scrap Use, 1969-78

	Total domestic purchased scrap[a] for	Purchased scrap for steelmaking[b] for	Purchased scrap steelmaking[c] for	Purchased scrap Steelmaking[d]
Year	Total pig iron	Pig iron in steel	Raw steel	Steel shipments
1978	.53	.36	.22	.31
1977	.52	.34	.21	.29
1976	.48	.32	.20	.29
1975 ..,.	.48	.32	.20	.29
1974	.54	.38	.24	.32
Average.	.51	.34	.21	.30
1973	.44	.32	.21	.28
1972	.47	.33	.21	.31
1971	.42	.28	.18	.25
1970	.37	.28	.18	.26
1969	.39	.28	.18	.28
Average.	.42	.30	.19	.28

aFor regression fit between ratio and time, correlation coefficient = 0.86, growth rate = 0.017 per year.
bFor regression fit between ratio and time, correlation coefficient = 0.74, growth rate = 0.008 per year.
CFor regression fit between ratio and time, correlation coefficient = 0.63, growth rate = 0.004 per year.
dFor regression fit between ratio and time, correlation coefficient = 0. 55, growth rate = 0.004 per year

SOURCES Total domestic Purchased scrap from Bureau of Mines, other data from American Iron and Steel Institute steel discards.* This made it possible to estimate current total obsolete scrap reserves. The Nathan study indicates that there were 577 million tonnes of potential reserves at the end of 1975 and 609.8 million tonnes at the end of 1977. This study used the concept of "potential reserves" of obsolete scrap, defined as quantities recoverable with the use of existing technology at high but realistic prices—that is, prices possibly several times higher than present levels. Specifically, the definition of potential reserves implies a positive price-supply relationship. At any given price above the present price, an additional amount of scrap will move into the hands of processors and, through them, to the iron and steel industry. Thus, price increases trigger larger supplies of difficult-to-process scrap, although not necessarily in a linear relationship—dramatically higher prices would be required to extract the last increment of scrap from potential reserves and place that increment in the ferrous supply system.

Hogan and Koelbe, in the Fordham study, reached the converse conclusion, that scrap would be in short supply in the early 1980's. Unlike Nathan, they did not use the total pool of obsolete scrap reserves as the basis for their current and 1982 estimates of available domestic scrap. Rather, they looked at the discarded materials from the Nation's total iron and steel inventory that it would be economically and technically feasible to recycle. They determined the current and 1982 projected iron and steel inventory by making annual additions to a 1954 Battelle estimate. They then estimated the portion of recyclable material by using the 1974 maximum discarded-materials withdrawal rate of 1.63 percent. This approach led to the conclusion that there will be a shortage of 9.9 million tonnes of obsolete scrap by 1982.

Like the Nathan study, the Fordham study considered the effect of scrap price on supply. The Nathan data showed greater sensitivity to changes in price than did the Fordham data. Using 1973-74 data, Hogan and Koelbe found that a 100-percent increase in price would yield a 7-percent increase in scrap supply. The Nathan report found that a price increase of that magnitude would yield an increase of somewhat more than 83 percent in the supply of obsolete scrap. * Thus, Nathan's finding of significant supply elasticity for scrap supports his conclusion that scrap supplies would be adequate under conditions of rising prices, while the finding of limited supply elasticity underlies Hogan and Koelbe's prediction of a future scrap shortage. Neither study, however, is impressive in its methodology or precision.

Very little attention has been paid to demand elasticity for scrap. Rossegger found that the demand for scrap is price inelastic. " In other words, demand for scrap is quite insensitive to changes in price, because the possibilities of substituting other materials are presently quite limited. Increases or decreases in the price of scrap will trigger only very modest decreases or increases in demand. Rossegger's findings have been confirmed in recent years, when demand for scrap has not decreased with high prices. In fact, several measures of domestic scrap use indicate that the trend is toward increasing consumption (table 94). The proportion of scrap to either pig iron (blast furnace output), raw steel (steelmaking furnace output), or steel shipments over the past decade has increased significantly.

Thus, on the basis of these studies, scrap supply can be expected to range from inadequate to adequate (at much higher prices) and scrap demand to grow regardless of price. The steel industry, as a major scrap consumer, has few options. To reduce the impact of cyclical shortages, it could maintain scrap inventories. In the long run, it could substitute other raw material, such as DRI, and support the imposition of export controls. **

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*There has not been a net withdrawal from the total pool of domestic obsolete scrap since 1956.

*Nathan's data show a supply elasticity of 0,83 for obsolete scrap for the 1961-76 period. For 1973-74 the elasticity was higher than 1.0.

[15] J. Rossegger, Human Ecology, vol. 12, November 1974.

**See below for a discussion of the latter two options.

As a rule, steel companies do maintain substantial inventories, in absolute terms and in relation to use, in order to offset short-term scrap supply and price problems. As prices rise, inventories decline, and when prices fall, inventories increase. This requires substantial investment: the domestic steel industry invests more than $500 million annually in carrying scrap inventories, and more in providing space and facilities to handle those inventories.

Recently, increasing demand for scrap has altered this traditional pattern of curtailing scrap purchases when prices are high. Scrap inventories are drawn down during periods of rising price, but net purchase receipts of scrap by steel mills and other consumers have continued to move upward to satisfy the less flexible requirement for scrap. This trend appears attributable to the increasing use of electric furnaces and to the growing exports of scrap.

Availability Concerns

Future availability at reasonable prices is not the only concern with regard to scrap. Other concerns include the adequacy of the scrap industry's processing capabilities in the face of growing demand; the availability of railroad cars to ship scrap; the structure of freight rates; and finally, the effect on the use of scrap of fiscal incentives for mineral exploration and mining. Some of these problems appear to have little effect on scrap supplies and steel production costs; others are now being remedied.

Processing Capabilities of the Scrap Industry.-A recent Battelle report concludes that present scrap-processing facilities can easily process enough scrap even when the demand is much greater than current levels.[16] No consideration is given to questions of cost and price. The report claims that 47.3 million tonnes of scrap were processed (operating an average of 50 hours per week) in the peak year of 1974. The report also claims that an additional 41.7 million tonnes or more of scrap could be processed under the following conditions:

- optimum raw material supply and market demand: 9.1 million to 11.8 million tonnes;
- improved scrap operations and maintenance programs: 7.3 million to 9.1 million tonnes;
- addition of a full second shift: 22.7 million to 27.2 million tonnes; and
- improved materials handling and plant flow: 2.7 million to 4.5 million-tonnes.

The report predicts that by 1980, 131.2 million tonnes of ferrous scrap could be processed annually. Thus, this report (without addressing the scrap cost issue adequately) supports the position that adequate scrap supplies exist for the future if scrap-processing capabilities are viewed as the primary problem. But because scrap suppliers are forecasting scrap shortages, the Battelle report's conclusions can be questioned.

Gondola Railroad Cars.—Scrap is moved via rail in gondola cars. Because most scrap is moved from scrap processors to steelmaker by rail, the gondola supply is a critical link in the availability of scrap. Many incidents of ferrous scrap supply shortages have been attributed to the unavailability of gondola cars.

The pool of gondolas available to scrap processors has been declining for some time.[17] Every year, more gondolas are retired than are added. From 1970 to 1979, there was a 23-percent decrease (37,878 cars) in the number of general-purpose gondolas. Daily shortages during 1978 were in the 3,000-to 5,000-car range.

One of the Interstate Commerce Commission's (ICC's) regulatory responsibilities under the Interstate Commerce Act is to make sure that railroads supply sufficient cars to satisfy shipping needs. To increase the gondola supply, ICC has approved an incentive per diem (IPD) system, although its decision is being appealed. IPD adds to the basic gondola

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[16] Battelle-Columbus Laboratories, *The* Processing Capacity *of the* Ferrous *Scrap* Industry, Columbus, Ohio, Aug. 10, 1976.

[17] Phoenix *Quarterly*, September 1978,

rental fee an extra cost that simultaneously penalizes railroads borrowing gondolas and rewards those railroads investing in gondolas.

The gondola-supply situation appears to be improving. In 1979, 6,000 replacement cars were scheduled for construction by 1980. This would slow down the loss of gondolas. Continued increases in rail capability for scrap shipment may occur but are not certain.[18]

Railroad Freight Rates.—A longstanding issue is whether railroad freight rates discriminate against ferrous scrap shipment and, hence, limit the supply of scrap. ICC recently found that discrimination against ferrous scrap exists in some parts of the country.[19] A study by OTA concluded that discrimination against scrap exists but that the effect on supply is small:

> The conclusion of this analysis is that substantial discrimination against secondary materials is found, if one adopts cost-based or equivalency-based railroad ratemaking.
>
> For example, a 36-percent decrease in the rail rate for iron and steel scrap would increase rail shipments by an estimated 0,2 million to 1 million tons (about 0.5 to 2.9 percent), but would cause a reduction in rail revenues of $100 million to $110 million per year. This loss is equivalent to about $100 to $550 per ton of additional scrap moved, and is not economically justifiable from the railroad’s perspective when iron and steel scrap is selling in the neighborhood of $50 to $100 per ton.[20]

Tax Disparities.— Federal tax regulations explicitly encourage exploration for minerals and the mining of virgin ores. The regulations that have most significance for scrap use are:

- depletion allowances—i. e., flat percentage deductions from gross income—for iron ore mining operations;
- expensing of exploration and development costs—i.e., immediate deductions for iron ore exploration and development expenses;
- capital gains tax rates on royalty payments to landlords that lease land for production of iron ore; and
- tax credits for payment of foreign taxes.

To the extent that these tax regulations apply only to the exploration and mining of virgin ore, they implicitly discriminate against the use of iron scrap. But a number of studies undertaken by various Federal agencies as well as by industry suggest that the impact of this discrimination is not substantial. For example, the 1975 total tax benefits from using virgin ore to produce a tonne of raw steel were found to be $1.38, or 1.7 percent of the cost of producing the raw steel,[21] an amount that could only marginally affect the use of ferrous scrap. The Department of Treasury recently concluded that “it is extremely unlikely that the tax subsidies could reduce the amount of recycling of scrap steel by more than one percent.[22]

Scrap Exports: Growing World Demand and Price Impact

Whether or not current and future exports of scrap by the United States will have adverse impacts on the domestic steel industry is an acute, highly debated issue. Scrap exports had been fairly stable since at least 1969, but they rose sharply in 1979 to approximately 10 million tonnes (table 95). Unlike the United States, many, if not most, of the steel-producing nations have very limited domestic supplies of scrap, and eight countries (Japan, Italy, Spain, Mexico, Canada, South Korea, Turkey, and Taiwan) accounted for 85 to 90 percent of U.S. scrap exports between 1973 and 1979.

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[18] American *Metal* Market, Aug. 9, 1979.

[19] Interstate Commerce Commission, “Further Investigation of Freight Rates for the Transportation of Recyclable or Recycled Materials,”’ Apr. 16, 1979.

[20] Office of Technology Assessment, Materials and Energy From Municipal Waste, July 1979.

[21] Booz-Allen and Hamilton, “An Evaluation of the Impact of Discriminatory Taxation on the Use of Primary and Secondary Raw Materials,” 1975.

[22] U.S. Department of the Treasury, Federal Tax *Policy and* Recycling *of* Solid Waste Materials, February 1979, p. 87.

Table 95.—Selected Data on Iron and Steel Scrap: Ferrous Scrap Relative to Scrap Consumption and the Impacts of Scrap Exports on Scrap Supply and Price (thousands of tonnes)

Year	Total scrap consumption	− Home scrap production	+ Change in consumer inventories	= Domestic net scrap receipts[a]	Ferrous scrap exports[b]	Total scrap shipments	Exports as a percent of total shipments	BLS scrap price index, 1967 = 100
1969	85,998	51,052	– 1,206	33,740	*8,322*	*42,062*	*19.8*	110.5
1970	77,602	47,686	+ 1,012	30,928	*9,401*	*40,329*	*23.3*	138.9
1971	74,888	44,596	+ 749	31,041	*5,674*	*36,715*	*15.5*	114.6
1972	84,687	46,424	- 295	37,968	*6,697*	*44,665*	*15.0*	121.8
1973	93,955	52,426	- 977	40,552	*10,210*	*50,762*	*20.1*	188.0
5-year average	83,426	48,437	– 143	34,846	*8,061*	*42,907*	*18.7*	134.8
1974	95,673	50,112	+ 1,000	46,561	*7,887*	*54,448*	*14.5*	353.2
1975	74,674	41,760	+ 421	33,335	*8,714*	*42,049*	*20.7*	245.6
1976	81,548	45,374	+ 1,374	37,548	*7,365*	*44,913*	*16.4*	259.0
1977	83,885	44,919	– 488	38,478	*5,602*	*44,080*	*12.7*	231.2
1978 (p)	89,889	47,110	- 979	41,800	*8,197*	*49,997*	*16.4*	264.6
5-year average	85,134	45,855	+ *266*	*39.545*	*7,553*	*47,098*	*16.1*	270.7

[a] Gross shipments minus shipments by consumers, receipts by mills and founding
[b] 1979 exports 10 million tonnes
[c] Domestic net scrap receipts plus ferrous scrap exports
(p) Preliminary

SOURCES Bureau of Mines (scrap consumption, production, etc.): U S Bureau of Census (exports), and Bureau of Labor Statistics (price index)

About 75 percent of all scrap traded internationally is from the United States.[23] As worldwide use of electric furnaces grows, so will demand for ferrous scrap, and additional pressure will be placed on the United States to export more scrap. A recent analysis forecasts a 30-percent increase in foreign demand for U.S. scrap by 1982 (excluding Canada and Mexico) .24 A recent article on this issue stated:

> Whatever future export demand will be, it can be certain that world scrap requirements are going to grow. Preliminary results of a detailed study on ferrous scrap by the Steel Committee of the Economic Commission for Europe (ECE) underline future expansion in scrap requirements. The ECE indicates that the world requirement for obsolete scrap will increase (measured from 157 million tons in 1974) by 39 percent to 218 million tons by 1985 and by 50 percent to 235 million tons by 1980,
>
> Considering the expected growth in world scrap requirements, we can reasonably anticipate in the future strong demand for U.S. ferrous scrap exports. If history is a guide, demand should show sharp cyclicality, and at some point, market conditions that approximate the tight supply situation of 1970 and the exceptional period of 1973-74 (hopefully not too much like 1973-74). As you recall, increasing steel production in the U.S. and the rest of the world led to significantly increased demand for scrap.
>
> The composite price of No. 1 heavy melting scrap increased 25 percent from $43 per ton in December 1972 to $54 per ton in June 1973 and then by another 46 percent to $79 per ton by December 1973, reaching a high of $145 per ton in April 1974,[25]

Some exporters contend that exports of scrap do not result in increased domestic scrap prices. * The fundamental reason for this contention is that there exists in the United States a considerable volume of obsolete scrap that could be added to the supply as the demand increases, although the cost of

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[23] I. M. J. Kaplan, "The Consumer's Viewpoint, " paper presented at the Ferrous Scrap Consumer's Coalition symposium, Atlanta, Ga., February 1980.

[24] W.W.Blauvelt, "A Free Market: Ferrous Scrap Demand and Supply, " paper presented at the Ferrous Scrap Consumer's Coalition symposium, Atlanta, Ga., February 1980.

[25] D. R. Gill, Exports of Ferrous Scrap, Iron and Steelmaker, March 1979, p. 30,

*For additional comments, see the discussion of the Nathan study above.

retrieving such scrap could be very high. Others, including most of the domestic steel companies led by AISI, argue forcefully for controls of scrap exports:

> . . . accordingly, it is the view of the U.S. steel industry that continuous monitoring of scrap exports by the U.S. government is essential. The industry has urged that the Congress revise the Export Administration Act of 1969 to require such monitoring. Additionally, the industry has recommended that a study be undertaken of policies other governments have implemented over the past decade with respect to exports of their ferrous scrap. Such a study should evaluate the extent to which the U.S. economy has been adversely affected by such policies.
>
> It can no longer be assumed that the U.S. can supply a growing world need for ferrous scrap while the rest of the world carefully guards its internal supplies. This policy will cause unacceptable domestic inflation, as is the case today, and if unchecked, will ultimately lead to domestic steel shortages. As the leading world supplier, the U.S. must assume a role of responsible leadership with respect to world access to the supply of ferrous scrap on a non-discriminatory, most favored nation basis conditioned upon full satisfaction of home demand.[26]

The proponents of scrap export controls also point to the conditions prevailing in the 1973-74 period. Steel demand was very high, and this caused large demand for both foreign and domestic scrap. Prices were very high. On July 2, 1973, the U.S. Department of Commerce imposed export restrictions on ferrous scrap under the "short supply" provisions of the Export Administration Act of 1969. No new orders for more than 454 tonnes of ferrous scrap could be accepted for the balance of 1973. Individual allocations were distributed according to exporter, country, and grade, based on each exporter's history of scrap exports during the base period, from July 1, 1970, to June 30, 1973.

Almost all of the domestic steel producers contend that the high prices of scrap experienced in the 1973-74 period will be repeated in the future unless some control of scrap exports is enacted. The domestic scrap exporters, on the other hand, argue that scrap exports have been stable over time, and therefore control of scrap is not necessary. Indeed, exports of ferrous scrap have been relatively stable when measured against total shipments. Furthermore, scrap exports make a relatively small, but positive, contribution to the balance of trade. In answer to the balance-of-trade argument, domestic scrap consumers point out that price increases spurred by exports more than offset the value of export tonnage. Moreover, much exported scrap contains valuable alloying elements which the United States must import. However, scrap with alloying elements is generally less marketable domestically than conventional carbon steel scrap.

Although scrap exports have been fairly stable, they do appear to correlate with price and price volatility of scrap (figure 34). A recent study of this issue states that:

> This study is intended to provide additional insight into the rapid escalation in prices which has characterized the United States market for purchased ferrous scrap within the last year. Its focus is on measuring the relative influence of U.S. exports and domestic demand on domestic ferrous scrap prices. The results of a number of statistical analyses directed at this end indicate that the foreign component of total demand, which is represented by U.S. exports, has had a substantially greater impact on U.S. ferrous scrap prices than has domestic demand during the last two years (January 1977 through January 1979). The influence of the domestic component of total demand for ferrous scrap on domestic prices was found to be statistically insignificant.[27]

An earlier study, which examined the dependence of U.S. scrap prices for 1973-78 on 25 factors, found that the most statistically significant correlations were first with foreign scrap prices and second with EEC steel

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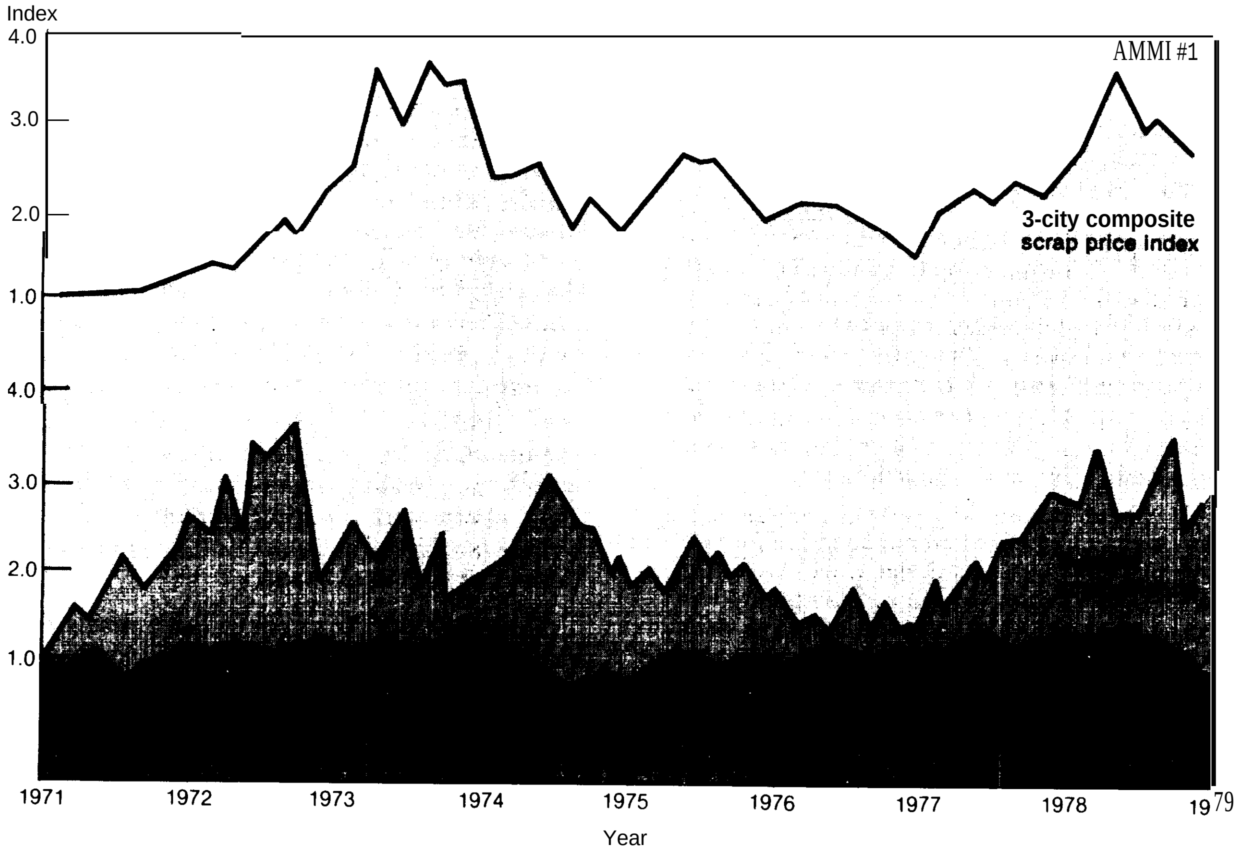
[26] American Iron and Steel Institute, Ferrous *Scrap Supply and Demand Outlook*, June 1979.

[27] Economic Consulting Services, Inc., The *Impact of U.S. Exports of Ferrous Scrap on U.S. Ferrous Prices: An Empirical Analysis*, Washington, March 1979.

Figure 34.—Scrap: Price and Export Levels; Domestic Purchased Scrap Requirements, 1971-79



SOURCE: *American Mefal Market,* U.S. Bureau of Labor Statistics

mill operating rates.[28] The latter variable was more significant than domestic operating rate or domestic scrap consumption. A methodological problem with findings relating exports to domestic prices, however, is that the prices may not be representative of all or most scrap markets. Data on scrap prices for cities from which exports are significant distort the picture for the entire country, which includes many markets not influenced by exports.

Perhaps the most significant long-range consequence of increasing scrap exports to meet greater foreign demands is the possibly detrimental impact of such exports on the nonintegrated steel producers, the Nation's most efficient low-energy and low-cost steelmaker. Rising scrap prices, driven by high foreign demand, would put a substantial cost-price squeeze on these firms and could drive them out of the market, especially if steel prices are subject to formal or informal Government controls that cannot be released quickly enough to offset rapidly rising costs. This impact is particularly acute now, when DR is not widely used domestically and when DRI is not readily available as an import.

When domestic demand and export demand for scrap impact the market at the same time, the issue of adequate supply for domestic use becomes acute. Foreign nations have been much more restrictive of scrap exports than has the United States. The United Kingdom presently has a licensing system under which the quantity and grades of scrap exported are controlled from time to time.

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[28] World Steel Dynamics, Core Report A, November 1978.

Norway, Belgium, and Canada monitor and/or license scrap exports. Denmark, Ireland, and Italy ban scrap exports outside the EEC. Japan imports most of its scrap. The new Export Administration Act gives the U.S. Department of Commerce the right to ensure that an adequate supply of domestic ferrous scrap is made available to domestic consumers. Domestic steelmaker have already requested that permanent monitoring be established, but the scrap industry opposes this step.

Impacts of Technological Change on Scrap Demand

Four technological developments will affect the price of and demand for ferrous scrap:

- the growing use of electric arc furnaces by integrated and nonintegrated steelmaker;
- greater use of continuous casting and changes in the basic oxygen furnace;
- further increases in the use of high-quality, high-performance steels, which impose more stringent requirements on scrap quality while reducing the future supply of low-alloy scrap, desirable for most scrap applications; and
- increasing use of DRI as an input substitute for scrap.

Scrap-Based Electric Furnace Steelmaking.—The use of electric furnace processing is increasing rapidly in the United States and throughout the world because it has relatively low capital and operating costs. This process uses a higher proportion of scrap input than do other processes; it also reduces the amount of prompt industrial scrap generated per melting unit. Thus, increased use of scrap-based steelmaking will increase the demand for scrap, while putting additional downward pressure on available scrap supplies.

Domestically, the use of the electric furnace is growing rapidly among nonintegrated steelmaker, and some of the integrated steel mills are beginning to use more electric furnaces in combination with their other steel production facilities. Presently, about one-quarter (22.7 million tonnes) of domestic steel is made in electric furnaces. Although ferrous scrap consumption in open hearth production in the United States has declined, this trend will be offset by growth of scrap consumption in electric furnaces by 1982, when new electric furnace installation, now underway or planned, will have been completed. It is likely that as much as half of future domestic new capacity will eventually be based on electric furnaces.[29]

Electric furnace use has grown at an even faster rate abroad. In the last 10 years, world electric furnace steel production has increased by nearly 75 percent, or almost 39 million tonne/yr. Almost 30 percent of the growth in world steel production has been in the electric furnace. One forecast suggests that worldwide electric furnace use will increase by more than 50 percent from 1978 to 1985, and by 1985 will account for 38 percent of the increase in world steel output.[30]

Continuous Casting and Basic Oxygen Furnace Changes.—These technological changes also have increased steel industry use of purchased prompt industrial and obsolete scrap. The increased yield from continuous casting, compared to conventional ingot casting, causes less inplant scrap to be produced. Thus, purchased scrap must replace "lost" home scrap in order to maintain liquid-iron-to-scrap ratios for steelmaking furnaces. This also assumes increased shipments of finished steel at existing levels of iron production (see ch. 9). In 1978, 32 percent or 28.5 million tonnes of all steel shipped was derived from purchased scrap. If continuous casting were increased to a 50-percent level on the 1978 base and produced a 12-percent increase in

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[29] Hogan forecasts an increase in electric furnace raw steel from 29.2 million tonnes in 1978 to 46.3 million in the mid-1980's. (W. T. Hogan, "Growth of the Electric Furnace, " paper presented at the Ferrous Scrap Consumer's Coalition symposium, Atlanta, Ga., February 1980.) A supplier of electric furnaces forecasts that "by IWO, half of all the steel will be made in electric furnaces, " (*Iron Age*, Feb. 4, 1980, p. MP-7.)

[30] American *Metal* Market, Jan. 17, 1980.

yield, then an additional 5.7 million tonnes of scrap would have to be purchased to satisfy steel production needs. * Under such circumstances, 36 percent or 34.3 million tonnes of all steel shipped would be derived from purchased scrap.

Equipment changes in basic oxygen steelmaking furnaces (BOFs) also permit a substantial increase in the amount of scrap used in production. These changes allow traditional scrap charges of 28 percent or less to be increased to 30 or 40 percent. Using a combination of preheating and silicon carbide, for instance, scrap use could be increased to the 35-percent level, with a net cost saving.[31] The economic advantage depends on the cost of scrap compared to that of hot metal from the blast furnace. For plants attempting to increase steel output without incurring the capital costs of installing new blast furnace capability, this approach may be attractive.

A more recent variation is to remodel BOFs with bottom as well as top blowing equipment and to modify Q-BOP (a proprietary version of a bottom-blown BOF) furnaces to allow for the preheating cycle.[32] This system, invented by a West German company and known as the OBM-S (advanced basic oxygen process with scrap preheating), is being adopted by the National Steel Corp. Increases of 27 to 42 percent in the amount of scrap used have been reported, as well as reductions in processing time. The capital cost of this retrofitting option is relatively high (about $10 million per furnace), so companies taking this route are likely to optimize scrap use in order to reduce total production costs.

Quality of Scrap.—While the need for increasingly higher quality scrap to make higher performance steels is mounting, the quality of the available scrap is declining. The increased use of alloy steels and recycled scrap, as well as the greater use of nonferrous materials in automobiles, has resulted in scrap containing more nonferrous elements such as zinc, copper, nickel, chromium, and molybdenum. These impurities, called "tramp," generally cannot be removed in the steelmaking process. Steel made from a 100-percent-scrap charge is only as "clean" as the scrap it is made from. Steel made with pig iron or DRI, along with scrap, does not have this cleanliness problem if the scrap percentage is sufficiently low.

The problem that the domestic steel industry may face in the future because of poor-quality scrap is spelled out in the results of a recent industry survey:

> The consensus of the returns was that the quality of ferrous scrap, as judged by tramp alloy contaminants, is generally declining, and that it could become a serious problem by 1985. The majority of the respondents stated that their customers will be seeking performance characteristics in steels by 1985 which are significantly to substantially higher than those which can be commercially achieved today. Further, this requirement is felt to be closely linked to scrap quality, Most of the respondents consider the tramp alloy content of their scrap to be a high-priority concern in this connection.
>
> The survey yielded considerable detail in regard to the tramp element which the responding mills routinely monitor, The implications of the rapidly-increasing usage of high-strength, low-alloy steels by scrap consumers turned out to be a controversial and uncertain matter to steelmen, Regarding the possibilities of consuming a significant volume of scrap recovered from municipal solid waste, a minor percentage replied "yes" and a minor fraction said "no,'" while the majority hedged with the answer "possibly."
>
> The consensus seemed to be one of doubt that technological developments in scrap processing and in steelmaking will compensate for the build-up of tramp elements in scrap, Closely related to this, the majority seemed to feel that direct reduced iron might become essential, in order to dilute the rising contaminant levels.

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*Assuming an average yield of 0.92.

[31] W. F. Kemner, "The Operating Economic and Quality Consideration of Scrap Preheating in the Basic Oxygen Process, " Proceedings of American Iron and Steel Institute technical meeting, Philadelphia, 1969.

[32] *33 Metal* Producing, June 1979, p. 56; November 1979, p. 67-71.

> All-in-all, the attitudes expressed regarding a long-range build-up of tramp alloy contaminants in ferrous scrap represents a stiff challenge to the scrap industry and its supporting sectors. It would seem to be crucial to lose no time in mounting an intelligent, well-coordinated campaign, nationwide, to attack this problem. The best results will doubtlessly require close cooperation between scrap suppliers and steelmakers.[33]

To reduce the tramp-element problem, low-grade purchased scrap ideally should be used in BOFs, and home scrap mixed with high-quality purchased scrap should be used in electric furnaces. However, industry structure does not permit such optimization; for example, electric furnaces are not always close to the sources of home scrap, Theoretically, there are three additional points of attack on the tramp-element problem:

- Product design. —Even though materials in products are becoming more sophisticated, products could be designed with recycling in mind. These products by their very design would facilitate identification and separation of various usable materials upon recycling.
- Improved scrap processing techniques, —This refers to better (more reliable, faster, more discriminating, and more economical) techniques of separating and identifying usable materials at the processing plant.
- New steelmaking techniques. —This refers to techniques of operation that would allow some impurities to be removed in the steelmaking process.

The steel industry's ability to influence product design as a means of reducing the tramp-element problem is limited, at best. The scrap-processing and steelmaking industries could pursue the second and third options, and they have incentive to do so because they are directly affected by the tramp-element problem. Scrap-processing improvement may have more potential than changing steelmaking techniques, but there is some chance for innovations in the latter area.

Direct Reduction. *—Of all current technological changes affecting the demand and price for scrap, DR is the only one that can reduce demand for scrap and thus reduce its price. Thus, a way to alleviate growing demand pressures on scrap and to moderate scrap price increases may be to produce or import DRI. This "clean" material can substitute for ferrous scrap in electric furnace steelmaking, and it also offers certain technical advantages.

Recent technological advances in DR suggest that it could become economically viable and could supplement ferrous scrap supply at a price competitive with that of scrap. The use of DRI can also help avoid some of the anticipated problems of tramp alloy contaminants in scrap. At the present time, DR facilities are limited in the United States (accounting for less than 1 percent of steel made), but this is not so in other countries. In the past, scrap availability and low scrap prices in the United States have acted as a disincentive to development of DR. As scrap prices rise, DRI will become more competitive. **

Targets for Increased Use of Ferrous Scrap

It is in the national interest to maximize the use of recovered materials, in part to save energy. It has been generally accepted that scrap embodies the energy (18.7 million Btu/ tonne) that was originally used to convert the iron ore to iron. Two statutory provisions have been enacted that deal with maximizing the use of scrap and other waste sources of iron generated in steel plants. These provisions do not adequately consider the long-range consequences of attempting to maximize the use of scrap and other recovered materials. The relevant provisions are:

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[33] R. D. Burlingame, "Trends in Scrap Quality for the 1980s,'" *Iron ond Steelmaking*, February 1979, p. 18.

*DR is described and discussed in ch. 6, and its role in the growth of nonintegrated steelmaker in ch. 8.

**The price of DRI, whether imported or manufactured domestically, will in the long run be a decisive determinant of increased electric furnace use.

- Section **461** of the National Energy Conservation Policy Act (Public Law 95-619) of 1978, which mandates that the Department of Energy (DOE) set voluntary targets for use of recovered materials to be observed by the entire ferrous industry—ironmakers and steelmaker, foundries, and ferroalloy producers.
- Section 6002 of the Resource Conservation and Recovery Act (Public Law 94-580) of 1976 amending the Solid Waste Disposal Act, which requires that Government procuring agencies procure items composed of the highest practicable percentages of recovered materials and instructs the EPA Administrator to promulgate guidelines for the use of procuring agencies in carrying out this requirement, it also requires suppliers to the Government to certify the percentage of recovered materials in the total material used.

The setting of targets or guidelines presents a number of problems. It may not be technically or economically feasible in all **cases to use** recovered materials to the extent suggested or indicated by the Government. The methodology and assumptions used to calculate targets can be tenuous and highly controversial. Steel producers are especially worried about infeasible voluntary targets that could become mandatory,

One problem with legislative attempts to maximize the use of ferrous scrap is that they apply indiscriminately to all segments of the steel industry and to all types of production processes. Moreover, many types of companies would find targets relatively easy to circumvent. For example, targets for purchased scrap could be circumvented if companies sell their home scrap to others and purchase other firms' home scrap. * In addition, set goals could in fact be counterproductive to the original objective of maximizing recovered materials use and saving energy. Should targets and guidelines effectively increase demand for purchased scrap, this would raise scrap prices. The impact of higher scrap prices on nonintegrated companies would be much worse than on integrated steelmaker. This could lead to a decrease in steel made by nonintegrated producers and less total scrap used. Additionally, integrated producers using more scrap in BOFs must also use more natural gas and electricity for necessary process modifications, thereby increasing energy use at least on a temporary basis.

Technically and economically, it is extremely difficult for integrated steelmaker to increase their use of recovered materials substantially. They would most likely incur costs that do not improve productivity. An important exception is an integrated company that increases its steel production, without increasing blast furnace capacity, by investing in technology to increase scrap use in BOFs or in electric furnaces that use purchased scrap almost exclusively. Even then, these investments must be sound economically in themselves on a plant-by-plant basis; targets based on industry averages maybe inapplicable.

Scrap targets or guidelines are not relevant for electric furnace steelmaking because at present that process uses only scrap. With the advent of DR and the availability of DRI, however, electric furnace steelmaker could use less scrap, so targets or guidelines could act as disincentives to the introduction of DR. Though the proportion of scrap used in any one electric furnace shop would decrease if it also used DRI, an expansion in electric furnace steelmaking, even using both scrap and DRI, could increase the total amount of purchased scrap used. The new average amount of scrap used in nonintegrated companies or electric furnace shops of integrated producers would likely be greater than the average for conventional integrated operations using BOFs.

It appears that EPA, for some of the reasons given above, will not actively pursue the setting of guidelines for ferrous scrap use. The Department of Energy has already set targets, but they appear to be quite low. For

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*Such an activity might only occur on paper through intermediaries, Actual transportation costs could be prohibitive.

the entire ferrous industry, the target for 1987 is that 41 percent of steel shipments be made from purchased prompt industrial and obsolete scrap. The actual value for 1978 was 40 percent, and for 1979 it appears to have reached 41 percent. OTA analysis indicates that if the use of continuous casting were increased to 50 percent on the 1978 base, scrap use would be 44 percent. If a 2-percent annual increase in steel production is added to a 50-percent continuous casting scenario, scrap use would be 48 percent by 1987. Changes in BOFs would increase the scrap-use rate still further.

Future Scrap Shortages

There can be no unequivocal answer to the question: will there be a shortage of ferrous scrap in the United States? A shortage is defined as a market situation in which there is a rapid and substantial rise in the price of scrap at the quality level required by a substantial fraction of users, but shortages can vary with geographic or cyclical aspects of ferrous scrap supply and demand. It is apparent that a number of major factors will influence the average supply and demand of ferrous scrap in the United States, and thereby either promote or reduce the likelihood of a general domestic shortage.

Physical Supply.—Although more and more steel scrap will exist in some form within the United States, steel consumption is growing at a relatively low rate and, hence, so is the magnitude of the scrap supply. The portion of the supply that is readily and economically retrievable will decline as: less scrap is produced in manufacturing, less steel is used in automobiles, less scrap is concentrated in a relatively small number of geographical areas, the cost of transporting scrap by any means increases, more and more nonferrous materials become intimately part of and mixed with ferrous materials, and product lifecycle considerations lead to longer lifetimes for steel products. Thus, these factors favor a future shortage of usable scrap.

Exports to Foreign Electric Furnace Steelmakers.—As the domestic and foreign trends toward more electric furnace steelmaking continue, foreign steelmaker will put greater demand pressure on U.S. scrap, and this will increase the likelihood of a scrap shortage. Should the current shortage of domestic coke continue, it would likely result in even greater use of scrap-based electric furnace steelmaking, although inadequate electricity generation could reverse this trend.

From an international point of view, the general shift of steelmaking capacity (especially from Europe) to the Third World will tend to reduce foreign demand for U.S. scrap, because steelmaking in those countries will be based on DRI. On the other hand, the relatively high level of foreign steel production costs, particularly in Europe, will make high-priced U.S. scrap competitive with alternate overseas sources while raising costs for domestic steel producers. And finally, an important factor that is often overlooked is the effect of currency exchange rates. As the dollar weakens against other currencies, U.S. scrap becomes more attractive to foreign buyers. Thus, foreign steel producers can bid up domestic scrap prices and still have an attractively priced raw material, but domestic raw materials costs will be adversely affected. Conversely, strengthening of the dollar could reduce foreign demand.

New Technologies.—Although the expected near-term increase in the use of continuous casting and scrap-use-enhancing changes in BOFs would increase the likelihood of a domestic scrap shortage, the development of coal-based DR would greatly reduce it. DRI clearly could be the most effective substitute for scrap and the most competitive means of limiting scrap price increases. However, until and unless scrap prices rise sufficiently to allow the lowest cost DR technology available to compete in the marketplace, DR is not likely to be adopted on a substantial scale in the United States. DRI imports seem to offer greater near-term potential than does domestic adoption of the technology. The increased development of DR in less developed countries with cheap natural gas could provide worldwide trade in DRI. It is distinctly possible that within the next decade DRI imports could obviate a domestic shortage of scrap. Farther in the future, more radical steelmaking technologies, such as nuclear steelmaking, magnetohydrodynamic steelmaking, plasma steelmaking, or direct (one-step) steelmaking, which could economically convert iron ore to steel, would greatly reduce the likelihood of scrap shortages.

Federal Policies.—A number of policy options could either increase or reduce the likelihood of ferrous scrap shortages. In particular, policies that would increase transportation costs, increase domestic demand for scrap, and facilitate scrap exports (including a declining dollar) could promote a domestic scrap shortage. Policies that could stimulate the development of new steelmaking technologies, such as DR and formcoking, could help prevent scrap shortages. In the absence of any policy changes, and without the influx of enough capital to construct major new blast furnaces, a scrap shortage is likely to occur if there is a continued steady growth of domestic demand for steel. An analysis by the president of a successful nonintegrated company appears valid:

> . . . scrap is going to be more valuable and in shorter supply.
>
> In how short supply? We have made an exhaustive study of this covering seventeen variables including such things as scrap generation, plant construction, market growth, the utilization yield and imports of coke, development of continuous casting, direct reduced iron production and imports, and many others. We've tried to evaluate all of these but manifestly with so many variables there can be many answers. Nevertheless, within what we believe to be reasonable parameters, a scrap surplus which has recently been allowing 10,000,000 tons a year to be exported will by the year 1985 allow only 5,000,000 tons which leads quickly to no surplus at all. I should emphasize that I see this drop in exports resulting from domestic price competition, not from government embargo.[34]

Of particular importance in the above statement is the viewpoint that increasing domestic demand, rather than Government export controls, will reduce exports. Even more interesting is a scrap supplier's expectation of a domestic scrap shortage under conditions of continuing exports:

> For the 18 months preceding August 1979 , . . domestic scrap demand . . . equalled the scrap demand during 1973 and 1974. As a practical matter, we had reached the balance between supply and demand, . . . Three to four years from now, we will be hard pressed to find enough No. 1 (high quality) grades of scrap to meet the demand.

When such a shortage occurs, what will happen?

> 1. Scrap can be diverted from export, but who will pay the extraordinary freight charges to move this scrap to regions of domestic shortage? And, what will be the effect on our nation's friends who are the major consumers of our export scrap?
> 2. Direct reduced iron can be purchased in the United States or imported, But who will invest the hundreds of millions of dollars required to build these plants? Further, who will commit to pay $150 to $175 per gross ton for the product ?
> 3. Integrated steel production can be increased. But who will invest the billions required and take the environmental risks associated with this solution?
> 4. Finally, we can do nothing and our increased domestic demand for steel will be satisfied by importing 25 percent or more of our needs by the mid-1980s.[35]

Concluding that there will be a scrap shortage some time during the next decade is risky. The number of uncertainties on both the supply and demand sides of the issue are so great that any forecast must be equivocal. This very uncertainty about future domestic scrap supplies makes policy decisions affecting scrap use, supplies, and exports quite difficult (see ch. 2).

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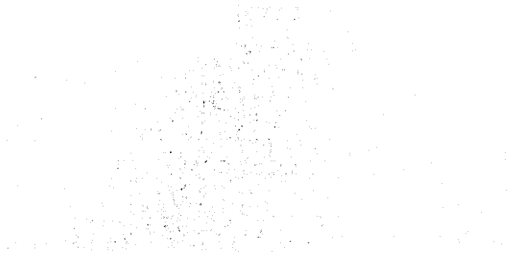
[34] W. W. Winspear, president, Chaparral Steel Co., speech to National Association of Recycling Industries, September 1979.

[35] Blauvelt, op. cit.

CHAPTER 8

Technology and Industry Restructuring



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Technology and Industry Restructuring

Summary

The structure of the domestic steel industry is changing. What is meant by structural change? Broadly speaking, structural changes in industries refer to permanent changes in the character and competitive positions of industry participants. Technology mixes, supply-demand relationships, geographical patterns of company locations, costs of entry into the industry, and raw material use may all be components of a structural change.

Structural changes can result from both regulatory and technological influences.[1] For example, deregulation changed the nature of the U.S. securities industry by freeing commission rates; this led to many mergers and acquisitions within the industry, an increased concentration of capital, and the virtual elimination of some types of companies. Similarly, deregulation of the airline industry is clearly bringing about a rapid growth of small regional carriers and the need for new Government policies for this industry segment. An example of technology-related structural change, on the other hand, is in the watch industry, where the introduction of solid-state technology by American and Japanese companies brought about a permanent change in the industry. In 1970, the Swiss had a 70-percent share of the world market; by the late 1970's, it was falling below 30 percent. Entirely new companies had entered the industry with new manufacturing technology and new products.

Permanent structural changes within an industry alter the impact of Government policies on the industry and create new needs that may require new policies. But even profound structural changes are difficult to recognize while they are taking place. One reason why OTA has examined the steel industry as separate segments was to be able to determine whether structural changes are occurring in the steel industry and, if so, to analyze their nature. OTA found that restructuring is in fact taking place, and that it may accelerate because of a number of factors, including new technology. This restructuring consists of growing competitiveness, expansion, and profitability of the two smaller segments of the industry: the nonintegrated carbon steel producers and the alloy/specialty steelmaker. As a result, traditional market shares in steel are shifting, and the industry is becoming decentralized.

Part of the emergence of the two smaller steel industry segments can be attributed to internal, technical adjustments within individual companies; that is, the extent to which companies match the nature of their production (its type and scale) with the type and quantity of products they manufacture. For example, the unprofitable integrated companies may be attempting to make too wide a variety of products, using steelmaking technology better suited to large-volume production of a few commodity products. Nonintegrated and alloy/specialty companies generally have a good match between production technology and product mix, and this enhances their profitability.

External forces have played some part in its restructuring. Demands for alloy/specialty products have increased. At the same time, nonintegrated companies in particular have not been reluctant to expand their product lines and move into markets dominated by integrated producers. The structure of the steel market reflects these factors. The market share of integrated producers is declining and, by 1990, it could drop from the present

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[1] R. R. Osell, "Structural Versus Cyclical Change—Implications for Strategic Planning," paper presented at American Institute of Mining, Metallurgical and Petroleum Engineers annual meeting, February 1979.

85 percent to about 70 percent. Nonintegrated steelmaker have tripled their output in the last decade. In 1978, they accounted for 13 percent of domestic shipments, and if adequate ferrous scrap and electricity are available they could account for 25 percent by the end of the 1980's. Because the domestic consumption of alloy / specialty steels is increasing at a rate about double that of carbon steels, alloy / specialty production is likely to expand by about a third during the next decade. (Table 96 presents recent production and financial data for the three industry segments.)

New technologies have and will continue to influence the shift in the structure of the steel industry. Electric furnaces and continuous casters have reduced production costs and simultaneously enabled the small companies to capitalize better on local markets for their products. It can be argued that technological changes would also enable the integrated companies to take better advantage of their process capabilities, but substantial obstacles deter the adoption of such changes. These obstacles include inadequate capital and conservative management,

The most important future technological developments for nonintegrated producers will be the introduction of rolling mills to make flat products, such as strip, and the use of direct reduced iron (DRI) to supplement scrap and facilitate the production of higher quality steels. The alloy / specialty steelmaker have excellent technological and cost competitiveness and potential for exporting their technology-intensive steels.

Table 96.—Summary Data on Steel Industry Segments, 1978

	Raw steel[a]		Steel shipment[a]		Return on Invest ment[b]	Steel only—pretax profits ($/tonne shipped)[b]	Employment costs ($/tonne shipped)[c]
	1,000 tonnes)	Percent	(1,000 tonnes)	Percent			
Integrated	107,889	87	75,522	85	-6.9	$9.60	$209
Nonintegrated	12,274	10	11,291	13	12.3	31.60	138
Alloy/specialty	4,125	3	2,014	2	11.1	81.33	341
Total[d]	124,288	100	88,827	100	7.3	$22.00	$163

SOURCES. [a] Based on data and approximations provided by AISI OTA has assumed an average yield for Integrated companies of O 70 and for nonintegrated companies of 0.92

[b] From table 23

[c] From table 23

[d] From AISI, financiat data includes nonsteel activities.

Internal Adaptation

An analysis of process and product stages of manufacturing companies permits a useful understanding of differences among them. A given company or industry segment is either process- or product-oriented; that is, process-focused firms tend to find the market for their product and process, while product-focused companies try to fit the best process and product to market opportunities:

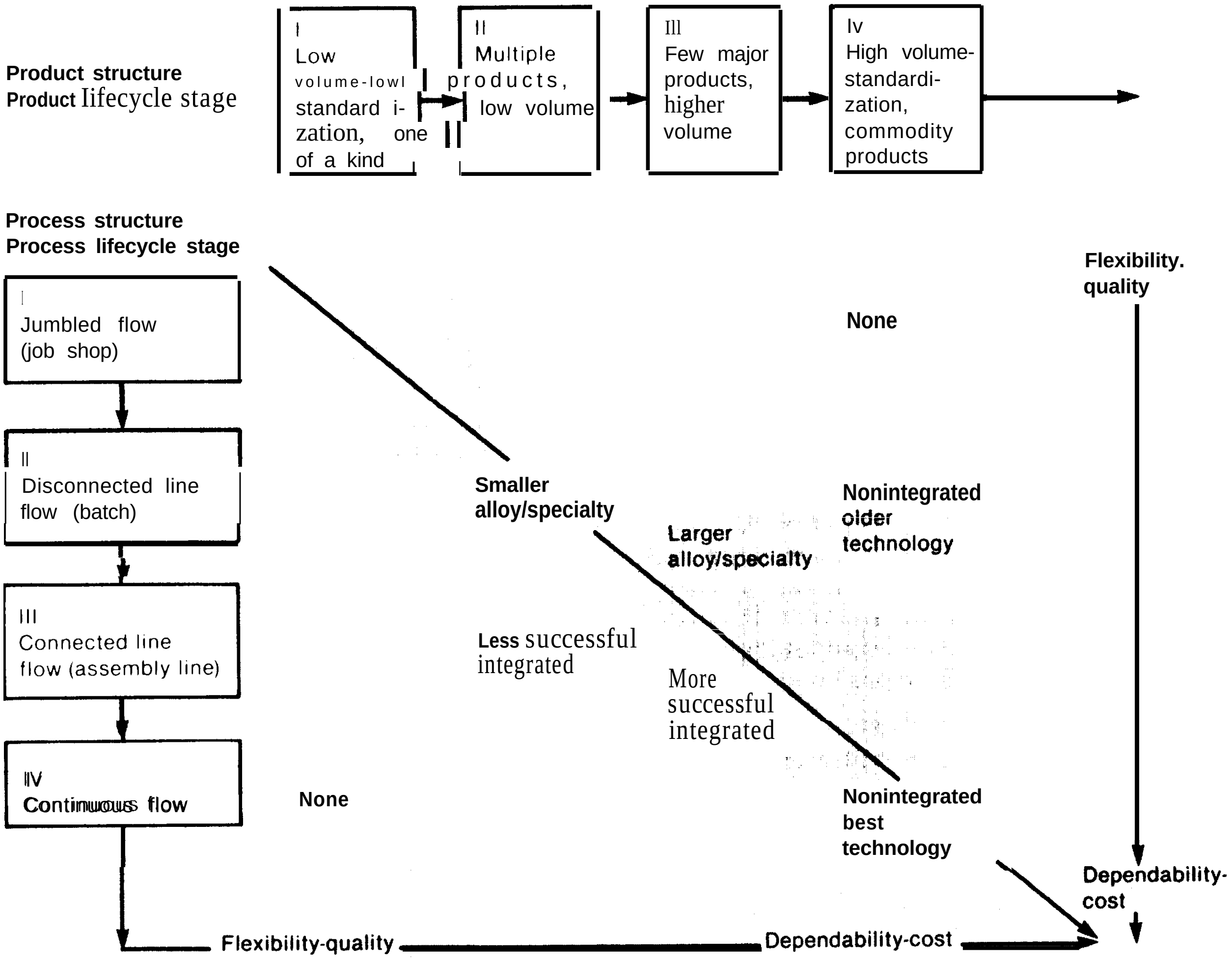
> Companies in the major materials industries—steel companies and oil companies, for example—provide classic examples of process-organized manufacturing organizations. Most companies that broaden the span of their process through vertical integration tend to adopt such an organization, at least initially. Then again, companies that adopt a product- or market-oriented organization in manufacturing tend to have a strong market orientation and are unwilling to accept the organizational rigidity and lengthened response times that usually accompany centralized coordination.
>
> Most companies in the packaging industry provide examples of such product- and market-focused manufacturing organizations. Regional plants that serve geographical mar-

ket areas are setup to reduce transportation costs and provide better response to market requirements.[2]

A hidden assumption in the above analysis, however, as in almost all descriptions of the domestic steel industry, is that there is one, single steel industry. This is not the case: although the largest segment of the industry, the integrated steelmaker, fits the description of process-organized companies, the other two segments far better match the description of companies that have a product or market orientation.

A manufacturing company's products can be characterized along a continuum that ranges from one-at-a-time production to continuous-flow production. For a company to have an optimum, low-cost production system, its stages along these continuums must match. Figure 35 illustrates this idea, using the relative product and process positions of different types of steel companies. The goal is to be on the diagonal of the matrix, so that a company's product stage is consistent with its process stage. The worst cases would be for a

Figure 35.—Correlation of Product Lifecycle Stages for Steelmaking Plants



SOURCE: Adapted from R. H. Hayes and S. C. Wheelwright, "Link Manufacture and Process Life Cycles," *Harvard Business Review*, January-February 1979.

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[2] R. H. Hayes and S. C. Wheelwright. "Link Manufacturing and Process Life Cycles," Harvard Business Review, January-February 1979.

company to try to produce a high volume of highly standardized products (product stage IV) with job-shop procedures (process stage I), or for a company with a continuous flow process (stage IV) to attempt to produce a small number of unique products (stage I). As a company or industry evolves, it does not have to move along the diagonal, but it will be more successful if it does.

According to this schematic, the low profitability of many integrated companies can be linked to the fact that they attempt to make too many different products in quantities unsuitably small for the nature of the steelmaking process they use. They do not capitalize on potential scale economies. Integrated steelmaking involves many steps that must be coordinated in order to produce at optimum levels. The economy-of-scale advantage of having a large blast furnace is negated by producing small lots of a great many different finished steel products, because different product types require different finishing equipment. This means investing in highly capital-intensive equipment that will not be fully or continuously used. Thus, unprofitable integrated companies are not appropriately rationalized—their product lines are too various for large-scale production, and the capital investment requirement for each product is too great to be justified by the size of the market for that product. The plant closings of several large domestic integrated steelmaker in the past few years are consistent with those companies' attempts to get back on the product/process diagonal by narrowing the scope of their product lines. Generally, they are halting production of products that are also made by nonintegrated companies or can be imported at competitive prices.

Some integrated companies, however, have the opposite problem: their process stage is too primitive for the high-volume production of a few products. Their production technology does not take advantage of the scale economies that high volume would allow, or their secondary processing is not volume-coordinated with primary processing, or both. The chief process deficiencies for these companies are small blast furnaces and ingot, rather than continuous, casting.

The nonintegrated companies are moving toward expanding their range of products, but in doing so, they more often construct new plants for specific products rather than expand existing plants. In the most efficient mills, there is a very smooth flow of materials for large-volume production of products by a combination of electric furnace steelmaking and continuous casting. The less efficient mills do not have the optimum process for the product stages they are in: the chief problem is the absence of continuous casting in plants that make a relatively narrow range of products; but some plants that do have existing continuous casting equipment produce too many products to allow long, efficient runs.

Alloy/specialty steelmaker vary considerably in their product stages, but generally their process and product stages are properly matched. Some firms produce a large variety of products, while others specialize in a few products made in relatively large quantities. A significant trend is toward expanding mill capacity while maintaining product mix, which permits more continuous processing using new technology. For example, many plants use continuous casters, which permit very rapid changeover to different sizes and shapes of products, and also offer considerable production-cost savings in the form of lower energy consumption and greater yields on expensive, high-alloy raw materials.

Nonintegrated Steelmaker

Fundamental Advantages and the Role of Technology

Nonintegrated carbon steel producers are often referred to as minimills, midimills, cold metal shops, or special-market steel companies. In some analyses, companies OTA classifies as alloy/specialty companies are included in the nonintegrated category. This classification may be correct in terms of the process technology these companies use, but it would not be correct in terms of the products they manufacture.

A few small domestic minimills have been operating since the late 1930's,[3] more than 40 were constructed during the 1960's, and about 10 more were added in the 1970's.[4] The term "minimill" derives from the very small size of the early generation of nonintegrated steelmaker: most made no more than 43,350 tonnes of product a year. Today, a number of plants and companies have capacities in the range of 272,100 to more than 907,000 tonnes (table 97). As a whole, nonintegrated steelmaking capacity and production have tripled in the past decade, and significantly more capacity, probably 0.9 million to 1.8 million tomes, is now in the construction or planning stages.

The nonintegrated companies are generally quite profitable compared to the larger integrated companies. Their success has been based on their use of new technologies and favorable product/market strategies:

- Nonintegrated mills have been quick to adopt promising technological changes: they spearheaded the adoption of electric furnaces, furnace improvements, and continuous casting, all of which contribute to relatively low production costs, low energy consumption, low capital costs, and high productivity. The rate of labor productivity improvement in electric furnace steelmaking has been particularly high: employee-hours per tonne decreased 25.3 percent between 1972 and 1977, compared with 6.9 percent in integrated steelmaking.[5] Further, because electric furnaces use scrap, they consume far less energy than do integrated steelmaking processes: in 1978, integrated plants used an average of 35.2 million Btu to produce a tonne of shipped product, as opposed to 9.9 million Btu for nonintegrated plants producing carbon steels. In recent times the price of scrap has been low relative to the cost of making new iron units from iron ore.

Table 97.—Approximate Plant, Capacity, and Shipment Data for Nonintegrated Mills

Source	Year	Number of plants	Product capacity	Shipment
(1)	1967	34		
(2)	1970	43	4,813,000 +	
(3)	1970			3,706,000
(4)	1972-73	48	5,918,000 +	
(5)	1974	40		2,979,000 +
(6)	1978	52	13,257,000	
(7)				11,291,000

NOTE: Definitions and classifications of nonintegrated carbon steel mills have not been Identical in sources of these data A (+) sign Indicates that figure appears to be based on less mills than those included in OTA system or on an admitted lack of complete data

SOURCES
(I) C L Konir, "The Big Source of 'Mini' Steel Plants." *Iron Age,* November 1967
(2) G J McManus, "Mlnl-Mills Leery of Mldl-Mill Size," Iron *Age,* May 21, 1970
(3) G J McManus, "No More MiniMllls?" Industry *Week,* November 1971
(4) Association. of Iron and Steel Engineers, "Directory of Iron and Steel Plants," 1975
(5) Temple, Barker, and Sloane, "Analysis of Economic Effects of Environmental Regulations on the Integrated Iron and Steel Industry, " July 1977
(6) IIIS *Commentary.* January-February 1979 Assuming 90-percent yield from raw steel capacity
(7) Approximation based on data from AISI.

- Plant construction costs and leadtimes are low. The nonintegrated plants can be built for 10 to 20 percent of the cost of a greenfield integrated plant. The elim-

---

[3] A. Cockerill ["The Steel Industry: International Comparisons of Industrial Structure and Performance, " Cambridge, 1974) noted that 40 mills were built in the United States during the 1960's. In 1970, 42 plants were noted to be in existence (G. J. McManus, "Mini-Mills Leery of Midi-Mill Size, " Iron Age, May 21, 1970). A 1978 listing includes 53 plants (*IISS* Commentary, January-February 1979).

[4] C. G. Schmidt and R. B. Lelteren, "Mini-Steelplants in the U. S.: Some Technological and Locational Characteristics, " *Land* Economics, vol. 52, No. 4, November 1976.

[5] U. S. Bureau of the Census data.

ination of primary ironmaking and finishing facilities for flat products and complex steel products accounts for much of this difference. The absence of ironmaking and the use of electric furnaces also reduce the amount of pollution abatement equipment needed. The simplicity of nonintegrated plants and the common use of available technology allow relatively quick new-plant construction, usually in 1 to 2 years.

- The product range of nonintegrated plants is narrow, consisting mostly of simple commodity steels in nonflat shapes such as reinforcing bar. Both of these factors permit long production runs with simple equipment.
- Plants serve and draw upon relatively local markets. Plant locations are selected to capitalize on the availability of local ferrous scrap and local labor and to produce for fast-growing local industries, particularly construction companies that use reinforcing bar. Their market strategy is to make special products for special markets, Confining their operations within small, surrounding geographical areas also minimizes transportation, sales, and marketing costs.

As a result of these practices, nonintegrated mills are generally the lowest cost steel producers in the country, and often their products are even priced lower than imports.[6] At the same time, the nonintegrated companies have performed very well for their owners and stockholders, so much so that they have become acquisition targets for other domestic and foreign industries.

The nonintegrated companies are sometimes accused (by integrated producers) of making the "easy," lowest cost and price steel products. But these companies have caused their products to become low-priced by virtue of their low production and capital costs and their well-managed operations. The current trend among integrated companies toward switching to the electric furnace-continuous casting process is surely recognition that the nonintegrated companies have made some wise choices.

The growth of nonintegrated steelmaker in the United States has been matched by similar growth in other countries. A European steel expert has commented on the growth of nonintegrated steelmaking in Europe:

> In recent years a sizable expansion of steelmaking capacity has taken place only in the scrap-based mini-mills. Representative is the 5 Mill, tons capacity of the Bresciani in Italy, who were able to underbid the integrated steelmaker in front of their home doors by a comfortable 50 dollars per ton in non-flat products, This development has been caused by the disregard for the scrap market that was practised for many years by the large integrated steelmaker.
>
> As a result, the integrated steelmaker have continuously lost market share in the non-flat product areas.[7]

Future Changes

New Products

The initial success and growth of nonintegrated steelmaker and of new entrants into the industry have been associated with producing simple products, notably reinforcing bar, but increasingly they are also producing more complex products and higher quality steels. About half of the nonintegrated plants produce only merchant and reinforcing bar, but about one-fifth do not make merchant and reinforcing bar at all.

Many plants make special-quality bars, wire rod, and structural. A few plants make plates, flange beams, I-beams, forging billets, and alloy bars. There is a clear trend toward making these higher grade products. Consider the following comments on one of the newest plants, designed solely for wire rod:

---

[6] On the west coast, which has the greatest import penetration (40 percent), imports have only 6 percent of the market for reinforcing bar, compared to more than 50 percent for structurals and sheet and strip products (*Iron* Age, July 31, 1978).

[7] W. H. Philipp, "Probable Course of Europe's Steel Industry,'" paper presented at American Institute of Mining, Metallurgical and Petroleum Engineers annual meeting, New Orleans, La., February 1979.

> “We will be the only rod mill in North America producing strictly rods,” says Thomas Tyrrell, marketing vice-president. “We will have no wire drawing subsidiaries, no rebar line and no potential to shift raw steel to other steel products, when market conditions make them more attractive than rods, ’
>
> The concept of isolating markets is not new to Co-Steel, which operates minimills internationally. Raritan River’s market is larger than the traditional minimill’s, where merchant bars and rebar are typical products, the wire rod will be sold over the entire eastern U.S. and possibly abroad. Another hallmark of the minimill—low investment costs per ton—is common to Raritan, And combining specific markets with efficient steelmaking is the key to minimill’s success.
>
> “The whole minimill concept is operational, ” says Tyrrell, “since operations are the key to cutting costs. As the theory goes, once you have the product at the lowest possible cost the market comes naturally. Our idea goes one step further, If our operations are the very best, we should be able to command a high price. ‘[8]

The future strategies of nonintegrated companies have been summarized as “upgrading product mix, concentrating on various shapes or sections that have been abandoned by the major mills and/or specializing in chemistry modifications for selected customers. ”[9]

The most important characteristic of most present products is that they are not flat products like sheet and strip. Because conventional rolling equipment for flat products is generally geared for economic production of several million tonnes annually, there is a long-held belief that nonintegrated companies could not move into this product area, and that if they did the change would greatly increase their capital costs. However, this is not necessarily the view within the nonintegrated segment. F. Kenneth Iverson, president of Nucor Corp., has stated that:

> Mini-mills started with a relatively simple product—refinforced bar. Now we make plate and wire products, rails, even structural grades. The only thing you can’t do with a mini-mill now is make sheet, but even that may not be out of the question in the future.[10]

The minimum optimum scale for flat-rolled products in a nonintegrated plant ranges from 0.5 million tonne/yr for narrow strip to 4.1 million to 4.6 million for very wide strip.[11] The low end of this range is consistent with larger size nonintegrated plants.

New Small Rolling Mill Equipment

Of greater significance is the current interest in developing new types of flat-rolling equipment for nonintegrated plants: “Voest-Alpine is also developing a flat-rolling mill for wide strip and medium hot strip, capable of production of 250,000 tons to 500,000 tons per year of hot strip at minimum cost.”[12] It should be noted that Voest-Alpine is an Austrian firm that sells continuous casting equipment worldwide and is also the owner of a new nonintegrated plant in New Orleans.

The most significant development in small-scale equipment for flat products is the hot reversing mill, which has already entered the marketplace. Sometimes called a Steckel mill, the reversing mill flattens steel by successive, back-and-forth passes through a single stand rather than through many stands, which is the method used in large sheet-rolling mills. The reversing mill eliminates the heat losses that occur when a flat strip travels through a continuous mill. In the reversing mill, the strip travels through the mill and is coiled in a furnace on the other side. Moreover, the simplicity of the reversing mill greatly reduces capital costs and shortens construction times.

A domestic equipment manufacturer has already sold several hot-reversing mills to nonintegrated companies. A Canadian nonintegrated steel producer with 408,150 tonnes of steelmaking capacity will produce steel

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[8] *Steelweek*. Apr. 23, 1979.

[9] *World Steel Industry* Data Handbook—U. S., McGraw-Hill, 1979.

[10] American *Metal* Market, Dec. 31.1979.

[11] D. G. Tarr, “The Minimum Optional Scale Steel Plant in the Mid-1970’ s,” manuscript.

[12] American Metal Market, Aug. 24, 1979.

pipe for a natural gas pipeline with this equipment. The equipment will be used to produce heavy-gauge flat-rolled high-strength steel, one-half-inch thick, in widths up to 72 inches.[13]

The cost of the Steckel mill is reported to be about one-tenth the cost of a conventional large sheet-rolling mill. One domestic nonintegrated producer has been making steel plate in such a mill for a number of years. The following comments by the equipment manufacturer point to the future potential of this equipment for small steel producers:

> In effect, we invented the mini-mill for flat-rolled products.
>
> I question whether any big, 4-million-ton-a-year hot strip mills are ever going to be built again. The steel industry, instead of being all things to all people and looking at a centralized plant for meeting all markets, is now coming to a unit size plant, which might be for a half million ton a year.[14]

An excellent illustration of the potential for small steel companies to apply technology not widely adopted domestically, and thereby to capture a market abandoned by large integrated companies and deeply penetrated by foreign steelmaker, is the case of the Berg Steel Pipe Corp. of Panama City, Fla., which has recently announced the opening of the Nation's largest diameter pipe mill.[15] Heretofore, the United States Steel Corp. was the largest domestic pipe producer with its 48-inch mill; the new plant will make pipe ranging from 20 to 64 inches in diameter, and will be able to produce approximately 181,400 tonnes annually, with an emphasis on pipe for oil and gas transmission and coal slurry pipelines. The use of the pyramid rolling process will be the first domestic application of an established European technology. Its chief advantage over the technology used in domestic mills is that changing production from one pipe size to another can be accomplished in a little over 30 minutes, as opposed to from 8 to 24 hours in conventional mills.

Direct Reduced Iron

It is likely that a decade from now the rather spectacular growth of nonintegrated steel producers will be linked not only to the use of electric furnace steelmaking and continuous casting, but also to the commercial exploitation of DRI. * The introduction of DRI as a supplement to ferrous scrap in electric furnaces will facilitate the manufacture of products. Direct reduction (DR) also provides a means of introducing new iron units of high purity into the steelmaking process, so that electric furnaces can make higher quality steels than they can with scrap. For a number of years, several natural gas DR plants in the United States have supplied DRI for electric furnace steelmaking, and imported DRI is becoming increasingly available.

The advantages and disadvantages of using DRI plus scrap as opposed to using only scrap in electric furnaces are summarized in table 98. There is general agreement within the steelmaking community that the net benefits of using DRI are substantial: both processing and the final steel products can be improved with the use of DRI, and it can lead to actual production cost decreases. Thus far, however, the relatively higher cost of DRI over scrap** and its limited availability have not allowed widespread use.

Economically, scrap costs have been low compared to the cost of DRI, so as long as industry growth could be maintained without going to higher quality products, the use of DRI was not justified. But, as discussed in chapter 7, with further growth of electric furnace steelmaking by both nonintegrated and integrated steel companies, ferrous scrap supplies may not be adequate in the future:

> The increasing problems faced by blast furnaces and BOF's—environmental and high capital costs—have caused a dramatic shift to, and increase in, electric furnace steelmaking. This has and will put an increasing strain on scrap supply and has

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[13] G. J. McManus, "Steckel Mills Reverse Trends in Steelmaking," *Iron* Age, Feb. 4, 1980.

[14] Ibid.

[15] *American Metal* Market, Mar. 18, 1980.

*Direct reduction is discussed in ch. 6.

**Presumably with increased R&D and improved DR Processes, the cost of DRI will decrease.

Table 98.—Electric Furnace Use of Direct Reduced Iron: Advantages and Disadvantages Compared to Using All Scrap

Advantages

1. Higher purity steels can be made even with a relatively large proportion of scrap.
2. Furnace productivity can be increased 10 to 20% because DRI can be continuously fed to furnace.
3. Continuous feeding increases useful electrical power 10 to 14%.
4. Continuous feeding reduces wasted time 5 to 150/..
5. Acoustical noise levels are reduced 10 to 15 dBa.
6. Metallic yield is increased.
7. The variability of product chemistry is reduced.
8. The cold formability of steels is improved due to lower content of nitrogen and other residuals, and rates of finishing can be increased.
9. Product surface quality is improved and rejection rates reduced.
10. There is a smoother, more efficient flow of material from melting to finishing.
11. Less storage space, plant materials-handling equipment, and inventory are needed.
12. Lower grade scrap can be used to reduce costs or deal with shortages or price fluctuations for high-quality scrap.
13. Price fluctuations should be less than for scrap.

Disadvantages

1. Need access to water transportation for DRI imports or capital for DRI plant construction (unless domestic merchant DRI plants are built).
2. Higher cost than producers using scrap only, if scrap prices are less than DRI cost.
3. Unless proportion of DRI in charge is kept relatively low (30 to 40%), nonmetallic impurities can cause increase in energy, time, and fluxing agents.
4. If bucket charging is used, nonmetallic cause lower productivity.
5. Lack of alloying elements which may be desired requires greater use of alloy additions.

SOURCES R L Reddy, Some Factors Affecting the Value of DRI to the Steelmaker, ” AIME Ironmaklng Conference, Detroit, Mlch , March 1979; R A Redard, ‘Is the Value of DRI to the Steelmaker Being Properly Assessed?” AIME Ironmaking Conference, Detroit, Mich , March 1979, R L Reddy, “Electric Arc Furnace Steel making With Sponge Iron, ” Canadian Mefallurgical *Quarterly, vol.* 1, pp. 1-6, 1979, J W Brown and R L Reddy. “Electric Arc Furnace Steelmaking With Sponge Iron ‘ *Ironmaking and Steelmaking, No* 1, pp. 24-31, 1979

> brought direct reduction to the fore. Its time has come. Without it, there simply is not enough scrap in the world to support current and projected electric furnace steelmaking.[16]

This increase in demand for scrap, along with higher scrap prices and increasing production of higher quality products, may all combine to make DRI a necessary and economically feasible raw material for nonintegrated producers.

Imports of DRI are becoming more available because a number of large-scale DR plants in natural gas-rich nations are becoming operational, and more are expected within the next decade. A recent analysis and forecast by a domestic steelmaker shows world trade in DRI increasing form 954,000 tonnes in 1979 to 4,350,000 tonnes in 1985. [17] Abundant DRI could act as abundant scrap did during the 1960's to spur the growth of nonintegrated steelmakers.[18] Much of the increased supply of DRI will be coming from Latin America, especially Venezuela and Mexico. It is generally accepted that the often-cited problem in transporting DRI, its potential to heat up and possibly ignite, either has been solved or will be within the near future. The fact is that bulk ocean shipments of DRI have been occurring for the past several years.

In the near future, furthermore, domestic steelmaker will probably have an alternative to imported DRI. Small-scale, coal-based DR plants may become available within the next 5 to 10 years. These reduction plants will need access to coal and iron ore, but they should be particularly attractive to the larger

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[16] H. B. Jensen, “New Alternatives for Charge Materials,” paper presented at Ferrous Scrap Consumers' Coalition symposium, Atlanta, Ga., February 1980.

[17] Ibid.

[18] “New greenfield direct reduction (DR) capacity is judged to amount to about 18 million tonnes during 1977-83-bringing total DR capacity to about 35 million tonne/yr. However, should scrap prices continue to rise substantially in the years ahead [which would be principally the result of a strong economy in the West), this could attract significant additional DR capacity. If our ‘judged doubtful” category were to materialize, another 18 million tonne/yr of DR production capacity would be added by 1983.” (World Steel Dynamics, April 1979.]

nonintegrated plants far from large domestic scrap markets. Yet another likelihood is the construction of domestic merchant DR plants. Although these might be coal-based facilities, a natural gas-based plant in Texas has been under discussion for some time. Because most large integrated steel producers are increasing their electric furnace facilities, their increased demand is likely to spur the construction of domestic DR plants.

The rapid rise in foreign electric furnace steelmaking is also leading to increased interest in the use of DRI. For example, it has been reported that Japan has already begun to import DRI from a new plant in Indonesia. ’g The cost of the DRI is approximately $125/tonne including freight, compared to imported ferrous scrap costs of $160 to $170/tonne. A joint industry consortium of 51 Japanese steel mills, with the Ministry of International Trade and Industry, is studying the increased use of DRI. It is clear that DRI will likely become a world trade commodity whose price will be determined by the demands of a multitude of users. Domestically produced DRI might be exported in much the same way that domestic ferrous scrap has been, which means that domestic steelmaker could face problems similar to those with scrap unless they have their own sources of DRI.

Future Expansion Forecast

Integrated steelmaker generally affect a lack of concern about the inroads made by the nonintegrated steel producers, but the financial community has become keenly aware of the growth and future importance of this industry segment at the expense of the integrated companies:

> . . . potential for a considerable restructuring of the domestic industry exists—toward many mini-mills and away from mammoth integrated plants.[20]
>
> Scrap-based steelmaking (will) remain just about the only true growth area in the steel industry (because) they have more modern, more highly automated facilities than the integrated producers and use continuous casting more extensively.[21]

The nonintegrated producers themselves are also expressing a high degree of optimism for the coming decade. One producer has described nonintegrated companies as the new nucleus of a strong-again U.S. steel industry .22 Quantitative forecasts in 1978 showed this industry segment doubling its output in the next decade[23] and increasing its share of domestic steel shipments to at least 25 percent by 1990.[24]

OTA finds these forecasts quite reasonable for two reasons. First, the past growth of the nonintegrated companies has been very high, by approximately 9 million tonnes of shipments during the past decade (see table 97). Second, these companies' record of success, excellent profitability, quick adoption of the best new technologies, and ready access to capital should permit this rate of growth to continue. It is reasonable to believe that these steelmaker could increase output by another g million tonnes of shipments during the 1980's.

Another way to assess the future potential of the nonintegrated companies is to consider what percentage of major types of steel products they will be capable of producing. Table 99 presents OTA estimates, using 1978 data for product mix and assuming that DRI will be used and that some flat products will be made on new types of rolling equipment. The result suggests that nonintegrated companies could potentially double their market share as well, to approximately 57 percent of these products and 25 percent of total domestic shipments of all steel products. These estimates are probably conservative, because the product areas shown are expected to represent an increasing proportion of all steel products and the estimates do not take this into consideration. What is most significant

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“American *Metal* Market, Feb. 6, 1980.

[20] J. C. Wyman, quoted in American *Metal* Market, Feb. 5, 1980.

[21] C. A. Bradford, quoted in American *Metal* Market, Feb. 5, 1980.

[22] F. Kenneth Iverson (Nucor Corp.), American *Metal* Market, Feb. 6, 1980.

“Forbes, Dec. 11, 1978,

‘‘Fortune, Feb. 13, 1978.

Table 99.—OTA Estimate of Potential Production for Nonintegrated Steel Companies, 1978 (thousands of tonnes)

	All-industry 1978 production[a]	Technically feasible and potential market for non integrated companies	
		Percent	Tonnes
Bars (excluding reinforcing)	10,992	**85**	**9,343**
Reinforcing	4,267	**100**	**4,267**
Wire rods	2,316	100	**2,316**
Wire products	2,277	100	**2,277**
Structural shapes (heavy)	4,233	10	424
Plates	7,801	25	1,950
Strip (hot-rolled)	931	25	233
Pipe and tubing	7,031	25	1,758
Total	39,848[b]	57	22,568[c]

[a] From AISI
[b] Represents 45 percent of total domestic shipments.
[c] Represents 25 percent of total domestic shipments.

about this finding is that for the next decade, most of the anticipated growth in domestic steel production could be accounted for just by growth of nonintegrated steel companies. *

Other than the availability of scrap and DRI, the availability of electricity is the main determinant of the growth of nonintegrated steelmaking. However, an increase of 9 million tonnes of shipments from this segment would lead to an increase in electricity purchases amounting to less than 1 percent of all electricity used by all domestic industry, and less than 0.5 percent of all domestic uses of electricity. ** Such an increase spread over 10 years and a number of locations, many of them in the South and Southwest, is not likely to represent enough additional load on domestic electrical generation companies to warrant special consideration. Nevertheless, unless adequate domestic electricity is available during the next decade, nonintegrated steelmaking could not grow to its full potential, particularly in major industrialized regions. Much depends on current plans and forecasts which will determine whether new electrical generation plants will be constructed.

Also noteworthy is that the analysis of future energy costs given in chapter 5 revealed that under most future energy cost scenarios nonintegrated steelmaker would face more rapidly rising costs than integrated steelmaker. Nonintegrated energy costs would still likely remain below those of the integrated steelmaker because of their lower energy needs, but the difference would be expected to narrow over the next several decades, particularly if these firms adopt DR and become partially integrated.

Alloy/Specialty Steelmaker

The alloy/specialty segment of the steel industry is difficult to define precisely. In the OTA disaggregation of the industry, companies in the alloy/specialty category are those that make the higher quality and higher priced steel products rather than commodity carbon steels. One recent compilation using this definition lists 33 such companies.[25]

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*This possibility is considered in detail in the projection of capital needs for a modernization and expansion program for the domestic industry presented inch. 10.

**At 605 kWh/tonne of raw steel, a 9. 1-million-tonne increase in production would result in an increase in steel industry electricity consumption of 5.5 billion kWh, compared to 1976 total domestic consumption of 257 trillion kWh, 1976 total industrial consumption of 103 trillion kWh, and 1976 steel industry purchase of 44.3 billion kWh, of which about one-third was for electric furnace steelmaking.

[25] Institute for Iron and Steel Studies, “ Commentary,” January-February 1979.

There is little problem in identifying these companies; the problem lies in measuring their output.

The terms "alloy" and "specialty" do not have precise, generally accepted meanings, The only available data base is from the American Iron and Steel Institute (AISI), which distinguishes four categories of steels: carbon, stainless, tool, and alloy. In the OTA disaggregation, stainless and tool steels are definitely in the alloy/specialty category, but much stainless steel and many materials in the alloy category used by AISI are made by commodity carbon steelmaker (integrated firms for the most part] and to a lesser degree by nonintegrated producers, rather than by alloy/specialty steelmaker. The alloy steels made by the alloy/specialty steelmaker are the higher alloy content, higher priced steels made in smaller quantities. Because these cannot be distinguished, the data for alloy steels other than stainless and tool steels overestimate those alloy steels made almost solely in alloy/specialty steel companies, probably by a factor of five. About half the stainless steel is made by integrated companies. Finally, other types of higher quality, higher priced steels made by the alloy/specialty steelmaker are not alloy at all, but rather variations of carbon steel that are made in small quantities compared to commodity carbon steels; some of these are called "custom made" steels. Examples of these steels include electrical steels, clad plates, thick carbon steel plate, and coated strip. Such steels are included in the carbon steel data of AISI and thus do not enter into OTA data for alloy/specialty companies.

Growth of Domestic Alloy/Specialty Steel Use

The basis for the relative success and growth of the alloy/specialty steelmaker is the increasing use of the steels these companies produce. Data on domestic shipments of alloy/specialty steels for the past decade are given in table 100. Growth in domestic shipments of carbon steels has been quite low—except for 1973 and 1974, domestic shipments remained virtually constant, with a 1.3-percent increase from 1969 to 1978. During this same period, shipments of alloy/specialty steels grew nearly 34 percent. Alloys other than stainless and tool steels had the most growth.

Data on domestic consumption of alloy/specialty steels are given in table 101. The use of

Table 100.—Domestic Shipments of Alloy/Specialty Steels, 1969-78

	Stainless		Tool		Other alloy	
Year	1,000 tonnes	Percent of total	1,000 tonnes	Percent of total	1,000 tonnes	Percent of total
1964	705	0.9	93	0.1	5,863	
1969	825	1.0	103	0.1	7,027	8.3
1970	643	0.8	80	0.1	6,218	7.6
1971	651	0.8	71	0.1	6,291	8.0
1972	775	0.9	82	0.1	6,972	8.4
1973	1,029	1.0	101	0.1	8,400	8.3
1974	1,220	1.2	102	0.1	9,130	9.2
1975	687	0.9	63	0.1	7,589	10.5
1976	924	1.1	69	0.1	7,285	9.0
1977	1,014	1.2	77	0.1	7,869	9.5
1978	1,080	1.2	83	0.1	9,492	10.7
1969-1978 percent change	30.9%		-19.370		35.170	
1979 (1st three quarters)	937	1.3	66	0.1	7,649	10.8

Carbon steel percent change 1969-78 (77,191 -78,172 =) 1.3%

All alloy/specialty percent change 1969-78 (7,955 - 10,655) = 33.9%

SOURCE Office of Technology Assessment.

Table 101.—Domestic Consumption of Alloy/Specialty Steels, 1969-78 (shipments + imports – exports)

Year	Stainless		Tool		Other alloy	
	1,000 tonnes	Percent of total	1,000 tonnes	Percent of total	1,000 tonnes	Percent of total
1964	656	0.8	99	0.1	5,724	7.2
1969	912	1.0	114	0.1	6,811	7.3
1970	727	0.8	94	0.1	5,923	6.7
1971	775	0.8	79	0.1	6,385	6.9
1972	861	0.9	93	0.1	7,207	7.5
1973	1,058	1.0	114	0.1	8,520	7.7
1974	1,255	1.2	118	0.1	9,076	8.4
1975	769	1.0	78	0.1	7,687	9.5
1976	1,016	1.1	89	0.1	7,397	8.1
1977	1,112	1.1	104	0.1	8,163	8.3
1978	1,196	1.1	122	0.1	9,712	9.2
1969-1978 percent change	31.2%		6.3%		42.6%	
1979 (1st three quarters)	994	1.2	107	0.1	7,799	9.7

Carbon steel percent change 1969-78(85,296-94,770) = 11.1%

All alloy/specialty percent change 1969-78(7,836- 11,030)= 40.8%

SOURCE Officeof Technology Assessment

these steels increased about four times more than carbon steels during 1969-78, and since domestic consumption outpaced domestic shipments, it can be concluded that imports captured an increasing fraction of the domestic alloy/specialty market. Imports penetrated the carbon steel market even more, however: domestic consumption of carbon steels from 1969 to 1978 increased by 11 percent, but shipments went up by only 1 percent. Summary data on imports as a percentage of domestic consumption are given in table 102. Imports made their greatest inroads on tool steels and their least on stainless steels. Nearly 8 percent of all alloy/specialty steels used in this country in 1978 was imported; for carbon steels the figure was 19 percent. Except for tool steels, imports of all steels decreased significantly in 1979.

Table102.— Imports as a Percentage of Domestic Consumption, 1969 and 1978

	1969	1978	1969-1978 change	1st three quarters 1979
Stainless	18.1	15.2	– 2.9	11.2
Tool	11.9	35.1	+23.2	40,7
Other alloy	4,5	6.6	+ 2.1	5.7
All alloy/specialty	6.2	7,8	+ 1.6	6.7
Carbon	14.4	19.3	+ 4.9	15.3

SOURCE Offlce of Technology Assessment

The worldwide use of alloy/specialty steels has increased for several reasons:

- advanced technology applications require steels with high-performance characteristics, such as strength and temperature resistance;
- energy conservation has dictated using less steel and more alloy in making automobiles;
- consumers are demanding durables with longer lives and reduced lifecycle costs, built of materials with more corrosion and wear resistance;
- alloy/specialty steels have a comparative cost advantage over other high-performance materials because the others are more energy-intensive in their processing; and
- the economic costs for and sociopolitical problems of minerals extraction are increasing, and this promotes the use of smaller amounts of higher technology steel.

Over the 15-year period from 1964 to 1978, domestic consumption of all alloy/specialty steels grew at an annual rate of 3.6 percent; this was more than double the 1.7-percent growth rate for carbon steel consumption. The growth rate of alloy/specialty steels is likely to increase in the years ahead. Thus, to the degree that imports do not capture an increasing share of the domestic market, domestic alloy/specialty steelmaker should be able to expand at a rate more than double the 1.5 to 2.0 percent per year anticipated for the industry as a whole (see ch. 5).

One factor that OTA has not examined which could limit alloy/specialty steel growth is the problem of shortages of alloying elements, for which the United States is very dependent on foreign sources. This problem has already received considerable analysis elsewhere.[26]

Potential for Exports of Alloy/Specialty Steels

Exports have traditionally played a more important role for alloy/specialty companies than for carbon steel producers. It is generally accepted that domestic alloy/specialty steelmaker are both cost and technology competitive in the world market. One measure of export competitiveness is the ratio of exports to imports; such data are presented in table 103 for the alloy/specialty steels, as well as for carbon steels, for the period 1964-78. Exports of carbon steels have not been large relative to imports, whereas exports of alloy/specialty steels, other than stainless and tool steels, have exceeded imports during 5 years of the 15-year period. A number of generic advantages have contributed to the favorable competitive position of domestic alloy/specialty steelmaker:

- They have a relatively strong technical base and probably a commanding advantage over foreign competitors in product development and secondary processing.
- The United States has relatively low energy prices, an advantage that could increase if DR processes using coal become widely used.
- The United States has a good supply of quality iron ore and ferrous scrap.
- The enormous domestic market, much of it technology-intensive, has encouraged alloy/specialty steel product innovations.
- U.S. labor costs and productivities are competitive with European and possibly with Japanese levels.
- The United States has a very sophisticated industry infrastructure.

These advantages are offset to an extent by the greater level of assistance provided by other governments (particularly in the area of low-cost financing for exports), and by some foreign industries' experience in and infrastructure for export sales and marketing.

Table 103.—U.S. Exports as a Percent of Imports

	Carbon	Tool	Stainless	Remaining alloy/specialty	All alloy/specialty
1978	9.3	10.6	36.0	65.6	56.7
1977	9.2	23.1	39.3	40.0	39.0
1976	16.5	21.4	42.3	72.7	62.5
1975	22.4	32.0	45.5	74.5	64.9
1974	34.1	34.6	77.8	115.2	100.5
1973	25.2	31.8	74.2	67.7	67.8
1972	15.4	20.0	42.3	40.2	40.2
1971	14.0	30.8	28.6	74.1	58.8
1970	49.2	11.1	47.5	198.5	141.3
1969	33.8	20.0	47.8	170.4	124.5
1968	11.2	15.4	51.2	43.2	45.3
1967	13,1	10.5	77.2	63.5	66.6
1966	14.4	11.1	65.0	80.4	69.6
1965	21.9	15.4	82.3	173.3	118.9
1964	49.1	22.2	168.4	315.5	225.8

SOURCE American Iron and Steel Institute

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[26] See, e.g., *Technical* Options *for* Conservation *of* Metals, Office of Technology Assessment, September 1979.

Nevertheless, one major domestic producer (Armco) has demonstrated that aggressive marketing can improve exports. In 1978, it exported 4.6 percent of its specialty steel, compared to 2.9 percent in 1977.[27] This export market change was the largest for any domestic steel area, and is even more impressive when the depressed worldwide demand for steel in 1978 is considered. Most foreign steel industries operated at low rates in 1978 and were unprofitable (see ch. 4), but domestic alloy/specialty producers were quite profitable. Another major domestic producer has reported that it regularly exports 10 percent of its production.[28]

The growing worldwide demand for alloy/specialty steels has not gone unnoticed by foreign steelmaker, and foreign alloy/specialty steelmaking capacity has been increasing. Data for the Japanese steel industry for 1965-77 are given in table 104. Japanese growth in alloy/specialty steels has been great, nearly a fourfold increase in production and exports in the 12-year period. This is roughly twice the rate of growth for Japanese carbon steel production and exports. Alloy/specialty steels imports have made less penetration into the Japanese market than have carbon steel imports, by about half. Japan is the single largest supplier in the world export markets for both carbon and alloy/specialty steels, and, except for some very narrowly defined alloy/specialty steels made by other nations, it is the United States' major competitor in those markets.

Stainless steels represent the single largest type of alloy/specialty steel in production and in world trade, and they are also subject to the most price competition. The Japanese and European shares of this market totaled 82 percent in 1976. In 1976, 47 percent of Sweden's stainless production and 39 percent of Japan's were exported, and the British Steel Corp. has planned to double its capacity and export 40 to 45 percent of its stainless. It is difficult to believe, however, that either Great Britain or Sweden can be more competitive than domestic producers in a fair market. It must be recognized, however, that there is now considerable excess worldwide capacity, which will make effective imple-

Table 104.—Japanese Production and Export of Alloy/Specialty and Carbon Steels, 1965-77

	1965	1977	1977/1 965
Alloy/specialty steel production (1,000 tonnes)			
Stainless	396	1,626	
Tool	110	207	
Other alloy/specialty	1,363	5,650	
Total,	1,869	7,483	
All alloy/specialty			
As percent of total production	4.7 ”/o	8.4%	79%
Production tonnage change 1965 -77			387
Exports as percent production of total	14.3	18.4	29
Percent exports to United States	NA	19.2	
Change in export tonnage 1965 -77			420
Change in import tonnage 1965-77			78
Carbon steels			
Change in production tonnage 1965 -77			165
Exports as percent of total production	27.6	38.6	40
Percent exports to United States	NA	20.7	
Change in export tonnage 1965-77			272
Change in import tonnage 1965 -77.			184

NA = not available

SOURCE Japan's Iron & Steel Industry 1978 Kawata, Tokyo. 1978

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[27] Armco, 1978 *Annual* Report; presumably the exports consisted mostly of electrical and stainless steels.

[28] R. P. Simmons, president, Allegheny Ludlum Steel Corp., testimony before the Senate Banking, Housing, and Urban Affairs Committee. Nov. 19, 1979; presumably the exports consisted mostly of stainless steel.

mentation of the new Multilateral Trade Agreement (see ch. 4) difficult. Nevertheless, the worldwide rate of growth for stainless demand (about 5 percent per year since 1964) should stay close to the 5.8-percent annual growth rate in foreign capacity, which has held since 1970. If the United States is to increase its stainless exports, then it must do so by making inroads on present foreign market shares, especially those of Europe and Japan.

Technological Improvements in Alloy and Specialty Steelmaking

The alloy/specialty steel companies have modernized considerably during the past several years, but even before this period they were more technology- and research-oriented than the rest of the domestic steel industry (see ch. 9). The increase in yield from raw to finished steel (see table 105) is partly a result of improving technology, primarily from increased use of electric furnaces (see table 106), continuous casting, and other relatively new steelmaking technologies. The yield for alloy/specialty steels remains lower than for carbon steels, however, because alloy/specialty steels are made in much smaller lots.

Table 105.—Percentage of Domestic Yields, 1969 and 1978 (shipments/raw steel)

	1969	1978	Change
All alloy/specialty	53.4	58.4	+ 5.0
Stainless	58.0	61.0	+ 3.0
Alloy (including tool)	52.9	58.1	+ 5.2
Carbon	68.2	73.7	+ 5.5

SOURCE Office of Technology Assessment

Table 106.—Percentage of Raw Steel Made in Electric Furnaces, 1969 and 1978

	1969	1978	Change
Stainless	100	100	0
Alloy (including tool)	34.9	41.0	+ 6.1
Carbon	10.7	19.5	+ 8.8

SOURCE Office of Technology Assessment

The role of technology in the future of alloy/specialty steelmaker will likely remain important. This industry segment spends considerable funds on R&D (see ch. 9), and it is likely to continue to develop and adopt new process and product innovations. The use of powder metallurgy fabrication has already begun to increase. Most significant is the larger potential of powder rolling technology, which is an energy- and materials-efficient way to produce sheet and strip products. Usually prealloyed powder is made from molten alloys. The powder is then rolled, cold or hot, and consolidated into a high-density, coherent metal. The process facilitates the production of very highly alloyed materials, which present problems in casting and which have limited plasticity for normal rolling of ingots into sheet and strip.

Another future development is the plasma arc melting furnace, a variation of the conventional electric arc furnace, which is just now being proven commercially. It appears to offer great efficiencies, and it may also facilitate the recycling of high-alloy-content waste materials. Chapter 9 provides greater detail on the past adoption of other important new technologies, such as continuous casting and argon oxygen decarburization, by alloy/specialty steelmaker.

Integrated Steelmaker

The future prospects for the nonintegrated and alloy/specialty producers appear quite favorable. Nonintegrated producers may undergo a 100-percent growth during the next decade, and alloy/specialty producers are likely to expand by about a third. In contrast, the growth of the integrated steelmaker will likely be small, perhaps 10 to 20 percent during the next decade, depending on the rate of growth of carbon steel consumption and the extent of imports. In addition to the shift of carbon steel production to the nonintegrated producers and the trend toward more use of alloy/specialty steels, the integrated segment of the industry has experienced the following structural changes during the past decade:

- There has been a shift in the raw materials used, primarily from original domestic sources of iron ores to the lower grade taconite ores and imported ores,
- Markets have shifted from the Northeast and North Central States to the South and West.
- Concern about heavily concentrated sources of pollution is increasing.
- There are greater oscillations in market demand and levels of profitability.
- Old plants are gradually deteriorating.
- Significant changes in the technology of steelmaking require a fundamentally new plant layout to achieve maximum efficiency.

These changes, which increase costs and the need for modernization, are continuing to contribute to the loss of market share by the integrated companies. Moreover, the ratio of capital investment to profitability for the integrated companies is the highest of the three segments. It is conceivable that by 1990 the products of integrated steelmaker will account for just over 70 percent of domestic steel shipments, compared to 85 percent in 1978. This does not necessarily imply that integrated plants will close—a very low rate of growth relative to the other industry segments may account for much of this market loss. However, it also does not imply that plants will not close. A number of smaller and older integrated plants would require very large sums to rejuvenate technologically, sums too large to be justified on strictly economic grounds.

CHAPTER 9

Creation, Adoption, and Transfer of New Technology

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CHAPTER 9

Creation, Adoption, and Transfer of New Technology

Summary

The domestic steel industry has a well-established record for generating product innovations, but it is less inclined to generate new steelmaking processes. The industry prefers to adopt proven technologies that have a record of successful commercialization. Even then, its adoption rates for new products, such as one-side galvanized steels, is very good; but it lags in adopting new process technologies, such as continuous casting and even the basic oxygen furnace. This lag is mainly a result of aging plant, poor industry growth, and lack of capital.

To the extent that adoption rather than creation reduces risk and R&D costs and provides near-term payoffs, it is a useful approach. But it also has major drawbacks: it leads to industry dependence on technologies that may be poorly suited to domestic needs; it reduces learning opportunities for innovative applications; and—most importantly—it does not enable the industry to stay ahead in the international market. Independent creation of new technologies and their successful adoption would enable the steel industry to gain technological advantage, rather than merely achieve delayed parity, This advantage would enhance the industry's competitive position in both domestic and international markets.

R&D expenditures by the domestic steel industry, as a percentage of sales, have declined over the years and are lower than in most other basic industries in the United States. The industry's basic research effort is particularly small. The low level of steel industry R&D may be attributed to a number of factors, including cautious management attitudes towards research, the high cost of demonstration projects, the industry's declining share of the domestic market, high regulatory costs, and low profitability.

Steel industry R&D has very little Federal support and is complemented by only a limited amount of steel R&D carried out by the Government and universities. Foreign steel R&D, on the other hand, is generally in a more vigorous state because of larger budgets and stronger government support, particularly for high-risk projects whose likely benefits promise to be widespread. Some foreign steel industries also benefit from the work of multisectoral steelmaking research institutes.

Domestic steel technology exports are limited. They are largely handled by equipment firms and are mainly in the area of raw materials handling. Foreign steel industries are increasing their efforts in technology transfer in order to offset declining steel product exports. To a much greater degree than domestic steelmaker, foreign companies have design, consulting, and construction departments that aggressively pursue the sale of both hard and soft technology to other nations, particularly the less developed countries (LDCs). Japan, West Germany, Austria, and Great Britain are major exporters of innovative steelmaking technologies.

Role of Technology in Solving Industry's Problems

In many industrial sectors in the United States and in foreign steel industries, technology is viewed as one of the principal means of reducing costs, gaining competitive advantage, and meeting societal needs and objectives. Some U.S. steel companies, however, are ambivalent and occasionally negative toward new technology and innovation. These attitudes are barriers to the development and adoption of new technology. Another impediment is the lack of emphasis on basic and applied research. This short-range orientation may result in failure to develop beneficial new technologies and in slow adoption of successful foreign innovations.

Many steel executives consider theirs to be a classic example of an industry characterized by a slow rate of technological change. They firmly believe that innovation is a risky undertaking with uncertain returns and that purchasing proven technologies is more cost efficient. This view, however, does not take sufficient account of the many recent major technological changes in steelmaking or of the changing competitiveness of the domestic steel industry.

Industry spokesmen contend—with considerable justification—that the rarity of major technological changes in the steel industry results from severe financial difficulties which prevent the construction of new facilities based on new technologies. However, not even increased capital availability and profitability—perhaps brought about with the assistance of appropriate Government policies—would ensure vigorous technological innovation unless the prevailing industry attitude toward new technologies also changes.

The robust and highly competitive Japanese steel industry can be used as a model of the maximum use of new technology: it achieved its premier position by applying innovative processes widely and improving them constantly. The real lesson of the Japanese experience, however, is that if Government policies facilitating capital formation are combined with a positive industry attitude toward the adoption of new technology, the widespread use of new steelmaking processes will indeed take place.

The U.S. steel industry needs new technology to cope with the changing nature of the economic, social, and political world in which it operates. New technology can improve the competitiveness of domestic steels with respect to quality and cost; it can also reduce industry vulnerability to inflation and other external factors. New and innovative technologies, some already commercially available and others with a significant likelihood of successful development and demonstration, offer potential for:

- reducing energy consumption, including the use of coke;
- making greater use of domestic low-grade coals;
- reducing production costs as a result of improvements in process yield (although yield improvements will also put upward pressure on the price of scrap):
- using more domestic ferrous scrap and other waste materials containing iron;
- improving labor productivity;
- reducing capital costs per tonne of annual capacity;
- shortening construction time of new plants; and
- allowing greater flexibility in using imports of certain raw materials and in importing semifinished rather than finished steel products,

Although new and improved steel technology, alone, is not sufficient to reverse unprofitability and inefficiency, it is an essential ingredient for the future economic health and independence of the steel companies.

Parity Versus Advantage

New technology may be developed through two processes: by true innovation, consisting of the creation and first successful commercial use of new technology: or by the adoption of innovations created by others. For production processes, most domestic firms stress adoption rather than innovation. They argue that the cost and risks of innovation outweigh the benefits and that it is cheaper in the long run to buy proven technology than to create it. Although the innovation process does in fact produce failures as well as successes, it also offers an opportunity for gaining the competitive advantages of earlier market penetration, cost reductions, and the possible sale of new technology.

Strictly economic analyses of the creation and adoption of new technology ignore two very important issues: the unique circumstances of the domestic steel industry, and the benefits of an ongoing learning process. Innovations from external sources, especially foreign sources, may not lead to new technologies appropriate to the particular characteristics and needs of the domestic steel industry. Domestic steelmaker understand this with regard to raw materials and products, but they undervalue the importance of developing unique process technologies, shaped by domestic resource opportunities. Furthermore, the domestic regulatory climate should be viewed as a constraint which can be dealt with most effectively through the creation of new technology specifically geared to meeting its requirements.

The industry admits that there is a gap in the adoption of new technologies between the United States and its competitors, but it denies that a knowledge gap exists. ' The industry gives little weight to the consideration that the foreign knowledge base is responsive to foreign needs and may be better suited to particular foreign conditions. A uniquely domestic steelmaking knowledge base cannot exist without domestic innovation based on research (basic and applied), development, and demonstration that are shaped by the current and anticipated needs and opportunities of domestic steelmaker. Even the Japanese, once noted for using foreign research and innovations, have now shifted their emphasis to creating their own.

The secondary effects of innovation from greater R&D experience are also lost in adopting rather than creating new technologies. The lessons learned in originating technology allow a firm or industry to move more rapidly up the learning curve of a major innovation. Japanese steelmaker, for instance, have benefited greatly from a constant flow of incremental innovations that spill over from their extensive experience with a major new technology and from their high level of improvement-oriented R&D on steelmaking software. These incremental innovations, based on new applications rather than on new fundamental knowledge, can significantly reduce production costs and increase productivity. The Japanese experience with continuous casting (discussed in a later section) is the most recent example of turning another nation's innovation into a host of incremental new technologies for use and sale. The U.S. steel industry, on the other hand, has relatively low levels of R&D, adoption, and experience with new technologies. As a result, the industry does not have the same opportunities for movement along learning curves or for incremental innovation.

Consequently, whatever new technology is purchased from foreign sources still leaves the purchaser one step behind the originator. By the time all is learned about the innovation, the foreign source is well on its way to exploiting the next one. It may be true that there is equality of knowledge among the world steel industries concerning fundamental innovations, yet it is an error to believe that knowledge about innovations is equivalent to innovating. Waiting to use someone else's innovation is a strategy likely to spell competitive loss in the long run. It takes years for steel plants to be designed and built, and those who innovate tend to stay ahead of their competitors.

IN. A. Robbins, proceedings of "The American Steel Industry in the 1980's—Crucial Decade."' AISI, 1979.

Major Versus Incremental Innovation

Possible technological solutions that might be considered for steel industry modernization are:

- to modernize existing operations by adding existing technology;
- to build new plants using the best available technology; or
- to develop and put in place at new plants radically innovative new technology.

These solutions differ in two major respects: in their capital costs, and in the amounts by which they can be expected to reduce production costs. The third, for example, is a high-cost, high-payoff solution; the second is somewhat less costly and somewhat less productive; the first is an incremental solution with incremental rewards. The choice among these solutions rests on how the costs and payoffs balance out,

The first solution, the extension of existing operations with available, improved technology (such as continuous casting), is generally considered to have the best balance between capital costs and reduction of production costs. The second option, involving construction of completely new plants using existing technology, would involve high capital costs that cannot be expected to be sufficiently offset by the limited production cost reductions it would bring. The third option, construction of new plants based on radically innovative technology, will not be technically feasible for at least a decade; once feasible, however, there is a possibility that high capital costs could be sufficiently offset by significant production cost savings. Thus, the first option, complemented with a vigorous research program in radical steelmaking innovations, could prepare the industry now for short-term revitalization with the potential for long-term, fundamental modernization.

Several important considerations argue against constructing new facilities using available incremental improvements. The major constraints are the high capital costs of greenfield construction and the need for immediate modernization and expansion. The capital costs of greenfield sites, estimated to be well over $l,l00/tonne of annual capacity, * are very high compared to the other two investment alternatives—" roundout" expansion costing about $550/tonne, and nonintegrated (minimill) expansion costing only $154 to $275/tonne of annual capacity. Given the high cost of capital, any reduction in steel production costs gained by using advanced steelmaking technologies in greenfield integrated plants is outweighed by significant increases in financial costs. The domestic industry's low profitability would make it difficult to obtain the necessary funds for this type of expansion.

The industry's immediate need for capacity replacement and expansion** also makes construction of new integrated plants less attractive than the roundout option. Conservative estimates place the time required for design, permit approval, and construction at about 8 to 10 years, although plans exist for one greenfield plant to be built in half that time. Such a timelag is incompatible with the industry's current needs, and the long construction time would also dim the prospect of achieving technological parity through greenfield expansion: during construction, major steelmaking innovations could become available for commercial application elsewhere. Furthermore, once a substantial number of new domestic plants are in place, integrated steelmaking technology in the United States would be static for some years. The lifetime of such plants is long, and the need for additional steelmaking capacity will have been largely met for the immediate future; by the time new capacity is needed, it is probable that other nations will have moved ahead with newer technologies.

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*Detailed analyses of these costs are presented in ch. 10.
* *Detailed analyses of this are presented in ch. 10.

Research and Development

Technological supremacy is most likely to be achieved through deliberate and continuous research, development, and demonstration. A recent analysis of radical steelmaking technologies suggests that several offer sufficient economic advantages to merit further research.[2] These include direct steelmaking and direct casting of steel. However, with a leadtime of approximately 10 to 20 years for the development of these and other radically innovative technologies, they would not have any impact on the industry's current problems. Nevertheless, commitment to long-term technological competitiveness would dictate proceeding immediately with R&D activities aimed at developing and using radical steelmaking technologies. This position has been summarized by Bela Gold:

> The very future of the domestic steel industry over the long run depends on intensive programs to develop such (radical technological) advances . . . . Such efforts must be combined with a more immediate program to modernize and expand the domestic steel industry through effective utilization of already available technologies as well as of relatively straightforward extensions of them. To do nothing—as is implied by the COWPS Report—or to wait until some miraculous new technological advances are developed (which could not be reasonably duplicated by foreign competitors in relatively short order) is likely to prove catastrophic not only for the U.S. steel industry, but also for related industries and major geographical areas.

In addition to developing radical innovations in the long term, it is important for the domestic steel industry to adopt incremental innovations in the near term, using available steelmaking technologies. This approach would use the less costly roundout alternative for increasing capacity and would call for constructing electric furnaces for use in combination with basic oxygen furnaces in nonintegrated plants (see ch. 10).

Long= Range Strategic Planning for Innovation

A number of industry difficulties, presented in chapter 4, might have been less severe had there been a well-prepared strategic plan for technological innovation. These problems include:

- increased production costs and declining eminence after World War II;
- lack of exports to meet rapidly rising steel demand in Third World and industrialized nations;
- lack of emphasis on exporting proven technology, which could have justified new investments in R&D and innovation activities:
- the large integrated steel producers' lack of response to demographic changes and to opportunities for using scrap in local markets by means of minimills; and
- lengthy and costly resistance to compliance with environmental regulations.

A number of studies[4] suggest that one of the principal reasons for the lack of U.S. steelmaking innovation lies in the lack of industry commitment to planning for technical innovation. Most domestic steel companies appear to conduct strategic economic planning, but few pay any attention to technological planning. This is reflected by their relatively low investments in R&D and pilot and demonstration work, and by their heavy reliance on foreign innovations. These factors

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[2] See Julian Szekely, "Radically Innovative Steelmaking Technologies. report submitted to OTA (no date), and ch. 4 of this report.

[3] Bela Gold, "Some Economic Perspectives on Strengthening an Industry's Technological Capabilities: With Appllications to the U.S. Steel Industry, " prepared for the Experts Panel on Exploring Revolutionary Steel Technologies, Office of Technology Assessment, meeting at the Massachusetts Institute of Technology, Apr. 25, 1978.

[4] For example, B. Gold, "Steel Technologies and Costs in the U.S. and Japan, " Iron ond *Steel* Engineer, April 1978; and J. Aylen, "Innovation. Plant Site and Performance of the American, British and German Steel Industries, " Atlanta Economics Conference, October 1979.

combine to form a barrier against innovation. In addition, domestic firms are inclined to sell promptly whatever innovative technology they create: they maximize immediate profits, instead of keeping the technology proprietary long enough to gain a competitive advantage.

Domestic steel industry management must examine the consequences of continuing to concentrate on: low-risk, incremental technological changes to the exclusion of high-risk, major changes; product rather than process changes; promotion of R&D managerial personnel from within rather than recruitment from other industries, universities, and Government; the enhancement of raw material (iron ore and metallurgical coal) profitability; traditional domestic markets; and defensive rather than aggressive business strategies.

Domestic Funding and Structure

The U.S. position of leadership in steel production and technology through World War II and the decade thereafter was achieved as much by its size and economies of scale, and by its organization and business practices, as by technical innovation. A review of the principal technological contributions made by the U.S. steel industry during the past several decades indicates a practical orientation toward labor efficiency improvement and product development, According to an industry survey of a relatively small sample of large steel companies in 1975, 81 percent of steel industry R&D funds were allocated to development, 12 percent to applied research, and less than 7 percent to basic R&D work (table 107).[5] However, the annual National Science Foundation (NSF) data series, R&D in Industry, indicates that less than 2 percent of steel industry R&D spending is in basic research, compared to 3 percent for all domestic industry and nearly 4 percent for nonferrous metal companies, *

Table 107.—Allocation of R&D Funding by Selected Sectors of Industry, United States, 1975

	Percent basic	Percent applied	Percent development
Steel	6.9	12.3	80.8
Aerospace	1.5	39.2	59.3
Automotive	0.1	83.4	16.4
Chemicals	10.9	37.9	51.2
Electronics.	2.1	27.0	70.9
Instruments.	5.3	7.7	87.0
Office equipment, computers . . .	1.9	5.3	92.8
Paper	1.4	21.1	77.5
Textiles.	0	9.0	91.0

SOURCE National Science Foundation, *Support of Basic Research by Industry, 1978,* (based on sample of companies belonging to Industrial Research Institute (I RI) and a survey by IRI)

According to NSF data (table 108), steel industry R&D increased by about 10.2 percent annually from 1963 to 1977, from $105 million to $256 million. However, annual real R&D spending increased by only about 22 percent during this entire period. For all U.S. industry, the growth in real R&D spending during the same period was about 18 percent.[6] More importantly, expressed as a percentage of sales, steel research actually declined from 0.7 to 0.5 percent during the same period.

R&D data for several steel producers are given in table 109. These data illustrate several points: R&D spending as a percentage of profits is rather large and closer to other industries than R&D spending as a percentage of sales; alloy/specialty steel producers spend more than integrated companies on R&D; and the trend of decreasing R&D spending in the past few years shown by NSF data is confirmed by company data.

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[5] The following comment on basic research appears to summarize the situation well for the domestic steel industry: “Fundamental research is the most prominent casualty of the American industry’s need to adapt to the realities of high costs and low profits, a situation that has prevailed and worsened over the past two decades. “ (33 Metal Producing, June 1979.)

*When using NSF data, it should be kept in mind that they tend to overstate steelmaking-related R&D somewhat. First. nonmetals R&D conducted by diversified steel companies appears to be included in the NSF data for ferrous industry R&D. Secondly, the ferrous industry category also contains R&D foundries and other metals-processing facilities not included in the scope of this study. Nevertheless, since NSF data are the best available, they will be used.

[6] National Science Foundation, R&D in Industry, 1977.

Table 108.—U.S. Steel R&D Spending (dollars in millions)

Year	Ferrous industry R&D spending	Percent of ferrous industry sales	Federal R&D spending	Percent of total Federal R&D spending	Steel industry environmental capital spending	Ferrous industry R&D – steel industry environmental capital spending
1963	$105	0.7	$2	1.9		—
1966 .	136	0.7	3	2.2	$56	2.43
1967	134	0.7	1	0.7	94	1.43
1968	134	0.7	1	0.7	102	1.31
1969	135	0.7	2	1.5	138	0.98
1970	148	0.7	1	0.7	183	0.81
1971 .,	142	0,7	2	1.4	162	0.88
1972	144	0.6	3	2.0	202	0.71
1973	159	0.5	4	2.5	100	1.59
1974	177a	NA	NA	2,2a	267	0.66
1975	211	0.6	3	1.4	453	0.47
1976	252	0.6	4	1.6	489	0.52
1977 ,,....	256	0.5b	4	1.5	535	0.48
1978	259	0.5	5	1.9	458	0.57

NA = not available
acalculated from total of $181 million, assuming $4 million for Federal spending
bFirst 8 companies 0.5 next 12 companies 0.6.

NOTES 1) Federal R&D spending is only for R&D in company laboratories, it does not include Federal R&D at Government facilities
2} NSF data based on sample of companies in the following SIC categories 331 blast furnace and basic steel products 332 iron and steel foundries 3,398 metal heat treating and 3,399 primary metal products not elsewhere classified. only the first is the traditionally defined domestic steel Industry as used in this assessment and for which AISI data apply One consequence of this is probably that R&D spending for just the 331 category is lower than that Indicated by the above figures particularly on a percent of Industry sales basis

SOURCES R&D data from NSF environmental capital spending from AISI

Table 109.—R&D Spending of Several U.S. Steel Companies, 1976-78

	Millions of dollars			Percent of sales			Percent of profits		
Company	1976	1977	1978	1976	1977	1978	1976	1977	1978
Integrated									
U.S. Steel	**$52.2**	**$49.8**	**$52.5**	0.6	0.5	0.5	66.2	36.1	21.7
Bethlehem	43,7	42.7	37.1	0.8	0.8	0.6	26.0	-9.5	16.5
Republic Steel	16.3	16,8	15.1	0.6	0.6	0.4	24.7	40.9	13.5
Average.				0.7	0.6	0.5	40.0	22.5	17.2
Alloy/specialty									
Allegheny Ludlum	9.2	10.7	13,3	1.0	1.1	1.0	131.4	42.1	34.9
Carpenter Technology	7.5	9.2	9.4	2.8	2.8	2.4	30.3	32.2	27.8

SOURCES Business *Week* July 3 1978 July 2 1979, and company annual reports

During the past several years, steel industry expenditures on research aimed at improving technological performance and reducing production costs have been lower than aggregate steel industry R&D spending levels indicate. This is because some R&D must be directed toward regulatory research necessitated by the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA) policies. According to one steel R&D executive:

> There is a trend toward more defense tvpe research . . . more time being spent on shorter range projects and projects designed to meet government mandates and regulations, and less time being spent on the kinds of long-term, high risk, innovative projects which will lead to the new ways of making steel in the future.
>
> Part of the problem is that what we are doing with this money is not what everybody would call research and development . , . but is pointed more toward short term objectives for a variety of reasons and not so much on the real innovative work and the fundamental research work that you might define as research and development .-

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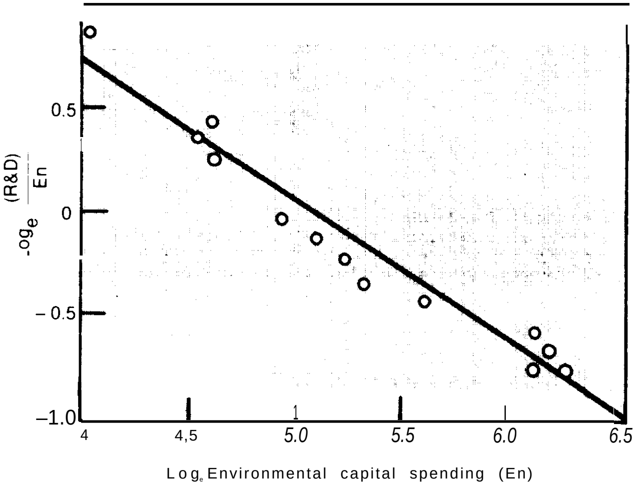
‘Proceedings, “The American Steel Industry in the 1980’s—The Crucial Decade, ”’ AISI, 1979.

There is no obvious relationship between R&D spending and environmental capital expenditures (see table 108), but the ratio of industrial R&D funding to environmental spending does appear to be related to the level of capital spending (figure 36). As capital spending for environmental needs increases, R&D spending decreases relatively. That such a statistically significant relationship should hold over the 13-year period for aggregated industry data is curious: nondiscretionary environmental spending because of governmental regulations appears to be controlling the level of R&D spending. However, since environmental spending is in the capital category and R&D spending is in the expense category, the cause-effect relationship, if one exists, may not be as simple as this curve implies.

Figure 36.— R&D and Environmental Expenditures Steel Industry, United States, 1965-78

$$\log_e \frac{(R\&D)}{En} = 0.682 \log_e En + 3.46$$

(Correlator coefficient) $r = -.973$



SOURCE Off Ice of Technology Assessment from data in table 108

The rate of R&D spending is not uniform among segments of the domestic steel industry. Alloy/specialty mills often allocate a larger proportion of their sales and profits to R&D than do large integrated steel companies (see table 109). Furthermore, integrated steel companies that have diversified are channeling a growing proportion of their R&D funds into nonsteel R&D spending. Using NSF data, apparent nonsteel R&D spending by steel companies increased between 1963 and 1977 from 14 to 32 percent of total R&D spending (table 110). Thus, R&D spending as a percentage of sales for diversified steel companies declined by even more than the data in table 106 indicate. Finally, it appears that nonintegrated steel companies spend much less on

Table 110.—Measure of Diversification of R&D Efforts in Ferrous Companies (dollars in millions)

	Ferrous industry R&D spending	Ferrous product field spending	Apparent nonferrous R&D spending of ferrous companies	
			Dollars	Percent of total
1963	$105	$ 90	$15	14.3
1966	136	104	32	23.5
1967	134	117	17	23.5
1968	134	119	15	11.2
1969	135	125	10	7.4
1970	148	127	21	14.2
1971	142	114	28	19.7
1972	144	137	7	4.9
1973	159	158	1	.6
1974	177	156	21	11.9
1975	211	144	67	31.8
1976	252	163	89	35.3
1977	256	172	84	32.8

SOURCE National Science Foundation

R&D than the other industry segments, although no published data on spending levels are available to document this.

In addition to significant within-industry R&D spending differences, there are major between-industry differences. Ferrous metals R&D as a percentage of net sales has been lower than that of other basic industries for 15 years or more. Between 1966 and 1977, ferrous metals R&D was only one-sixth to one-half the level of other basic industries like nonferrous metals and chemicals (table 111).[*] Steel industry R&D also ranks very low among a broader range of manufacturing industries—at about 20 percent of the all-manufacturing average, it ranks above only the food, textile, and lumber industries. Similarly, the number of R&D scientists and engineers per 1,000 employees is smaller for steel than for any other industry except for textiles and apparel, about 15 percent of the average for all reported industries (table 112).

Low R&D levels relative to other industries and declining R&D relative to sales can be attributed to a number of economic factors. The pilot and demonstration plant stages of steelmaking research are very expensive compared to R&D in other sectors of the economy, and the steel industry is thus exposed to a much greater degree of risk than are other industries. The decline in the steel industry's share of the domestic market has also increased the market risk of capital-intensive R&D. Related to a declining market share has been a real decline in steel industry investments since about 1965 (ch. 3), which has narrowed the industry's choices among production processes and equipment. And finally, as steel profitability declined professional managers of iron and steel companies have exercised considerable caution with respect to R&D activities. In the case of conglomerates, these managers must allocate R&D funds among various activities: they are undoubtedly influenced by profitability trends in these activities.

Nonindustry R&D.— Steel industry R&D is complemented by only limited efforts else-

Table 111.— R&D Funds as Percentage of Net Sales in Ferrous Metals, Nonferrous Metals, Chemicals, Petroleum Refining, and Stone, Clay, and Glass Products Industries, United States, 1963-77

Year	Ferrous metals	Nonferrous metals	Chemicals	Petroleum refining	Stone, clay, and glass products
1963	0.7	1.1	4.3	1.0	1.6
1966	0.7	0.8	4.4	0.9	1.5
1967	0.8	1.0	4.6	0.8	1.8
1968	0.7	1.0	3.8	0.8	1.6
1969	0.7	1.0	3.9	0.9	1.7
1970	0.7	1.0	3.9	1.0	1.8
1971	0.7	1.0	3.7	0.9	1.8
1972	0.6	0.9	3.6	0.8	1.7
1973	0.5	0.9	3.5	0.7	1.7
1974	0.5	1.0	3.5	0.6	1.7
1975	0.6	1.2	3.7	0.7	1.2
1976	0.6	1.2	3.7	0.6	1.2
1977	0.5	1.1	3.6	0.7	1.2
Annual averages					
1966-77	*0.6*	1.0	3.8	0.8	1.5
1968-72	0.7	1.0	3.8	0.9	1.7
1973-77	0.5	1.1	3.6	0.7	1.4

SOURCE National Science Foundation

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[*] Steel industry sources claim that the record understates actual research efforts, since considerable research is for operational and tax accounting purposes undertaken in production departments and reported as a production expense, See, for instance, Frederick C. Lagenberg, president, American Iron and Steel Institute, "United States Steelmaking Technology-Second to None, " in *Proceedings of the* Steel Industry Economics Seminar, AISI, 1977, p. 43.

The same tax laws also apply to other industries, and therefore similar reporting practices could prevail in other industries although the extent probably varies from industry to industry. Valid conclusions can be made about the comparative standing of steel industry R&D.

Table 112.—Competitive U.S. Trade Performance in Comparison With R&D

	U.S. share of exports, 1962	Company R&D as percentage of sales, 1960	Federal R&D as percentage of sales, 1960	Total R&D as percentage of sales, 1960	‘Scientists and engineers engaged in R&D as a percentage of employment, January 1961
Aircraft	59.52	2.6	19.9	22.5	7.71
Scientific and mechanical measuring equipment	36.52	4.1	7.7	11.8	NA
Drugs	33.09	4.7	0.1	4.8	6.10
Machinery	32.50	2.7	1.6	4.3	1.39
Chemicals, except drugs	27.32	3.4	0.7	4.1	3.65
Electrical equipment	26.75	3.7	7.2	10.9	4.40
Rubber products	23.30	1.4	0.7	2.1	0.95
Motor vehicles and other transport equipment	22.62	2.4	0.7	3.1	1.14
Other instruments	21.62	4.4	2.1	6.5	NA
Petroleum refining	20.59	1.0	0.1	1.1	2.02
Fabricated metal products	19.62	1.0	0.5	1.5	0.51
Nonferrous metals	18.06	0.9	0.2	1.1	0.64
Paper and allied products	15.79	0.7	0.0	0.7	0.47
Lumber, wood products, furniture	12.26	0.5	0.1	0.6	0.03
Textiles and apparel	10.26	0.4	0.2	0.6	0.29
Primary ferrous products	9.14	0.6	0.0	0.6	0.43
Rank correlation with first column		0.84	0.73	0.92	
Linear correlation with first column		0.59	0.84	0.90	

NA = not available

SOURCE D B Keesing, “The Impact of Research and Development and U S Trade, ” J. Political Economy 75, 38-48, 1967

Table 113.—Federal Support of Industrial R&D, 1977

	Federal R&D funds (percent of total R&D)
Ferrous metals and products	1.9
Nonferrous	7.4
Aircraft and missiles	77.8
Electrical equipment and communication	45.5
Motor vehicles	12.5
Chemicals	9.0
Instruments	11.1

SOURCE National Science Foundation, R&D in Industry, 1977

where in the private sector and in Government and academic institutions. The industry relies heavily on its supplier industries and companies for technological developments, but for a variety of reasons, including the low level of new steel plant construction in the United States, these supplier companies have been losing their share of the world market and are themselves spending less on R&D. Federal contributions to support steel R&D have also been meager. On average, since 1966, Federal agencies have spent $3 million annually, or 1.9 percent of total steel industry R&D, to support ferrous metals and products R&D (table 108), In fact, Federal support of ferrous metals R&D is lower than for any other category of industrial R&D (table 113). Commenting on this imbalance in Federal R&D, the administration’s major policy statement on the steel industry, the so-called Solomon report, notes:

> Despite the fact that steel is an important basic industry, Federal contributions to the steel industry’s R&D expenditures are low, representing only 1.9 percent of the industry’s R&D spending—compared with 9 percent for the chemical industry, 14 percent for the machinery industry, 47 percent for the electrical equipment industry, and 78 percent for the aircraft industry,[8]

Academic institutions also make a limited contribution to steel R&D. The American Iron and Steel Institute (AISI) provides about $1 million annually for university research projects. Federal funding for steel-related R&D at universities may approximate this level, al-

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[8] Solomon Report, 1977.

though no detailed data on university research in ironmaking and steelmaking appear to be available. The relatively low level of academic effort devoted to this area can be inferred, however, from the research interests of metallurgy and materials faculty: in a 1976 survey, thought to be representative of the past decade, less than 3 percent of faculty members listed interests in the areas of iron, steel, or ferrous research.[9] There are larger numbers of academic researchers working on subjects applicable to the steel industry than this figure would suggest, but they may be only indirectly concerned with iron, steel, or ferrous metals research. Low levels of steel research by professors also reflect the poor image steel research has in the academic community. The National Academy of Sciences has identified this low level of academic activity in materials processing as a barrier to progress and innovation:

> Materials-processing technology also suffers from insufficient attention in our engineering colleges. Fewer than 10 percent of the materials faculty (who themselves comprise only a small fraction of the engineering faculty) are experts in materials processing and manufacturing. These fields do not enjoy the status accorded some other academic disciplines, and little current research in the schools is relevant to major developments in materials processing. The near absence in our universities of research in materials-processing and manufacturing technology denies the country a potential source of new ideas and innovation. Furthermore, it means that the universities are not exposing young people to current advances in the field.[10]

It is apparent that steel R&D must be strengthened, and that current R&D must be redirected, for the industry to lower its overall costs, Some of the emphasis on improving labor productivity should be shifted toward attaining substantial raw material and energy savings through technological changes. Capital cost reductions are also necessary. During the late 1960's, U.S. raw materials costs were low and labor costs high compared to European producers.[11] Under such conditions, it was reasonable that considerable U.S. steel R&D effort—mainly innovation in operating efficiency—centered on labor-intensive operations such as rolling. But a heavy emphasis on improvements in labor productivity may no longer be appropriate. The costs of energy, materials, and capital have increased during the past decade to such a degree that they now deserve more prominence in R&D strategies. This inappropriate allocation of steel R&D effort is especially serious in view of the U.S. steel industry's need to modernize. More intensive research into and use of continuous casting and other raw-material-saving innovations would have made this need less pressing. *

Foreign R&D Activities

Foreign steel-related R&D activities differ radically from those in the United States: they have significantly larger budgets; they are conducted with considerable government assistance; and they are often undertaken in multisectoral steel production research institutions,

Foreign steel producers spend more on R&D than those in the United States. The U.S. steel industry's steel-related R&D expenditures have been about 0.5 to 0.6 percent of sales in recent years; in Japan, they are slightly more than 1 percent. Furthermore, Japanese steel-related R&D expenditures

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[9] *Metallurgy/Materials* Education *Yearbook*, American Society for Metals, 1976. This represents 27 of the 936 listed faculty members, 6 of whom were at Canadian schools; the remaining 21 were at 16 U.S. schools. There were 92 schools represented in the survey.

[10] National Academy of Sciences, Science *and* Technology—A *Five* Year Outlook, Freeman, San Francisco, Calif., 1979, p. 322.

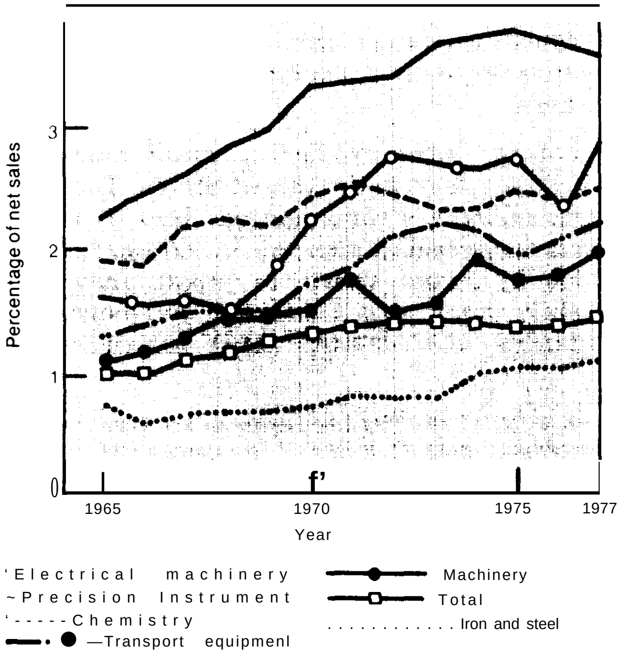
[11] A. K. McAdams ("Big Steel, Invention and Innovation Reconsidered," Quarterly *Journal of* Economics, 91 :457-82, August 1967) provides the following data:

costs	United States	ECSC
Labor, total	40%	20%
Energy, materials, supplies,	45	70
Investment and interest	10	5
Miscellaneous	5	5

*It is interesting to note that U.S. Steel Corp. in May of 1977 formed a task force to develop a comprehensive procedure to ensure that potentially attractive new steelmaking processes are effectively evaluated.

have grown gradually but steadily over time (figure 37), even though Japanese steel sales and profits have declined since 1974. In 1974, steel R&D occupied 3 percent of the total number of researchers in Japanese industry, and accounted for 5 percent of total industry R&D spending;[12] in 1973-75, the equivalent figures for U.S. steel R&D were 0.9 and 1.3 percent, respectively.[13] As in the United States, however, steel R&D ranks lower than R&D expenditures in other sectors of the Japanese economy. French and West German steel industry R&D as a percentage of sales is roughly similar to U.S. levels,[14] but there is somewhat more difference in R&D spending per net tonne of raw steel produced; in 1972, the United States spent $1.30, the European Community $1.46, and Japan $2.26 per tonne of steel output.[15]

Figure 37.— R&D Expenditures in Japan as Percentage of Net Sales by Sectors



SOURCE Japanese Government 1979

Regional and intersectoral (industry, university, government) steel R&D cooperation is typical in foreign steel-producing countries, but not in the United States. Here, joint R&D efforts by domestic steel producers are inhibited by Federal antitrust policies, but in many other steel-producing countries such cooperative efforts are encouraged. Further, much foreign steel research is undertaken by research institutes jointly supported by industry, university, and government. The Steel Directorate of the Commission of European Communities has a mechanism for regional R&D coordination. It arranges for significant steel-related R&D funding, and the costs are shared among the steel companies and the member countries. At the present time, the annual funding level by the Steel Directorate, alone, is about $36 million. Member country governments supply $20 million of this funding, an amount about four times greater than the U.S. Government's support of steel R&D.

Japan

The Agency for Industrial Science and Technology (AIST) is the part of the Ministry of International Trade and Industry (MITI) that coordinates and influences R&D within Japanese industry. The stated purpose of AIST is the "promotion of R&D of industrial science and technology and diffusion of obtained results."[16] One of the many AIST programs, the national R&D program, deals with large-scale projects that require "a great deal of expense, risks and long-range period."[17]

When initiated in 1973, the policy criteria guiding the selection of projects were that:

- Projects should have a prospect for high social returns by providing technical advances for a wide sector of the economy.
- Projects should be unable to be undertaken by private firms because of "market failure," including an absence of profit motives and high risk.

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[12] Agency for Industrial Science and Technology, 1977.

[13] National Science Foundation, op. cit.

[14] Hajime Eto, "Relationship Between Basic and Improvement Innovations—Development of Innovation Policy of Japan," presented at IIASA, December 1979.

[15] H. Mueller, "Factors Determining Competitiveness in the World Steel Market," Atlanta Economic Conference, October 1979.

[16] "Agency for Industrial Science and Technology," MITI, 1978.

[17] Agency for Industrial Science and Technology, op. cit.

- Projects should use technologies that can be clearly specified: extensive basic research should not be required.
- Projects should be carried out cooperatively by universities, government laboratories, and industry; projects involving only one firm are usually rejected.[18]

One of the major AIST R&D projects has been the nuclear steelmaking program, with the goal of a commercial nuclear steelmaking capability by 2000. A sizable amount (about $54 million) was allocated for the first phase of the program in 1973-79, and project implementation continues on schedule.

Another part of AIST supports R&D activities in private industry. There are four components of this program:

- Subsidies for *R&D:* "The total subsidies granted in (the) past 29 years . . . amounts to approximately 40.2 billion yen ($168 million) for 4,112 programs. "
- Tax credits for increased R&D expenditures: "If R&D expenses exceed the largest amount of such expenses of any preceding accounting periods since 1966, 20 percent of such excess amount may be deducted from the corporation tax. The maximum amount deductible is 10 percent of the corporation tax, "
- Low-interest loans: AIST plays an important role in allocating long-term loans through the Japan Development Bank to encourage the use of new technology developed by private enterprises. "The sum of loans furnished in 1976 was approximately 36 billion yen ($150 million) for 38 items. "
- A research association for mining and manufacturing technology: "for the promotion of joint research among private companies and the research associations, "[19]

AIST has been conducting technology assessments since 1975; the Japan Industrial Technology Association also helps disseminate technical information by spreading R&D results achieved mainly by AIST laboratories and institutions. In addition, AIST carries out for industry a technological survey that defines R&D themes and describes ongoing R&D activities.

The AIST laboratories and institutes also play a direct R&D role. There are 16 of these, and many, such as the National Research Institute for Pollution and Resources and the Government Industrial Development Laboratory, carry out work of interest to the steel industry. The Industrial Development Laboratory, for example, has a project on high-pressure fluidized reduction of iron ore, as well as one on coal gasification.

The Japanese steel industry, during the period since World War II, has shifted from basic research to very applied R&D. This shift, largely stimulated by demonstrated deficiencies in manufacturing and other technologies, set the stage for Japan's massive industrialization after the war.

> Japanese physicists developed high quality steel in the interwar period. But the Japanese production process of iron and steel was inefficient for mass production, and lack of quality control resulted in big variance of quality which cancelled out the theoretically calculated high quality. The basic innovation founded on great physical discoveries was found useless without suitable production technology.
>
> * * *
>
> A great deal of effort was [therefore] put into automation technology development rather than to improvement in quality of iron and steel itself.[20]

A recent survey of Japanese steel industry personnel, apparently conducted by MITI, found that the most significant changes for the iron and steel industry were expected to be a future de-emphasis on market-driven innovation and resource saving, and an increase in R&D in other fields. The latter would appear to indicate a trend toward diversification. Furthermore, nearly three-quarters of the industry personnel believed

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[18] Ibid.

[19] Ibid.

[20] Eto, op. cit.

that there would be incremental innovation within 5 years, and 10 percent believed that there would be an epoch-making innovation in the next 10 years. There are, indeed, indications of a decline in private-sector R&D, which the respondents attributed variously to higher costs, greater risks, declining profits, and a global stagnation in both basic research and technical innovation.

West Germany

The Federal Ministry for Education and Science in West Germany plays a strong coordinating and sponsoring role in the area of industrial research. The attitude of the German steel industry is that basic research should be done in the universities and the development work in the industry. The West German Government apparently accepts this division of labor.

As in Japan, government support for steel-related R&D can also be found in West Germany. Government-funded projects are established and supported on a long-term basis. Four-year projects are normal, with renewal periods ranging from two to four years. Such support creates a large core of people to guide R&D projects to successful outcomes, and German technology in steelmaking and processing normally stays abreast of competition from other countries, This has helped West German steel plant equipment purveyors to capture a fairly large share of business from both developed and developing countries. Several research organizations also draw West German Government support to solve steel industry problems:

- Verein Deutscher Eisenhuttenleute (VDeh)
- Iron Works Slag Research Association (Reinhausen)
- Iron Ore Dressing Study Group (Othfressen)
- Iron and Steel Application Study Group (Dusseldorf) ˉ-

The aim of these groups is to find solutions to practical problems encountered by steel plant operators. Government funding is tied to close cooperation between these research organizations, the steel plants, and the senior faculty at the universities and polytechnical schools.

Sweden

The emphasis of Swedish R&D appears to be on the alloy and specialty steels and on the development of major steelmaking innovations that can be exported to foreign steel industries. Swedish research is particularly active in coal-based direct reduction, direct steelmaking processes, and plasma steelmaking.

In addition to significant, though recently declining, private-sector R&D, the government funds a number of research establishments. These include the Swedish Institute for Metals Research and the Royal Institute of Technology, both in Stockholm, and the Foundation for Metallurgical Research (Mefos). Mefos was promoted for the Swedish steel industry by Jernkontoret, the Swedish Iron Makers Association, which is owned collectively by the steel works of the country. Mefos has 65 employees and an annual budget of $3.8 million. About 50 percent of its annual expenditures, outside of contract research, come from the Swedish Government.*’ The foundation operates two full pilot plants, constructed and equipped for a total investment of about $16 million.

R&D and Trade Performance

The export performance of an industry increases with increasing levels of private and government R&D spending, as well as with increasing numbers of scientists and engineers engaged in R&D.[22] The data of tables 112 and 114, as well as more recent trade data, strongly suggest that increasing U.S. steel imports and decreasing participation in world

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z ' *Steel Technology Bulletin*, Swedish Trade Office, December 1979,

Z-’ The causal relation of R&D in determining export performance was shown to be significant in W. H. Branson and H. B. Junz, “Trends in U.S. Trade and Comparative Advantage, ” *Brookings Papers on Economic Activity*, vol. 2, 1971.

Table 114.—U.S. R&D Intensity and Trade Performance

Description	R&D Intensity[a] (percent)	Trade balance exports-imports, 1976 (millions of dollars)
Above-average R&D intensity		
Communications equipment. .	15.20	$ 793.7
Aircrafts and parts	12.41	6,748.3
Office, computing equipment . .	11.61	1,811.4
Optical, medical instruments .	9.44	369.6
Drugs and medicines	6.94	743.5
Plastic materials	5.62	1,448.0
Engines and turbines	4.76	1,629.2
Agricultural chemicals.	4.63	539.3
Ordinance (except missiles)	3.64	553.0
Professional and scientific instr.	3.17	874.8
Electrical industrial apparatus .	3.00	782.5
Industrial chemicals.	2.78	2,049.4
Radio and TV receiving equip.	2.57	– 2,443.4
Average	—	1,223.0
Below-average R&D intensity		
Farm machinery ., ...	2.34	**696.2**
Electric transmission equipment	2.30	798.1
Motor vehicles.	2.15	– 4,588.6
Other electrical equipment	1.95	311.2
Construction, mining	1.90	6,160.4
Other chemicals	1.76	1,238.5
Fabricated metal products.	1.48	1,525.7
Rubber and plastics	1.20	– 478.8
Metalworking machinery	1.17	736.4
Other transport	1.14	72.1
Petroleum and coal products. . .	1,11	NA
Other nonelectric machines .	1,06	3,991.3
Other manufactures	1,02	– 5,137.4
Stone, clay, and glass.	0.90	–61 .3
Nonferrous metals	0.52	– 2,408.9
Ferrous **metals . . . .**	0.42	-2,740.4
Textile mill products, ...	0.28	40.3
Food and kindred products	0.21	– 190.0
Average	—	2.0

aMeasures of R&D intensity and trade balance are on product line basis The ratio of applied R&D funds by product field to shipments by product class, averaged between 1968-70

SOURCES Department of Commerce, BIERP Staff Economic Report U S Bureau of the Census

export markets are linked to the domestic steel industry's relatively low levels of R&D spending. A counter example can once again be found in Japanese R&D and the connection between Japanese performance in technology and exports:

> Japan, which has no significant natural resources, runs a positive trade balance. The U. S., which has many natural resources, runs a large deficit. A key difference is in our use of technology. The export accomplishments of Japan in optics, steel, automobiles, and consumer electronics provide obvious examples of what the Japanese can do when they set technological and export goals. In all of these fields they have used their resources more effectively than we . . . We should match it with our best efforts and people. [21]

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[21] J. B. Wiesner, The Chronicle of Higher Education, Nov. 13, 1978.

Adoption and Diffusion of New Technology— Case Studies of Six Technologies

Adoption Strategies

Any successful technological innovation has certain benefits associated with it; these may be reductions in the costs of input factors (like raw materials and labor) or improvements in product quality. The changeover to new technology also has the attendant costs of adjustments in employment levels, skill requirements, production quotas, and associated supervisory arrangements. For an innovation to be adopted, obviously, the benefits should outweigh the capital and changeover costs. The adoption decisions made by the management of individual firms collectively determine the rate at which a technological innovation diffuses throughout an industry, and capital investment is a major factor in the firms' adoption decisions. *

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*A third variable, labor relations has generally not created any difficulties with the introduction of new steelmaking equipment (see ch. 12).

The issue of capital formation, then, is a crucial one. A company's sources of capital funds may be external, or they may be internal—that is, generated from cash flow. Governments, by their tax policy, influence the cash flow companies have available for reinvestment. If a company has sufficient discretionary funds, it will base its investment decisions on its evaluation of the return on investment from alternate projects, the perceived risk of each project, and the urgency management associates with each project.

The diffusion of major innovations falls into one of three categories: those involving capacity addition, those involving replacement of obsolete facilities, and those involving displacement of functioning facilities.[24] The economic considerations in a decision to adopt a technological innovation are quite similar for capacity expansion and for replacement of obsolete facilities, but they are slightly different for displacement.

When management considers capacity expansion or replacement to be necessary, it is likely to prefer new technology to established technology if the new technology offers either improved product quality (and increased revenue) at little or no increase in cost, or equivalent product quality with at least a modest cost reduction. Both options, however, depend on the prior elimination of technological uncertainties about minimum acceptable performance; even in expansionary periods, the adoption rate of a new technology may remain modest so long as its technical uncertainties outweigh prospective gains. Moreover, if innovations offer advantages in only a limited range of plant sizes or only part of a product range, technological diffusion may be delayed while methods are developed to adapt the technology to the remainder of the size or product range. And finally, a short supply of inputs may delay rapid adoption of technology. Adoption rates would be expected to rise sharply, then, as cumulative practical experience removes uncertainties about acceptable performance and as further technical advances allow the innovation to be applied advantageously to a broad array of products and facility sizes.

The economic criteria for adopting innovations that displace currently functioning facilities are more stringent than for those that add to capacity or replace obsolete facilities. First, an innovative facility that is to replace a functioning facility producing an equivalent product must produce at costs comparable to those of the technology it replaces. If a company has recently undertaken major modernization or expansion programs, any undepreciated investment must be written off, so management is less likely to adopt innovative technology to replace functioning facilities. In evaluating displacements, the changeover costs associated with adjustments in employment levels, skill requirements, production quotas, and associated supervisory arrangements must also be considered. If the displacement of capacity is effected with no increase in capacity, the potential gains may be lower than if capacity can also expand. In such a case, direct displacement is likely to be substantial only if the older facilities have heavier requirements for input factors that are in short supply, or if demands increase for product qualities not attainable by the older facilities.

Six Case Studies of Technological Changes

The six case studies chosen examine major innovations representing different aspects of steel technology, different national origins, and different levels of adoption. Information on the six innovations is summarized in table 115.

Argon-Oxygen Decarburization (AOD) Process

This process is generally considered to be a major process innovation of U.S. origin. It belongs to a class of pressurized-gas stainless steel processes developed during the mid-1950's and early 1960's, and has been in com-

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[24] B. Gold, W.S. pierce, and G. Rosseger, "Diffusion of Major Technological Innovations in the U.S. Iron and Steel Manufacturing,"' The Journal of Industrial Economics, vol. 18, No. 3, July 1970, pp. 218-41.

Table 11 5.—Summary Information on Six OTA Case Studies

	Type of innovation		Stage of steel making			Place of major innovation activity	Level of adoption	
Innovation	Process	Product	Ironmaking	Steelmaking	Casting-fabrication		World-wide	United States
Argon-oxygen decarburization	X	—	—	x	—	United States	High	Very high
Basic oxygen furnace	X	—	—	x	—	Austria	Very high	Very high
Continuous casting	X	—	—	—	x	West Germany	High	Low
Formcoking	X	—	x	—	—	United States	Very low	Very low
Steel mill waste recycling	X	—	x	—	—	Japan	High	Very low
One-side galvanized steel	—	x	—	—	x	United States	Moderate	High

SOURCE Off Ice of Technology Assessment

mercial production since the late 1960's. Other processes in this class include the basic oxygen furnace (or "oxidation-reduction") process, the vacuum oxygen decarburization (VOD or LD-VAC) process, and the steam, ammonia/oxygen, or Creusot-Loire Uddeholm (CLU) process.

An AOD furnace uses pressurized argon and oxygen to prepare molten alloy steel. The use of argon in combination with oxygen allows decarburization of the melt without excessive oxidation of the chromium, which is quite expensive and has a high affinity for oxygen. In the AOD steelmaking and refining process, less chromium is lost and lower cost chromium charge material can be used,

The AOD process was invented in 1954 by Union Carbide at their Niagara Falls facility. Several years of R&D followed, and Union Carbide began a cooperative AOD development program with Joslyn Stainless Steels in 1960. In conjunction with experiments in the arc furnace, Union Carbide continued to explore the idea of using a separate refining vessel, In 1969, 15 years after AOD's original invention, Joslyn started a 100-percent, full-scale AOD system. The successful demonstration and commercial operation at Joslyn and the aggressive technical marketing effort by Union Carbide spurred the rather rapid adoption of this technology by U.S. alloy/specialty companies.

Computer techniques for optimizing AOD were also developed in the United States and came into use in 1972.[25] This practice has since been widely adopted throughout the world to about the same extent as in the United States.[26] The use of the AOD process is now being extended to the manufacture of other specialty alloys, such as tool-and-die, high-speed, and forging steels. A great many foundries have also installed AOD vessels within the last few years.

Since its first commercial use by a U.S. steel company, the AOD process has been widely adopted throughout the world for the production of stainless steel. Worldwide installed AOD annual capacity increased from 90,700 tomes in 1970[27] to 5,705,000 tonnes by mid-1978.[28] Of this, about 40 percent, or 2,282,000 tonnes, is in the United States,[29] U.S. installation of AOD capacity since 1970 has been almost double that of Western Europe and more than double that of Japan (figure 38); of all major steel-producing countries, only Italy has adopted AOD technology faster than the United States (table 116). The United States is clearly the leader, by far, in installing AOD technology.

U.S. adoption of AOD technology was encouraged by the generally high domestic growth rate for stainless steel consumption. The overseas marketing effort was delayed pending the results in the U.S. domestic market, and this appears to have contributed to differences in the rates of AOD diffusion for the United States and other countries. Also, some plants in Japan and Europe had recently

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[25] R. K. Pitler, "Worldwide Technological Developments and Their Adoption by the Steel Industry in the United States," prepared for the General Research Committee of the American Iron and Steel Institute, Apr. 13, 1977.

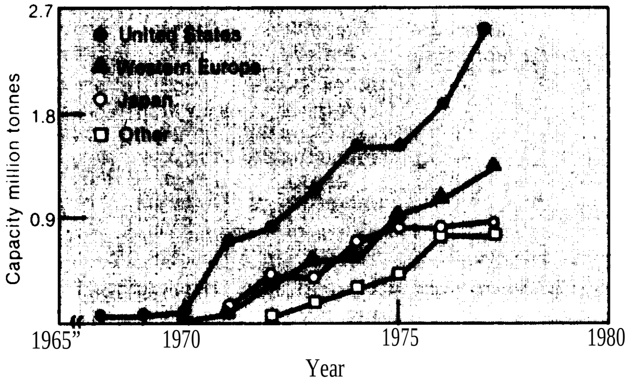
[26] Ibid.

[27] Ibid.

[28] Richard Daily, "Round-Up of AOD Furnaces,' Iron *and* Steelmaker, July 1978, pp. 22-29.

[29] Ibid.

Figure 38.—Installed Argon-Oxygen Decarburization Capacity



SOURCE American Iron and Steel Institute

Table 116.—Adoption of AOD Technology in Various Countries of the World (in tonnes)

Country	1978 installed AOD capacity	1974 production of stainless steel ingot
United States	2,250,000	1,955,000
Japan.	762,000	2,037,000
West Germany	454,000	688,000
France	272,000	570,000
Sweden	390,000	519,000
Italy	372,000	311,000
United Kingdom	400,000	224,000
Others	554,000	446,000
Total.	5,454,000	6,750,000

SOURCES, Institute for Iron and Steel Studies, INCO World Stainless Steel Statistics, 1976

adopted competing technology. For such plants, a switch to AOD would offer only incremental cost savings, and in addition undepreciated equipment would have to be written off. In some of the LDCs, the availability of industrial gases could be responsible for the delay in adopting AOD technology.

The rapid growth of the AOD process can be attributed to its reduction of raw material costs. The process permits refining almost any initial melt chemistry and achieves high recoveries of almost all elements. High-carbon chromium charge can replace more expensive low-carbon ferrochrome. In addition to chromium, improved recoveries of manganese, molybdenum, nickel, and titanium have been reported. Other savings stem from less overall silicon consumption, lower electric furnace costs because of less power consumption, reduced electrode consumption, and less refractory wear.

AOD operating cost savings range from an estimated $55 to $110 or more per tonne of stainless steel. Even larger savings are typical for the higher chromium and other specialty alloys. Between 20 and 30 percent of these stainless steel savings are attributable to lower energy-related costs. Payback periods ranging from 6 months to 2 years have been estimated. In addition to allowing cost economies, the process also improves product quality: sulfur content is lower, inclusion distribution is improved, temperature and chemical homogenization are better, and final dissolved oxygen, nitrogen, and hydrogen are reduced.

Summary .—The main motivating factors for the rapid adoption of AOD technology are:

- reduced raw materials cost, because of improved yields of alloying elements and the use of lower cost raw materials;
- improved product quality;
- low-cost increases in capacity, because AOD vessels can be retrofitted in existing melt shops; and
- an aggressive technical marketing effort by the process developer, a company in the “supplier” category.

Some of the barriers are:

- the recent installation of competing pneumatic technology in Europe and Japan, which reduced the economic incentive to switch to AOD when it became available;
- the availability of industrial gases, which may have hindered adoption of AOD technology in the LDCs; and
- delays in government approval of licenses in certain countries.

Basic Oxygen Process

The basic oxygen furnace (BOF) has revolutionized steelmaking, and it is generally considered the most significant major process innovation for steelmaking in modern times. Total BOF tonnage has grown faster in Japan and the European Economic Community (EEC) countries than in the United States. About 62 percent of all U.S. steel, 75 percent of West German and French steel, and 80 percent of Japanese steel are made in the BOF,

BOF technology reduces costs and improves productivity. The BOF comprises a vertical, solid-bottom crucible with a vertical water-cooled oxygen lance entering the vessel from above. The vessel can be tilted for charging and tapping. The charge is normally made up of molten pig iron ("hot metal") plus scrap and fluxes, although small quantities of cold pig iron and iron ore may also be charged, The distinguishing feature is that the heat produced by the reaction of oxygen with various constituents of the charge is used without other sources of energy to bring the metal to the desired final conditions of composition and temperature. Occasionally, the heat balance may be altered by the introduction of supplementary fuel to permit melting of above-normal amounts of scrap.

In 1949, experimental results from a small BOF pilot plant in Switzerland showed that it was possible to refine iron by use of oxygen and to remove phosphorus and sulfur by the use of basic linings and fluxes. In addition, a significant proportion of scrap could be added—close to half the weight of the iron in some cases. Scientists at VOEST continued development work on the BOF at Linz, Austria, where the first successful heat was made in October 1949. This development resulted in the first commercial plant, which began operation in 1952 with 32-tonne vessels. Many problems had to be met as growth continued. Some of the improvements were carried out in Austria, and as other nations began to use the BOF, they accelerated the pace of improvements. The BOF has grown from a 30-tonne novelty to the leading steel process in the world, with vessels more than 10 times the original size. To achieve such growth during 20 short years of industrial life is remarkable.

Most of the world's BOF capacity came onstream in the 1963-70 period, and the rate of BOF installation has since declined substantially. The earliest plants were installed in the early and mid-1950's, with vessels ranging from 27 to 45 tonnes; none had a design capacity exceeding the 73 tonnes of Jones and Laughlin's BOF in 1957. Thereafter, the number of yearly installations and the size of the vessels continued to increase, with four installations of over 200 tonnes starting up by the end of 1962.

It has been pointed out that the U.S. industry was more aggressive than Japan or the EEC in introducing this technology as opportunities occurred to increase capacity; however, only limited U.S. capacity expansion took place during the 1952-76 period when large numbers of BOFs were being installed throughout the world. Until **1969,** BOF adoption rates for the United States, Japan, and Europe were in fact roughly similar. Since that time BOF capacity in Europe and particularly in Japan has continued to grow. Despite limited steel industry growth, the U.S. steel industry has had a reasonable growth-rate record for the BOF, largely as BOFs replaced open hearth capacity. Europe and Japan, on the other hand, experienced substantial capacity expansion during the post-war period, and more BOF capacity was put into place in Japan and the EEC countries than in the United States (see figure 39). *

Most of the U.S. companies that have adopted BOF technology are large integrated plants producing carbon and low-alloy steels, and most have hot metal available—a prime requirement for the BOF. U.S. companies can easily purchase BOF technology from other companies and vendors, so it is not necessary for them to support extensive R&D work before installing BOF capacity, nor do they need pilot or demonstration plants, A company can decide on the size of the equipment it needs and purchase it from the vendors, who will

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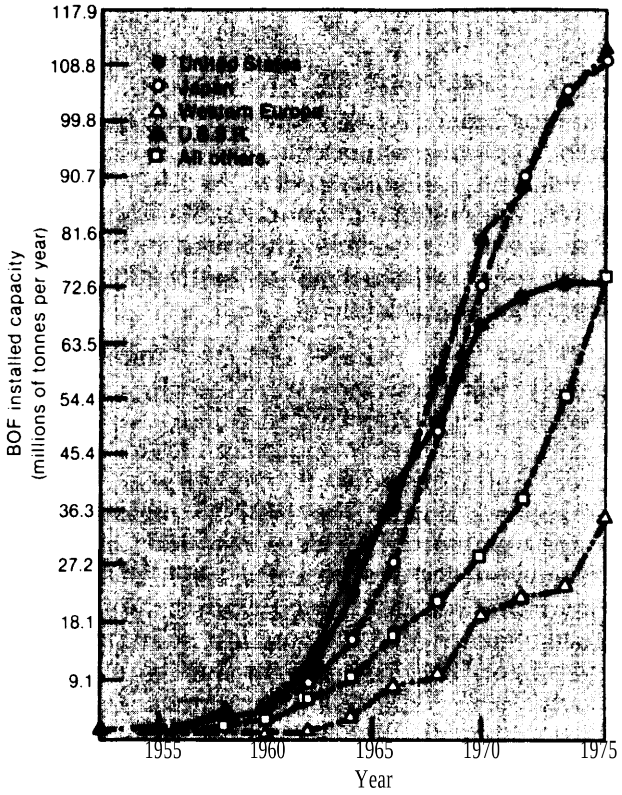
*The higher Japanese and EEC growth rates for the installation of BOFs has contributed to growing exports from these countries to the United States and the rest of the world.

Figure 39.—Growth of BOF Installed Capacity



SOURCE. American Iron and Steel Institute

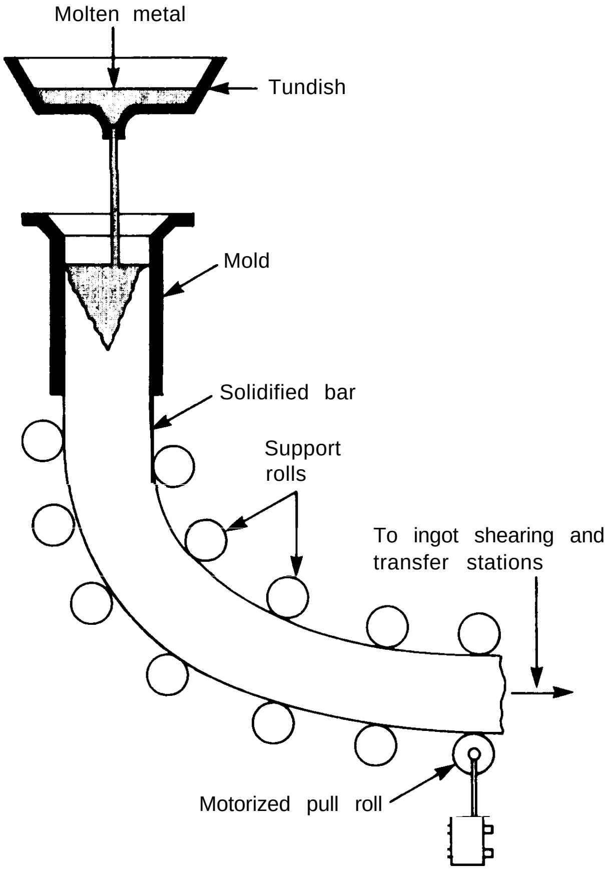
also provide technical and operating know-how. None of the operations in the United States, however, has received any Government assistance in adopting BOF technology, whereas in Europe and Japan a number of companies received help from their governments in securing capital for BOF adoption.

Continuous Casting*

Continuous casting was originally patented in 1865 by Sir Henry Bessemer. However, engineering and equipment problems were not solved and the process was not commercialized until the early 1960's, when significant amounts of steel began to be continuously cast in a number of the world's steel industries. Today, continuous casting is the preferred choice in new steelmaking plants, although there are still some types of steel that have not been converted from the older ingot casting method to continuous casting.

Continuous casting replaces with one operation the separate steps of ingot casting, mold stripping, heating in soaking pits, and primary rolling. In some cases, continuous casting also replaces reheating and rerolling steps (figure 40). The basic feature of all continuous casting machines is their one-step nature: liquid steel is continuously converted into semifinished, solid steel shapes by the use of an open-ended mold. Clearly, continuous casting makes long production runs of a particular product easier and more efficient than ingot casting. The molten steel solidifies

Figure 40.—Continuous Casting Apparatus



SOURCE. *Technology Assessment and Forecast, Ninth Report,* Department of Commerce, March 1979.

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*A detailed discussion of continuous casting has been given in Benefits *of* Increased Use *of* Continuous Casting by *the* U.S. *Steel Industry*, OTA technical memorandum, October 1979.

from the outer cooled surfaces inward during the casting process, so that finally a fully solid slab, bloom, or billet is produced. This product can then either be processed in a secondary rolling mill or be shipped as a semifinished steel product.

Energy Savings and Increased Yield.—The continuous casting process saves energy directly, by eliminating energy-intensive steps, and indirectly, by increasing yields. The elimination of intermediate casting steps reduces the consumption of fuels (natural gas, oil, and in-plant byproduct gases) and electricity by approximately 1.1 million Btu/tonne cast. In Japan, where one-half of all steel is continuously cast, the direct energy savings is apparently about 50 percent over traditional ingot casting. Further energy is saved indirectly by the substantial increase in yield from continuous casting, perhaps an additional 2.2 million Btu/tonne.

Increased yield also means that less scrap is generated. End losses, typical with individual ingots, are eliminated, and oxidation losses are reduced because less hot metal is exposed to the air. The simplicity and improved control of continuous casting also improve overall efficiency. All these improvements mean that more shipped steel can be obtained from a given amount of molten steel. When yield increases by 10 percent, an additional tonne of shipped steel is gained for each 10 tonnes of molten steel; continuous casting increases yields by at least 10 to 12 percent, and in some cases by 15 to 20 percent. The raw materials used to produce these "extra" tonnes of steel, including iron ore and coke, have also been saved.

Total direct and indirect energy savings average 3.33 million Btu/tonne continuously cast, which can lead to a significant cost saving. These are average energy savings for many types of steels, but although actual savings may vary considerably the figure is probably conservative. For example, one detailed analysis showed a saving of 6.0 million Btu/tonne for the traditional integrated steelmaking route of blast furnace to basic oxygen furnace, and 2.9 million Btu/tonne for the scrap-fed electric furnace route used by nonintegrated mills. * It is probably safe to say that the total energy savings because of continuous casting are normally equal to about 10 percent of the total energy used to make finished steel products. A comprehensive survey by the North Atlantic Treaty Organization of steel industry experts throughout the world, which considered 41 energy-conserving measures for steelmaking, concluded that continuous casting had the best combination of potential energy conservation and return on investment.[30]

Other Advantages and Benefits.—Continuous casting can also be recommended on the basis of its potential for higher labor productivity, better quality steel product, reduced pollution, lower capital costs, and the increased use of purchased scrap.

Because continuous casting eliminates many of the steps required by ingot casting, all of which require direct labor input, it results in higher labor productivity. The Department of Labor reports that 10 to 15 percent less labor is required in continuous casting than in ingot casting.[31] Productivity growth also results from the increase in yield of shipped steel, from improved working conditions, and from at least 5 hours reduction in production time from the pouring of molten steel to the production of semifinished forms. Advances have recently been made in eliminating time losses that occur when products of different size or composition must be made sequentially.

Most industry experts also report an improvement in the quality of some continuously cast steels, resulting from the reduced number of steps and greater automatic control of the process. There have been steady improvements in the process, particularly in the production of slabs for flat products that require high surface quality.

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*This analysis (by J. E. Elliott, in The Steel Industry and the Energy Crisis, J. Szekely (cd.), Marcel Dekker, N. Y., 1975, pp. 9-33) assumes a 10-percent increase in yield, which is probably conservative.

[30] "The Steel Industry," NATO/CCMS-47, 1977.

[31] U.S. Department of Labor, Bureau of Labor Statistics Bulletin 1856, 1975, p. 4.

It is generally recognized that continuous casting reduces pollution, as well. It eliminates soaking pits and reheating furnaces, and its lower energy requirements also reduce pollution—hot steel is exposed to the atmosphere for a shorter time than in ingot casting, so there are fewer airborne particulate. Increased yield also means that less primary steelmaking is required for any given level of shipped steel, so less coke is manufactured in integrated plants using blast furnaces; coking is steelmaking's largest source of pollution, particularly for toxic substances.

It is generally agreed that continuous casting reduces capital costs because it eliminates intermediate processing equipment. A study of five new steel technologies by Resources for the Future concluded that continuous casting has the greatest potential for capital cost saving* and recommended the adoption of continuous casting both in new facilities and to displace existing ingot casting capacity.

Finally, continuous casting increases the use of purchased scrap. "Home" scrap (produced in-plant) is normally recycled back to the steelmaking furnaces or the blast furnaces, or both. With higher yields, purchased scrap must replace the lost home scrap in order to maintain liquid-iron-to-scrap ratios. The price of purchased scrap has generally been lower than production costs for hot steel made from new iron units; under such circumstances, increased use of purchased scrap is an advantage.

U.S. and Foreign Rates of Adoption of Continuous Casting.— During the past several years, the Japanese have made frequent reports concerning the continued adoption of continuous casting and its effects in reducing energy consumption and increasing yield in steelmaking operations. Despite these advantages, the United States has fallen behind almost all foreign steel industries in adopting this beneficial technology. Continuous casting has been adopted at a much faster rate in countries like Japan, West Germany, and Italy than in the United States, England, or Canada (figure 41). In 1978, Japan continuously cast 50 percent of all its primary steel and West Germany, 38 percent; in the United States the level was only 15 percent. The Soviet Union has the only major foreign steel industry with a lower level of continuous casting than in the United States (table 117). This is explained by that country's unusual commitment to the open hearth process, which does not readily interface with continuous casting equipment. *

The high rate of adoption of continuous casting by many countries, particularly Japan, is largely explained by the considerable expansion of their steel industries in the late 1960's and early 1970's. The benefits of continuous casting are so compelling that it is the obvious process to choose when new steel plants are constructed, More recent construction of steel plants in Third World nations has also revealed the unequivocal advantages of continuous casting.

Although much of the increased use of continuous casting in the Japanese steel industry has been related to its expansion, in more recent years the Japanese have also pursued a replacement strategy. They will probably meet their goal of 70-percent continuous casting production within a few years. This will be a remarkable achievement, particularly in view of a number of negative factors facing that industry: low rates of capacity utilization, the closing of many older facilities, continued loss of world export markets, and very low profit levels. One reason these adverse factors have not impeded continuous casting adoption is that the Japanese Government and the banking system have channeled suffi-

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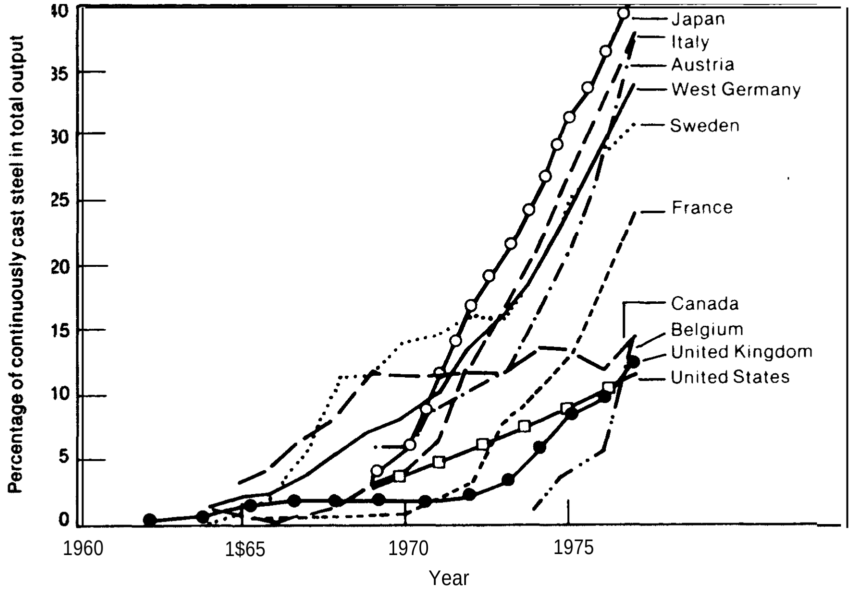
*The other four technologies were: scrap preheating, direct reduction based on natural gas, coal gasification for direct reduction, and cryogenic shredding of automobilederived scrap. (W. Vaughan et al., "Government Policies and the Adoption of Innovations in the Integrated Iron and Steel Industry, " 1976, Resources for the Future.)

*The energy-intensiveness of the Soviet iron and steel industry is suggested by its 13-percent share of total energy consumption, compared to about 3 percent for the United States. This must be considered a consequence, in part, of its low use of continuous casting.

Figure 41 .—The Diffusion of Continuous Casting



SOURCE Organization for Economic Cooperation and Development International Iron and Steel Institute

Table 117.— Percent Raw Steel Continuously Cast

Country	1969	1975	1977	1978
United States	2 9	9.1	11.8	15.2[a]
Japan.	4.0	31,1	40.8	50.9[b]
Canada	11.8	13,4	14.7	20.2
West Germany	7.3	24.3	34.0	38.0
France.	0.6	12.8	23.6	27.1
Italy	3.1	26.9	37.0	41.3
United Kingdom.	1.8	8.4	12,6	15.5
U.S.S.R.	–	6.9	8.3	–

[a] AISI has reported that for the first half of 1979 the full Industry usage rate was 161 percent

[b] A lower value of 46.2 percent has been reported by the International Iron and Steel Institute, presumably this figure is for calendar year 1978 while the 509 percent figure is for Japanese fiscal year 1978 (April 1978. March 1979) and is indicative of the rapidly Increasing usage

SOURCES AISI, IISI: Japan Steel Information Center, *Iron and Sfeelmaker,* 1978

cient capital at favorable interest rates to the Japanese steel industry.

The most important factor explaining the low rate of U.S. adoption of continuous casting is the low rate of new steel plant construction during the past several decades. A substantial number of small new nonintegrated steel plants using scrap-fed electric furnaces ("minimills'") process all their steel by continuous casting. This segment of the industry, however, represents onlv about 10 percent of domestic raw steel tonnage. Data-revealing the significant differences in continuous casting use among the three main industry segments and types of plants are given in table 118, Use by integrated steelmaker, just over 9 percent, is far below the nonintegrated carbon steel producers' use rate of nearly 52 percent. The nonintegrated companies may soon have the capacity to make 80 percent of their steel by continuous casting,

The main issue confronting the domestic steel industry with regard to greater adoption of continuous casting is: Can replacement of existing ingot casting facilities with continuous casting be justified economically? One integrated steel company, McLouth, replaced all its ingot casting with continuous casting, and another, National Steel, has embarked on such a course. By late 1980, National will process 40 percent of its steel in this manner, Recently, CF&I Steel Corp. announced its intention to increase its use of continuous casting from 18 to 100 percent by replacing all of its ingot facilities.

Table 118.—Continuous Casting in Segments of U.S. Steel Industry, 1978

industry segment	Raw steel (1,000 tonnes)	Continuously cast (1,000 tonnes)	Percent continuously cast
Integrated—carbon steel			
Nonelectric furnace.	95,048	8,841	9.3
Electric furnace	8,715	2,375	27.2
Integrated—alloy/specialty steels[a]	4,125	680	16.5
Subtotal. . . . ., ...	107,888	‘-1 1,896	‘11 .0
Non integrated			
Carbon steels	12,274	6,323	51.5
Alloy/specialty steels.	4,125	680	16.5
Subtotal. . . . ., ...	16,399	7,003	‘42.7
Total.	124,287	18,899	15.2

[a] The total of 9,096 raw steel tonnage and 1,499 continuously cast tonnage was split between Integrated companies producing mostly carbon steels and companies considered as alloy/specialty producers

SOURCE. AISI, Including estimates on amount of steel made by integrated companies in electric furnace shops

A 1990 time frame appears realistic for substantial expansion of domestic continuous casting capacity, considering the large size of the domestic industry, the long leadtimes for construction, the problems of capital availability, and the possible need for Federal assistance, which would require extensive congressional deliberation. There is no simple calculation that can determine unequivocally how much continuous casting the domestic steel industry should use. At best, the feasibility of several possibilities can be examined. It appears that levels of from 25 to 50 percent are feasible and that 50 percent would be necessary to achieve even minimum competitiveness on the international market. The 25-percent level has been suggested in several recent analyses of the steel industry. However, this level reflects nothing more than extrapolation of the past adoption rate for the industry to about 1990.

A 50-percent level of adoption of continuous casting is physically achievable in the United States by 1990; that is, there are no engineering or technological reasons why this level could not be attained. OTA calculations have shown that at this level of adoption the national yield rate could be increased to at least **76** percent. * The 50-percent goal can be supported by the following factors:

- In 1974, when the domestic industry was doing exceptionally well, A.D. Little, on the basis of a survey of industry opinion, concluded that by 1985 there would be 53-percent use of continuous casting.
- The Japanese and U.S. steel industries are similar enough in product mix and size to suggest that if the Japanese can produce 50 percent and probably 70 percent of their steel by continuous casting, then a level of 50 percent for the U.S. industry is technically feasible.
- In a 1979 OTA-conducted survey of steel industry opinion on future technological changes, the respondents projected a U.S. level of 54-percent adoption by 1990 and 74 percent by 2005.
- If appropriate Federal policies were designed to stimulate greater conversion to continuous casting by providing some means of obtaining the necessary capi-

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*The yield of 76 percent may appear to be lower, especially relative to that of the Japanese, as noted previously; but we have not assumed any large-scale closing of older U.S. steel plants, which could increase the base yield for the industry at the expense of capacity loss.

tal, then it would be economically feasible to obtain the 50-percent use level (greater details on costs are given below).

One top major steel company executive who has provided much useful information to the OTA assessment has suggested feasible targets of 50 percent for 1987 and 70 percent for **1990.** Similarly, one long-time steel industry[1] analyst on Wall Street has just suggested that "the U.S. could get to 40 percent by 1985 if the money was available. "

Economic Benefits of Adopting Continuous Casting.—The economic justification for replacing existing ingot casting facilities with continuous casting is not examined; summary data are provided in table 119. There are two key areas to be discussed and quantified before proceeding to a calculation of return on investment: the significance of the increase in yield with regard to new steelmaking capacity; and the direct production cost savings provided by continuous casting.

With higher yields, a given amount of raw steel will produce more finished steel and less scrap. Both are of significance for steel plant profitability: the first allows capacity expansion at very low capital cost; the second increases reliance on purchased scrap at prices typically lower than the cost of home scrap. But what has not been fully appreciated by some U.S. steel industry and policy analysts is that continuous casting is also an economical way to increase the steelmaking capacity of existing plants. Building major new integrated facilities in the United States appears impossible under existing or projected economic conditions, and new minimills will still represent relatively small tonnages. The substantial increase in yield from raw steel to semifinished steel that continuous casting makes possible means that more steel can be shipped from a given amount of molten steel.

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[1] Charles Bradford of Merrill, Lynch, Pierce, Fenner and Smith, in an interview in *Steelweek*, Sept. 24, 1979.

Table 119.—Economic Costs and Benefits of Adopting Continuous Casting (CC)[a]

Percent CC	Incr. in CC tonnage (thousands of tonnes)	Energy 10^{12} Btu	Incr. in yield	Incr. in steel shipped (thousands of tonnes)	Total steel shipments (thousands of tonnes)	New industry yield	CC[b] capital cost ($/tonne)	Total CC capital cost ($ mill.)	Deer cost/ incr. profit[c] ($/tonne)	Total annual benefit ($ mill.)	Return on Investment	Payback period (years)
25	13,424	44.1	0.10	1.342	90.169	0.73	$44	$ 592	$28	$185	0 3 1	3 ?
							44	592	55	222	038	2 7
							66	888	28	185	0.21	4 8
							66	888	55	222	0.25	4,0
			012	1,611	90,438	073	44	592	28	192	033	3.1
							44	592	55	237	0.40	2.5
							66	888	28	192	0.22	4 6
							66	888	55	237	0.27	3.8
							66	888	83	281	0,32	3.2
							88	1,184	83	281	024	4 2
50	44,496	147.2	0.10	4,450	93,277	0.75	44	1,962	28	613	031	3.2
							44	1,962	55	736	0.38	2 7
							66	2,944	28	613	021	4.8
							66	2,944	55	736	0.25	4.0
			012	5,340	94,167	076	44	1,962	28	638	0.33	3.1
								1,962	55	785	0.40	2 5
							66	2,944	28	638	0.22	4.6
								2,944	55	785	0,27	3.7
							66	2,944	83	932	0.32	3.2
							88	3,925	83	932	024	4.2

[a] Base case 1978 CC usage = 142 percent or 17,648,000 tonnes of 124,287,000 tonnes of raw steel production assumed to remain constant, total domestic shipments = 88,827,000 tonnes, yield = O 715, al I calculations done for replacement of ingot casting in Integrated (blast furnace. based) plants by CC

[b] Three levels of capital cost for CC have been used $44/tonne is somewhat greater than recent expenditures by National Steel for a major facility; $66/tonne has often been quoted and may be appropriate in those situations where ingot casting facilties to be replaced have not been fully deprecated or where more complex shapes are being cast, $88/tonne IS undoubtedly a high cost estimate but may be realistic for those cases where downstream finishing facilities must be added to take advantage of Increased capacity resulting from a greater yield

[c] Decreased cost/increased profit (for the increased steel shipped) resultin9 from the hot metal-purchased scrap differential and the normal operating profit

[d] Total annual benefit IS calculated on the basis of a $11/tonne combined sav. ings for the additional CC tonnage and the product of the Increase in steel tonnage shipped and the hot metal to scrap savings, the latter IS undoubtedly a crude but conservative estimate of the additional profit resulting from increased yield and capacity. there IS substantial company to company variation in both hot metal production cost and net income per tonne shipped

SOURCE Office of Technology Assessment

In view of the large amount of capacity lost to equipment obsolescence and industry contraction, and the steady increase in domestic steel consumption, an economical way to increase the capacity of existing plants offers considerable benefits, including the avoidance of increased dependence on imports. Past experience, such as in 1974, has shown that import dependence during a period of tight world supply of steel and sharply escalating prices for imports can be a significant inflationary factor in the domestic economy. National security could also be threatened, because it might be difficult to obtain required steel at any price.

Virtually all current analyses point to considerable shortfalls in capital for the domestic steel industry and a growing demand for steel in the years ahead. At the same time, the world supply of steel may be very tight by the mid- to late 1980's because of continued contraction of Western European steel industries, insufficient new capacity in Third World countries to meet their own rapidly increasing demand, and likely insufficient domestic capacity in Soviet bloc nations and the People's Republic of China.[33]

Production Costs, Profits, and Return on Investment.—Although capacity increases from higher yield are a direct benefit of continuous casting, increased yield may have a "hidden" cost that should also be considered: the need to purchase scrap to substitute for that not generated by the continuous casting process. The profit of the additional shipped tonnage is determined by the ratio of the cost of the liquid steel ("hot metal") to that of the purchased scrap; the lower the cost of purchased scrap relative to in-plant costs to produce the liquid steel, the greater the profit from the increase in yield and capacity. This ratio is difficult to determine, but from many discussions with steel industry personnel it has been determined that the cost of hot metal is typically in the range of $132 to $198/tonne; and although the price of scrap varies considerably over time, it has generally been somewhat less than $110/tonne.

Another factor to consider is the normal operating profit that would accrue to the additional steel shipments from the increase in yield; this operating profit is typically $28 to $55/tonne. Because of the wide variations in all cost and profit figures among companies and among plants of any one company, and because of a desire to make conservative estimates of returns on investments, three levels of profits are used —$28, $55, and $82/tonne —for additional steel shipments gained through the greater yield of continuous casting; two levels of yield increase are assumed—10 and 12 percent.

Before proceeding to the return-on-investment calculation, an additional profit factor must be considered: the reduction in production costs for all the steel continuously cast. The decrease in energy consumption is the primary source of these production cost savings: 10 years ago, energy was approximately 10 percent of steelmaking costs; today, it is more than 20 percent. About one-third of the energy saving from continuous casting for the domestic steel industry results from reduced purchases of electricity and fuels, such as natural gas and oil; the other two-thirds is from in-plant energy byproducts that can be put to other productive uses. Because the price of energy and its contribution to the costs of steelmaking appear destined to rise, the future cost-reduction importance of continuous casting will increase. Discussions with industry personnel indicate that the total reduction in production costs resulting from reduced energy use, improved labor productivity, and reduced environmental costs is at least $11/tonne cast for a typical plant. For many plants, it would be two to three times greater.

Conclusions.— The results of a complete set of calculations for the return on investment for substitution of continuous casting for ingot casting in existing integrated plants are given in table 119. Three levels of capital

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[33] See for example, CIA reports, "World Steel Market—Continued Trouble Ahead," May 1977; "China: The Steel Industry in the 1980's and 1990' s," May 1979; and "The Burgeoning LDC Steel Industry: More Problems for Major Steel Producers,'" July 1979.

costs for the casting equipment have been used: $44, $66, and $88 per annual tonne capacity. These have been chosen on the basis of limited published data and extensive discussions with industry experts. Even with what is believed to be relatively conservative assumptions, the economic rewards of such a substitution are substantial. More than a 20-percent return on investment is likely, although the precise return will be plant specific.

The calculations so far have assumed that raw steel production remains static at the 1978 level. A 2-percent annual increase in domestic shipments from 1978 to 1990 would require additional production of 23.9 million tonnes of steel. Significantly, the attainment of a 50-percent level of continuous casting (on the 1978 capacity base) could supply 5.4 million tonnes of this increase without the need for additional raw steel capacity, and that level of continuous casting would also substantially reduce the amount of additional new steelmaking capacity required to meet the remainder of the increased demand. Hence, total capital needs for the industry would be much lower than for simply adding new steelmaking capacity.

Most integrated domestic steel companies, however, have not used their limited amounts of discretionary capital to install continuous casting capacity. Instead, their investments have been for a variety of other purposes:

- to finance short-range capital projects with payback periods of 1 to 2 years, including technological improvements that minimize capital expenditures as well as implementation times;
- to replace old open hearth furnaces with either basic oxygen or electric steelmaking furnaces, which may give older plants a better return than continuous casting would;
- to make needed repairs or replace worn-out equipment and to comply with regulatory requirements; and
- to diversify out of steelmaking in order to improve profitability or to compensate for the cyclic nature of the steel business.

The industry also cites other reasons for not replacing more ingot casting with continuous casting:

- the difficulty of justifying replacement of operational ingot casting facilities that have not been fully depreciated;
- the costs and difficulties of substantially modifying an operating plant;
- additional capital requirements for downstream facilities to process increased semifinished steel production;
- technical problems with some types of steels and, in some cases, relatively small production runs;
- difficulties in expediting EPA permits and costs of other modifications of facilities EPA may demand before granting construction permits for continuous casting; and
- uncertainties about the degree of competition from imported steel.

Formcoking

Formcoking is a process that makes blast-furnace-grade coke, of uniform size and quality from low-cost, low-quality "noncoking" or steam coals. Formcoke has an advantage over coal-based direct reduction (see ch. 6) because the process generates valuable coke byproducts such as coke oven gas. Formcoke technology has several potential benefits:

- the ability to use less expensive and/or more available domestic feed coals;
- equipment that is less expensive and more flexible than conventional byproduct ovens;
- assurance of high-quality product that can substitute for conventional metallurgical coke;
- lower total production costs than with conventional methods; and
- reduction of pollution in the cokemaking process.

Many formcoking processes have been conceived in the last 40 years, but none of them has yet achieved full commercial operation. Table 120 lists some processes that appear promising in the near future on the basis of technical performance and commercialization status.

A number of steel companies throughout the world have supported the development of formcoke technology. The United States led in the early development, but most of the ongoing development is occurring abroad, particularly in countries that provide significant government support of their domestic steel industries: England, West Germany, the U. S. S. R., and Japan. Eight of the ten leading formcoking processes and a score of less advanced concepts have been developed outside the United States. Only the FMC Corp. has operated a significant commercial plant producing a formcoke that has been successfully tested in blast furnaces.

U.S. companies have spent considerable sums on formcoke development because of inadequate coking capacity. The FMC process will be evaluated on a demonstration-plant level by Inland Steel with assistance from the Department of Energy (DOE). Also supported by DOE, U.S. Steel has been developing a laboratory-scale “clean coke process” with the intention of producing a number of other chemical products, together with coke, from noncoking coals.

At this stage in its development, the most important factors limiting the adoption of formcoke are technical in nature and are concerned with energy use and coke quality. A recent EPA report noted that:

> Although a new process called “formed coke” has been developed that may meet environmental and OSHA standards, this process is not a panacea because of its high energy input and some uncertainties concerning its performance in large-scale blast furnaces.[34]

However, it appears that the FMC process may meet environmental standards.

Interruptions in coke supply have a significant impact on blast furnace performance, so operating companies are rightly concerned about the reliability of this undemonstrated technology. Another important factor is the probably lower quality and quantity of byproducts produced by formcoking processes compared with those produced by conventional byproduct ovens. * In the present period of diminishing energy resources and rising aromatic chemical values, this possibility

Table 120.—Ten Most Promising Formcoke Processes

Process	Developer	Country
FMC formcoke	FMC Corm.	United States
BFL	Bergbau-Forschung and Lurgi Mineralotechnik	West Germany
Consol-BNR process.	Consolidated Coal Co. with Bethlehem Steel, National Steel, Republic Steel, Armco Steel, and C. Itoh and Co.	United States
Sapozhnikov process	The Ukranian Coking Institute	U.S.S.R.
ANCIT process.	Eschweiler-Bergwerks-Verein	West Germany
Sumitomo process.	Sumitomo Metal Industries	Japan
HBN process	Les Houilleres du Bassin du Nord et du Pas-d-Calais	France
ICEM process.	ICEM (Romania)	Romania
Anscoke process ., ...	Broken Hill Proprietary Co., Ltd.	Australia
APCM process	Associated Portland Cement Manufacturers and Simon-Carves, Ltd.	United Kingdom

SOURCE A D Little for Off Ice of Technology Assessment

“Environmental Protection Agency, Analysis of Economic *Af-fects of* Environmental Regulations on the Integrated *Iron* and *Steel* Industry, vol. I, 1977, pp. 228-29.

*The FMC Formcoke process can yield a byproduct gas with an energy content of only 200 to 250 Btu-scf, compared to the 400 to 500 Btu-scf gas produced by a byproduct coke battery.

may be a major impediment to adoption of formcoke technology by integated steelmaker. Uncertain capital costs for formcoking processes make comparisons to conventional byproduct ovens difficult. The experiences of the British Steel Co. and Ruhrkohle in West Germany have demonstrated the high cost of trying to develop this new technology. Because of the limited experience in constructing and operating formcoke plants, their costs are not well known and investments in such technology pose a very real technical and economic risk.

In addition to these technical concerns, the abundance of domestic coking coals has given some domestic steelmaker little reason to be interested in developing formcoking processes. U.S. steel companies have far less economic incentive to develop formcoking processes than do steel companies in countries that do not have adequate domestic reserves of coking coal. A recent OTA survey of steel industry technical personnel asked respondents to predict the domestic use of several technological changes in coke manufacture for the years 1990 to 2005. The major changes were improved coke oven design, coal preheating and hot charging, and formcoke. The respondents indicated that the fraction of coke made with these technologies in 1990 would be 41, 32, and 10 percent, respectively. There is some indication that formcoke may not develop quickly, but that modifications of existing technology will affect the industry substantially within the next decade.[15]

Steel Mill Waste Recycling

In an average good steel production year, approximately 11.8 million tonnes of high-iron wastes are generated annually. These wastes are found in flue dusts, mill scale, and various in-plant particulate. Historically, most of these wastes have been recycled within the steel mills, particularly in sinter plants. Many of these operations are being curtailed, however, because of environmental considerations related to volatile organic compounds and particulate matter emissions.

Japan is probably the only country in the world where there is a strong emphasis on recycling those in-plant fines; it has been estimated that the Japanese recycle more than 70 percent of their residues. Environmental regulations force Japanese steelmaker to reuse their high-iron dusts. To comply with the regulations, a Japanese steelmaker may use the resources of sister companies or form a joint venture to devise as economical a processing sequence as possible. The solution that evolves is a combination of careful housekeeping with the adaptation of process equipment borrowed from other technologies. The know-how acquired is for sale or license, should other steelmaker be interested in it.

Only in-depth studies can determine whether any of the commercial fines-recycling processes is profitable on its own or is the least expensive way to comply with local environmental regulations. Table 121 summarizes the dust-treatment processes that are presently available in the United States. There are three categories of recycling processes:

High-temperature reduction (dezincing processes). —If inplant fines are brought to about 6000 C under oxidizing conditions, followed by a reducing action at around 1,000° to 1,1000 C, lead volatilizes as PbO in the first stage and zinc volatilizes as metallic vapor in

Table 121. —High-iron Waste-Recycling Processes Commercially Available in the United States

Commercially operated *processes* (all in Japan)
- Kawasaki (1968)
- Sumitomo (1975)
- Ryoho Recycle (Mitsubishi and Toho Zinc Aen) (1975)
- Sotetsu Metals (Waelz process, Germany 1925) (1974)
- Lurgi (SL/RN) (1974, Nippon Kokan)

Other potentially **competing *processes***
- Imperial smelting (United Kingdom)

Agglomeration *processes* at low *or* moderate temperatures
- Berwind —Reclasource (United States)
- Grangcold—A. B. Granges (Sweden)
- Aglomet —Republic Steel (United States)
- MTU— Pelietech (United States)

SOURCE A D Little for Office of Technology Assessment

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[15] OTA, Survey of Technical Personnel, 1979.

the second stage. An hour or two at the higher temperature is usually sufficient to volatilize 95 percent of the zinc present. The vaporized zinc and lead can be recovered as contaminated oxides or, by more sophisticated processing, can be recovered as metals. The iron fraction is prereduced to some degree, but it may or may not be recovered for subsequent reuse in steelmaking.

Agglomeration at low *or* moderate temperature (nondezincing).—These processes do not change the chemical characteristics of the recycled materials. A binder, such as cement clinker, calcium carbonate, or polymerized asphalt, is used to provide the physical strength needed during handling and furnace operations. These processes are comparatively cheap, and they produce briquets or pellets containing all the carbon collected in the various fines. The blast furnace is the normal outlet for such products.

Hydrometallurgy. —A number of patents have been granted on wet-mill-waste-recycling processes. Assignees include private domestic interests, the U.S. Government, and foreign interests, A great variety of schemes have been proposed; there is no commercial application of any significance today.

Domestic acceptance of steel mill waste recycling will be predicated on mandatory regulations set forth by EPA and State and local regulators. With its capital so limited, the steel industry is reluctant to invest in these types of processing technology and would prefer that third parties own and operate recycling facilities. Pelletech, Inc., is actively pursuing this approach, as Reclasource and Aglomet did in the past. The foreign process developers are not interested in third-party arrangements.

By far the most important group of companies who may seek to diversify into this business are the slag processors, who presently work along with the steel industry. Most steel plants, with the exception of a few owned by U.S. Steel Corp. and Bethlehem Steel Corp., use a slag processor. Slag processors are secretive about their business because their supplies of raw materials are limited to whatever the steel mills give them and the demand for and prices of their products are limited by the realities of the natural aggregate marketplace in which the crushed slag competes. Some of the scrap processors have the financial resources to process steel dust as well as scrap. Most of the companies are very protective of their positions with the steel industry, and for defensive reasons they may want to tie up steelmaking dusts for future processing, by either themselves or others.

One-Side Galvanized Steel

The most important manufacturing processes for producing one-side galvanized were developed in the late 1960's. Significant quantities of this product have been on the market only during the last 5 years, and the future of one-side galvanized as a major steel product is still far from established. With the exception of one Japanese steel company, all one-side galvanized steel is produced by domestic steelmaker.

One-side galvanized steel differs from other technological innovations examined in these case studies in that it is a product rather than a process. In contrast to the adoption of new process technologies, which are controlled by the producer or a third party, adoption of a new product is determined in the United States by the consumer. Although a producer may offer a new product, it is the potential purchasers who make the decisions that determine the extent of its acceptance in the marketplace. In this case, market concerns about the large quantities of salt used on pavement in this country led to Detroit's interest in a corrosion-resistant, paintable steel. The call went out from domestic car manufacturers to steel producers during the late 1960's for a steel product coated, preferably with zinc, on one side only, and with the following performance characteristics:

- resist rusting on automobile surfaces that are normally exposed to corroding elements, that is, the bottom of the car;
- accept a highly glossed paint coat, free of spangles and other imperfections nor-

really associated with galvanized steel; and
- provide a zinc-free surface so that spot welders can make strong welds and diminish tip fouling.

The steel industry responded quickly to the call for help from Detroit. Existing one-side galvanizing processes were not considered economically feasible for producing the massive tonnages Detroit requires, * and the R&D sections of the major steel firms began a search for new processes. Each major steel producer developed its own innovative and patentable approach to producing one-side galvanized.

The processes can be grouped into four general categories: hot dip, differential hot dip, electrolytic, and a combination of hot dip and electrolytic. According to the most recent estimates, the U.S. steel industry in 1978 produced 181,400 tonnes of one-side galvanized by hot dipping and 317,450 tonnes by electrolytic processes (including hot dip / electrolytic combinations). These quantities were produced by six independent steel companies. A list of these companies, including the only foreign producer of one-side galvanized, is given in table 122.

Steelmaking companies that have successfully adopted one-side galvanized technology share a number of characteristics. These include the following:

- All manufacturers of one-side galvanized are integrated steel producers who produce diversified lines of steel products. One-side galvanized represents but one of their many products.
- They are mature companies. The producers of one-side include some of the oldest steel companies in America. The only foreign producer of one-side, Nippon Steel, is the oldest steelmaking firm in Japan.
- They possess organized R&D programs. Without these programs, the innovative processes for producing one-side could not have been developed as rapidly as they were.
- They possess the capital needed to invest in a new product like one-side without jeopardizing their survival should the market for one-side galvanized disappear.
- They all had close connections with the automotive industry prior to the development of one-side galvanized. The plants in which one-side is produced are located in close proximity to automobile manufacturers.
- They were all producers of galvanized products prior to the development of one-side and had expertise in zinc-coating applications.

The willingness of company management to take a risk on an unestablished product appears to have been the most important characteristic behind the adoption of one-side technology. Even today, the producers of one-side cannot be certain that in 10 years Detroit will accept one-side galvanized as a manufacturing material. In fact, it would appear that the domestic automobile industry is beginning to favor two-side galvanized over one-side because of the increased corrosion protection two-side offers. Interestingly, each of the producers of one-side galvanized also markets Zincrometal, a major competitor of one-side, to minimize the risks associated with Detroit's uncertain attitude towards one-side.

Table 122.-Producers of One-Side Galvanized Steel

Company	Plant location	Process
U.S. producers		
Armco Corp.	Middletown, Ohio	Hot dip
Inland Steel Co.	East Chicago, Ind.	Differential hot dip
National Steel Corp.	Portage, Ind.	Hot dip/electrolytic
Republic Steel Corp.	Cleveland, Ohio	Hot dip
Sharon Steel Corp.	Sharon, Pa.	Electrolytic
U.S. Steel Corp.	Gary, Ind.	Electrolytic
Foreign producers		
Nippon Steel Corp.	Japan	Differential hot dip

SOURCE A D Little for Office of Technology Assessment

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*One steel producer, Sharon Steel Corp., had been manufacturing one-side galvanized for a number of years for sale to the automotive industry on a limited basis. Another steelmaker, U.S. Steel, had developed and pilot tested a one-side process in the late 1950's.

Unlike process technologies, insufficient capital has not been important in determining which companies adopted one-side galvanized steel as a new product. Two categories of steel companies have not adopted one-side technology: companies like Bethlehem Steel, which backed competing products; and companies like the European steelmaker, which do not feel that the product is worth manufacturing until Detroit firmly decides on the type of steel product it needs.

An enormous disparity exists between the rates at which domestic and foreign steel producers have adopted one-side galvanized technology. Until 2 years ago, only U.S. steel companies offered a one-side product. The reason for this disparity can be traced directly to the U.S. automotive industry, which is the only automotive industry in the world that demands large tonnages of galvanized steel. Foreign steelmaker are only partially dependent on U.S. automakers as customers, and they can afford to wait until Detroit settles its mind before committing capital to new product ventures. Domestic steelmaker, much more vulnerable to the current fancies of the domestic automotive market, could not afford the possibility of losing their biggest customer.

With regard to imported cars, only Japanese carmakers rely chiefly on zinc-plated steel sheets to meet corrosion-resistance requirements, and then only on cars exported to Canada and the United States. This explains why the only producer of one-side galvanized outside of the United States is a Japanese steelmaker. Nippon Steel first began shipping the new product to major automotive manufacturers in Japan and the United States about 1976, and began full-scale marketing of one-side galvanized steel sheets for automobile use in 1978. Although exact production figures are not available, it is safe to say that Nippon's production of one-side galvanized is far less than the combined production of U.S. manufacturers.

Nippon Steel uses a hot dipping method to produce one-side. While passing through a molten zinc bath, one side of the basemetal steel sheet is galvanized thinner than the other side. After galvanizing, the thinner coating is mechanically brushed off in a continuous process in order to completely remove the zinc film and produce a bare steel surface with adequate roughness. The well-controlled roughness of the uncoated side ensures excellent paint finish characteristics.

Conclusions From Case Studies

The slow pace of most domestic adoption of process innovations is primarily a result of the industry's financial problems and limited growth. Both factors have slowed down BOF construction during the past two decades. The relatively slow adoption of continuous casting by the domestic steel industry can be attributed indirectly to the impact of poor financial performance and directly to poor steel industry growth. Construction of continuous casting facilities is best undertaken in a new steel production facility; retrofitting existing facilities with continuous casting is more difficult and more expensive.

The rapid domestic diffusion of AOD technology is attributable to the fact that this technology is used principally by the alloy/specialty steel segment. This segment has had significantly better earnings and far better financial status than the integrated segment. Significant production cost reductions brought about by the AOD process, combined with a rapid increase in the demand for alloy/specialty steels, also contributed to the high adoption rate for this technology. The rapid adoption of one-side galvanized steel was also unique in several ways. Domestic steel industry R&D and innovation have always emphasized product development, which requires far less capital than process innovations. Furthermore, there was a close collaboration between steel producers and the domestic automotive industry, the consumer that represents the single largest market for domestic steel producers.

In addition to limited capital availability, the relatively old age of steel production facilities in the United States compared to those of its principal international competitors has contributed to the slow adoption of process innovations. Obsolete facilities pose technological as well as financial problems for the introduction of innovative technologies within existing plants—the many sequential steps of steelmaking create problems of coordinating old and new facilities. The age of domestic mills thus accounts for lags in introducing continuous casters and is also cited as one of the principal reasons why mill-waste-recycling technology has made relatively modest gains in the United States as compared to Japan.

Another important factor is that many of domestic steel producers are unwilling to adopt innovative technologies unless they have already had large-scale commercial success. Furthermore, domestic steel mills continue to depend on established methods of raw material supply. For instance, the historical availability of excellent coking coal has limited interest in formcoke development, and historically ample scrap supplies have led to only marginal interest in waste recycling. Finally, service industries play a powerful role in creating and developing new technology and providing it to steel companies. It appears that this dependency is unique to U.S. steelmaker; many foreign steel companies do their own design, engineering, construction, and equipment work.

Technology Transfer

There is very little steel technology transfer from domestic steel firms to other countries, and the technologies that are transferred are mostly related to raw material handling rather than steel production. To the extent that domestic steel production technologies are transferred abroad, it is done by domestic equipment manufacturing and engineering firms. Conversely, Japanese, and to a lesser extent West German, steel companies develop and transfer significant amounts of steel production technologies, equipment, and facilities to other countries, including the United States.

From the United States

Earlier in this century, domestic steel companies had a strong role in the transfer of major U.S. steel production technologies to other steel-producing nations. However, the direction of this technology transfer has been reversed since the end of World War II.

Most of the melting, refining, and ingot casting technology presently used by U.S. steel companies had its origin in foreign countries. The only major U.S. process technology that has been quickly adopted by all domestic and foreign steel industries is the AOD process, and this domestic technology was transferred abroad, not by a domestic steel producer, but by a manufacturer of equipment. A large part of domestic steel technology transfer to other countries similarly takes place via domestic equipment manufacturers and engineering firms. In Japan and Europe, it appears that steel firms that create new technologies for their own use are the principal channels for subsequent technology transfer. Tables 123 and 124 summarize the channels of technology transfer to and from the United States as perceived by U.S. steelmaker.

There is some technology transfer from the United States to foreign nations by domestic

Table 123.—Channels of Steel Technology Transfer Between the United States and Japan

Type of channel	Percentage use
Cross-licensing/licensing	20
Engineering/design firms	15
Steel producers	40
Retro engineering	5
Suppliers of manufacturing equipment	10
Technical papers	5
All others	5

[a] Refers to indirect access to foreign technology; no direct purchase available Information is used to duplicate technology

SOURCE Survey of U S steel executives by Sterling Hobe Corp for OTA.

Table 124.—Channels of Steel Technology Transfer Between the United States and Other Nations Except Japan

Type of channel	Percentage use
Cross-licensing/licensing .,	30
Engineering/design firms	30
Steel producer	5
Retro engineering	5
Suppliers of manufacturing equipment	15
Technical papers	2
All others	13

SOURCE Survey of U S steel executives by Sterling Hobe Corp for OTA.

steel mills. However, available data suggest that such transfer is not substantial. Recently, two major domestic firms, U.S. Steel and Bethlehem, have been holding discussions about the export of U.S. steel technology to China, but no sales had been concluded as of 1979.

A major investment for scaling-up an innovative process is often required before its potential applicability and profitability can be fully demonstrated and foreign sales made. This is a large obstacle in the U.S. steel industry, with its low rates of new plant construction and lack of capital for demonstration plants. Government capital assistance may be the only way by which process development can be sustained by the industry.

Experience with the electroslag remelting (ESR) process illustrates the economic constraints that tend to limit domestic technology innovation and transfer. The ESR process was invented in the United States during the 1930's and 1940's and became commercially successful around 1966. This process gained little domestic recognition until a U.S. Air Force agency investigated the special claims a Soviet research laboratory made for ESR. The Air Force awarded a 4-year ESR manufacturing technology development contract for less than $500,000 to Carnegie-Mellon Institute during the early 1960's. The attention that was focused on the ESR process and the prompt dissemination of pertinent information to various segments of the industry resulted in an explosive growth in use of the ESR process. U.S. capacity for ESR steels climbed from 5,442 tonne/yr to more than 163,260 tonnes—close to Soviet capacity levels—between 1965 and 1977. *

Interestingly, neither the original inventor nor the company supporting the work received any benefits from ESR process growth in the United States, because the rights to this technology had been sold prior to its initial commercialization in 1965, The technology is presently owned by the Pullman-Swindell Corp.—an engineering, consulting, and manufacturing conglomerate. Pullman is now in the process of acquiring certain Soviet ESR process rights and licenses for marketing in the United States. Thus, a U.S. investor company will be marketing in the United States the Soviet refinements of a technology originally invented and developed here. However, eventual success of the Soviet ESR technology is far from certain. Thus far, the Soviets have had only modest success in transferring this technology on a worldwide basis, mainly because of their inability to provide proof of the economic viability of the technology.

The domestic steel industry has strongly protested the loans the U.S. Export-Import Bank (Eximbank) provides to foreign competitors to buy domestic steelmaking technology. Many U.S. steelmaker are concerned about the Bank's willingness to finance steel expansion abroad, arguing that low-interest rates are permitting unreasonable investment in unneeded steel capacity, which results in unfairly traded steel exports to the United States. In response to such concerns, the Bank has noted that such loans are needed because they generate U.S. exports and domestic jobs—especially for firms selling technology. According to John L. Moore, president and chairman of Eximbank:

> The net positive economic impact in just the steel products area is over 4,000 man-years of U.S. labor. These employment figures become even more positive when the favorable impact from the related exports of U.S. coal and spare parts are added.[36]

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*In 1965. domestic ESR steelmaking capacity was limited to 5,442 tonnes of annual production, all of which was used by one company in the Pittsburgh area, compared to 181,400 tonnes of annual ESR capacity in the Soviet Union.

“American Banker, Oct. 22, 1979, p. 2.

Domestic equipment makers have had opposite concerns about Eximbank loans for the construction of steel plants abroad. These companies have asserted that inadequate export financing causes domestic firms to lose sales of technology abroad. The Bank's position has been that lack of price competitiveness, rather than inadequate export financing, has been the principal factor responsible for limiting technology exports. Along these lines, Bank representatives have noted that:

> We found that most of the cases lost were awarded to foreign firms because the American exporter was not competitive in the price offered. In 51 of our recent "lost offers," the U.S. product was priced out of the running. In fewer than 10 percent of the cases did inadequate financing appear to be the reason for losing the bid—and most of those were lost against "foreign aid type" financing.

A distinct handicap for U.S. exporters of technology is the inability of the Bank to finance loans to certain nations undergoing substantial steel industry expansion, including the People's Republic of China and the Soviet Union. Eximbank representatives commented on the resulting decline in U.S. competitiveness in technology exports:

> U.S. firms, however, are constrained from competing in certain key countries of the world, mainly the People's Republic of China and the U. S. S. R., because competitive financing by Eximbank is not yet available to those countries. As a result, the Japanese and the Germans, particularly, have taken advantage of early entries into those countries and have concluded contracts of major proportions to provide technology and equipment, financed by low-interest rate loans . . . Except for the sale of technology to the Russians by one of the three U.S. producers having expertise in making that particular type of steel, the United States has evidently lost out on all the potential equipment and engineering sales . . . [and also on] the longer term benefit of actual experience of building the most modern silicon steel plant anywhere.[38]

By Foreign Industries

Unlike the United States, most foreign steel-producing nations, even those with small steel industries such as India or Austria, practice aggressive transfer of their steel technologies. The undisputed leader is Japan.

Japan

Most major Japanese steel companies are engaged in steel technology transfer as well as some design and construction. These companies have well-established ties with West German, British, Austrian, Swedish, and U.S. companies engaged in technology transfer projects through licensing, equipment manufacturing, and joint project efforts. The Japanese steel industry, working in partnership with the Japanese Government, has sold its steel technology on a global basis more successfully than any other country. *

The Japanese, who move technologists to other countries to put their projects in place, are motivated by the need for technology exports to compensate for the loss of steel export markets. They are also aware of the need for access to raw materials. The sacrifices made by individuals engaged in such ventures are well rewarded by the companies they serve and by society in general. Time spent overseas on technology transfer projects is viewed as a service to the country, and the Japanese are proud of their contributions to world technology and to the welfare of their own country.

Commenting on international steel trade, the general manager of Kawasaki Steel's international department has noted that "We realize that we cannot continue to export large amounts of crude steel. Therefore, the industry is putting emphasis on exports of technology, to countries like China, Brazil, and those in Southeast Asia."[39] The assimila-

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[37] Ibid.

[38] "Testimony of D. E. Stingel, Director, U.S. Export-Import Bank, before Senate Subcommittee on International Finance, Nov. 19, 1979.

*The success of this Japanese strategy is shown by the fact that in 1975 their steel industry's technology exports were almost twice as great as imports [a positive balance of 5,800 million yen a year or $24 million at 240: 1). This probably has improved greatly in recent years,

[39] T. Dahlby, "Japan Seeks a Long-Term Strategy for Prosperity," Far Eastern Economic Review, Aug. 25, 1978, p. 45.

tion of designs and technical know-how from different sources has enabled Japanese companies like Nippon Kokan, IHI, Hitachi, Daido Steel, and Mitsubishi to provide the most modern plants to developing countries. The LDCs, in turn, promote the construction of steelworks using the electric furnace process or integrated steelworks employing the BF-BOF process or DR-EAF process, with their technological choices dependent largely on prevailing domestic conditions, such as size of steel demand and existence of natural resources.

There appears to be little concern that Japan is cutting its own throat by selling technology that will strengthen developing countries' production capacities:

> Steelmaker are selling basic technology while improving their own technology for the production of more sophisticated items such as large-diameter steel pipe and higher quality crude steel.

Even so, how long can the Japanese maintain their technological lead? The Kawasaki executive replies that:

> There are no major technological breakthroughs on the horizon for the next 10 to 15 years. Now we are only involved in a fairly sophisticated rounding out process by raising the productivity per worker, but there is a limit.[40]

The search for raw materials and energy has also stimulated Japanese steel companies, in partnership with their government and other companies, to launch an aggressive compensation-trade program based on barter with developing countries. A number of such projects are presently underway in the Middle East, Brazil, Indonesia, and several other developing countries (table 125), and Japan is aggressively pursuing the exchange of steel technology for Mexican oil. In the Japanese steel industry, the guiding philosophy is to beef up divisions handling design and to win contracts in developing countries by offering package deals, including technology licensing, feasibility studies, construction, and engineering advice. By selling the experience gained in building their own highly efficient industry, Japan's major steelmaker are hoping to make up for the export markets they have lost through increased competition and the relatively slow growth of demand in industrialized nations.

Table 125.—Major Japanese Steel Technology Transfer Projects Involving Barter Trade

Abu Dhabi—A Government-Kawasaki Steel ioint venture steel plant; $4 billion.

Qatar— Kobe Steel 20°10, Tokyo Boeki 10°/0, balance local for Midrex DR and mini steel plant; $980 million.

Nigeria— Kyoei Saiko and Nissho-lwai, joint venture DR and ministeel plant; reportedly $440 million.

Saudi-Arabia-Petromar DR plant; ownership: Italy, Marcona 40%, Estel 25%, Japan (Nippon Steel) 25%, United States (Gilmore Steel) 1O°/o; investment, unofficial, $950 million. Project reorganized recently to include Korf Group.

Sudan— Kyoei Seiko joint venture mini steel plant; $250 million.

Tunisia—C. Itoh (Japan), Korf Industries (West German), and Government of Tunisia; Midrex DR plant; investment figures unavailable.

Morocco—Kawasaki Steel 12.5%, Konematsu Goshu 12.5%, balance local; ministeel plant; $200 million.

Iran— DR plant at Bandar Abbas; Japanese participation: C. Itoh, Marubeni, Mitsubishi, Kawasaki Steel. A compensation-trade venture for over $800 million.

Indonesia —Ministeel plant; financial investment by C. Itoh 74%, technology by Kowasaki steel 6%, balance by private Indonesian capital. A compensation-trade venture for approximately $300 million.

Greece—Hellenic Steel; C. Itoh and Co. (Japan) 25°/0 and Estel (Netherlands) 20%; investment unavailable.

Brazil-Siderurgica Brasileira; Nippon Steel 490/.; Japanese investment over $1.8 billion —Usiminas; Nippon Steel 19%; investment unavailable.

SOURCE: Office of Technology Assessment

Nippon Steel serves as a good example of Japan's commitment to steel technology export.[41] About 10 percent of its sales are technology sales, and the company has promoted the development of steel production in LDCs in particular. It recognizes LDC interest in

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[40] Ibid.

[41] U.S. Steel Corp. has recently signed a 3-year contract with Nippon Steel for technical aid. "The contract with Nippon is U.S. Steel's third, and by far the most extensive, call for help from abroad, Although most other domestic steelmaker have been getting help from foreign steel companies for years, Wall Street analysts and industry insiders have long suspected U.S. Steel of harboring a corporate arrogance that led it to ignore foreign technological developments. But the extent of the new contract with Nippon confirms that U.S. Steel is prepared to scour the world for the best steelmaking technology available. " (*Wall Street Journal*, Feb. 14, 1980.)

such matters as the use of domestic resources, the role of a strong steel industry in accelerating the growth of steel-consuming industries, and foreign currency savings. As of early 1979, Nippon Steel's overseas engineering activities had extended to 37 nations, 85 firms, and 285 projects.[42]

Kobe Steel has also accelerated its technology sales efforts. It has improved the quality of its overseas activities, stepped up information exchange, and expanded the scope of its activities from mere product sales to investment, procurement, plant construction, and management and operation guidance. The company employs qualified personnel and gives them language training in special schools or sends them to schools in foreign countries. Moreover, it exchanges personnel with foreign companies and accepts foreign trainees,[43] Kawasaki Steel Corp. 's technology exports in 1978 contributed only 5 percent of the company's business, but it expects to increase them to 10 percent within 5 years.[44]

Japanese steel firms are also increasing their technology trade with China, whose modernization plans offer an obvious market for Japanese exports. Under a long-term trade pact signed early this year by Tokyo and Peking, Japan will export roughly $10 billion worth of plants and construction machinery to China during the next 10 years. The biggest single export project involved is a $3 billion deal for Nippon Steel to build a 5.4-million-tonne/yr steel mill in Shanghai, due for completion in 1980.[45]

West Germany

German steel technology has penetrated both the industrialized and developing countries. Important coke-producing, ironmaking, steelmaking, and metals-working technologies have originated in West Germany and spread to different parts of the world. West German technology transfer methods are as varied as the countries served. Technology sales have traditionally been pursued by West German industry and government in a highly competitive manner, using technologies developed through the active participation of the West German academic and research communities.

The West German Government offers substantial incentives in the form of loan guarantees of up to 90 percent for the export of steel technology and equipment to developing countries. Intergovernmental agreements are actively sought and implemented on a compensation-trade basis. Such barter agreements usually last from 5 to 10 years and have provided for the establishment of entire steel plant complexes in India, Brazil, Iran, Argentina, Venezuela, and Mexico. West German credits extended in India during the past 12 years have exceeded $1.32 billion, to Iran $0.8 billion, to Brazil $1.63 billion.

West German steel plants and equipment construction companies have comprehensive agreements for technical cooperation with Japanese companies engaged in similar ventures. Often such cooperation overlaps with technology agreements with U.S. and British builders of steel-melting and metal-working equipment.

Several West German companies are currently engaged in the export of steel technology. Europe's largest steel group, Thyssen, has a joint venture with Armco Steel in West Germany, and it owns the Thyssen Purofer direct reduction (DR) process, through which it has interests in DR plants in Iran and Venezuela. The Thyssen Group also controls the Dortmund-Horder degassing process, which is used in U.S. and Japanese steel industries.

The United States has received a number of steel-related technologies from West Germany. West German technology entered the United States during the 1960's mostly in the form of licenses, know-how, and personnel exchange. During the 1970's, successful West German corporations established joint ventures, limited partnerships, and even operating companies in the United States for

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[42] *Nippon Steel* News, January 1978,

[43] *Kobe Steel* Report, January 1979.

[44] "Kawasaki Steel: Using Technology as a Tool to Bolster Export, " Business Week, Jan. 29, 1979, pp. 119-20.

[45] *Steel* Week, Oct. 23, 1978.

timely transfer of steel technologies. The West German company of Laybold-Heraeus opened manufacturing, sales, and service subsidiaries in the United States during the 1960's; it has aggressively pursued the application of vacuum technology to solve a host of steelmaking problems, as well as steel treating and steel protection. In cokemaking and allied coal technology, Koppers Co. in the United States has good access to West German technology through cross-licensing agreements with Lurgi.

Another entrepreneurial West German steel company spreading its technology to the United States is the Korf Industries Group. This firm formed the Midrex Corp. in the United States, and has successfully promoted the Midrex DR process, developed originally by an American company. The Korf Group has successfully promoted minimills in the Untied States based on the use of scrap and DRI. Korf also has projects in Iran, Trinidad, Tunisia, and the U.S.S.R. for the installation of Midrex DR plants with capacities ranging from 227,000 to over 590,000 tonne/yr.

Demag is the leading German builder of complete metallurgical plants and equipment, and it enjoys a worldwide reputation. It has excellent working relationships with U.S. companies, such as Mesta, Wean United, and Blaw-Know, and the technology transferred by Demag is reliable and up-to-date. Demag also cross-licenses and shares its engineering know-how with American builders of rolling mills, forging presses, and other steel plant equipment. International cross-licensing and technology-exchange practices prevailing in metallurgical equipment building make it very difficult to assess the actual monetary values of such technology transfers.

Austria

Austria sits between the East and West in Europe, and receives steel-processing technology from both sides. It often serves as a "window" for Western industries to observe and assess steel technology developments in Eastern European countries, including the U.S.S.R.

The Austrian steel industry originated the BOF steelmaking process and made it available to several of the world's steel industries. This technology was the forerunner of the present-day basic oxygen steelmaking process and of recent variations such as the Q-BOF.

Austria received technology transfer revenues from the United States of about $26 million during 1978. In turn, Austria has received less than $1 million worth of steel-related technology from the United States.

The major Austrian steel technology exporter is Voest-Alpine. This government-owned steel conglomerate is well-known worldwide for its plant design, engineering, and construction expertise. Voest-Alpine has established joint ventures with other European partners in the United States (the Louisiana-Bayou Steel Corp.), Turkey, India, Brazil, Argentina, Colombia, and Iran. Other Voest companies have many technology licensing arrangements with the U. S. S. R., Czechoslovakia, Hungary, South Africa, India, and the United States. Dravo Corp. of Pittsburgh is the principal holder of Voest licenses for steel process technology in the United States. The technology portfolio of Voest-Alpine claims to have more than 1,500 patents related to steel technology.

United Kingdom

There are no barriers to technology transfer between the United States and the United Kingdom. Steel company interests on both sides are engaged in acquisitions and joint ventures for technology transfer and market shares for products. Until about 5 years ago, British engineers and technologists, with advanced technical and industrial skills, had complete freedom to find employment in the United States, so advanced steel technology transfer to the United States occurred largely through the mass movement of highly qualified and experienced engineers. Except through this source, the United States has not received any major steel technology from the United Kingdom during the last two decades.

Many large British companies are engaged in integrated steel technology transfer. Davy Ashmore has recently completed steel technology transfer projects in the United States, Mexico, and Sweden. The company recently acquired complete control of Arthur G. McKee Co. of Cleveland, a well-established design, engineering, consulting, and construction company. This acquisition seems to have strengthened both the technology base of Davy Ashmore and the financial base of Arthur McKee.

Guest, Keen and Nettleford (GKN) has recently increased its engineering and technology transfer activities. The company is well established, with steel technology transfer projects in West Germany and in Australia through its interest in John Lysaght, an integrated steel producer. At present, GKN and John Lysaght are under the umbrella of Australia's biggest company, the Broken Hill Proprietary Co. (BHP). BHP also owns Peabody Coal Co. in the United States, and this ownership includes West German and Japanese interests under the name of Theiss Campier Mitsui Coal Pty Ltd. This arrangement provides all parties involved with good access to the latest British, West German, U. S., and Japanese technologies related to coke, iron, steel, and transportation,

India

Moving away from an emphasis on domestic self-sufficiency, India has emerged during the past 5 years as an exporter of steel, By the end of this century, India plans to export annually 9.1 million to 13.6 million tonnes,

The steel industry in India has made considerable progress in technology and is now self-reliant, Countries in the Middle East, Africa, and Southeast Asia are looking to India for major technical support for the development of metallurgical industries. The Steel Authority of India has established one of the largest consultancy and engineering organizations in Southeast Asia, with more than 1,700 trained engineers and specialists in various disciplines. This agency, named Metallurgical and Engineering Consultants (India) Ltd. (MECON), is rendering services at home and abroad in the development of integrated steel mills, alloy / specialty steel plants, raw materials preparation and agglomeration, sponge iron and DR plants, and other chemical and metallurgical plants. MECON has know-how licensing agreements in the United States, the United Kingdom, West Germany, Czechoslovakia, Sweden, East Germany, and Japan. *

Another Indian consulting organization, M. N. Dastur and Co., has gained a considerable international reputation for its expertise in preparing feasibility and project reports. This company is advising governments and private industries in Venezuela, Brazil, Colombia, Libya, Iran, Saudi Arabia, Nigeria, Yugoslavia, and the developing countries of Southeast Asia. MECON and the Dastur Co. jointly plan and implement metallurgical and chemical industrial plant development with technology that is purchased from overseas services, then "repackaged" and marketed to developing countries. Both organizations compete with similar organizations from industrialized countries for projects in any part of the world.

India has reportedly received steel technology transfer income in excess of $6 million since **1975.** Raw technology purchases by India from the United States during the last 5 years reportedly amounted to $14.5 million for 69 agreements. West Germany has 413 collaboration agreements with India in the steel technology sector, 114 of which are joint ventures, with the West German industries holding more than 40 percent equity interest. All these projects have been initiated since 1971.

Summary Comparisons

Technology transfer plays a critical role in determining the technological competitiveness among steel industries. Moreover, as

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*Personal discussions of OTA contractor Dr. K. Bhat with Mr. R. Dave, Manager, Bombay Office of M. N. Dastur and Co., Ltd.

steel export markets are lost to expanding indigenous industries, technology sales determine to an increasing degree the economic success of these industries. Nevertheless, there is a dearth of detailed information on steel technology transfer. Summary descriptions of steel technology transfer in the United States, Japan, West Germany, Austria, the United Kingdom, and India are given in table 126. Generally, the nations that are most successful in steel technology transfer have supportive government policies and steel companies that have strong R&D programs and pursue technology transfer as an integral part of their operations.

Table 126.—Features of Technology Transfer in Different Nations

Country	Role of technology transfer in steel industry	Type of technology transferred	Role of Government	Salient aspects of technology transfer
Japan.	Integral part of most major steel companies. Supplement to steel experts.	Basic ironmaking and steel making.	Strong—provides planning, advice, financing.	Consists of all soft and hard transfers, including construction and advice.
West Germany . .	Moderate. German equipment and construction companies active.	Strong in secondary finishing and heat treatments. Direct reduction.	Strong, assists with financing.	Strong and complex associations with foreign design/engineering construction companies.
Austria	Strong in State-owned steel company.	Steel making.	Strong because of ownership of steel industry.	Very aggressive in Third World Western and Eastern sections.
United Kingdom.	Slight. Mostly in design/engineering/construction companies.	Basic ironmaking and steel making.	Minimal.	Weak because of declining steel industry.
India	Strong in State-owned industry.	All phases.	Strong because of ownership of steel industry.	Very aggressive in Asian, Middle Eastern, and African LDCs.
United States.	Moderate. A number of design/engineering/construction firms are active.	Strongest in raw materials processing and steel products.	Minimal.	Strength lies outside of all but a few large steel companies.

SOURCE Office of Technology Assessment

CHAPTER 10

Capital Needs for Modernization and Expansion

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CHAPTER 10

Capital Needs for Modernization and Expansion

Summary

The U.S. steel industry has a record of relatively low levels of capital expenditures, This record has been coupled with a history of decreasing capacity, decreasing technological competitiveness, very modest gains in productivity, and aging facilities. The industry frequently cites inadequate capital as the most critical barrier to the greater adoption of new technology, but the real issue is what its capital spending buys in terms of new technology and new capacity.

Although the industry's capital spending has had a downward trend during the past two decades in terms of real dollars spent on productive steelmaking facilities per tonne of steel shipped, it is also cyclical, Peaks occur every 7 to 8 years, and they follow peaks in net income by 1 or more years, The industry uses increasing amounts of capital for nonsteel expansion activities and continues to distribute relatively large cash dividends to stockholders, even when sales and profitability are depressed.

There are three routes to revitalizing the technological base of the industry: modernization and replacement; roundout or "brownfield" expansion of existing facilities; and new plant or "greenfield" construction. OTA's analysis of the minimum modernization and capacity expansion needs for the coming decade indicates that a cost-effective approach is to maximize the use of roundout expansion at existing integrated plants and to construct more electric furnace steelmaking facilities, particularly in nonintegrated companies producing a limited range of products. The high capital costs of greenfield integrated facilities based on the best available technology are not sufficiently offset by reduced production costs. This situation may change eventually if major technological changes are applied to integrated steelmaking.

The American Iron and Steel Institute (AISI) estimates that it will require $4.9 billion' annually to modernize and expand steelmaking capacity. OTA calculates that modernization and expansion could be achieved by spending approximately $3 billion annually over the next 10 years followed by large expenditures for new integrated facilities in the **1990's.** The industry scenario increases capital spending for productive steelmaking by 150 percent over the past decade's average; the OTA scenario increases it by approximately 50 percent. The AISI and OTA scenarios agree that approximately $2.2 billion annually will be needed for meeting regulatory requirements, nonsteel investments, and other increases in working capital. Total capital spending is thus $7.0 billion annually by industry estimate and $5.3 billion by OTA calculations.

Given the basic assumptions of this analysis, such as increased steel shipments and, hence, increased total revenues, to what extent can the industry meet its own capital needs? The industry has not provided an analysis of capital formation and cash flow. The OTA analysis of capital sources and needs points to a capital shortfall of at least $600 million annually through 1988, assuming 1978 levels of profitability, dividends, and nonsteel activities are maintained. This is considerably less than the deficits projected by the industry analysis. If modernization and expansion lead to a modest 2-percent saving

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*Unless otherwise noted. all figures in this chapter are in 1978 dollars.

in production costs, then by 1988 return on equity could increase from the 1978 level of 7.3 percent to about 12 percent, and could provide a basis for more vigorous industry growth and expansion in the years beyond. The same reduction in production costs, coupled with a Federal policy that added approximately $600 million to the industry's cash flow, would increase the return on equity to almost 15 percent.

OTA finds that the international capital cost competitiveness of the domestic steel industry has suffered relative to Japanese and European steelmaker. Some reasons for this are outside the control of the industry, but other factors, such as design and equipment supplier choices, are within its control.

Three Ways to Modernize and Expand Capacity

Inadequate capital has probably hampered the adoption of new technology by the domestic steel industry. The rate of capital spending has declined during the last two decades, from an average of $36.3/tonne shipped during 1959-68 to $27.1/tonne during 1968-78.[1] But this is not the entire picture. During the 1950-78 period, there was a cyclical pattern to the industry's capital spending, with peaks occurring every 7 to 8 years. Thus, in 1952, 1960, 1967, and 1975, the respective levels of capital expenditures were $45.9, $43.0, $46.4, and $40.5/tonne shipped. The spending peaks correspond to replacement rates of about 4 percent, compared with the more typical replacement rates for the past several decades of 2 or 3 percent. The peaks in capital spending follow peaks in net income by 1 or more years.[2]

A more fundamental issue is not when the capital spending occurs or even its level, but the extent to which it produces new technology and new capacity in the industry. Because the costs of steelmaking equipment and facilities have risen faster than the general level of inflation, capital expenditures buy less today than before. Table 127 compares changes in the steel equipment cost index with changes in other price and production cost indexes. Nominal inflation, shown by the consumer price index, has been less than that for equipment, energy, and labor costs indexes. Steel prices have increased at a lower rate than capital equipment costs but not significantly so for the past 5 years. This slowdown in equipment cost increases may be due to greater use of foreign-produced capital equipment, which has generally become available in the U.S. market at considerably lower costs than from domestic equipment manufacturers. Also, relatively low levels of replacement and plant additions may have reduced domestic demand for capital equipment and discouraged price increases.

As capital spending declined following the 1975 peak, so did domestic steel capacity.

Table 127.—Change in Steel Equipment Cost Index Versus Other Cost and Price Indexes

Index	Ratio for 1978- 1965	Ratio for 1978 – 1973
Steel equipment cost[a]	2.79	1.95
Consumer Price Index.	2.07	1.47
Steel price index	2.61	1.90
Steel industry wages[b]	3.19	1.86
Metallurgical coal	7.28	3.26
Electrical power.	2.71	2.11

[a] From *World Steel Dynarnamics,* April 1979, derived from ECSC data through 1976 and estimated by WSD thereafter

[b] Based on dollars per hour including fringe benefits, from the U.S. Department of Labor

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[1] D. F. Barnett, "Capital Requirements for Modernization," Atlantic Economic Conference, October 1979. These values are for productive steelmaking and exclude spending for regulatory needs and nonsteel activities,

[2] Cyclic capital investment linked to cyclic profits has been cited as a cause of underinvestment, "As a result of this cyclical investment policy, the industry has not been able to replace its high-cost, outdated, inefficient, steelmaking capacity as fast as was necessary to remain competitive with foreign producers. " (R. S. Thorn, "The Trouble With Steel, " *Challenge,* July-August 1967.)

From 1977 to 1979, about 6.35 million tonnes, or 4 percent, of total raw steelmaking capacity was lost. The loss would have been greater were it not for considerable increases in electric furnace steelmaking capacity in both integrated and nonintegrated companies, which partially offset the closing of older integrated plants. Today's production capacity is about the same as it was in 1960, Because a significant percentage of steelmaking facilities are obsolete (see ch. 4), it is likely that in the near term, when demand for steel is expected to decline as a consequence of a general economic slowdown, the closing of older and obsolete plants will continue or increase,

Steel capital spending is generally for the purposes of modernization, brownfield, or greenfield expansion. These terms maybe defined as follows:

Modernization.—Traditionally, spending in this category has been directed at replacing unusable and wornout equipment in order to maintain the operating capacity of a plant. The terms maintenance and replacement are also used. A point of confusion is whether capital spending in this category is associated with capacity expansion. Some analysts assume that capacity does not increase when facilities are modernized, maintained, or replaced, Although it is true that these expenditures are not primarily intended to add capacity, improvements in technology and equipment design do result in increased capacity, generally because of higher yields; the replacement of ingot casting with continuous casting is an important example of such increases (see ch. 9). Also significant is the fact that with newer facilities it is possible to operate a plant at higher sustained rates of capacity utilization.

Because most steelmaking equipment is long-lived, it is reasonable to assume that by the time it is replaced, the new equipment, representing newer technology, will be more productive than the old. Thus, replacement is likely to involve capacity increase, unless as an economy measure the new equipment is selected purposely to keep capacity stable. In some cases, however, the capacity increase that new equipment makes possible may apply only to a particular step of the steelmaking process; it does not necessarily affect capacity for the entire plant and cannot always increase steel shipments from that plant. Steelmaking is a sequential process, and plant capacity levels will be constrained to the lowest capacity link in the sequence. But generally, capital spending for modernization either leads to significant improvements in capacity or sets the stage for future expansion by removing individual "bottlenecks" in the production process.

Roundout or Brownfield Expansion.—These terms have been used to describe capital spending that has as its main purpose increasing capacity in the total steelmaking operation. Both roundout and brownfield expansion occur on the site of an existing plant. One type of roundout is the installation of higher capacity equipment at one or more of the "bottleneck" steps that limit capacity for the whole plant. In some cases, plants are constructed and designed so as to anticipate future roundout; when roundout does occur, it is an add-on expansion, rather than a replacement. Brownfield expansion is a form of roundout, usually on a large scale, that involves better balancing of individual operations than a simpler roundout.[3] A radical form of brownfield expansion, theoretically possible but apparently not used or contemplated, is the tearing down of an existing plant and the construction of a new plant on the same site.

The chief limitation of roundout as a means of increasing capacity is that the basic technology and layout of a plant are maintained. Roundout costs less per net increase in capacity than new plant construction, but there will usually be fewer improvements in productivity and efficiency of inputs. A plant designed from the ground up, on the other hand, may use new types of equipment throughout and be designed to realize economies of scale. New plants also allow optimizing geographical location when markets and sources of

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[3] J. C. Wyman, "The Steel Industry: An American Tragedy?" Faulkner, Dawkins, and Sullivan, February 1977.

raw materials have shifted. For example, access to major waterways is more important today than in previous decades, because more use is being made of domestic iron ores located far from major centers of steelmaking and ports of entry for imported ores.

The exact capacity increase that roundout makes possible is a significant issue. A Fordham University study in 1975 estimated that roundout could expand capacity for finished steel products by 11.8 million tonnes.[4] Inland Steel estimated that roundout potentially could expand product capacity by 14.5 million tonnes,[5] and its chairman has said that rounding out can satisfy the industry's growing needs, presumably at current import and demand growth levels, through the 1980's without the need to build new plants.[6] The chairman of National Steel has indicated that by 1985 roundout expansion could lead to a net increase of 4.5 million to 5.4 million tonnes of product capacity, assuming that the current rate of plant closings continues.[7] The chairman of Bethlehem Steel has noted that his company's 4.5-million-tonne/yr plant at Burns Harbor, Ind., was designed to accommodate expansion to 9.1 million tonnes.[8] An A. D. Little study based on extensive interaction with the industry stated that:

> Our calculations of capital requirements to achieve capacity expansion were based on our assessment of the types of facilities needed to add 40 million tons of capacity from the beginning of 1975 to 1983. We have assumed conservatively that this expansion could be achieved largely by "rounding out" of plants rather than building more expensive, new "greenfield" plants. The industry anticipates that 40 percent of this growth in capacity will be realized from the installation of new facilities, and that the balance will be accomplished by the modernization or "rounding out' of existing facilities.[9]

This study estimated that roundout expansion could produce 21.8 million tonnes of raw steel or 16.3 million tonnes of product capacity, a figure confirmed by at least one other study;[10] a third study resulted in rather large estimates of 27.2 million tonnes of product capacity expansion for the United States and 36.3 million tonnes for Japan.[11]

Greenfield Expansion.—This type of expansion involves building a new steel plant on a site not previously used for steelmaking. It is the highest cost approach to capacity expansion, especially if capital cost estimates for greenfield integrated plants include the cost of raw materials processing capacity. (There appears to be a consensus that the proper methodology is to include such costs, because that capacity is an integral part of the plant; given a choice, OTA capital cost estimates include the costs of raw material processing capacity.)

It is accepted that greenfield expansion provides the greatest opportunities for installing optimum new technology and plant layout and offers maximum production cost savings. These advantages, however, usually will not offset the large capital costs. Table 128 shows several comparisons of greenfield to roundout expansion. There is agreement that greenfield expansion cannot be justified, either on the basis of the price necessary to obtain an acceptable level of profitability or in terms of the net increase in costs. The case of energy conservation exemplifies this conclusion: by spending $11/tonne on retrofit equipment, a steel company could save 1.1 million Btu/tonne; a greenfield replacement of the same productive facilities could save 8 times that much energy, but it would cost at least 120 times as much to accomplish.[12] Given current policies and price levels, the capital and financial costs are too high relative to the benefits from the best available integrated steelmaking technology to favor greenfield expansion.

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[4] Fordham University, "Financial Study of the U.S. Steel Industry, " August 1975.

[5] W. H. Lowe, "Capital Information in the Steel Industry, " *Proceedings of Steel* Industry Economics Seminar. AISI, March 1977.

[6] Fortune, Feb. 13, 1978, p. 129.

[7] Industry Week, June 11, 1979, pp. 186-188.

[8] Ibid.

[9] "Steel and the Environment: A Cost Impact Analysis, " A. D. Little, May 1975.

[10] E. Frank, quoted in Industry Week, May 15, 1978.

[11] H. G. Mueller, "Structural Change in the International Steel Market, " Middle Tennessee State University, May 1978.

[12] *Iron* Age, Nov. 12, 1979, p. 40.

Table 128.—Cost or Price Increases Required by Integrated Greenfield Expansion (dollars per tonne)

Source	Comparison basis	Greenfield	Roundout	Greenfield difference
Marcus[a]	Price-1 3°/0 return on equity 1st year	$541	$356	+ $185
	midlife	431	333	+ 98
	price- 12% discounted cash flow, *36%* debt midlife	526	366	+ 160
Republic Steel[b]	Price-15% return on investment	NA	NA	+ 165
COWPS[c]	Manufacturing costs	573	396	+ 177
Mueller[d]	Manufacturing costs	473	396	+ 77

NA = Not available

[a] P. Marcus, ‘Steeling Against Inflation, ’ Mitchell, Hutch Ins, May 1977.

[b] W.J DeLancey, C.E.O. New *York Times,* June 181979

[c] Council on Wage and Price Stability “Prices and Controls in the U S Steel Industry, ” 1977

[d] H.G. Mueller Structural Change in the International Steel Market, Middle Tennessee State University, May 1978

An excellent example of how roundout can be far more cost effective than new plant construction is the following case of blast furnace modifications. U.S. Steel Corp. paid $100 million for modifying a s-year-old blast furnace because it had failed to reach its designed capacity of 5,900 tonnes of iron daily;[13] with the modifications it is expected to produce 6,800 tonnes daily. Assuming that 80 percent of the capacity has been reached, that the new furnace will operate 300 days/yr, and that the yield from blast furnace iron to finished steel is 70 percent, the cost of new finished steel capacity is just over $11 l/annual tonne. This is less than 10 percent of the cost per tonne for a green field integrated facility.

Capital Requirements for Modernization and Expansion

Calculating future capital requirements necessitates making a great number of assumptions about supply, demand, and unit costs, AISI has recently made a major study of capital requirements in the steel industry.[14] OTA believes the AISI study assumptions are reasonable and has used those assumptions and designed its scenarios so as to be comparable with the AISI study. Both studies project capital requirements for the period through 1988, using 1978 as the base year.

Domestic steel consumption is assumed to increase by approximately 1.5 percent per year. This is a conservative forecast, which under present economic conditions appears valid, although it is conceivable that an economic turnaround in the next few years and a period of major capital spending throughout industry could push consumption significantly higher (see ch. 5). The projected tonnages of shipped steel for 1988 and the actual tonnages for 1978 are given in table 129. There is a net increase of 17.2 million tonnes of domestic shipments during the 10-year period. It is also assumed that imports account for 15 percent of domestic consumption through 1988, as compared to 18 percent of domestic consumption in 1978. This is a critical assumption, which depends on a combination of Government policies and foreign economic conditions and choices. If appropriate condi-

Table 129.—AISI and OTA Assumed Increases in Domestic Steel Use and Reduction in Imports, 1978 and 1988 (million tonnes of shipped steel)

	1978	1988
Domestic shipments	89	106
Exports ., ...	2	3
Imports	19	18
Domestic consumption.	106	121

SOURCE Offlce of Technology Assessment

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[13] The *Wall Street Journal,* Feb. 14, 1980.

[14] AISI, “Steel at the Crossroads: The American Steel Industry in the 1980’s,” 1980.

tions do not prevail, imports could rise substantially above the assumed 15-percent level before 1988 (see ch. 5).

AISI's capacity expansion figures are for net capacity increases; that is, capacity reductions at the current rate of decline (2 percent per year) are more than offset by increases stemming from the modernization program. Capacity utilization is assumed to increase from the 86.8 percent that prevailed in 1978 to an average of 90 percent in 1988. This is technically feasible, and perhaps conservative.[15] During the past 2 years, there have been sustained periods of capacity utilization well over 90 percent—during 1979, for example, the average operating rate was more than 93 percent from March through mid-July.[16] Nevertheless, 90-percent utilization of capacity would increase steel shipments by 3.3 million tonne/yr.

AISI further assumes that modernization will improve the total yield of the steelmaking process from the present 71.5 to 77 percent by 1988, which will provide another 7.1 million tonnes of shipments per year. OTA finds this assumption quite realistic if the industry substantially increases its use of continuous casting and makes other improvements. AISI assumes that continuous casting will increase from the 15-percent level in 1978 to 45 percent in 1988. OTA believes that 50-percent use of continuous casting is feasible and would increase industry yields to 76 percent.

The 10.3-million-tonne total increase in actual steel shipments obtained through replacement of facilities in the AISI analysis is attributed to neither roundout nor brownfield expansion, but rather to modernization. Personal communication with AISI personnel indicated that they refer to their modernization program as brownfield expansion accomplished in a piecemeal fashion, which leads eventually to the equivalent of construction of new plants. Four examples of the replacements in AISI's modernization program are the replacement of older blast furnaces with larger and more efficient modern ones, the replacement of all existing open hearth steelmaking furnaces with electric furnaces and basic oxygen furnaces on an equal tonnage basis, the replacement of ingot casting with continuous casting, and the replacement of one-half of existing coking capacity with new ovens. These examples do not appear to be consistent with previous use of the term "modernization" within the industry, but they are consistent with past definitions of roundout activities.[18] However, the unit capital costs of the AISI modernization program are higher than most estimates for rounding out.

Unit Capital Costs for Modernization

Data on roundout and greenfield unit capital costs for integrated plants from a number of sources in addition to AISI are given in table 130. The table shows that the average of the capital cost estimates from a number of sources is in excellent agreement with the values used by AISI, although the AISI value for roundout is higher than all but one of the other estimates. In the table all dollar figures for years prior to 1978 have been converted to 1978 dollars by the use of gross national product (GNP) implicit price deflators for nonresidential investment as provided by the U.S. Bureau of Economic Research. For both roundout and greenfield costs, there is no significant difference between estimates for 1975 and those for the past 2 or 3 years. This indicates that it is not necessary to adjust costs to take into account the increase in the steel equipment cost index, and the AISI analysis does not use such an adjustment to account for the lower purchasing power of in-

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[15] *World Steel* Dynamics (April 1979) indicates that in 1978 domestic effective or available capacity was 92 percent of rated capacity, and for 1971-76 it was 95 percent.

[16] *American Metal* Market, Jan. 4, 1980, p. 3.

[17] "Benefits of Increased Use of Continuous Casting by the U.S. Steel Industry," OTA technical memorandum, October 1979.

[18] "While rounding out usually connotes an expansion of existing facilities, obviously' the same logic applies to modernization through replacement of facilities in place.'" (Council on Wage and Price Stability, "Prices and Costs in the U.S. Steel Industry," October 1977.)

Table 130.—Integrated Carbon Steel Plant Capital Cost Estimates for New Shipments Capacity (1978 dollars/tonne of capacity)

Source	Year	Roundout	Greenfield
A. D. Little[a]	1975	**$628**	**$1,296**
Fordham [b]	1975	**880**	**1,474**
COWPSC	1976	**710**	**1,502**
U.S. Steel[d]	1976	NA	**1,220**
Marcus [e]	1976	630	**1,514**
Inland Steel[f]	1977	520	**956**
Mueller [g]	1978	715	**1,210**
Republic Steel[h]	1979	372	**1,367**
Average		636	**1,317**
(Standard deviation)		(160)	**(190)**
AISI[i]	1980	743	**1,287**
AISI—on actual shipment basis (90 percent of capacity)	1980	**825**	1,441

NA = Not available

[a] A.D. Little, "Steel and the Environment A Cost Impact Analysis," 1975, these estimates appear to Include a relatively small amount of nonintegrated mills

[b] Fordham University, "Financlal Study of the U S Steel Industry," 1975

[c] Council on Wage and price Stability, " Prices and Controls in the U S Steel In-

[d] Industry Week, Apr 15, 1976, P 11

[e] P Marcus, 'Steeling Against Inflation, " Mitchell, Hutch Ins, May 1977

[f] W H Lowe, vice president for finance, "Capital Formation in the Steel Industry, " *Proceedings of the Steel Industry Economics Seminar,* AISI, 1977.

[g] H G Mueller, "Structural Change in the International Steel Market, " Middle Tennessee State University, May 1978

[h] W J Delancey, C E O , *New York TimeS,* June 181979

[i] AISI, "Steel at the Crossroads The American Steel Industry in the 1980' s," 1980, and personal communication that *greenfield cost was $430/tonne of actual shipments and operating rate was 0.9,* and that the roundout costs although not called that are indeed of that nature even though they are listed in the expansion category

Table 131 .—Capital Costs for Nonintegrated Carbon Steel Plants (Greenfield) (1978 or 1979 dollars)

	Dollars	cost (dollars per tonne capacity)	Annual product capacity (tonnes)
Fordham Univ.[a]	1978	$278	NA
Chapparal Steel Co[b]	1979	320	450,000
Huron Steel Co.[c]	1978	220	225,000
Bayou Steel Co[d]	1979	211	550,000
Raritan Steel Co.[c]	1978	207	450,000
North Star Steel Co.[e]	1979	193	350,000
Florida Steel Co.[f]	1979	157	300,000
Chapparal Steel Co.[g]	1979	165	NA
Nucor Corp.[h]	1979	154	300,000
Average		212	
AISI (apparently for broader product mix of integrated companies)[i]	1979	545	

NA = Not available

[a] Fordham Unlversity, "Financial Study of the U S Steel Industry, " 1975

[b] American Metal *Market,* Dec 7, 1979 (for a plant to produce more complex and costly products such as plates and structural beams)

[c] lron and Steel *Engineer,* February 1978 (for a plant to produce special quality bar products)

[d] *Iron Age,* Apr 23, 1979

[e] American Metal Market, Oct 4, 1979 (for a **plant to** produce special quality bar products)

[f] American Metal *Market,* Nov 21, 1979

[g] W W Winspear, president, Chapparal Steel, September 1979

[h] American Metal *Market,* Aug 5, 1979

[i] AISI, "Steel at the Crossroads The American Steel Industry in the 1980's" 1980, and personal communication that the categories of electrical furnace facility expansion corresponded to a green field plant

vestments during the period of the forecasting.

Comparison of Capital Cost Estimates

Capital cost estimates from a number of sources for greenfield plants of nonintegrated companies and the AISI figure for electric furnace facilities are given in table 131.* Here too, there is no indication that, other than using the GNP deflator, an adjustment is necessary due to a more severe increase in the equipment cost index. The relatively large variation among the estimates for nonintegrated steelmaker is due to rather large differences in their product mixes. In several cases, the plants have been designed to make higher grades of steels and products, and thus their capital costs are greater than the traditional nonintegrated plant, which emphasizes the production of such simple products as reinforcing bar. The average cost of $21 l/tonne for the nonintegrated plants is markedly less than the AISI figure of $544/tonne.

One reason for the higher cost figures of AISI may be that they are based on electric furnace steelmaking in integrated companies. These companies generally have higher capital costs than nonintegrated companies, because they produce a broader line of products than do nonintegrated companies; this diversity requires extensive forming and finishing facilities that the electric shops of nonintegrated companies do not normally have. The AISI analysis apparently assumes that the nonintegrated companies will not expand capacity in the future; however, considering the recent rapid growth of nonintegrated steelmaker (see ch. 8), this is a questionable assumption.

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*The much lower costs in table 131 as compared to table 130 result largely from the absence of facilities to convert iron ore to metallic iron. Instead, ferrous scrap is charged to electric steel making furnaces.

Table 132 shows the unit costs and plant mix used in the AISI analysis and the equivalent figures used in the OTA scenario. For integrated and nonintegrated plants, OTA used the averages given in tables 130 and 131, and for the electric furnace facilities of integrated plants, the AISI costs. For the replacement program, OTA has also used the 25-percent electric furnace fraction in integrated plants. OTA has assumed no replacement of facilities in nonintegrated companies, because these plants account for only 10 percent of present total capacity and most are relatively new. The higher cost alloy and specialty plants are omitted explicitly in both the OTA and AISI calculations. These plants account for only about 3 percent of domestic capacity, and they have been modernizing and expanding during the past several years and appear to have excess capacity. Thus, no significant error will be introduced by excluding them from this 10-year projection and analysis.

Table 132.—Unit Capital Cost for Replacement and Expansion in Integrated and Electric Furnace (Integrated and Nonintegrated) Plants (1978 dollars per tonne)

	Replacement			Expansion			
					Greenfield		
	Integrated	EF (int.)	Average (25% EF)	Integrated roundout	EF (int.)	EF (non int.)	Average (50% EF)
AISI[b]							
Actual shipments	$1,293	$550	$1,100	$825	$605	NA	$677
Capacity	1,164	495	990	743	545	NA	644
OTA							
Actual	1,320	550	1,128	708	605	$234	564[d]
Capacity	1,188	495	1,015	638	545	211	508[d]
Actual							459[e]
Capacity							413[e]

NA = Not available

[a] Using the AISI procedure of replacement = 0.9 X greenfield costs

[b] AISI, "Steel at the Crossroads The American Steel Industry in the 1980's." 1980

[c] Actual shipments = 0.9 of shipment capacity

[d] 50% nonintedgrated; 25% electric furnace Integrated; 25% integrated

[e] 100% nonintegrated with the $413/tonne cost obtained as follows: assuming 50% @ $275/tonne, 25% @ $440/tonne, and 25% @ $660/tonne for plants producing higher quality/cost products on a capacity basis The justification for the $660 cost is as follows Half is for the steel plants and half for a direct reduction plant Beggs has forecast an increase of about 25 million tonnes of direct reduced iron in the United States by 1985 and a total of $2 billion for capital spending on direct reduction plants for the period 1980-90 Assuming that $1 billion is used to obtain the 25 million tonnes, the capital cost per tonne of DRI is about $330 (1978 $) It is more realistic to assume this increase in domestic DRI production and the predicted 73 million additonal tonnes of products made in electric furnaces for the 1978-88 period of the OTA forecast This corresponds approximately to about one-quarter of the additional electric furnace steelmaking using direct reduction (D Beggs, ' Issues and Answers on the Future of Direct Reduction in the U S '33 *Metal Producing,* January 1980.)

Table 133.—Eight Scenarios for Expansion and Modernization Strategies and Annual Capital Costs for Actual Shipment Increases (million tonnes/year)

	Modernization/replacement				Expansion			
	Capacity affected[a]	Cost/tonne	Cost/Year (billions of 1978$)	Net annual tonnaqe increase by 1988	Tonnage increase	Cost/ tonne	Cost/year (billions of 1978$)	Total annual capital costs (billions of 1978$)
AISI[b]	4.0%	$1,100	$4.4	10.3	6.9	$715	$0.5	$4.9
OTA[c]								
Scenario A	2.0	1,128	2.2	6.8	6.9 3.5	564 708	0.4 0.3	2.9
Scenario B	2.0	1,128	2.2	10.3	6.9	564	0.4	2.6
Scenario C	98.9	25	2.5	6.8	6.9 3.5	564 708	0.4 0.3	3.2
Scenario D . . .	2.0	708	1.4	6.8	6.9 3.5	564 708	0.4 0.3	2.1
Scenario E . . .	98.9	28	2.7	10.3	6.9	464	0.3	3.0
Scenario F	4.0	708	2.8	10,3	6.9	459	0.3	3.1
Temple, Barker, & Sloane, 1975-83[d]	75.3	28	2.1	0	29.9	464	1.6	3.7

aEither a small fraction of currentt capacity can be replaced at a relatively high cost per tonne, or an alternative methodology is to assume a smaller per tonne spending level on the entire capacity base

bAISI Steel at the Crossroads The American Steel Industry in the 1980' s,' 1980

cThe OTA scenarios incorporate the following assumptions

	Modernization	Expansion
A	200. replacement rate at cost Similar to AISI, operating rate at 90°. = 33 million tonne/yr yield increase = 35 millilon tonne/yr (1/2 AISI value)	69 million tonne/yr from OTA variable plant mix and 35 million tonne/yr from integrated plant roundout
B	Same as A except obtatain same 103 million tonne/yr as AISI at one-half the cost, justified on basis of costs for five types of facilities replacement	69 million tonne/yr form OTA variable plant mix
C	Based on historical spending rates a cost per average tonne of actual shipment for 1979.88 levels to A results	Same as A
D	2% replacement rate using roundout cost for Integrated plants giving results of A	Same as A
E	Cost per tonne from TBS study based on process step analysts gives AISI result (10.3 million tonne/yr)	69 million tonne/yr using TBS expansion cost
F	4% replacement rate at Integrated plant round out cost gives 10.3 million tonne/yr	69 million tonne/yr from 100% nonintegrated plant expansion

dTemple Barker and Sloane Analysis of Economic Effects of Environmental Regulations on the Integrated Iron & Steel Industries, 1977

place in both nonintegrated and integrated electric furnace steelmaking and in nonelectric integrated steelmaking (greenfield for the former and roundout for the latter). In scenario A, to compensate for the lower capacity increase from modernization, an additional expansion of capacity corresponds to more integrated roundout.

In OTA scenario C, modernization is based on a capital spending average applied to the total steelmaking capacity base, rather than some part of it; and unit capital cost of $25.3/tonne is derived from historical data. The expansion program is the same as that for scenario A.

In OTA scenario D, the modernization program is based on roundout costs for integrated plants, applied to one-half the capacity base used in the AISI analysis—this in contrast to OTA scenarios A and B, in which the higher unit costs analogous to the AISI procedure are used (i.e., based on 90 percent of greenfield integrated costs). The expansion program is the same as in scenario A.

OTA scenario E uses the unit costs and methodology of the Temple, Barker, and Sloane (TBS) study[19] for the modernization and expansion programs.

OTA created scenario F in order to include a scenario that represents a major change in the structure of the domestic steel industry, yet a change consistent with minimal capital requirements. In this scenario, all expansion occurs in nonintegrated companies. This could happen even if the nonintegrated companies merely doubled their total annual tonnage by 1988, not an unrealistic possibility (see ch. 8). However, this rate of nonintegrated company growth would likely entail

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[19] Temple, Barker, and Sloane, "Analysis of Economic Effects of Environmental Regulations on the Integrated Iron and Steel Industry," Environmental Protection Agency, July 1977.

capital cost increases for plants to make higher quality steels and more complex products; a small fraction of plants might even introduce direct reduction facilities to supplement scrap use after 1985. Thus, in this scenario unit capital costs increase from $211/tonne of shipment capacity to $412 in 1988. The modernization program is based on roundout of integrated facilities or replacement of specific facilities as discussed in the next section.

Interestingly, the total annual capital costs are quite close to each other in all six OTA scenarios, ranging from $2.1 billion to $3.2 billion per year and averaging $2.8 billion. All are less than the AISI figure of $4.9 billion per year. Scenario F is considered the most important option for the next decade.

Differences in Modernization Results

For the modernization category, an important difference between some of the OTA possibilities and the AISI approach is the unit capital cost. AISI used a relatively high modernization cost, $1,100/tonne, applied to a large base, an annual average of 98.9 million tonnes of shipments. The OTA estimates were based on lower unit costs consistent with past trends for roundout, which are lower than those for modernization. This lower unit cost is applied either to the same capacity tonnage base as is the AISI case, assuming a 4-percent replacement rate, or to half this tonnage, which results in markedly lower annual capital expense. The AISI method leads to an annual modernization cost of $4.4 billion, the largest single contribution to its estimated total annual capital needs. All the OTA modernization scenarios lead to additional capital costs of between $1.4 billion and $2.8 billion per year. While the OTA modernization program at $2.8 billion annually might suffice for the 1980's, there would be a need in the 1990's for large investment in new integrated facilities.

The lower estimates for modernization in the OTA methods are consistent with past per-tonne spending and the capacity expansion that resulted from that spending. For the past 10 years, the average annual industry capital spending on productive steelmaking (excluding regulatory costs and nonsteelmaking activities) was just over $2 billion. The industry maintains that this level of spending has been inadequate. During that period, however, very high operating rates were attained for sustained periods. Moreover, there were also very large increases in the use of continuous casting, continued replacement of open hearth furnaces with basic oxygen furnaces, and substantial increases in electric furnace steelmaking. The favorable effects these changes had on capacity were masked to some degree by the loss of capacity from closing obsolete plants. But what has evolved is more efficient capacity than before, capable of operating at higher rates with lower production costs.[20]

A more explicit way of obtaining modernization capital needs is to consider the actual costs for replacement of particular technologies and phases of steelmaking. Using several categories of technologies discussed by AISI, OTA has estimated total modernization needs for scenario F (table 134). The total for the 10-year period is $28 billion.

This total compares to $44 billion in the AISI scenario. A discussion with AISI officials and industry representatives[21] provided detailed information on the anticipated uses of capital for the AISI scenario that was not provided in the formal AISI report. Although AISI and industry representatives agreed with categories one through four of table 134, a major difference existed for category five, replacement of finishing mills. For this use, AISI used a cost per tonne of $550 applied to

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[20] The effectiveness of past capital spending has been underestimated by most analysts. For example, "The recent plant closings have created a widespread impression of general decrepitude. But the steel industry has been extensively modernized since 1960, with capital expenditures totaling $3o billion. The best proof of its health is that the industry has managed, after all, to hold on to most of the business in the world's least protected major steel market, and has survived until now without special government favors. " (E. Faltermayer, "How Made-in-America Steel Can Survive, " Fortune, Feb. 13, 1978.)

[21] Meeting on Mar. 13, 1980 with representatives of U.S. Steel Corp., Inland Steel, Bethlehem Steel, and AISI.

Errata Sheet

The reference on page 319 to table 135 was a typographical error. It should have read table 134A. Table 134A was omitted and appears below.

Table 134A. -Capital Costs for Finishing Mill Replacement, Scenario F, 1978-88

Type of finishing mill	Unit capital costs (1978$/tonne output)			percent 1978 capacity replaced[d]	Approximate average annual shipments affected[e]		10-Year capital costs for mill replacement (1978$ billions)
	Hogan[a]	TBS[b]	OTA[c]		Percent	Tonnes (10^6)	
Plate.	$310	$288	$297	45	10	10	$1.3
Hot **strip.**	95	100			17	17	.3
Cold strip.	na	321	330	29	19	19	1.8
Wire rod.	na	713	660[f]	17	3	3	
Galvanizing		460	462	9			.3
Heavy structural	528	561	550	15[g]	5	5	
Rod, ...	186		220	20[g]	17	17	.8
Seamless pipe.	396	514	495	15[g]	4	4	.3
Other	na	na	4409		15	16	1.4
				Total.	100	98	7.0
Weighted average.		$312		22			
Assuming 75-percent facility availability y and 20-percent additional replacement		$418		26			11.0

na = not available.

[a] **W.** T. Hogan, et al., ***Financial Study of the U.S. Steel Industry,*** Department of Commerce, August 1975, baaed on company interview.

[b] Attributed to Temple, Barker, and Sloane as given in P. Marshall, Report **to the Council on Wage** and Price Stability, World *Steel Trade: Current* **Trends and Structral Problems,** Hearing, House Ways and Means Committee, Sept. 20, 1977.

[c] OTA has used this value **to calculate costs, as baaed on data of** Hogan ***and*** **TBS end** other available information.

[d] Amount over 25 yers old according to AISI, Steel ***At*** *The Crossroads: The American Steel* ***Industry in the 1980's, 1980.***

[e] **Using product mix** for 1978 se reported by AISI and rounding off.

[f] This **may be highly overestimated since a new** wire **rod steelmaker (Raritan Steel Co.) has recently constructed an entire new** steel **plant for** approximately $220/tonne capacity, only half **of which is likely to be for finishing.**

[g] **Assumed by OTA on the basis of both generally** available information and confidential information from industry Sources.

Table 134.—Capital Cost Estimates for Major Facility (Technology) Replacements, 1978-88—Scenario F

Change	Approximate cost per tonne[a] (1978 $)	Approximate 1978 capacity changed (percent)	Approximate tonnage affected (annual million tonnes)	Total capital cost . (billion 1978$)
1. Replacement of older, s-mall blast furnaces with larger modern ones	$110	250/.	27	$ 3
2. Replacement of open hearth furnaces with basic oxygen furnaces	55	100	18	1
3. Replacement of ingot casting with continuous casting	88	35	32	3
4. Replacement of old coke ovens with new ones	220	50	27	6
5. Replacement of old finishing mills with new ones (in integrated plants)	418	26	25	11
6. Replacement of old electric furnaces	83	33	9	1
7. Raw materials and miscellaneous	—	—	—	3
Total cost ., ...				$28

[a] Obtained from discussions with Industry personnel news reports on plant construction, and by using data in "Analysis of Economic Effects of Environmental Regulations on the Integrated Iron and Steel Industry, " Temple Barker and Sloane for EPA. 1977 (converted to 1978 dollars and rounded off)

SOURCE Office of Technology Assessment

40 percent of 1978 capacity and 36.3 million tonnes. This results in spending $20 billion on finishing mills, as compared to $11 billion for scenario F.

The details of the OTA calculation of finishing mill replacement costs are given in table 135. The methodology consisted of using unit capital costs for particular types of finishing mills and specific amounts of capacity replacement based on replacing the oldest facilities, and applying these costs to the product mix reported by AISI for 1978. Adjustments were then made to compensate for 75-percent availability of finishing mill facilities and to increase replacement by 20 percent to account for facilities that would reach excessive age during the l0-year modernization period.

Of the $16 billion difference in total modernization capital needs between scenario F and the AISI scenario, $9 billion is accounted for solely by the difference in finishing mill replacement. Although there is no doubt that the greater spending by AISI would result in more new finishing mill facilities at the end of the decade, three qualifications should be noted: the AISI scenario calls for spending $2 billion annually on finishing mill replacement, a rate equal to the total capital spending on productive steelmaking facilities for the past

Table 135.—Projections of Annual Capital Needs *(1978* **dollars in billions)**

	Wyman[a] (1977)	Inland Steel[b] (1977)	U.S. Steel[c] (1978)	AISI[d] (1980)	OTA
Increase in shipments (million tonnes)					
Replacement/maintenance	$2.3	$2.2	$2.2	$4.4	$2.8
Expansion	.7	1.6	1.7	.5	.3
Regulatory compliance	1.0	**1.1**	**1.0**	*.8*	*.8*
Nonsteel	.3	.5	.4	.8	.7
Subtotal	4.3	5.4	5.3	6.5	4.6
Debt repayment/increase in working capital	.3	NA	NA	.5	.7
Total	$4.6	$5.4	$5.3	$7.0	$5.3

[a] J.C. Wyman, "The Steel Industry: An American Tragedy?" Faulkner, Dawkins, and Sullivan, February 1977

[b] Through mid-1980's, W H Lowe (vice president for finance, Inland Steel Corp.), "Capital Formation in the Steel Industry," *Proceedings of Steel Industry Economics Seminar,* AISI, March 1977

[c] **Through mid-1980's** B.D. Smith (vice president and comptroller, U S Steel Corp.), "Capital Formation in the Steel Industry," proceedings "The American Steel Industry in the 1980's—The Crucial Decade, " AISI, April 1979, dollars converted to 1978 dollars by multiplying by O 87

[d] Through 1988, the deflcit results from present Capital recovery periods; AISI, "Steel at the crossroads: The American Steel Industry in the 1980' s," 1980

10 years, of which only about 10 percent was spent on finishing mills; although some steelmaker have old finishing mill facilities, they are still more profitable than the industry average;[22] and the capital costs of finishing mills are probably lower today than in past years because of the availability of foreign equipment at prices considerably below those of some domestic equipment makers. The tenfold increase in purchases of finishing mills for the AISI scenario could probably not be supplied by domestic finishing mill manufacturers; extensive use would probably have to be made of foreign equipment. The average unit finishing mill cost of $550 per tonne compares to the $418 value estimated by OTA. Use of the latter cost would decrease the AISI total finishing mill replacement cost from $20 billion to $15 billion.

After differences in spending for finishing mill replacements are accounted for, the remaining $7 billion difference between the AISI scenario and scenario F results from miscellaneous replacements and raw materials facilities. Category six in table 134 is for replacement of electric steelmaking furnaces at a cost of $1 billion. AISI has indicated a total of $4 billion for miscellaneous replacement capital spending, including electric furnaces. Furthermore, AISI had indicated spending of $7 billion for replacement of raw materials facilities. Category seven in table 134 is for raw materials and miscellaneous spending with a cost of $3 billion.

OTA has found it extremely difficult to determine specific needs for raw materials facility spending. Much of the spending for this purpose is not reported by steel producers as part of their steelmaking operations, and much is by companies outside of the steel industry, such as coal and iron ore companies, and by foreign sources of imported iron ore who account for one-third of domestic ore use. Moreover, the industry has spent considerable sums in this area during the past two decades, including much for iron ore pelletizing facilities. If AISI is correct in its estimate for capital needs in the miscellaneous category including electric furnaces and OTA is correct in its estimate for electric furnace needs, this would mean that $3 billion, or 15 percent of the annual capital spending for the past 10 years, is actually needed for miscellaneous spending. In this case, the $3 billion for raw materials development in scenario F would disappear. It may be more realistic to assume that approximately $2 billion would be available for raw materials spending in scenario F. This would be equivalent to approximately 10 percent of the annual capital spending for the past decade, rather than the 35 percent of the past decade's annual spending in the AISI scenario.

In the TBS[23] study based on AISI data on plants of member companies, most of the estimates for replacement capital needs are in approximate agreement with the costs in table 134. The largest difference is for the raw materials area. Making suitable adjustments for capacity differences and other factors to make the comparison valid, the TBS study found a need for $60 million annually for raw materials, or less than 10 percent of the AISI figure and only 30 percent of the estimate of $200 million annually most likely for scenario F. The total annual capital needs for replacement over a 10-year period in the TBS study is $23 billion, compared to $28 billion in scenario F and $44 billion in the AISI scenario. In addition to having unusual access to the AISI plant operating data, which allowed a detailed process-by-process cost analysis for capital needs, a great many industry personnel were involved with the TBS study. Moreover, their analysis is based on consideration of integrated plants only and extrapolation of this to the entire steel industry. Hence, the effect of noninintegrated companies' lower costs is not factored in.

With the level of spending for modernization in scenario F, the replacement cycle for

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[22] For example, Inland Steel Co., generally recognized to be the most profitable large integrated producer, has some very old finishing mills. Two of its three hot strip mills are over 40 years old, and the average age for its four cold strip mills is 22 years, (*World Steel* Industry Data Handbook—The *United* States, McGraw-Hill, 1978.)

[23] Temple, Barker, and Sloane, op. cit,

steelmaking facilities can be calculated. The cycle is obtained by dividing the capital cost per tonne of annual shipment by the annual capital expenditure. With capital spending of $2.8 billion annually, the annual spending per tonne of shipments equals $25, which is the industry average for 1969-78. There is greater uncertainty as to the correct cost for the replacement of shipment capacity. AISI uses a cost which is 90 percent of the capital cost for constructing a new, greenfield facility. On this basis, scenario F leads to a replacement cycle of 37 years, * compared to 30 years for the industry during 1959-68, 40 years for 1969-78, (an average of 35 years for the 20-year period), and 25 years for the AISI scenario. However, OTA cannot find any specific way of justifying the use of the 90-percent figure in obtaining the replacement capital cost. Considering the value of many elements of existing plants that would continue to be used, as well as the scrap value of facilities removed, it is likely that average replacement capital costs would be less than 90 percent of greenfield costs; other analysts have estimated the ratio of replacement to greenfield costs to be 67 percent” or even as low as 45 percent.[25] For scenario F, if the ratio is 80 percent then the replacement cycle is 33 years. for 75 percent the cycle is 31 years, and for 67 percent it is 27 years.

In any event, the utility and relevance of using the facility replacement cycle are not beyond criticism. Using average industry costs and average industry age does not accurately describe the process of replacing portions of existing plants. Each type of equipment is likely to have a different maximum lifetime during which it performs at design efficiency, and a different age because of prior replacement and modernization. Current facilities, although relatively old, may have costs that still allow acceptable profit levels. * Advancing technology also limits the usefulness of average age: the age at which specific types of equipment become obsolete can increase, depending on the original choices regarding design and construction, or decrease, depending on the advent of radical new technology. Age may also be an invalid indicator of the need to replace because, more often than not, the facilities have not been operated at full or rated capacity for the entire chronological period corresponding to age. Furthermore, the quality of labor practices combined with increasing use of computer control can reduce the wear and tear on facilities and extend their useful lives,

Nevertheless, it is pertinent to evaluate what the AISI modernization capital needs would be on the assumption that the replacement rate is kept at 4 percent, but the unit cost is reduced from the assumed 90 percent of greenfield costs to a lower value. The result for a 75-percent figure is that modernization capital needs decrease from $4.4 billion annually to $3.7 billion. The $2.8 billion annual spending of scenario F would be obtained if replacement costs are 57 percent of greenfield costs, which seems reasonable based on the estimates cited above, assuming an increase in market share for the lower capital cost nonintegrated producers.[26]

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*The calculation is based on using the integrated replacement cost of $1,129 tonne for 87 percent of the industry and the greenfield cost for nonintegrated plants of $234/tonne for 13 percent of the industry.

[24] P. Marshall, report to the Council on Wage and Price Stability, “World Steel Trade: Current Trends and Structural Problems,” hearing of the House Committee on Ways and Means, Sept. 20, 1977.

[25] W. ‘I’. Hogan, et al., “Financial Study of the U.S. Steel Industry,” U.S. Department of Commerce. August 1975.

*The situation is analogous to an old automobile which has had many of its critical components replaced at different times. How useful is it to describe the automobile as, for example, 30 years old, if it is still functioning in an acceptable manner? It may still be less costly to replace parts rather than replace the entire automobile. The situation changes dramatically when a major technological innovation occurs for a component that is not compatible with the other, older components.

[26] See especially Marshall, op. cit. Assuming a growth of nonintegrated company market share from 13 to 25 percent for the 10-year period, greenfield integrated costs of $ 1,253/tonne, and a 4-percent replacement rate, Marshall’s 67-percent ratio of replacement to green field costs leads to an annual replacement cost of $2.9 billion. Using his 67-percent figure and the slightly lower AISI unit cost of $1, 100/tonne and replacement rate of 3.25 percent, the annual cost of replacement would be $2.6 billion.

Differences in Expansion Results

OTA used lower unit costs than AISI for capacity expansion, based on roundout costs that are historically lower than greenfield costs for integrated plants. Moreover, OTA has assumed the continued growth of the nonintegrated electric furnace segment and factored in their low capital costs in the total for capacity expansion. When OTA assumed less capacity increase from modernization, capacity was assumed to increase by an identical amount through roundout expansion of integrated plants. In scenario F, capacity expands as much as assumed by AISI, but entirely through greenfield construction of nonintegrated plants (at greater unit cost because of product-line expansion). This does not imply that integrated capacity does not expand, only that it does so by means of roundout rather than greenfield construction.

Neither the AISI study nor the OTA scenarios incorporate any greenfield construction of integrated plants, although the AISI modernization costs are 90 percent of greenfield integrated unit costs. As previously noted, a consensus exists that integrated greenfield construction cannot be justified because of the higher costs and higher prices it would entail (see table 128). The implicit assumption in the AISI analysis is that major changes in Government policy, such as allowing faster capital recovery, will enable the industry to spend at the high levels proposed in their scenarios.

Differences in Lower Spending Scenarios

There is another part of the AISI analysis (designated as their scenario 11) which is a continuation of current trends. The annual cost for productive steelmaking investment is given as $3 billion. Although the spending level is the same as OTA scenario F, the anticipated results differ. AISI asserts that this level of investment would lead to maintenance of existing production capability and the same average equipment age if the unit cost is just under $1,100/tome (the figure used in their high replacement scenario summarized in table 133). That is, the replacement rate is under 2 percent but there is no improvement in production capacity resulting from improved operating rate or increased yield. However, it is also suggested that up to 20 percent of production capacity would be eliminated because of low profitability.

This scenario seems questionable in view of the experience and results within the industry during the past decade, when annual spending was at the $2 billion level. While a loss in capacity has occurred during the past decade, the ability to produce more steel from the remaining capacity appears to have actually increased, This is because the most obsolete facilities have been closed, and substantial modernization was obtained at the $2 billion per year level.

Total Capital Needs and Shortfalls

Capital Needs

To understand the significance of these capital cost calculations and of the difference between the OTA and AISI estimates, it is necessary to examine the steel industry's total capital needs. Summaries of the AISI estimates and three earlier industry projections of capital needs, as well as OTA findings, are given in table 135. OTA projects capital requirements for modernization and expansion at $3 billion annually; although this finding corresponds to OTA scenario F, it is representative of the range for all the OTA scenarios. OTA concurs with the AISI estimate for the costs of compliance with Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) regulations, $0.8 billion annually, although OTA believes that toward the end of the period OSHA-related costs will tend to be greater than the annual $0.1 billion assumed by AISI; but this difference should be offset by declining EPA-related costs.

On the basis of unpublished survey data, AISI projected that $800 million would be needed annually to finance nonsteel diversification. OTA put this amount at $700 million because it is more consistent with the trend of the past decade. Barnett of AISI, on the grounds that 22 percent of the capital spent on productive steelmaking facilities has been spent on nonsteel activities, concludes that this need will absorb $660 million a year. As shown in table 135, previous estimates for nonsteel spending range from $300 million to $500 million annually. ’

Adding in the amounts needed for increases in working capital—$().7 billion by OTA estimate, as compared to AISI's $0.5 billion annually—AISI arrives at a total capital requirement of $7.0 billion annually, while the OTA scenarios find a total need of $5.3 billion per year between 1978 and 1988. The OTA total agrees with 1978 industry estimates of $5.4 billion and $5.3 billion, as well as a 1977 estimate of $4.6 billion by a Wall Street analyst. ”

Capital Availability

The AISI study did not provide a detailed analysis of capital formation and cash flow in the steel industry. Personal discussion with AISI officials has revealed that the deficit under the existing laws would be $2.3 billion annually. Table 136 compares results for the OTA scenario with an earlier analysis and with an actual 1978 cash flow and cash use as derived from official AISI information for 1978.

Net income has been adjusted upwards in order to be consistent with the assumed increase in shipments for the 1978-88 period. Income as a percentage of revenues was at first held to the 1978 level of 2.8 percent, but this cannot be the case if the modernization and expansion program reduces production costs was assumed, which added $225 million

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*There are no data to support a trend of increasing diversification of steel companies, but attention to such diversification has been increasing. Analysis of company annual reports and Securities and Exchange Commission 10-K reports reveals vastly different diversification activities, from nearly none for some companies to very considerable levels for others, Neither is there an apparent link between diversification and steel profitability. Nevertheless, the argument is often made that diversification absorbs capital needed for steelmaking modernization and expansion. The industry's position is that profitable diversification provides a positive cash flow, which supports less profitable steelmaking investments. Moreover. diversification provides stability to the normally cyclic steel business. A steel industry modernization and expansion program that improves profitability could reduce interest in and need for diversification.

‘-Wyman, op. cit.

Table 136.—Average Annual Capital Sources and Uses (1978 dollars in millions)

	Wyman (1977)’	Industry actual 1978[b]	OTA scenario
Aftertax profit (including deferred taxes).	$2,100	$1,452	$1,871’
Depreciation, depletion.	1,600	2,258	3,100
Increase in long-term debt.	600		451[d]
Cash dividends.	(800)	(598)	(650)
Net cash flow	3,500	3,112	4,772
Capital expenditures	4,300	2,852	4,600
Debt repayment and increase in working capital	**300**	**260**	**746’**
Cash use	4,600	3,112	5,146
Deficit	1,100	0	574

[a] J.C. Wyman, "The Steel Industry An American Tragedy ?" Faulkner, Dawkins, and Sullivan, February 1977; depredation times were greater in 1977 than now

[b] AISI data (Annual Statistical Report—1!376) for companies representing 88.8 percent of domestic raw steel production have been converted to all industry figures by dividing by 089

[c] Assuming as does AISI, an average annual domestic shipment level of 991 million tonnes. and that prices and sleel/nonsteel contributions are the same as 1978, yields total revenues of $58.8 billion if net income as a percent of revenues is the same as 1978 (2 8 percent) then profit (net income) is $1,646,000

[d] If the stockholder's equity is assumed to increase (in constant dollars) at 1 percent per year, then the midterm equity increases to $20.788 million as compared to $19,779 million for 1978, and maintaining a debt-to-equity ratio of 44% provides an increase of $451 million

[e] Increase in working capital is approximated by taking 13 percent of increase In total steel sales

to the aftertax profit of $1,646 million (based on 1978 profitability). The issue of cost savings is discussed further in the next section.

The increase in depreciation results from the rising level of capital spending during the period, but present capital recovery rates have been assumed. The increase in long-term debt has been calculated by assuming that part of the increased capital spending and modernization of the industry will be financed by a small increase in stockholder's equity, and then applying the same debt-to-equity ratio of 44 percent that existed in 1978. The average total net cash flow of $4.5 billion represents these three items minus stock dividends, which have been increased over the 1978 level by approximately 10 percent.

The issue of dividends and their relative constancy regardless of performance (see ch. 4) is linked to the question of the potential for forming more capital through new equities. The industry usually maintains that it keeps dividends at relatively high levels, even though profitability is low and perhaps declining, in order to maintain stock prices. Despite this policy, however, the performance of most steel company stocks, with the exception of those of some of the nonintegrated and alloy/specialty companies, has not been good. Data on real dollar trends for several of the major steel companies are given in table 137. Real net income has fallen substantially during the past 10 years, and real return on common stock has decreased even more. The real cost of goods sold has risen more than the real value of sales.

To illustrate the relationship of dividends to performance, it is instructive to examine the best and worst performing major steelmaker, Inland and U.S. Steel, respectively. The comparison in constant dollars will be made for 1979 versus 1974, both years being in the "up" business cycles for the domestic steel industry. For Inland Steel earnings per share decreased 47 percent and dividends decreased 30 percent; for U.S. Steel earnings per share declined by 130 percent but dividends dropped by only 26 percent. Interestingly, the most diversified major steelmaker, Armco, shows the least drop in earnings per share at 27 percent, with exactly the same decline in dividends per share. Armco generally has the best economic performance as well, for example in terms of net income as a percent of sales. This is due to its diversification, since data on its steelmaking operations show it to be less profitable than Inland Steel. Thus, there is a linkage between profitability and diversification on the one hand, and dividends which accurately reflect economic performance on the other.

Many analysts have concluded that it is highly improbable that new equity issues

Table 137.—1968-79 Real Dollar Changes in Profitability and Common Stock Performance for Selected Steel Companies

Company[a]	Real growth of net income (percent/year)	Change in 1979/68 real return on common stock (percent)	Real growth of sales (percent/year)	Real growth of cost of goods sold (percent/year)
Bethlehem Steel	-13.87	– 48.00	2.18	2.92
National Steel	– 2.80	– 45.84	5.60	6.49
Republic Steel , ...	-1.87	– 59.79	3.16	3.95
U.S. Steel	**– 0.13**	**– 39.06**	**3.04**	**3.76**
Armco[b].	2.29	11.77	5.03	5.59
Average of 100 largest U.S. industrial corporations, ...	4.75	– 25.54	6.16	6.63

[a]These Companies represent 56.4 percent of 1978 domestic shipments.
[b]Armco is the most diversified of the major domestic steelmakers.

SOURCE Interactive Data Corp., Washington, D.C.

would be successful, except for the nonintegrated and alloy / specialty companies with excellent records of growth and profitability. It is plausible, however, that the prospect of a major modernization and expansion program, facilitated in part by supportive Government policies, would allow dividends to be reduced and the funds to be used to help finance modernization and expansion. The perception of greatly improved future earnings might not only prevent any dramatic decline in stock prices, but actually increase investor interest in obtaining capital appreciation rather than income. In such a scenario, new equity issues might be successful; the key factor would be coupling dividend reduction with major investment in cost-cutting new technology for the future.

Capital Shortfalls in the OTA Scenario

In the OTA scenarios, the total cash the steel industry would need to finance capital expenditures for modernization and expansion, plus the increase in working capital, amounts to **$5.3** billion annually for 1979-88. At the same profitability levels as 1978, the industry would be about $600 million per year short of this requirement. This is considerably less than the deficits projected by industry analyses. If modernization and expansion reduced total costs by an average of 2 percent[28] for the lo-year period, then about $900 million would ultimately be added to the annual net income, even after taking into account the rise in financial costs caused by the debt increase, Return on equity would then increase to about 12 percent.

A policy option of accelerating depreciation, which is discussed in chapter 2, could provide enough additional income to finance the $600 million per year deficit in the OTA scenario. If, in addition to such an increase in cash flow, production costs are assumed reduced by 2 percent in the OTA modernization program, then return on equity would be close to 15 percent and return on sales about 5 percent. These returns would bring the steel industry up to the average for all domestic manufacturing.

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[28] The 2-percent reduction in total costs is conservative. The future saving for continuous casting alone should give a 5-percent cost saving when replacing ingot casting. (OTA, "Benefits of Increased Use of Continuous Casting, " technical memorandum, October 1979.) For the newest integrated mill in North America, the Steel Co. of Canada projects that efficiencies of new technology will produce a cost savings of 15 to 20 percent, and of that amount, 10 percent will result from continuous casting. (American *Metal* Market, Feb. 29, 1980.) Applying a 5-percent cost savings for continuous casting to an increased adoption by 35 percent of the industry yields a 2-percent saving for the whole industry. Crandall has suggested a 3-percent saving "if all opportunities were exploited in the very near future, (R. W. Crandall, "Competition and 'Dumping' in the U.S. Steel Market," Challenge, July-August 1978). Gold's analysis of the COWPS study suggests an 8-percent saving in operating costs, which would have to be reduced by increased financial costs. (B. Gold, "Steel Technologists and Costs in the U.S. and Japan, " Iron *and Steel* Engineer, April 1978.) AISI's analysis includes a potential savings in operating costs of 30 percent and in total costs of 15 percent after 25 years of the capital spending program already discussed. There is a lag between capital spending and realized cast savings. Thus, the 2-percent saving used here appears reasonable for the first 10 years of the program.

International Capital Cost Competitiveness

The lower capital costs in foreign steel industries have long been used to impugn the rate of technological innovation by the domestic steel industry. Japan's post-World War II success in steel has often been linked to its low capital costs:

> At an annual average cost of $1.2 billion, it meant a dramatic capacity expansion from 28 million tons at the end of 1960 to 115 million tons at the end of 1970. The expansion of 87 million tons compares to an estimated net expansion of around 20 million tons in the U.S. and Canada. For an annual average expenditure of $1.2 billion, Japan bought itself about 4.5 times as much added capacity as the U.S. and Canada did for an expenditure of $1.8 billion. [29]

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[29] Wyman, op. cit.

One factor in this has been that steel mill construction costs in Japan have been less than 40 percent of U.S. levels, for which the following reasons have been given:[30]

- lower wage and price levels in Japan, which result in cheaper building materials and equipment as well as lower wages for construction workers;
- cost analysis on a facility basis, rather than on the basis of entire plants or projects;
- faster construction times because there is less labor trouble and because steel companies, rather than general contractors or consultants, supervise all or most construction;
- constant capacity improvement after, as well as before, installation of equipment; and
- use of larger economy-of-scale designs.

The following additional factors also help to explain lower Japanese costs:[31]

- an overvalued dollar vis-a-vis the yen during the postwar period;
- coastal locations, which eliminate many infrastructure expenditures;
- the absence of raw material resources, which led to imports rather than construction of raw material processing facilities for or in integrated plants; and
- rationalization of the entire industry through cooperation between banks, industry, and government, which prevented competing steel companies from duplicating facilities, notably high-cost finishing mills.

It is generally accepted that the dollar difference between Japanese and U.S. capital costs has been decreasing. In part, this is because labor costs are increasing more rapidly in Japan than here, because the value of the dollar is declining, and because domestic companies are increasing their use of foreign sources of equipment and consultation. Table 138 provides some recent data that illustrate the diminishing difference between Japanese and American capital costs, and also compares costs for a typical developing nation. It shows a 27-percent advantage to Japan over the United States, and a 27-percent advantage to the United States over the developing nation for a greenfield integrated plant. This last difference may be greater, because most developing nations usually have a substantial lack of basic industrial infrastructure.”

Table 138.—Estimates of Capital Costs for the United States, Japan, and a Developing Nation
(1978 dollars per tonne of product capacity)

	Brownfield or roundout additions to integrated plant	Green field integrated plant
United States	$715	$1,210
Japan	660	880
Developing nation	880	1,540

SOURCE H.G. Mueller, ‘(Structural Change in the International Steel Market, ” Middle Tennessee State University, May 1978

A comparison of the 1976 capital cost of similar items of steel plant equipment in different countries—correcting for differences in plant size and design and for differences in construction cost, and based on prevailing exchange rates—reveals that the United States has the highest capital costs, Europe’s are in the middle, and Japan has the lowest. Western Europe enjoys 22-percent lower costs than the United States, while Japan’s are 41 percent lower.[33]

Aylen’s analysis of American, British, and West German capital costs[34] has led him to the following conclusions regarding the cap-

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‘(’Gold, op. cit.

''Wyman (op. cit.) provides an interesting analysis of the relationship between low domestic capital spending during the past several decades and the monetary policy of the United States. An overvalued dollar, he believes, forced U.S. capital spending overseas and has led to a ‘‘dismantling” of domestic industry. ‘‘While ‘dismantling” its basic industry, the U.S. “created’ a high technology base.''

[32] A recent analysis has indicated that actual costs for greenfield steel plants in developing nations are twice the original estimates. (Iron & Steelmaker, December 1979, p. 37,)

''A. J. Jarvis, “Inflation and Capital Investment in the United Kingdom, ” transactions of the 5th International Cost Engineering Congress, Utrecht, November 1978.

“J. Aylen, “Innovation, Plant Size and Performance: A Comparison of the American, British and German Steel Industries, ” Atlantic Economics Conference, October 1979.

ital spending and costs of domestic steelmaker:

> . . . the recognized investment series for U.S. iron and steel from the Bureau of Economic Analysis or the American Iron and Steel Institute overstate steel industry capital spending on plant and equipment by as much as 180 or 190 percent when compared with European levels, owing to the combined effect of a broader definition of steel industry activities, which include diversified activities, and the relatively high cost of steel plant in America.

With regard to the generally low level of U.S. capital spending (described in ch. 4) and its impact on technology choice, Aylen notes that:

> The higher cost of steel plants in the U.S. provides one explanation as to why the industry has invested at a relatively low rate per ton. High capital costs encourage substitution of other factors of production for capital. In contrast to its absolute capital cost disadvantage, the American steel industry has an absolute energy cost advantage. The American steelmaker has a stronger incentive than his European counterparts to hang on to old, energy-intensive processes such as open hearth steelmaking, poor technology blast furnaces, and conventional casting facilities.

Aylen adds, moreover, that because of the impact of capital improvements on other inputs, the full impact of capital cost differences among nations goes beyond the actual contribution of capital costs to fixed steelmaking costs:

> Admittedly capital costs per se might not introduce much absolute cost difference between steelmaker. But they do induce differences in investment behaviors with long run implications for overall factor productivity and unit costs.

Using a hypothetical reduction of 20 to 30 percent in U.S. capital costs for steel plants, Aylen simulated the effect of having capital costs similar to those in Europe. He found that from $2.9 billion to $4.8 billion would have been generated from 1960 to 1978, or the equivalent of an extra 2 to 3 years" investment at average annual rates. He concludes that, with replacement and roundout, the United States could have obtained an additional 11.3 million tonnes of raw steel capacity, or 8.6 million tonnes of actual shipments. "Such extra marginal investment would have been sufficient to improve innovation rates and raise plant size in the American steel industry to average OECD [Organization for Economic Cooperation and Development] standards. "

Aylen puts the capital investment of the domestic steel industry in perspective and deals fairly and succinctly with the criticism it has often received:

> .,. the American steel industry's failure to invest and innovate can be seen as a perfectly rational response to prevailing factor prices, rather than evidence of any inherent inefficiency. This is not to say that the steel industry should not bear part of the blame for the high costs of plants. Why must the industry order such lavish plants by Europen standards? Why have steel producers not been tougher clients when dealing with plant suppliers? Why does the industry not buy certain items of equipment more widely from European or Japanese plant suppliers?

Although importing steelmaking equipment is clearly detrimental to the balance of payments and to the welfare of domestic equipment manufacturers, it might be preferable in the long term to losing substantial domestic steelmaking capacity, with a concomitant increase in steel imports.

In conclusion, there is a distinct difference in capital cost competitiveness between the domestic and foreign steel industries. This could be remedied in the future by:

- making more steel in nonintegrated companies that use simpler, less costly equipment, and whose capacity utilization rate would be very great (see ch. 8);
- using more lower cost foreign-designed and foreign-manufactured equipment;
- using more economy-designed and economy-priced equipment in integrated plants;
- putting more pressure on equipment

manufacturers and design, engineering, and consulting firms to achieve lower costs; and

- undertaking more in-house equipment design and construction.

Radical, long-term changes in steelmaking may also bring reductions in capital costs. If domestic steelmaker take the lead in these developments, it will increase the likelihood that the necessary capital equipment will be manufactured in this country.

CHAPTER 11

Impacts of EPA and OSHA Regulations on Technology Use

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CHAPTER 11

Impacts of EPA and OSHA Regulations on Technology Use

Summary

In the past, the policies of the Environmental Protection Agency (EPA) have had a greater impact on the steel industry than those administered by the Occupational Safety and Health Administration (OSHA). In the future, however, OSHA policies will grow in importance as more regulations become operational.

Congress has expressed a strong interest in regulatory technologies that are more cost effective than present ones and that will further reduce public health hazards. It is the steel industry's position that available control technologies are generally capable of meeting regulatory standards, but Federal agencies suggest that considerable environmental R&D is still needed. EPA spends less than $1 million per year on steel-specific R&D, but much larger sums on environmental R&D that is incidentally applicable to the steel industry. Industry reports that its environmental R&D spending is about $75 million per year, although a considerable amount of this appears to be for engineering work. Regulatory technology R&D by the steel industry suffers in part because of the high costs and limited private gains associated with it.

Some regulatory approaches, such as the use of technology-based standards, were developed to encourage private-sector improvements in abatement technologies. Other statutory provisions go beyond encouragement by requiring or "forcing" private-sector development of new regulatory technologies. The various environmental statutes and the Occupational Safety and Health Act (OSHA Act) encourage the use of technology-based performance standards. Although these standards allow industry more flexibility they have not encouraged major industrial innovations that are the subject of this report. Available regulatory incentives, such as delayed compliance, have generally been inadequate in encouraging fundamentally new and cleaner steelmaking technologies such as continuous casting or direct casting of sheet or strip. Regulatory incentives have been more successful in providing the initial impetus for incremental improvements in abatement technologies. Examples include improved coke oven controls.

There has been considerable disagreement about the economic and technical feasibility of the regulatory technologies that Federal agencies have identified as being capable of attaining specified control levels. EPA's technology-forcing approach allows for diffusion of new environmental technologies that are not yet commonly used by the steel industry, but judicial decisions have directed EPA to give greater weight to economic considerations when identifying feasible control technologies for nontoxic pollutants. EPA has yet to develop guidelines for private-sector environmental technology R&D. OSHA's technology transfer authority is more limited: OSHA may not require major private-sector R&D efforts, but it may call for the diffusion of the latest techniques within any given industry whenever toxic or hazardous materials are involved.

The steel industry has reported EPA- and OSHA-related capital investments during the 1970's of about $365 million per year, or about 17 percent of its total annual capital investments. * These expenditures have placed greater limits on steel industry modernization

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*These estimates have not been adjusted downward for regulatory overlap between agencies.

than has been the case with other basic industries. Annualized capital and operating costs for environmental requirements alone typically add between 4 and 6 percent to production costs.

EPA and OSHA regulations applicable to the steel industry will impose major capital investments and operating changes on the industry well into the mid-1980's because of statutory requirements. Federal projections of steel industry regulatory investments during the 1980's suggest only modest increases compared to the 1970's, while industry estimates suggest that average levels of regulatory investment would almost double between now and the mid-1980's. Differences between industry and Government projections result from differences in the assumptions underlying their estimates. Among the factors affecting future levels of regulatory investment are: facility replacement rate, expansion plans, technological choices affecting investment decisions, interpretation of regulations, the scheduling of regulatory investments, and broader industry trends with respect to profitability and shipments.

EPA data indicate that industrial development bonds (IDBs) have in the past been used for half of all environmental capital spending. Assuming this pattern continues, industry will need to generate from internal sources between $275 million and $400 million annually, in addition to similar amounts financed with IDBs to finance regulatory compliance through the mid-1980's. These expenditures are relatively modest compared to the massive total capital needs that the industry expects during the next several years.

The need for regulatory compliance has accelerated industry decisions to phase out and replace aging facilities. Thus, economic and regulatory forces have tended to reinforce one another to some extent. Regulatory policies have had the most severe impact on integrated plants, which have a high proportion of aging equipment and high production costs. The impact on nonintegrated electric furnace facilities has been less severe. These newer mills have a narrower and less complex range of processes to control, and most of their control equipment was designed for installation at the time of construction.

Recent regulatory reform initiatives may be more effective in encouraging steel industry development and use of improved regulatory technologies. EPA's "revised offset" policy may create difficulties for companies wishing to expand, because it requires high abatement investments in existing plants to offset future pollution increases for the new plant in the same region. The Agency's "bubble" concept could make facility replacement more cost effective, although some concerns remain about allowable tradeoffs between different types of pollutants generated in the same plant. Moreover, EPA's current "limited life facilities" policy may require some hard decisions about the continued operation of marginal facilities by the early 1980's. And finally OSHA appears to have a growing interest in using its authority to issue variances to standards for innovative purposes.

Introduction

The direct and indirect effects of EPA and OSHA regulations on the domestic steel industry are significant. In part this is because most of the process technologies the industry uses were developed around the turn of the century, at a time when awareness of the impact of industrial pollution on public and occupational health and safety was very limited. Pollution abatement and hazard reduction were therefore relatively minor considerations in the design of steelmaking equipment.

The steel industry is one of the largest sources of pollution in the Nation, with the integrated segment alone accounting for nearly one-fifth of all domestic industrial pollution. The industry is increasingly coming into compliance. Nevertheless, more than half of the steel industry's operations but less than half of its plants are now in compliance with environmental requirements. * Steel mills present a wide range of environmental problems—conventional and harmful solid waste, excess liquids, gases, and noise. High-temperature water, zinc, manganese, lead, and suspended oil and grease also present major difficulties. Coke ovens, blast furnaces, and sinter plants in particular pose complex environmental problems because they emit sulfur dioxide, tar vapors, coal, coke, dust, and other organic compounds. The industry also has very high rates of occupational injury and illness, Steelworkers are exposed to a variety of harmful and toxic emissions (table 139), generally in much higher concentrations, more frequently, and for longer periods than is typical of the general population. [1] This results in high medical expenses, and high compensation payments for death and disability among the industry's half a million employees. United Steelworkers of America data indicate that

Table 139.—Occupational Health Hazards in Steelmaking

Operation	Contaminants	Medical condition
Coking	Coke oven emissions	Cancer and respiratory disease
	Heat	Heat stroke and heat exhaustion
	Silica	Silicosis
Byproduct	Benzene	Leukemia and lymphoma
	Coal tar pitch	Skin cancer
	Organic chemicals	Liver and nervous system damage
Blast furnace	Blast furnace gas	Carbon monoxide poisoning
	Iron oxide fumes	Siderosis
	Heat	Heat exhaustion
Steelmaking furnaces	Metal fumes	Possible cancer and siderosis
	Noise	
	Heat	
Molten metal pouring	Metal fumes	
	Heat	
	Lead	
	Fluorides	
	Asbestos	Asbestosis and masothelioma
	Silica	
Rolling mill	Noise	
	Heat	
	Oil mist	Nose and throat irritation
Steel conditioning	Metal fumes	
	Metal dust	
Pickling	Hydrochloric acid	Mucous membrane irritation
	Sulfuric acid	Mucous membrane irritation
		Chemical pneumonitis
		Heart disease
Maintenance	All hazards	
Galvanizing	Zinc oxide fumes	Metal fume fever
	Lead	
Forging	Noise	
	Heat	
	Oil mist	
Foundry	Silica	
	Heat	
	Noise	
	Oil mist	
	Organic chemicals	
	Metal fumes	

SOURCE Unifed Steelworkers of America, Safety and Health Department

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*For instance, 45 percent of domestic iron and steel facilities are out of compliance with air pollution control regulations. (EPA, Industrial Analysis Branch, letter to OTA, Mar. 18, 1980.)

[1] E. J. Calabrese, *Methodological Approaches to Deriving Environmental and Occupational Health Standards*, New York, Wiley, 1978, p. 223.

131 deaths took place from August 1977 to December 1979 as a result of occupational hazards. Excess death rates have been reported for some phases of steelmaking. For instance, OSHA's final environmental impact statement (EIS) on coke ovens found an excess of over 200 cancer deaths per year among coke oven workers.

Industry's regulatory obligations have emerged during a period of declining competitiveness on the international steel market (see ch. 4). The U.S. share of the world export market has declined during the past decades, while imports have grown in volume. The industry's most recent modest expansion took place during the early 1960's, and a large number of domestic plants are now relatively old, small, and inefficient. Projected capital requirements for regulatory compliance are a relatively small portion of total capital needs for the next decade (see ch. 10), but the industry's capital shortfall affects its efforts to meet regulatory compliance goals as well as its larger modernization programs.

Dealing effectively with the particular hazards that accompany steelmaking raises many issues concerning: 1) the development and costs of fundamentally new regulatory technologies, and 2) the interaction between Government regulations and the operation and modernization of the industry. It may not always be possible to carefully distinguish R&D for regulatory compliance from other R&D efforts, capital investments for compliance from other capital investments, and, innovations due to regulation from other innovations. In addition, comprehensive and verifiable cost data are not always available.

Consider also the following interconnected factors. The goal of Federal regulatory policies is to encourage the development and use of improved abatement or process technologies. Limited replacement and modernization of facilities, however, may make the development of new technologies more difficult. Federal economic and regulatory policies have a major influence on industry's levels of both capital spending and operating costs for modernization and compliance. On the other hand, a vigorous replacement and modernization program might make newer, more cost-effective compliance options available, thereby lowering those costs. In short, broader trends of industry operation and profitability, as well as Federal tax, trade, and pricing policies, have major impacts on both the development and the adoption of new regulatory technologies by the steel industry. Thus, Federal environmental and occupational hazard regulations are contributing factors rather than forces singularly affecting and affected by industry modernization.

Statutes That Regulate Steelmaking

Summary

EPA regulations are based on a number of specific statutes, while OSHA is guided by general authorizing legislation rather than a series of specific statutes. Compared to current investment levels and industry practices, major regulatory technology investments and operating changes will have to be made from now until the mid-1980's to meet requirements of the Clean Air Act, the Federal Water Pollution Control Act, and the Resource Conservation and Recovery Act. The OSHA Act also imposes certain requirements, but their impacts have been limited so far and their future impacts are uncertain, in part because of regulatory overlap.

A growing number of regulatory standards applicable to the steel industry are technology based. This allows industry some flexibility and encourages innovation in complying with the regulations. Vigorous industry innovation has not yet been attained, however, in part because the economic incentives appear limited relative to potential benefits for companies considering abatement R&D. Recent regulatory reforms such as EPA's "bubble" policy, attempt to incorporate economic incentives in regulatory measures. OSHA's authority to issue variances to standards could perhaps also play a greater role in technology development aimed at improved or cheaper regulatory compliance. In addition to standards that encourage new technology, EPA and OSHA also have the authority to "force new technology" when toxic or hazardous pollutants are involved. EPA's approach allows for the diffusion of the latest environmental technologies between industries while OSHA may call for the transfer of promising new technologies within or between industries such as steel.

Questions of economic and technological feasibility have been of great concern in developing standards. Compared to its earlier actions, EPA must now give greater weight to economic considerations. OSHA must narrowly consider the technological feasibility of proposed standards. Both agencies have to assess economic impacts of proposed major regulations in compliance with Executive Order 12044.

Statutes

The basic policy framework for steel industry regulation is provided by several statutes, particularly the Clean Air Act (CAA) and the Federal Water Pollution Control Act (FWPCA). CAA and FWPCA will continue to have considerable impact on steel operations at least until the mid-1980's, when high-performance abatement technologies or in-process changes will have to be installed. EPA's Resource Conservation and Recovery Act (RCRA) and the OSHA Act will also have a growing impact on existing steelmaking technologies.

EPA has an ongoing process of promulgating air emission standards for specific steelmaking processes in order to adequately protect public health and property as required under CAA. The Agency is also in the process of revising steel effluent guidelines for the regulation of waterborne pollutants so that all pollution may be eliminated from navigable waters by 1985, as required by FWPCA.

RCRA also is of growing importance to the steel industry. This statute directs EPA to regulate the disposal of hazardous solid waste, and final steel industry guidelines have only recently been promulgated. This legislation may become the major impetus towards increasing the steel industry's use of recycling and other in-process changes that reduce the volume of solid, hazardous waste it generates.

OSHA's principal responsibility is to ensure safe and healthful conditions in the workplace. OSHA is guided by general authorizing legislation embodied in the Occupational Safety and Health Act of 1970 rather than by a set of specific statutes, as is the case for EPA. The OSHA general duty clause, hazard-specific standards, and judicial interpretations are the basis for most OSHA compliance requirements applicable to the steel industry. Specific OSHA standards having an impact on the steel industry include those concerning sulfur dioxide and machine guarding. The fire and electrical codes are also significant. However, OSHA's impact on the steel industry has thus far been rather limited because its major standards are narrower and more recent than those of EPA. The coke oven standard, for instance, has only been in effect for a short time, * and a number of others are not yet fully operational, including the benzene standard and the proposed noise standard.** Some future impacts of OSHA standards have already been felt, to varying degrees, under environmental regulations that apply to the same steelmaking processes, as in the case of the coke oven standard.

EPA and OSHA performance standards are technology based to the extent this is possible. Such standards identify demonstrated control technologies and, to a lesser extent, in-process changes that are capable of meet-

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*The final coke oven standard, promulgated in 1976, did not become enforceable until January 1980 because of extended litigation.

**The benzene standard is being contested by a number of industries. The interim noise standard is based on voluntary industry standards and OSHA has actively considered revising this and other interim standards.

ing minimum abatement levels. CAA and FWPCA call for three types of standards that vary in degree of stringency. Steelmaking facilities not emitting hazardous pollutants generally must be equipped with environmental technologies capable of meeting low- and medium-stringency levels in existing and new plants, respectively. Any steelmaking facilities or point sources emitting hazardous pollutants must be equipped with the high-stringency, high-performance environmental technologies. Compliance schedules for the two lower stringency standards were set for the late 1970's, and standards regulating hazardous pollutants will have to be met by 1982-83.

OSHA's approach is similar to EPA's in that it also requires more stringent performance levels for new facilities and for all existing point sources emitting hazardous pollutants. Specification standards, commonly adopted at the outset of the OSHA program, are now being revised to provide industry with greater flexibility in attaining compliance. Recent OSHA standards have generally been of the performance type. It is OSHA's view that the rigidity of existing specification standards is frequently overstated. Section 6(d) of the OSHA Act enables employers to obtain a variance from any standard. Such variances allow employers among others to select innovative means while providing for optimum employee protection as required by the standard. Such variances may apply to a single location or they may be extended to all employers within an industry, as in the case of a soon-to-be published variance dealing with arsenic and lead exposures in the automobile industry.

EPA has the responsibility of stimulating private-sector development of innovative process or control technologies that will result in greater pollution abatement or lower cost systems. To encourage the diffusion of new technologies, EPA may call for one industry to share an equipment development it uses if that equipment can be applied effectively in another industry.[2] When calling for the transfer of such technology, EPA must keep in mind a proper balance between health impacts and questions of economic and technological feasibility.

The OSHA Act has given OSHA the general authority to require industry implementations of regulatory technology that is "looming on the horizon."[3] If forcefully implemented, this approach could have the effect of stimulating the development of technologies capable of improved or cheaper performance whenever hazardous substances are involved. The scope of OSHA'S major technology-forcing mandate applicable to steelmaking is now being considered for review.

Feasibility of Standards

Industry feels that both EPA and OSHA have gone too far with their technology-based standards,[4] and its objections, often presented before the courts, are generally based on considerations of technical or economic unfeasibility. The American Iron and Steel Institute (AISI) and individual companies have challenged a number of standards, including those governing water pollution and the OSHA coke oven standard. The statutes originally appeared to have given EPA greater latitude than OSHA with respect to technological and economic requirements for the control of toxic or hazardous pollutants; subsequent court interpretations, however, seem to have reduced the authority of both agencies.

In general, EPA now has to give greater prominence to economic considerations, although it may still require technology transfer between industries. OSHA, on the other hand, now has narrower authority over the stimulation of technological innovations that reduce occupational risks. OSHA is considering to promulgate an interpretive field memorandum governing the steel industry that could place constraints on OSHA's ability to require major R&D efforts for improved coke

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[2] Suggested in-process changes do not have to be common industry practice whenever toxic pollutants are involved. (EPA, office of the General Counsel, letter to OTA, Nov. 30, 1979.)

[3] OSHA Act, Public Law 91-596, sec. 6(b)(5),

[4] AISI, letter to OTA, November 1979.

oven compliance, EPA notes on the subject of feasibility that:

> Although the Court rejected all challenges to the technical and economic feasibility of the BPT [best practicable technology) limitations, it held that certain BAT (best available technology) and NSPS (New Source Performance Standards) limitations were "not demonstrated. " In addition, the Court remanded all of the regulations because, in its view, EPA had not adequately considered the impact of age of plants on the costs or feasibility of retro-fitting controls, or the impact of the regulations on water scarcity in arid and semi-arid regions of the country.[5]

Commenting about court review of steel-finishing effluent guidelines, EPA notes:

> Here again, the Court rejected all challenges based on technical feasibility. But here, too, the Court held that EPA had failed to adequately consider the age / retrofit and water scarcity issues. In addition, the Court held that the agency had failed to adequately consider ''site-specific' costs and the economic posture of the industry. (However,) the Court's remand was not based on the severity of economic impacts, but on the ground that EPA promulgated the regulations on the basis of a draft economic analysis.'[6]

Thus, while EPA's authority over questions of technological feasibility has been generally unchanged, * these and other court cases have given greater prominence to economic issues and local concerns.

State agencies can be more responsive to local concerns than EPA, because they have greater latitude than EPA to consider the economic or technological implications of environmental requirements affecting specific plants in polluted areas, For instance, in the past few years a number of States have granted variances to individual steel plants solely on the basis of economic burden or technological feasibility, while still planning to meet statewide goals for improved environmental protection. The role of State governments in regulating steel plant construction will probably expand in response to a June 1979 Federal court decision, while EPA is likely to be excluded from reviewing construction standards for smaller emitting sources.

OSHA considers both economic and technical feasibility when developing proposed standards. When several court rulings indicated that OSHA was not limited to issuing standards based solely on devices already fully developed,'[7] OSHA interpreted the rulings as enabling it to "force industry to develop control technology whenever quick action is needed to regulate worker exposure to toxic and hazardous materials."[8] The steel industry, concerned about OSHA's ability to require industrial development of new technologies as a means of improved compliance, initiated its own court challenge to the concept. In a 1978 case, the court invalidated OSHA's R&D requirement for coke oven engineering and work-practice controls with respect to fundamentally new technologies.[9]

As a result of the appeals court decision, OSHA will not place an industrywide requirement on steel companies to research and develop new technology for improved compliance with the coke oven standard. Instead OSHA will require controls for noncomplying batteries in addition to those specified in the standard as necessary and feasible for individual batteries. This may require the use of additional controls that have been shown to be potentially adaptable to individual batteries being considered, OSHA is now preparing an interpretative field memorandum which may indicate that it can request of steel firms

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[5] EPA, Office of the General Counsel, letter to OTA, Nov. 30, 1979, p. 7 (basic steel effluent guidelines].

[6] Ibid.

*Informal comments from within and outside EPA occasionally suggest that the Agency has not yet vigorously pursued its "technology forcing" mandate. For related comments, see "Limited Private and Public Sector Effects, " p. 34o.

[7] Society of Plastics industries v. Occupational *Safety* and *Health Administration,* 509, F. 2d 1302, 1309 (1 975); *American* Federation of Labor v. Brennan, 53o F. 2d log, 131 (1975): American Iron *and Steel institute v. Occupational Safety and Health* Administration, 577 F. 2d 825,830-839 (1978).

[8] W. Grover, "OSHA Now Technology-Forcing Agency,"' Occupational Safety and Health Reporter, p. 453.

[9] The court also noted that the steel industry had not made sufficient effort to make use of already operating technologies. (*AISI* V. *OSHA,* 577 F. 2d 825,834-835 (1978).)

incremental improvements in engineering and work-practice controls applicable to particular batteries without requiring major R&D efforts.[10] As a result of these and other challenges to its technology-forcing powers, it appears that OSHA's authority to require major private sector R&D efforts aimed at improved compliance with the coke oven standard now has been reduced. [11]

It is conceivable that in the long term EPA could play a stronger role than OSHA in stimulating new technology when worker protection from toxic materials is at stake. Only EPA, under narrowly specified conditions described in the 1976 Toxic Substances Control Act, can require a firm to discontinue use of toxic or hazardous materials. The need to substitute alternate raw materials could, under certain conditions, stimulate new process design and the development of safer substitute materials and processes.

OSHA's influence over regulatory cost impacts may also be changing. Thus far, OSHA standards have been judged economically infeasible only if they are likely to cause serious disruption of an industry. But standards may be deemed economically feasible even though they are financially burdensome, reduce profitability, or affect the continued viability of individual companies.[12] In order to enforce a greater consideration of macroeconomic issues by OSHA, the petroleum industry has sued OSHA, asking that cost-benefit analyses be required for major proposed regulations such as those concerning benzene. The steel industry joined the petroleum industry as one of six co-parties in this case. Industry argues that provisions analogous to risk assessment or cost-benefit analysis are found in most environmental statutes (including the OSHA Act), that most regulatory agencies undertake such analysis of major proposed regulations, and that OSHA should therefore do the same by identifying the tradeoffs between employee protection and regulatory cost impact when developing standards. The Supreme Court is now considering an OSHA appeal, which argues that the petroleum industry view is incorrect as a matter of both statutory mandate and policy. OSHA does not accept the assumption that costs and benefits from regulations are comparable since human life and health do not have an applicable dollar value.

Innovation

The premise underlying technology-based performance standards is that they provide an incentive to innovation by identifying, rather than prescribing, technologies capable of attaining specific standards. Such innovation, in turn, could help lead industry to use improved or cheaper regulatory technologies. EPA and OSHA have therefore been concentrating on technology-based performance standards. Performance standards are periodically reviewed with the objective of revising allowable emission limits in cases where improved abatement or process technologies have been developed during a given time frame.

Despite their inherent flexibility, however, performance standards alone do not appear to have been an effective mechanism for encouraging industrial innovation of regulatory technologies. Instead of encouraging the development of new technologies, performance standards may actually encourage the risk-averting strategy of adopting technologies that qualify under the technology-based limits established by the agencies. At that point there is no further incentive for the private sector to develop new technologies that might make possible more effective—or even cheaper—environmental compliance. [13]

The following findings illustrate the limitations of the innovation incentives that performance standards have provided in prac-

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[10] "Discussion with OSHA staff in the Office of Field Coordination, Feb. 22, 1979.

[11] " Occupational Exposure to Lead, " Federal *Register, Nov.* 21, 1979, pp. 54474-54475,

[12] Industrial Union Department, AFL-CIO v. *Hodgson,* C.A. D.C. 1974: 499 F. 2d 467; USCA 29655 (notes of decisions). See also OSHA legislative history.

[13] A, Merrick III, Freeman, The *Benefits of* Environmental Improvement: Theory and Practice, Resources For The Future, Johns Hopkins University Press, 1979, pp. 56-57.

tice. A comprehensive 1977 review of EPA effluent standards concluded that industry installed abatement technologies equivalent to EPA-suggested technologies, rather than new equipment specifically designed for further improvements in compliance.[14] New technology development has also been rather slow in the area of occupational hazard reduction. For instance, OSHA's forthcoming requirements for new coke ovens are expected to be similar to those for existing batteries because there has been so little subsequent development* of new control technologies.

It is possible that recent regulatory reform initiatives will provide supporting incentives needed to more effectively encourage private sector innovation. But only a thorough review of the application of these reforms over time can provide documentation concerning their full impact on the development of new technologies. Some of these reforms, such as EPA's bubble approach and the offset policy are expected to provide economic incentives that conventional regulations appear to be lacking. They give industry the flexibility to select the least costly measures for pollution abatement.[16] OSHA also has some regulatory flexibility by means of variances that may be issued to applicable standards under certain conditions. The first major industrywide variance to a standard is expected to be issued shortly to the automobile industry. Procedures may need to be developed for variances specifically aimed at new technology development. Variances could be issued on a case-by-case-basis. Another approach would be to consider the issuance of industrywide innovation variances based on steelmaking equipment replacement cycles. If properly applied and supported by economic advantages, variances also might provide more effective innovation incentives than some of OSHA's prevailing regulatory approaches.

Conclusion

Statutory requirements administered by EPA have imposed definite compliance schedules requiring major steel industry investments through the mid-l980's. The industry is also faced with a growing number of OSHA-administered compliance schedules. These have been set administratively, however, and reasonably could also be changed at that level,

Although the development of cheaper and more effective control technologies is an important goal, there has been little such activity because of limited economic incentives. Instead, in order to reduce private-sector engineering and development work, industry has focused its attention on the adoption of available regulatory technology. As part of its cost-cutting goals, the steel industry has developed a strong interest in cost-benefit analysis of proposed technical standards that regulate steelmaking processes. A pending Supreme Court decision should help resolve this issue. Recent regulatory reform initiatives may be a first step towards more effective innovation incentives made available to the industry.

“National Commission on Water Quality, staff report PII-68, 1977.

*Incremental improvements such as magnetic lid lifters and water-sealed sandpipe caps have been developed during this time.

“Discussion with OSHA staff in the Office of Field Coordination, Aug. 13, 1979.

[16] EPA, “Proceedings: First Symposium on Iron and Steel Pollution Abatement Technology,” Interagency Energy/Environmental R&D Program report, Chicago, Ill., 1979, p. 11.

Pollution Abatement R&D

Summary

Congressional interest in R&D for regulatory technology and less polluting steelmaking processes stems from growing concerns about the cost effectiveness of regulatory requirements and about environmental and occupational health hazards. There is a belief that new, high-performance regulatory or cleaner process technologies will also create additional flexibility for economic growth in heavily polluted regions by making attainment of environmental standards more feasible. *

In addition to improving production efficiencies, several major new steelmaking processes reviewed in this report are also less polluting than complementary or substitute conventional technologies. Pollution abatement is brought about either directly through reduced energy or raw materials use or indirectly through reduced discharges. Cleaner steelmaking technologies still in various stages of development and adoption include: continuous casting, coal-based direct reduction, direct casting of sheet and strip, formcoking, and electric furnace steelmaking.

Of the major technologies considered in this report, formcoking and electric furnace steelmaking have been affected most by Federal encouragement. The former primarily by means of DOE support and the latter mainly by EPA and OSHA. In general, however, Federal agencies have had a greater impact on incremental rather than on fundamental technology change. Modest technological improvements have tended to result from the initial "push" provided by Federal regulations. Examples include: pushing emission controls and improved door seals for coke ovens. Developmental work, induced by regulations, is still underway in areas such as biological treatment of coke oven plant waste and basic oxygen furnace (BOF) fugitive emissions control technology. However, private sector efforts to make abatement still cheaper or more effective, have generally not been widespread or successful once standards have been in existence for some time. For instance, nonfugitive emissions control technology for BOFs has not changed significantly during the past 5 years. "

The steel industry estimates it now spends about 15 percent, or $75 million, of its annual R&D budget on environmental matters. EPA supports only a small amount of regulatory technology R&D, and OSHA maintains no program in this area. Applicable statutes imply that the private sector is primarily responsible for regulatory technology development, although these responsibilities are not specified. The steel industry believes the responsibilities should fall mainly on equipment suppliers, but it also contends that already available technology can deal adequately with virtually all environmental problems. The agencies argue otherwise.

There are some major problems affecting regulatory technology R&D, including: unclear EPA directives regarding private-sector R&D, an emphasis on costly "end-of-line" technology, inadequate regulatory incentives, including lack of economic incentives.

Limited Private and Public Sector Efforts

Regulatory technology RD&D is aimed at developing improved control systems or in-process changes that will make steelmaking processes environmentally or occupationally less hazardous or that will reduce the cost of compliance with Federal requirements. The steel industry has conducted regulatory technology research for many years, but it is difficult to ascertain how much work has actually been done. A limited amount of environmental technology research is underway in company laboratories and in an AISI-sponsored program.[18] Informal 1979 AISI data would suggest that about 15 percent of steel industry R&D expenditures are devoted to pollution abatement projects. With about $500 million of steel R&D per year, this would amount to about $75 million annually for regulatory R&D by the steel industry. It is difficult to quantify the extent of this research, however, because often it is connected with

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*New facility construction can be most readily accommodated when regional environmental standards have been attained. OSHA does not have the authority to approve industry construction plans for regulatory impact, Thus, regional economic growth potential is not directly affected by OSHA policies.

[17] Ibid., p. 39.

[18] During the past 5 years, the cost of the AISI program has averaged about $600,000 per year, AISI letter to OTA, November 1979.

other process development projects. A considerable portion of industry environment R&D appears to involve engineering work. Thus, actual environmental technology R&D undertaken by the steel industry is likely to be significantly less than $75 million annually. A small amount of OSHA-stimulated research is undertaken in universities, by industry, and by the industry-sponsored Industrial Health Foundation, which concentrates on technical assistance to industry.

The industry feels that pollution control equipment makers have first responsibility for new regulatory technology development. Furthermore, industry contends that, with the exception of a few technically complex situations such as coke oven controls, technology already exists to handle steel's environmental problems.[19] Recent EPA studies, on the other hand, suggest an overwhelming need for environmental technology R&D covering a variety of steelmaking processes.

> virtually every process in the iron and steel industry currently requires environmental technology R&D to either improve the level of control, lower the costs or both. The most significant concerns are for cokemaking, blast furnaces and basic oxygen furnaces. Continued assessment of discharges from the various steelmaking processes are urgently needed to uncover hazardous and toxic situations that need applications of controls or RD&D if controls are not available.[20]

The Federal Government plays a limited role in regulatory technology development for steelmaking, OSHA offers technical support to other agencies and individual companies concerning the feasibility of engineering controls necessary for compliance.[21] OSHA has the general authority to conduct or sponsor research and demonstration projects relating to innovative techniques for dealing with occupational safety and health problems. * However, OSHA's interpretation of the legislative history accompanying its authorizing statute is that Congress did not give OSHA a substantial mandate for regulatory technology R& D.* This consideration, along with budget constraints, appears to have been responsible for the lack of an OSHA regulatory technology R&D program, EPA, on the other hand, does undertake and sponsor some environmental technology R&D, Since fiscal year 1976, EPA has provided slightly more than $500,000 annually on a cost-sharing basis with the industry for improved environmental controls, largely for coke ovens. The Agency also cosponsors with AISI a very modest R&D program.[22] However, EPA does support a larger amount of industrial environmental technology R&D that is applicable to the steel industry.

The electric utility industry and pollution abatement equipment manufacturers have developed regulatory technologies, such as ''scrubbers, that are now being used by the steel industry. Foreign steel industries, particularly in Japan, also have developed several advanced control technologies. EPA currently has a foreign technology evaluation project underway to identify potential applications in the domestic steel industry. Technologies being evaluated include control of fugitive air emissions from the BOF, control of wastewater from coke plants and blast furnaces, and general identification of technology to increase recycling or reuse of materials. EPA has already identified some exemplary technologies and will support engineering work to determine domestic applicability; findings and cost evaluations are expected in 1980.[23]

Constraints Affecting Regulatory Technology R&D

Regulatory technology R&D conducted by or for the steel industry suffers from several

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[19] Ibid.

[20] EPA, Industrial Environmental Research Laboratory, Metallurgical Processes Branch, letter to OTA, Nov. 13, 1979.

[21] OMB, U.S. *Budget* for FY 1979, p. 656.

*29 U.S. Code 669,

*Discussion with staff at the OSHA Office of Solicitors. June 2, 1980.

[22] This program has been funded during the past 4 years at approximately $150,000 annually. (Nov. 13, 1979 EPA letter to OTA.)

[23] EPA, Industrial Environmental Research Laboratory, Metallurgical Processes Branch, letter to OTA, Nov. 13, 1979.

weaknesses, including limited policy guidance on private-sector R&D, emphasis on "end of the line" (EOL) control technologies, and lack of economic incentives.

Limited Policy Guidance on Steel Industry R&D.—Although EPA has the authority to stimulate the development of innovative environmental technologies, the Agency does not have any guidelines detailing what circumstances call for steel industry environmental technology R&D. This option could be used whenever available technologies are inadequate for meeting new facility standards or controlling toxic pollutants. OSHA, as a result of its 1978 AISI court case, does have clear policy guidance. OSHA's "technology forcing" policy concerning coke ovens is now limited to the diffusion of marginal technological improvements within or between industries; this decision could set a precedent for other OSHA "technology forcing" regulations.

Emphasis on EOL control technologies.— Both EPA and the steel industry concentrate their R&D programs on EOL technologies that capture pollutants produced by existing processes, rather than technologies that modify the processes so that they produce less pollution in the first place. Very little work has been done on major "changes in process" (CIP), such as recycling, alternative uses of water, and materials recovery from wastewater streams. Limited steel industry replacement and expansion activities also direct industry interest towards available retrofit technologies.

The prevailing EOL orientation is reflected in pollution abatement capital expenditures. From 1973 to 1977, the industry reported spending on the average only 5 percent, or $25 million, of its pollution abatement funds on CIP equipment (table 140). Compared to EOL technologies, CIP equipment leads to more cost-effective environmental control because more efficient use is made of raw materials and waste products, but often it also calls for more technologically complex changes. Furthermore, CIP equipment is most efficiently installed at the time of plant construction. But the slow pace of steel industry modernization and expansion has been a major constraint on the pursuit of this more cost-effective abatement approach. Industrial groups have argued that EPA exceeds its statutory authority whenever it considers in-process modifications. Nevertheless, the growing concern about toxic pollutants is likely to lead to increased research and investment in CIP technologies.*

One area receiving even less attention than CIP research is the development of process alternatives.** For instance, EPA has not yet

Table 140.—Air and Water Pollution Abatement Expenditures as Reported by the Basic Steel Industry, 1973-77 (millions of dollars)

	Air				Water				Air and water			
	Total	EOL	CIP	CIP%	Total	EOL	CIP	CIP%	Total	EOL	CIP	CIP%
1973 .....,	$142.0	$110.5	$31.3	22.18	$ 58.4	$ 54.1	$4.3	7.4	$200.4	$164.6	$35.8	17.86
1974	179.2	155.9	23.3	13.0	105.3	101.7	3.6	3.41	284.5	257.6	26.9	9.47
1975	302.5	295.2	7.3	2.41	279.0	17.5	2.8	1.0	581.5	312.7	10.1	1.73
1976	339.7	325.1	14.6	4.29	301.9	26.4	7.3	2.41	641.6	351.5	21.9	3.41
1977	317.5	302.9	14.7	4.62	283.4	29.9	3.1	1.09	600.9	332.8	17.8	2.96
Annual average (1973-77) . .	256.18				217.28							

NOTE: EOL—end-of-llne methods, involvlng the separation, treatment, or reuse of pollutants after they are generated but before they are emitted from the firm's property. CIP—changes.in-process methods, involving the modification of existing production processes or the substitution of new processes to reduce or eliminate the pollutants generated

SOURCE. U S Department of Commerce, Bureau of the census, *Current Industrial Reports Pollution Abatement Expenditures, 1973.77,* (table 2A)

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*EPA's fiscal year 1980 environmental research budget was doubled to almost $12 million to support a greatly increased industrial wastewater program.

**Concerned about EPA's concentration on immediate problems, and responding to National Academy of Sciences and OTA findings, Congress directed EPA for the first time in 1977 to allocate 15 percent of each R&D program to a separate long-term environmental R&D program.

issued air performance standards and cost-impact analyses for the promising new technology of continuous casting. OSHA does not have a strong long-term regulatory research program either: although it has encouraged small improvements in coke oven control technologies, * it has not actively considered less hazardous processes that could reduce industry's dependence on cokemaking. The limited initiatives that have largely been taken in this area have been taken by EPA, whose regulatory actions have tended to reinforce presently available options, such as the electric furnace as a partial replacement of coke-based steelmaking, rather than fundamentally new processes,

Until last year, the National institute for Occupational Safety and Health (NIOSH) did not undertake any evaluation of emerging technologies,** even though the Institute has a clear mandate to explore the safety and health implications of new process technologies.[24] During 1977 congressional testimony, NIOSH representatives discussed attempts to strike a balance between short- and long-term research in support of future standards development. NIOSH 1980 program plans indicate that a number of new technologies will be assessed.[25]

EPA also has started a modest anticipatory R&D program aimed at exploring the environmental impacts of fundamentally new process technologies. For instance, EPA has evaluated coal-based direct reduction (DR) and concluded that pollution abatement capital costs are one-third less and operating costs one-fifth less than for the conventional coke oven-blast furnace-BOF-hot metal route. Recirculation of fuel gas is expected to bring about even lower pollution levels compared to conventional DR processes. The environmental cost advantages of coal-based DR steelmaking result mainly from reduced water pollution problems. Reducing steel industry reliance on coke ovens by increasing the use of electric arc furnaces (EAFs) involves process changes that can make a major contribution to the lowering of pollution levels .[26]

In continuing support of anticipatory research, EPA noted in its 1979 Research Outlook that:

> EPA research to examine the mineral problem must shift from a focus on existing mineral processing industries to evaluations of new technologies and the corresponding development of environmentally sound control approaches.

Perhaps even more significantly, the Agency added that:

> In the long term, environmental criteria must become an inherent part of a design of new methods and technology for minerals production.

Companies, such as 3M in its "Pollution Pays" program, strongly advocate the integration of regulatory criteria into the investment decisionmaking process. This approach could also be considered by the steel industry because potential cost-saving advantages are associated with the timely consideration of regulatory requirements in investment planning.

EPA now supports limited R&D aimed at evaluating substitute pollution control methods or "cleaner" steelmaking processes. Nevertheless, neither EPA nor OSHA are in a strong position to encourage steel industry demonstration or use of these new steelmaking technologies. Industry is already concerned about regulatory consideration of in-process changes; even greater resistance

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*EPA's role has been equally—or more—important in this area, in part since the Agency has a longer history of enforceable steel industry regulations.

**Some work is now underway on new energy technologies, but no long-term research has been proposed by NIOSH on emerging steelmaking technologies.

[24] The OSHA Act directs NIOSH to undertake special RD&D related to occupational safety and health as is necessary to explore new problems, including those created by new technology in occupational safety and health, which may require ameliorative action beyond that which is otherwise provided for in the operating provisions of the Act, (OSHA Act, Public Law 91-596, sec. 20(a)(4).)

[25] Discussion with Dr. John Froines, deputy director, NIOSH, Aug. 22, 1979.

[26] The EPA-sponsored report (600/ 7-76-034C) compares coal-based DR/EAF steelmaking with the conventional alternative coke oven-blast furnace-BOF route, American *Metal* Market, Oct. 2, 1979.

could be expected should regulatory agencies also actively encourage the industry to adopt new process technologies.

Limited Economic Incentives.—Perhaps the most important barrier to regulatory technology development by the private sector is the lack of strong economic incentives. Available regulatory incentives, in and of themselves, have been insufficient to encourage low-profitability industries to innovate in environmental technology. These incentives, developed during the early 1970's, provide for extended compliance in existing plants or temporary waivers for new plants that will incorporate innovative technologies.[27]

Unlike EPA, OSHA is not bound by statutory deadlines, and it can set compliance deadlines adminstratively, taking into account factors such as occupational risks, industry economics, and technology development. The coke oven standard, for example, provides for delayed compliance schedules on the basis of economic feasibility. Once deadlines have been set, however, OSHA may only issue variances to specific operations that need time to respond to material, equipment, or staffing problems.[28] Although innovation is not specifically identified, it could perhaps be subsumed under the allowable category of equipment problems. Thus far, however, the steel industry has not actively responded to available regulatory incentives like deadline extensions. During the past few years, the steel industry has only submitted two proposals to EPA for innovative controls in existing plants; EPA did not approve these proposals because similar control technologies were already being used by other industries.

It is clear that the temporary waivers and deadline extensions are not attractive enough to induce companies to assume the technical, financial, and strategic risks involved in innovating. The only cost protection EPA's innovation incentives provide to participating companies is to free them from noncompliance penalties of up to $25,000 per day while demonstration work is going on. Neither EPA nor OSHA legislative mandates provide regulatory guarantees or financial support should the innovative approach fail to meet regulatory requirements. There is also a strategic mismatch between potentially broad economic and environmental benefits resulting from successful innovation and the limited private gains to be made by the innovative firm. Under these circumstances, investment in such innovation may promise too much risk and too little profit from a private point of view. The low rate of new facility construction and replacement is also a major constraint on the development of improved regulatory or process technologies. Without effective public-private risk sharing, there is little incentive to bring new technologies online.

Conclusion

The steel industry has only a limited environmental R&D effort, a considerable portion of which appears to be devoted to engineering work, and Federal R&D is also very limited. Applicable statutory provisions for regulatory incentives designed to stimulate the development of improved and cheaper regulatory technologies have not been very successful, thus far, with the steel industry. A number of applicable technologies have been developed by foreign steel industries or other domestic industries such as the electric utility industry, Several process modifications and alternatives hold considerable promise for reduced pollution. Increased incentives for R&D and innovation, perhaps including public-private risk sharing, may be needed to bring these technologies online.

“The Clean Air Act gives EPA the authority to extend compliance of existing mills by 5 years (“delayed compliance order”) to allow for the demonstration of improved or cheaper control technologies. For new facilities demonstrating innovative process or control technologies, EPA may grant variances from applicable standards for up to 7 years (innovation waivers). Should the new system fail during this time, the Agency will grant an additional temporary compliance waiver to give the company time to install conventional controls. For innovative water pollution abatement technology, EPA is authorized to issue a 3-year waiver for innovative production or control technologies having the potential of industrywide application for companies wanting to replace existing production capacity. There do not appear to be any regulatory incentives for retrofitting existing plants with innovative control technologies. (Public Law 95-95, sec. Ill(j), l13(d)(4); U.S. Code and Admin News, legislative history of Public Law 95-95, p. 1276; U.S. Code and Admin News, Public Law 95-217, p. 4375.)

[28] U. S. Code Annotated 29, subsec. 655(d), Labor—Safety and Health, “Variances From Standards.”

Regulatory Cost Impacts

Summary

EPA and OSHA regulations affect modernization and competition most directly by imposing additional capital requirements and increasing production costs. However, it is difficult to measure the extent of these burdens; data availability is a problem. During the 1970's, the steel industry reported spending on average 13.1 percent, or $280 million, of its annual capital investments for environmental compliance and about 5.8 percent, or $85 million, of its annual capital investments for industrial health and safety purposes. Actual spending levels have been lower than for several other industries, but the opportunity cost of regulatory requirements vis-a-vis industry modernization has been higher for steel because of its relatively low total capital spending. Annualized capital, operating, and maintenance costs for environmental requirements presently add between 4 and 6 percent to production costs.

Regulatory cost projections are based on considerable uncertainty. Available cost-impact studies generally show different costs for the same proposed regulatory requirements. Federal agencies have estimated that EPA and OSHA capital costs for air, water, and coke oven compliance will total approximately $550 million annually until the mid-1980's, while AISI has estimated total regulatory capital costs at $800 million annually.[29] Reliable cost estimates may not become available until just prior to implementation of standards, when requirements will be final and qualifying control technologies will be known. Furthermore, cost savings resulting from improvements in regulatory technologies may not occur until after the standards are promulgated. A recent EPA report underscores the point that steel industry expenditures for abatement equipment are generally less than was expected on the basis of projections. The increase in production costs as a result of environmental capital and operating costs is expected to remain rather stable, ranging between 4 and 6 percent. About 48 percent of regulatory capital costs have in the past been financed through IDBs. Assuming a similar pattern in the future, between $275 million and $400 million will need to be generated annually outside the bond market for investments in regulatory equipment.

Past and Current EPA and OSHA Compliance Costs

There are several series of data for steel industry reported capital expenditures on regulatory investments. The Department of Commerce and AISI have series relating to environmental equipment, and McGraw-Hill has one reflecting investments for occupational health and safety equipment. All these sources depend on industry data. Reporting procedures suggest that costs be allocated on the basis of the productive or regulatory function the equipment serves, in an effort to limit the data base to purely regulatory investments. No attempt is made to differentiate investments required by statute from those made voluntarily or to differentiate investments made in response to more than one regulatory requirement. when these series are adjusted for differences in industry definition, the environmental expenditure reports are fairly similar, with the AISI data conforming most closely to the OTA definition of the steel industry.

Industry reported that annual capital investments for required environmental investments during the 1970's averaged 13.1 percent, or $280 million, of total capital spending. pollution control investments have gradually increased, particularly since 1975. In 1978, the steel industry reported that environmental capital spending was about 18 percent, or $450 million, of total capital invest-

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NE PA, The Cost *of Clean Air* and *Clean* Water, report to Congress, 1979; D.B. Associates, Economic *Impact of* Coke Oven Standards, vol. 1, report prepared for OSHA, 1975. Federal estimate is not adjusted downward for possible regulatory cost overlap; industry estimate includes a much broader range of regulations than Federal estimate.

ment (table 141). Assuming that half of the environmental investment was financed with IDBs, about $225 million, or 9 percent, of total capital spending must have come from internally generally funds, loans, or stock offerings. * Environmental capital expenditures seem to have been more burdensome for steel than for other major polluting industries. The chemical, petroleum, and electrical utility industries spent no more than about 10 percent of their total capital investment on pollution abatement during the 1970's (table 142). Relatively higher regulatory spending may to some extent have affected steel's profitability and limited its capital spending for modernization and R&D.

Table 142.—Pollution' Abatement Investments as a Percentage of Total New Plant and Equipment Expenditures, Four U.S. Basic Industries, 1973=79
(millions of dollars)

	Steelmaking	Chemicals	Petroleum	Electric utilities
Sic.	331			491
1973. . . .	$1,407	$4,324	$ 5,409	$16,250
	16.6%	10.170	10.9%	9.2%
1974. . . .	$2,030	$5,628	$ 7,868	$17,649
	12.170	8.3%.	10.170	8.9%
1975. . . .	$2,926	$6,300	$10,947	$17,030
	13.5%	10.8%	11.8%	9.6%
1976. . . .	$2,954	$6,723	$11,744	$18,942
	15.170	11.3?40	10.8%	10.5%
1977. . . .	$2,815	$6,902	$14,185	$21,743
	16.60/0	10.1 '/0	8.2%	10.4%
1978. . . .	$2,622	$7,205	$15,560	$24,590
	16.8%	7.9%	8.3%	10.O%
1979 planned	$2,908	$8,106	$17,504	$27,308
	18.4%	7.1 0/0	8.00/0	9.70/0

aAir, water, and solid waste.

SOURCE: U.S. Department of Commerce, Survey of Current Business, June 1978 and June 1979.

EPA and OSHA regulations, along with their impacts on capital requirements, have led to changing employment requirements. When extra workers are needed for the operation of retrofit equipment, labor productivity tends to decline. In other instances, mainly when less polluting substitute technologies such as continuous casting or electric furnaces are involved, labor productivity increases and there is a decline in the total number of employees. A second employment effect is of a distributional nature. If a plant closes down, perhaps in part because of regulatory requirements, employment will decline in the affected area. This decline may be offset by production increases in other steel companies, unless the output of the closed

Table 141.–Total and Regulatory "Current Capital Costs" for the U.S. Steel Industry, 1969.79

Year	Total capital investment		Net income	Pollution control capital investment		Pollution control as percentage of capital investment		Pollution control as percent of net income	Occupational health capital investments	
	Commerce	AISI	AISI	Commerce	AISI	Commerce	AISI	AISI	(million)	Percent of total
1969	NA	2,046.6	$ 879.4	NA	$138.0	NA	6.7	15.69	—	—
1970	NA	1,736.2	531.6	NA	182.5	NA	10.5	34.33	–	–
1971	NA	1,425.0	562.8	NA	161.5	NA	11.3	28.69	–	–
1972		1,174.3	774.8		201.7	NA	17.1	26.03	193.0	12.3
1973	$1,407	1,399.9	1,272.2	$234	100.1	16.63	7.1	7.86	121.0	6.9
1974	2,030	2,114.7	2,475.2	245	198.8	12.06	9.4	8.03	92.0	3.5
1975	2,926	3,179.4	1,594.9	396	453.0	13.53	14.2	28.4	70.0	1.9
1976	2,954	3,252.9	1,337.4	146	489.2	15.09	15.0	36.57	34.0	0.9
1977	2,815	2,319.3a	377.3a	470	407.6	16.7	17.5a	108.0[a]	41.0	1.2
1978	2,622	2,538.3	1,291.9	441	457.9	16.8	18.0	35.44	41.0	1.2
1979	NA	NA	1,297.2	NA	650.9	NA	NA	50.17	NA	NA

aExcluding Bethlehem Steel, which incurred a $355 million loss in 1977 due to plant closings.

NOTE: AISI estimates are for the steel industry proper, Commerce Department estimates are for all environmental expenditures by steel companies, including for occasionally substantial nonsteel expenditures.

SOURCES Commerce—Survey of Current *Business,* June 1978 (survey started in 1973; solid waste for all years); AISI—Armual Statistical *Report,* 1978 (air and water) only; Special *Survey* (air and water only), McGraw Hill, Annual Surveys of Investments in Employee Safety and Health, vols. 1-7, 1973-79

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*Data provided by the EPA Office of Planning and Management suggest that the steel industry has in the past financed close to half of all pollution abatement investments with IDBs, plant is replaced by imports. The increasing use of scrap and electric furnaces, accelerated by regulatory considerations, may also be leading to a loss of jobs, or at least a shift of employment from basic ironworking to the scrap industry.

EPA expects the level of capital investment for regulatory compliance until the mid-1980's to be lower than does AISI, but it expects that annual investments will gradually increase over this period, while AISI assumes roughly similar levels. According to EPA, between 1977 and 1986 the steel industry will invest $41.+1 billion, or about $490 million annually, in pollution abatement equipment to comply with clean air and water requirements.[30] AISI, on the other hand, predicted in 1978 that 1976-85 capital investments for compliance with all environmental regulations would be $4.9 billion, or about $550 million annually.[31] In 1980, AISI estimated that environmental plus occupational health investments will amount to $800 million per year until 1988.[32]

Operating and maintenance costs for regulatory equipment are an additional cost burden, and as more pollution abatement systems are installed these costs will increase. Using the **1978** AISI estimate, **1979** annualized air and water pollution abatement costs (capital recovery, operating, and maintenance) were about $2.5 billion.[33] This is about $0.5 billion higher than comparable EPA estimates (table 143). The AISI data are annual averages of cumulative investment projections, while the EPA data attempt to reflect actual capital investments expected to be made each year. Thus, EPA estimates for capital investment and annualized costs increase over time in accordance with anticipated compliance with future regulatory requirements, and AISI projections show higher near-term capital recovery and operating costs than does EPA. The EPA estimates more accurately represent actual industry practices, while the AISI data for annualized pollution abatement costs overestimate current expenditure levels somewhat by including certain investments well before compliance deadlines.

Using industry estimates for annualized environmental costs, one finds that they added **6.4** percent to production costs in **1979.** Using the lower EPA annualized estimates, reflecting in part lower current expenditure levels relative to future requirements, the figure is 5.1 percent (table 143). *

OSHA-stimulated capital costs have on the average been considerably less than those for environmental regulations. Thus far, major occupational regulations have covered a narrower range of steelmaking processes, and implementation of major OSHA regulations is a more recent development. Capital investments for occupational safety and health during the **1970's** averaged **$85** million per year or about 5.8 percent of total capital spending, but there is no clear trend yet in these expenditures. In **1978,** steelmaker reported investing $41 million for industrial safety and health purposes (see table 141).

Steel industry investment levels for occupational safety and health were on average less than half those of other basic industries, such as the chemical and electric utility industries, but they represented a higher proportion of total capital spending (table 144). Steel industry opportunity costs for occupational safety and health have on the average been higher than for other industries. Thus, compared to other basic industries, steel may be under greater pressure to forgo investments in new production equipment because of OSHA-related investments.

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[30] EPA, *The Cost* of *Clean Air and Water*, op. cit.

[31] ADL/AISI, *Steel* and the Environment, 1978, p. 1 (1979 dollars).

[32] AISI, *Steel at* the *Crossroads,* 1980, p. 44.

[33] About $1.3 billion of this amount is for operating and maintenance costs only. This is in contrast to the $500 million estimate for O&M in AISI's *Steel* at the Cross Roads (prepublication draft), 1980, p. 11-7.

*EPA estimates that annualized capital and operating costs for environmental requirements have in the past added 4.6 percent to steel production costs and prices. [EPA, Industrial Analysis Branch, letter to OTA, Mar. 18, 1980.)

Table 143.-Effect of Environmental Requirements on Steel Production Costs and Prices, 1979-83 (1979 dollars)

	Annualized P.A. costs[a] (millions)			Annualized P.A. costs per tonne shipped[b]	Production costs per tonne[c]	Total revenue per tonne	P.A. as percentage of production costs per tonne	P.A. as percentage of total revenue per tonne
	Operating and maintenance	Capital recovery	Total					
ADL/AISI								
1979.	$1,360.60	$1,151.30	$2,512.00	$27.08	$422.40	$467.50	6.4	5.8
1983	2,261.50	1,926.00	4,188.50	41.88	574.20	605.00	7.3	6.9
EPA								
1979.	1,260.30	734.64	1,995.04	21.50	422.40	467.50	5.1	4.6
1983.	2,456.65	1,411.93	3,868.35	37.98	574.20	605.00	6.6	6.3

NOTE: P.A. = pollution abatement.

1) Annualized P.A. costs; capital, operating, and maintenance costs for air and water requirements 1983 AISI estimate Includes fugitive emissions, but 1979 estimate does not.

2)8% annual inflation assumed between 1979 and 1983.

3) Shipments: 197992.5 million tonnes.
198399.8 million tonnes,

aArthur D. Little (for AISI). Steel *and the Environment: A Cost Impact Ana;ysis,* 1978, p. 3.

bEnvironmental Protection Agency, "The Cost of Clean Air and Water," report to Congress, 1979

cWorld Steel Dynamics, *Core Report J. Steel Prices, Costs, and Proflts, 1979.*

Table 144.-Reported and Planned Investment in Employee Safety and Health, Four Basic Industries, 1972-82
(in millions of 1978 dollars and as percentage of capital spending)

	1972		1973		1974		1975		1976	
Iron and steel	$193	12.3%	$121	6.9%	$92	3.5%	$ 70	1 .90/0	$ 34	0.9%
Chemicals.	72	2.1	89	2.0	119	2.1	200	3.2	234	3.5
Petroleum.	68	1.3	196	3.6	216	2.7	263	2.5	128	1.1
Electric utilities	203	1.4	144	0.9	229	1.3	170	1.0	150	0.8
All-manufacturing average	52.1	3.0	67.0	3.2	87.6	3.4	92.2	3.1	64.6	2.2

	1977		1978		1979 planned		1982 planned		1972-78 annual average	
Iron and steel	$41	1 .2%	$41	1.7%	$41	1.4%	$116	3.3%	$84.5	4.0%
Chemicals.	212	3.1	249	3.5	243	2.9	349	3.6	167.8	2.7
Petroleum.	250	1.8	490	3.2	600	3.4	222	1.1	230.1	2.3
Electric utilities	194	0.9	448	1.8	413	1.4	577	1.8	219.7	1.1
All-manufacturing average	87.2	2.6	114	3.0	127.5	2.8	111.2	2.3	79.2	2.9

SOURCE McGraw-Hill, 1st through 7th *Annual Surveys of Investrnent* in *Employee Safety and Health, (1973-79).*

There are no comprehensive data on annualized operating and maintenance costs of OSHA regulations or on the impact of these regulations on cost and price competitiveness. It stands to reason that the cost impact will be far less than that of environmental regulations. More importantly, there are no thorough analyses of the cost impact of EPA and OSHA regulations, together. The full costs of regulation will be less than the sum of the costs for meeting EPA and OSHA standards separately, because standards overlap both within and between the two sets of regulations.

Need for Improved Regulatory Cost Projections

Steel industry capital expenditures for pollution abatement during the next few years will be concentrated in investments such as high-performance environmental equipment for the control of fugitive emissions and for the treatment of carcinogenic or hazardous air and water pollutants, OSHA-related cost increases are expected to be associated mainly with required process changes—such as closed systems, improved ventilation, and acoustical redesign—and operational changes leading to reduced coking times.

Both EPA and OSHA conduct economic-impact analyses of major proposed regulations. In addition, EPA periodically prepares comprehensive industry impacts of the cost of regulations. The steel industry also sponsors economic-impact analyses of regulatory requirements. However, economic-impact studies concentrate only on anticipated regulatory costs. There is little or no effort to compare these costs with the benefits resulting from new or extended regulations, nor do the studies compare the cost effectiveness of regulatory control technologies for the steel industry with those for other industries. And finally, these projections generally do not consider the offsetting effects (which can be considerable) of fiscal incentives or public-financing options on capital need estimates for regulatory compliance. Both planning and decisionmaking will be aided if future projections take these factors into consideration.

Future Regulatory Cost Impacts

Available cost studies often show different cost impacts for the same regulations. For instance, EPA annualized environmental cost projections for capital and operating expenditures into the mid-1980's are 8 percent less than those prepared by AISI for the same period (see table 143), while the Agency's capital expenditure projections are approximately 20 percent lower than AISI's (table 145).

Each successive projection has increased the predicted cost of regulatory compliance. A 1970 EPA report to Congress identified particulate as the steel industry's major pollutant and projected 1975 operating and maintenance costs for air pollution compliance to be around $250 million.[34] A 1979 report for EPA estimates that similar expenditures for the 1981-86 period are expected to be $780 million per year.[35] These increases over time and by the same agency are the result of inflation, better forecasting, and the installation of additional equipment needed to control hazardous pollutants.

Even regulatory cost projections developed around the same time and covering approximately similar regulatory areas frequently show rather different estimates of future capital investments and operating costs. Differences between industry and Government projections are largely attributable to different assumptions concerning facility replacement rates, expansion programs, technological choices, interpretations of regulations, and the scheduling of regulatory investments. The more extensive the industry's investment in integrated facilities—as in the High Investment scenario discussed in chap-

Table 145.—Annual Steel Industry Investments in Abatement Equipment (air, water, coke ovens): Projected Increases, 1970-85 (millions of 1978 dollars)

	Industry estimates		Federal estimates	
1978	**Pollution** abatement	$450.00	EPA	$441.00
	Industrial health	41.00	OSHA[b]	41.00
		$499.00		$482.00
1985	Pollution abatement	700.00	EPA[c]	490.00
	Industrial health	100.00	OSHA[d]	68.00
		$800.00		$558.00
1978-85 increase		60%		1570

aAll applicable regulatory requreements.
bSteel industry reported data since no Federal estimates are available.
c1977-86.
d1976-85

SOURCES: *Survey of Current Business,* June 1978, McGraw-Hill, Survey of Investment in Employee Satety *and* Health, 1979, American Iron and Steel Institute, *Annual Statistical Report, 1979,* Environmental Protection Agency, The Cost of *Clean Air and C/can Wafer,* Report to Congress, 1979, D.B. Associates, *Inflationary Impact Statement Coke Ovens,* report prepared for OSHA, 1976, American Iron and Steel institute, Steel at the *Crossroads, 1980*

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[34] Department of Health, Education, and Welfare, The Cost *of Clean* Air, second report to Congress, March **1970, Senate Document 91-65.**

[35] EPA. The Cost *of Clean* Air and Water, op. cit.

ter 10—the greater regulatory capital costs will be. Technological choices and the facility replacement rate will also significantly influence future regulatory capital costs: for instance, electric furnaces and continuous casters require less regulatory investment than parallel conventional equipment, and a high replacement rate reduces the need for costly retrofit equipment.

In addition to uncertainty about future changes in the economy, Federal policies, and industry investment decisions, the following factors also contribute to differences in regulatory cost projections:

- Different interpretations of regulatory requirements:
  - —AISI cost projections are reported to include compliance costs for some facilities scheduled for shutdown by the early 1980's; only if shutdown took place after 1982 would these facilities be subject to environmental regulations.
  - —AISI assumes a 20-percent coke oven capacity increase will be needed to replace existing capacity expected to be lost under a strict interpretation of the standard; the OSHA-sponsored analysis appears to include only retrofitting of existing capacity .3’
- Unknowns about qualifying regulatory technologies:
  - —Uncertainties about qualifying abatement technologies have produced widely different cost estimates for specific EPA standards such as those concerning fugitive emissions, storm runoff, and BAT requirements for air- and water-quality control .37
  - —Industry-sponsored economic impact studies of the proposed coke oven standard included capital costs for automatic and remote control systems that, according to the United Steelworkers of America, would only be required of new and rehabilitated batteries.[38]
- Differing allocation of joint costs for productive and control equipment.—This is an issue whenever investments are made in new production processes simultaneously aimed at improved productivity and environmental compliance. Examples include capital costs for waste-product recycling systems and perhaps even electric furnaces. Available time series on investments in regulatory equipment attempt to allocate costs on a functional basis. It appears, however, that steel companies tend to allocate joint costs disproportionately to the regulatory function, thereby overestimating compliance costs. For instance, the EPA Enforcement Office argues that AISI charged the cost of facility closures, modernizations, or replacements as environmental costs even though substantial production benefits may be realized. If steel industry modernization programs are stepped up in response to growing demand, the issue of proper allocation of joint costs will grow in importance.
- Lack of access to independent industry data.—In its 1977 report on EPA, the National Academy of Sciences noted that:

  > EPA is inevitably dependent on the industries it regulates for much of the technical and economic information it uses in decision-making (among others with respect to) the assessment of the costs and technical feasibility of pollution processes to achieve pollution control. The impact of many decisions on industry creates a potential conflict of interest that may cause industry either inadvertently or intentionally to distort or withhold necessary information.

  The Academy recommended that:

  > EPA should develop sufficient scientific and technical expertise with the Agency

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[36] *Federal Register*, Oct. 22, 1976 p. 4674846749; Temple, Barker, and Sloane, "The Financial Impact of Proposed Coke Oven Standards on the U.S. Steel Industry, " report prepared for AISI n.d., p. 7; Policy Models, Inc. *A* Methodological Approach *for* Use in Assessing *Impact of* Government Regulation *of* the *Steel* Industry, report prepared for the Council on Wage and Price Stability, 1977, p. A-33.

[37] Organization for Economic Cooperation and Development. Emission Control Costs in the *Iron* and *Steel* Industry, Paris, 1977, p, 151.

[38] *Federal Register*, Oct. 22, 1976, p. 46749; Policy Models, Inc., op. cit., p, A-9; Federal Register. Oct. 22, 1976, p. 46748.

> or through independent institutions (and that EPA) should institute procedures to assure the quality, reliability, relevance and completeness of data provided by industry for EPA's use.[39]

Similar observations very likely also apply to OSHA. Both agencies have taken steps to strengthen their economic analysis activities in response to the growing interest in the economic implications of regulatory requirements.

It is important to recognize that projections are essentially best available estimates of predicted industry regulatory investments. Not only do projections differ between sponsoring organizations and over time, they also appear to be higher than actual expenditure reports with they attempt to predict. EPA recently reported that steel producers spent less money meeting antipollution regulations than either the industry or EPA had predicted. The Agency found that for the 1975-77 period, industry investment estimates for water pollution control were three times higher than actual costs incurred. EPA estimates were about 1-1/2 times higher than actual steel industry regulatory expenditures. *

Future steel industry investment in regulatory equipment is, according to Federal estimates, expected to increase by 13 percent to about $550 million annually until the mid-1980's. The industry, on the other hand, expects that future levels will be almost double current investments, averaging $800 million per year (see table 145).

While U.S. regulatory investments are expected to increase over the next several years, Japanese steelmaker are beginning to experience the opposite trend. The financial burden of pollution abatement seems to have been highest in Japan from 1971 through 1976 (table 146). These efforts were closely linked to the installation of new equipment; upon completion of the last expansion projects in 1977, the industry's pollution control expenditures have declined significantly and recently they have been below those of the American industry. Because American steel firms are still in an earlier stage of complying with regulatory requirements, their expenditures for this purpose are likely to remain for some time at a considerably higher level than those of Japanese firms. In Japan, where a large portion of capacity is of relatively recent vintage, antipollution devices could be designed to fit the new equipment. This has led to lower costs per tonne of steel produced than the retrofitting of such devices on old equipment. Moreover, a greater effort was made in Japan than elsewhere to utilize captured waste gases for power generation; this reduces the requirement for purchased energy and thus helps offset to some extent the cost of operating the antipollution equipment .[40]

Using AISI and EPA projections for the distribution of regulatory investments over time, 1983 annualized air and water pollution abatement costs (operation and maintenance) are expected to be around $4.2 billion and

Table 146.—Steel Industry Environmental Control Investment Outlays: United States and Japan, 1970-71
(in millions of dollars and as a percentage of total capital expenditures)

	1977	1976	1975	1974	1973	1972	1971	1970
United States	$407.6	$489.2	$453.0	$198.8	$100.1	$201.7	$161.5	$182.5
	17.5°h	15.OYO	14.2%	9.4%	7.1 %	17.170	11 .30/0	10.5%
Japan	555.3	920.1	685.2	555.6	367.9	284.4	219.2	NA
	15.2	20.6	18.4	18.6	17.3	13.4	8.9	NA

NA = not available

SOURCES American Iron and Steel Institute, *Annual Statistical Report,* 1978, Hans Mueller and Kiyoshi Kawakito, The *International Steel Market Present Crisis and Outlook for the* 1980's, 1979, *p.* 27.

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[39] National Academy of Sciences, Decision Making in the Environmental Protection Agency, 1977, vol. II, p. 12.

*Washington Post, June 19, 1980, p. A7.

[40] Hans Mueller and Kiyoshi Kawakito, The International *Steel* Market: Present Crisis and Outlook *for* the 1980's, Middle Temessee State University, conference paper No. 46, 1979, pp. 26-27.

$3.8 billion, respectively. AISI 1983 capital recovery estimates for pollution abatement equipment are a higher proportion of total annualized regulatory costs than is the case for EPA estimates. This difference reflects the higher cumulative capital investments and capital costs assumed by the steel industry (see table 143). The AISI data show a 66-percent increase in annualized pollution abatement costs between 1979 and 1983, while EPA data suggest that annualized costs will not quite double during this period (see table 143). The EPA trend may be the more accurate one because its data are based on gradually increasing costs that anticipate compliance with the more stringent environmental requirements of the mid-1980's.

EPA projections for cumulative 1979-83 capital recovery and operating costs for clean air and water compliance are within 10 percent of the AISI projections, and future steel production cost and price impacts are projected to be rather similar. Using AISI and EPA data, annualized clean air and water compliance costs are expected by 1983 to add 7.3 and 6.6 percent, respectively, to steelmaking costs. If these regulatory costs are fully passed on to consumers, steel prices are expected to increase between 6 and 7 percent (see table 143).*

There are no comprehensive cost projections for all OSHA standards applicable to the steel industry, although individual future cost estimates are prepared during the standard-setting process. A major standard that is presently operational is for the reduction of coke ovens emissions. An OSHA-sponsored estimate suggested in 1975 that this standard would impose annual capital and operating costs of at least $22o million.[41] The benzene standard, now being considered by the Supreme Court, is not expected to impose additional capital requirements on the steel industry because of its compliance overlap with the coke oven standard.[42] If implemented in its present form, the benzene standard could add between $5.5 million and $6 million per year in steelmaking costs. Cumulative annualized capital and operating costs for coke oven and benzene standards are expected to be around $275 million per year (1978 dollars).

Still further into the future are regulatory costs for compliance with final OSHA noise standards, which are still being developed. One source estimates a compliance cost impact of about $100 million annually. *

Financing of Regulatory Equipment

One important option often overlooked when analyzing steel industry regulatory capital requirements is IDB financing.[43] Such financing reduces the need for internally generated capital for investments in regulatory technologies. IDBs make large amounts of outside funds available at low cost and for long periods of time.

All types of permanent facilities, such as piping, pumping, and treatment units, can be financed with such bonds. During the early 1970's, Congress authorized State and local governments to sell IDBs to help companies obtain the financing needed to meet Federal pollution control requirements. The public entity issues tax-exempt revenue bonds, repayment of which is based solely on the credit of the business. The public entity is the nominal owner of the property which is conveyed to the business under a lease, lease purchase,

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*Preliminary EPA estimates suggest that air and water control requirements will increase steel prices by no more than 4 percent. (EPA, Industrial Analysis Branch, letter to OTA, Mar. 18, 1980,)

[41] OSHA estimates annual capital and operating costs of $218 million, and AISI estimates $1.28 billion. Expressed as a price increase per tonne of coke produced, OSHA anticipates a $2.75 increase and AISI an increase of $14.62. OSHA attributes its estimated increase largely to a projected 18-percent decrease in the productivity of the coking process, AISI's estimate, on the other hand, is based on cost increases associated with reduced productivity, external financing costs, and price increases to raise the rate of return on investment to the manufacturing average of 12.4 percent. (Federal Register, Oct. 22, 1976, p. 46749; Temple, Barker, and Sloane, op. cit., p. 6: Policy Models, Inc., op. cit., p. A-33.)

[42] OSHA, *EIS:* Benzene Standard, vol. 1, pp. 5-6.

*The final noise standards are expected to be quite different from the proposed standards, and final cost projections are likely to differ as well.

[43] For instance, OSHA- and industry-sponsored cost impact studies of proposed coke oven regulations differed in their treatment of IDBs. (*Federal* Register, Oct. 22, 1976, pp. 4674846749; Policy Models, Inc., pp. A-9-Io; Temple, Barker, and Sloan, op. cit., p. 7.

installment sale, or similar contract. The business may also obtain tax advantages, such as the 5-percent investment credit and accelerated amortization. The Internal Revenue Service determines whether the interest paid to bond purchasers is subject to income tax.[44] On average, IDBs mature in 23 years and have an average interest rate of 6.8 percent.[45]

All major industries have increasingly relied on low-cost IDB financing to help meet capital requirements for regulatory compliance. Between 1971 and 1977, the steel industry obtained at least $960 million in outside funds through IDB financing. This amounts to 48 percent of past annual pollution abatement investments. IDBs continue to be more attractive to the steel industry than available fiscal alternatives including a recent revision of the tax code which increased the investment tax credit for pollution abatement equipment from 5 to 10 percent. The steel industry's potential tax savings from this source, estimated at $6.5 million for 1978, are not likely to be realized because of the continued industry preference for IDB financing.[46] Continued IDB financing for environmental equipment could reduce future capital requirements from internal sources by the same 48 percent, thereby reducing total internally generated capital needs. *

Future capital shortfalls that may result in part from regulatory compliance are affected by broader industry trends in shipments and profitability. These trends are heavily influenced by industry investment strategy and also by Federal price, tax, and trade policies. Regulatory costs are of concern to the steel industry in part because these expenditures may divert capital from the industry's replacement and expansion plans. Capital diversion, however, is a relative concept. Since the Renewal scenario discussed in chapter 10 projects lower total capital needs than the High Investment scenario for the 1978-88 period, the former would involve a greater proportionate diversion of capital from replacement and expansion to regulatory compliance than the latter. Government and industry regulatory capital need projections of $550 million and $800 million annually would be 18 percent and 26 percent respectively of the total capital needs under the Renewal scenario, but 11 percent and 16 percent respectively under the High Investment scenario. However, since the Renewal scenario emphasizes expansion by means of nonintegrated plants, regulatory capital needs may be less than even the $550 million of $800 million projections.

Conclusion

Federal projections for meeting OSHA and EPA steel industry standards suggest that by 1985 annual investments for regulatory compliance will increase by 13 percent over 1978 levels, to about $550 million, while the steel industry predicts that by 1985 capital spending for a broader range of regulatory requirements will increase by 35 percent over 1978 levels, to about $800 million per year.

Federal and industry regulatory investment projections may be integrated with the Renewal and High Investment scenarios discussed in chapter 10 to determine the magnitude of future capital diversion from steel industry modernization to regulatory compliance. Industry data suggest that in 1988, capital diversion from modernization to compliance would have increased by 2 percent to a total of 16 percent. Federal data, when integrated with the lower Renewal scenario, suggest that capital diversion could increase by as much as 4 percent to a total of 18 percent. However, when integrated with the more costly High Investment scenario, Federal estimates of capital diversion from modernization to compliance could decline by more than 2 percent to slightly below 12 percent.

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[44] EPA and the Council on Environmental Quality (CEQ), Federal Assistance *for Pollution* Prevention and Control, 1979, p. 9.

[45] EPA, Office of Planning Management, informal survey, 1980.

[46] To receive a 10-percent investment credit, steel companies must choose between IDB financing and 5-year amortization. (EPA and CEQ. Ibid, p. 9).

*See ch. 10, table 135.

These divergent conclusions arise in part from differences in estimates of total capital need and also from the omission of solid waste and other emerging regulatory costs from available Federal projections. A final reconciliation of these divergent conclusions may have to await the time, just prior to implementation of standards, when requirements will be firm and qualifying control technologies will be known,

Regulatory Requirements and Modernization

Summary

Environmental policies have thus far had a greater impact on steel industry investment decisions than have those administered by OSHA. To the extent that industry has responded to these policies by making investments in retrofit equipment, they have generally increased production costs, and modestly decreased labor productivity. On the other hand, the need for selective facility replacement has made it necessary to enter into environmental agreements earlier than might otherwise have been the case. Industry economics are presently such that it can be cheaper and more productive to replace rather than retrofit in order to comply with environmental standards. In this sense, regulations have accelerated industry modernization. Regulatory requirements have had their most serious impact on integrated companies with a large proportion of aging facilities; they have affected nonintegrated electric furnace producers less than other industry segments.

Three major policies are currently of special concern to the steel industry, all of which pertain to EPA air quality matters. The cost effectiveness of the revised offset policy has become well established, but potential difficulties remain should a steel company wishing to expand have to "buy" emission offsets to compensate for the additional pollution expected from a planned facility, EPA's bubble concept promises cheaper compliance options for existing and replacement facilities, but there is some concern about possible tradeoffs between different types of pollutants within the same plant. And finally, the limited-life facilities policy is of major concern to the industry because there is no alternative phase-out schedule for marginal plants beyond the 1982 statutory compliance date.

Limited Modernization

Regulatory policies, particularly those of EPA, appear to have slightly accelerated the steel industry's modernization process. EPA issues construction permits for new or expanded facilities, while OSHA enforcement activities are limited to inspection of existing production facilities; the latter do not directly affect construction or expansion plans. OSHA does have an indirect impact on industry modernization plans because regulatory requirements become effective as soon as a new facility is operational.

The most apparent effect of environmental regulations on modernization has resulted largely from recent EPA/industry settlements, which included the closing of old, heavily polluting facilities and the construction of modern replacement facilities. For instance, during the fall of 1978 EPA concluded an agreement with Republic Steel committing the company to the construction of a new electric furnace shop and related facilities in one location while phasing out outdated coke batteries, suiterplants, and blast furnaces elsewhere by 1982.

With a high proportion of outdated facilities, for which retrofitting is not cost effective, the industry is poorly equipped to respond to present high demand for steel products and the anticipated greater demand of the 1980's. The need for facility replacement has led the industry to comply by selectively updating or modifying existing plants: most commonly, outdated integrated facilities such as coke ovens, blast furnaces, and open hearths have been replaced by less polluting electric furnaces requiring comparatively low capital investments.

Both regulatory requirements and industry economics influence industry investment decisions. The industry reports that 1.3 percent of all steelmaking capacity was phased out between 1973 and 1975 because of regulatory requirements; subsequent shutdowns for this reason have been of a much smaller magnitude.[47] A 1978 EPA survey, however, found that market conditions and business considerations were major factors in phaseout and replacement decisions that were in part spurred by environmental requirements. The survey identified 28 facilities, owned by 12 companies, with one or more processes that may close down or be replaced; it was found that contributing business factors included the availability and cost of transportation, changing market conditions, and corporate investment plans for replacing antiquated facilities or rounding out existing facilities. In some instances, plants were found to be either so outdated or in such dire financial straits that shutdown would simply be inevitable regardless of EPA action.[48]

Industry's view is that if compliance has to be achieved, it should be accomplished by making "safe" investments that require comparatively small layouts and fit into a plant's existing infrastructure. Along these lines, electric furnaces have frequently turned out to be an economically more attractive compliance option than extensive rehabilitation of old facilities or replacing them with identical new facilities.[49] Initial capital investment and operating costs for electric furnaces are relatively low, and their return on investment as a replacement for outdated facilities is generally very satisfactory.

Industry Differences

EPA and OSHA regulations often affect different steel companies and plants in different ways. OSHA regulations, in particular, have a greater impact on integrated plants than on nonintegrated or alloy/specialty companies. The degree of process integration and the age of the facilities are two of the most significant determinants of regulatory expenditures different companies face.

Degree of Process Integration.—It appears that environmental requirements are a more significant element in the cost of steel for integrated plants than for the smaller nonintegrated plants, which involve a less complex range of steelmaking processes. Furthermore, pollution abatement in these plants is already quite efficient because most of their control equipment was designed for installation at the time of construction.

AISI data show that environmental cost impacts are more severe for nonintegrated than for integrated plants, but independent OTA data indicate there is little difference between segments when considering environmental investments relative to replacement value. However, when considering sales the OTA data show a lower cost impact for nonintegrated plants. AISI data show that current environmental costs are about 7 percent of replacement value for integrated plants and 15 percent for nonintegrated plants. OTA data show that nonintegrated environmental costs would be no more than 7 percent of replacement value, approximating those of integrated mills. This comparison of environmental cost relative to capital cost is clouded, however, by the fact that nonintegrated plants have lower capital costs per tonne of steel produced than integrated producers. Comparing the environmental costs relative to shipments, AISI data suggest that the segments are affected about equally, at about 5 to 8 percent. OTA data, on the other hand, show that environmental costs can be as low as 0.5 percent of shipment costs for nonintegrated plants equipped with wastewater recycling equipment (table 147).

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[47] McGraw Hill, 1st through 7th annual surveys of *Investment in Occupational Safety and Health*, 1973-79.

[48] EPA Enforcement Office, *Steel* Documentation *Book*, 1979.

[49] *Steelmaking* Today Supplement, Sept. 24, 1979, pp. 3-4A; "Bethlehem Steel to Add Minimill Capacity," New York *Times*, Aug. 7, 1979.

Table 147.—Type-of-Plant Differences in Pollution Control Capital Costs (1979 dollars)

	Number of plants		Capital costs (millions of 1979 dollars)		Percentage of replacement value		Percentage of total shipment cost	
Facility type	AISI	OTA	AISI	OTA	AISI	OTA	AISI	OTA
Integrated	33	—	$4,572.0		6.9%	—	7.6%	—
Nonintegrated[a]	8	5	54.0	$9.16	15.0	6.7%	5.0	0.4%

NOTE Investment levels reflect approximate 1979 practices The AISI data are based on 1975 information, validated in a 1978 study and adjusted for changes in the producer price index for capital goods.

aThese plants are all equipped with wastewater recycling equipment and have zero discharge. Thus, environmental capital and operating costs only pertain to meeting air quality standards.

SOURCES: Arthur D Little, Steel *and the Environment. A Cost Imrpact Analysis,* 1975, revised 1978; OTA data from confidential communication with major nonintegrated steel company

Changes in annual unit costs for emission control will be greatest for finishing facilities because fluctuations in the rate of capacity utilization are greatest for this equipment. As the operating rate goes down, the annual cost of pollution abatement equipment per tonne of steel produced will increase.[50]

Age, Economies of Scale, Location, and Financial Performance.—In some instances, the oldest equipment bears a disproportionate cost burden because of comparatively high retrofitting costs. Frequently, compliance is made easier by replacing outdated equipment with more efficient and less polluting facilities. Unit pollution abatement costs tend to be lower for new facilities in part because they are larger than the old facilities: various engineering estimates indicate that a 100-percent increase in operating capacity can lead to a 20- to 25-percent decrease in unit treatment costs for airborne pollutants. Economies of scale for waterborne effluent control are somewhat higher—25 to 30 percent.[51] The geographic location of a firm's steel-producing capacity also can materially influence regulatory cost impacts. Water pollution control, for example, is often less costly in dry regions, where natural evaporation can inexpensively reduce the volume of discharge. Smaller and older integrated firms are most severely affected by regulatory cost impacts because they frequently have limited, if any, financing options for investments in newer and safer steelmaking technologies. Financially and technologically weak firms may have no choice but to undertake relatively inexpensive stopgap measures, which tend to be counterproductive to the long-range goals of a viable business enterprise.[52] As a result, their relative positions in the industry may slide even further.

Potential Modernization Problems

In response to private-sector concerns that EPA's offset policy for new facility construction would preclude such activity in heavily polluted areas, the Agency revised its policy in 1977. Under the revised offset policy, new construction is allowed if the new facility uses very stringent emission controls and if more than equivalent reductions are made from existing sources owned by the same or different companies in the same or contiguous States. Virtually all recent EPA/industry consent-decree settlements have provided for industry investment in new facilities that follow offset policy principles but attain some net reduction in area emissions.

It is not expected that the revised offset policy will inhibit new facility construction on the basis of regulatory cost considerations alone. There was concern that the requirements for new facilities were too stringent, and thus too costly, compared to requirements for existing plants. Following this reasoning, the more stringent requirements generally applicable to new steelmaking facilities could encourage firms to defer new construction. Thus, firms could continue operat-

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[50] OECD, op. cit.

[51] Ibid., pp. 88-90.

[52] N. A. Ashford, *Crisis in the Workplace: Occupational Disease and Injury* (a report to the Ford Foundation), Cambridge, MIT Press, 1976, p. 315-316.

ing their older, less efficient plants longer than they might have in the absence of these stringent requirements. This reasoning seems to suggest that environmental requirements alone can shape investment decisions. However, investment decisions are based on overall cost (rather than merely environmental cost) for new or existing plants and on the rate of return on alternate investments. Relative stringency of environmental requirements is only one of several factors influencing such decisions,

A 1979 EPA-sponsored report analyzed investment scenarios for certain steelmaking processes by comparing environmental cost requirements of retrofit with new facility replacement.[53] The authors found that only two investment options were attractive (using typical industry criteria for return on investment), and neither of these options favored retrofitting as a favorable way to meet environmental requirements. The preferred options were: 1) replacement of conventional casting processes with continuous casting and 2) contraction of existing facilities coupled with construction of new electric furnaces. Steelmaker are in fact actively pursuing the latter option, thereby implicitly confirming EPA's conclusion that replacement can provide a more attractive return on investment than the alternative of retrofitting aging equipment—despite the fact that such replacement facilities would have to meet more stringent environmental standards.

The revised offset policy might still create difficulties should a company decide to expand its productive capacity to a point that would create additional pollution. Preliminary EPA findings, however, suggest that most steel plants will be able to find internal offsets for expansion under the revised offset policy, and the few plants unable to develop internal offsets would be able to trade offsets with other plants.[54] The major concern may not be with the availability of tradeoffs but with the cost of trading emission offsets between companies. If unable to efficiently develop internal tradeoffs, a steel company might have to "buy" emission offsets from establishments that are able to control pollution more cheaply and effectively, thus placing an extra economic burden on the industry. Although a "market" in offsets might minimize the total cost of achieving emission reduction in a region, steel producers would probably pay a relatively high price because of the complexity and high cost of pollution abatement in the industry.

Recently EPA also. adopted the "bubble concept" for existing plants and replacement facilities. The bubble concept applies the offset principle at the plant level and enables EPA to regulate entire plants as single sources rather than as a collection of separate emission points. This approach increases regulatory flexibility by enabling the industry to impose stringent controls where it is least costly and to relax controls on emission points with similar pollutants but higher control costs. Because it emphasizes cost effectiveness, EPA expects that the bubble concept will provide industry with increased incentive for innovation in environmental control technology.

The bubble concept is particularly appropriate for steel mills because of the many emission sources in a typical plant. Recent EPA analyses suggest potential cost savings of 5 to 11 percent, or $1.2 million to $1.9 million per year, for moderate controls on average-size integrated plants in industrialized regions of the country. Potential cost savings for nonintegrated minimills are 20 percent, or $20 million per year, for stringent controls.[55] The flexibility inherent in the bubble concept would also apply to equipment replacement: rather than replace old facilities and control the new source of emissions, management could opt to install other new equipment with

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[53] Mathtec, Inc., "The Effect of New Source Pollution Control Requirements on Industrial Investment Decisions," report prepared for EPA, 1979, p. 76.

[54] EPA, Industrial Analysis Branch, letter to OTA, Mar. 18, 1980.

“Putnam, Hays, and Bartlett, "An analysis of the cost impact of plant-wide emission controls (the bubble concept) on four domestic steel plants," prepared for the Economic Analysis Division of EPA, 1979.

tighter and less costly controls elsewhere in the plants.[56]

The steel industry is also concerned about the impact that the limited-life facilities policy will have on modernization. This policy does not provide the special treatment for aging plants that industry has sought; it merely permits the conditional operation of noncomplying facilities for which there are agreements involving replacements or phaseouts no later than December 1982.[57] Implementation of this policy may accelerate the closing of old, inefficient facilities and thereby increase the productivity of the industry. The leadtime is short, however, possibly to short for the timely replacement of aging facilties with major new facilities. There is considerable concern that large replacement expenditures crowded into short periods may overtax the financial capability of the industry and further capacity contraction.

Like EPA, OSHA does not exempt marginal, noncomplying facilities whose planned phaseout is beyond applicable compliance deadlines. OSHA appears to have greater administrative flexibility than EPA, however, because the duration of variances for individual facilities is not specified in the authorizing legislation. An executive task force reviewing OSHA regulations has recommended that:

> OSHA begin to identify standards for which compliance could be mandated in tandem with normal equipment replacement cycles instead of by retrofitting.[58]

OSHA may issue variances aimed at innovative compliance approaches on a case-by-case basis or perhaps, industrywide by considering modernization rates. Informal OSHA comments suggest that, until recently, variances may have been under utilized.

Current enforcement and compliance activities may also have a serious impact on future coke and scrap problems if they fail to give sufficient consideration to new substitute steelmaking technologies. A number of steel companies have found it profitable to construct additional cokemaking capacity, because the use of company-owned coal and the sale of coke byproducts generate fiscal benefits and additional revenues that can far outweigh the regulatory costs associated with cokemaking. However, a more prevalent response to regulatory and market forces has been to install electric furnaces to replace outdated integrated equipment like coke batteries, sinter plants, and blast furnaces—industry economics are presently such that it is often cheaper to build electric furnaces than to retrofit or make replacements in kind. As a result, U.S. coking capacity declined from 61 million to 49 million tonnes between 1975 and 1978. Domestic coke supplies are now being supplemented with imported coke, some of which is processed abroad from American metallurgical coal. Growing use of scrap will help offset some of the anticipated coke shortage while undoubtedly also contributing to increases in the price of scrap. Industry and EPA alike have underassessed the long-term raw material pressures and the technological alternatives that could reduce the likelihood of future shortages or price increases. One of these alternatives, continuous casting, reduces the need for coke and other process materials by increasing yield. Improved coke rates in newer blast furnaces will also help reduce the need for coke. Still another option, domestic or imported direct reduced iron, could be used as a superior complement to limited scrap supplies. Although major integrated companies have made only minimal efforts in these areas, smaller firms are actively pursuing continuous casting and considering the merits of direct reduction.

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[56] *33 Metal* Producing, January 1980, p. 23.

[57] Industry sources suggest that large-scale retrofitting of old facilities is less often required abroad than in the United States. Old plants, particularly in Japan, have to be retrofitted only to meet the most serious violations. (AISI, *Steel* at the Crossroads, prepublication draft, 1979, p, II-7.)

[58] Interagency Task Force on Workplace Safety and Health, "Making Prevention Pay, " 1978, p. I-3.

Conclusion

Regulatory requirements have been and will continue to be a major cost burden on the domestic steel industry. As additional pollution control equipment is installed during the next few years, the industry's capital, operating, and maintenance costs will increase accordingly. Future industry decisions regarding facility replacement, capacity expansion, and selection of steelmaking technologies, as well as trends in productivity and shipments, will all have some influence on future capital investments for regulatory compliance. Federal agencies expect that regulatory investments for air, water and coke oven pollution abatement will increase modestly to around $550 million per year by the mid-1980's. These estimates do not include anticipated capital investments for emerging requirements, including those for noise abatement and hazardous solid waste disposal. Industry projections suggest that regulatory capital investment will increase by almost 60 percent to $800 million annually to meet all present and future requirements. IDB financing, heavily used by the industry as a source of regulatory capital, will help offset potential financing problems. Once compliance has been achieved by the mid-1980's, pollution abatement equipment investments could well level off, while operating costs—depending on the replacement rate—could either level off or increase.

Had these requirements emerged during a period of vigorous industry renewal and expansion, their costs would have been considerably less burdensome. Retrofitting, the prevailing compliance approach, is not a very economical way of responding to Federal mandates. Additional RD&D is needed to find and encourage the use of more cost-effective, high-performance regulatory technologies. The potential private gains from regulatory research are limited, however, and the industry prefers to use already available control systems. Future industry decisions regarding replacement and expansion, its selection of steelmaking technologies, and trends in its productivity and shipments will heavily influence future capital investment for regulatory compliance.

Federal regulations, particularly those administered by the EPA, have in effect forced companies that wish to modernize or expand to enter into compliance agreements with the Agency. This has accelerated industry phaseout and replacement of marginal facilities, so that environmental and occupational policies have had beneficial, as well as detrimental, effects on the industry. Economic considerations have recently been receiving greater weight in the identification of qualifying control technologies, and the industry hopes that the feasibility of future regulatory technologies will also be fully considered.

CHAPTER 12

Employees and the Development and Use of New Technology

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CHAPTER 12

Employees and the Development and Use of New Technology

Summary

An industry's human resources are a vital factor in its ability to develop and adopt more competitive process technologies or to produce improved products. Steel industry personnel may be differentiated on the basis of education and compensation method. For the purposes of this study, technically trained personnel are employees with academic degrees in physical or computer sciences or engineering disciplines. Also included in this category are nondegree salaried employees, such as "melters," who have a high degree of technical expertise, training, and responsibility. Employees in the labor category generally have lower levels of education than technical personnel and are paid on an hourly basis.

The steel industry uses smaller numbers of technically trained personnel, and those personnel have lower levels of education, than is typical of most other industries. Slightly more than half of all technical personnel are employed in production and quality control, followed by somewhat less than one-fifth in engineering and R&D. Integrated firms employ large numbers of technical personnel in production, while alloy/specialty firms have a high proportion in quality control and marketing. These differences in the use of technical personnel are, to some extent, a reflection of the relative importance of these areas to the two industry segments. The nonintegrated segment employs the fewest technical personnel, consistent with the greater simplicity of both its processes and its products.

Research personnel are mainly responsible for market-oriented research that will lead to evolutionary changes in process and product. Their number declined during the early 1970's and has since slowly climbed back to **1970** levels.[1] Steel-related research in foreign nations provides more long-term intellectual and professional opportunities for technically trained personnel than in the United States. This may be attributed to greater government support for research abroad and also to the greater involvement of foreign steel companies in the sale of machinery and technology.

Opportunities for personnel-based technology transfer in the United States are limited, partly because movement by technical personnel into steel from nonsteel high-technology industries is negligible, and partly because the support given to continuing education by the steel industry is generally limited. A technical manpower shortage, now developing in a few selected areas, could become serious if the industry were to embark on vigorous modernization, R&D, and innovation programs.

The adoption of new steelmaking equipment or technology affects steelworkers in the labor category in several ways. Retraining programs may be needed and job classifications may need to be changed to accommodate skill changes. Plant labor practices need to allow for greater flexibility in work assignments.

There is some concern, particularly among those in the academic community familiar with the steel industry, that apprenticeship and retraining programs do not adequately train people for changing job requirements associated with the adoption of new technologies. On the whole, however, it appears that labor conditions have not been a constraint

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[1] Bureau of the Census, "The Number of Scientists and Engineers in the Basic Steel Industry, 1970-1977," 1978.

on the adoption of new or more modern steelmaking equipment. Job classification schedules are periodically updated to accommodate gradual shifts in skill requirements resulting from technological change; and local practices do change, at least among those immediately affected, to allow for the efficient introduction of new technologies.

Technically Trained Personnel

OTA's information on technical personnel is largely based on a representative sample of companies responding to a written survey conducted by an OTA contractor. The companies covered in the survey represent close to 60 percent of the integrated producers, almost one-fourth of the nonintegrated firms, and more than one-third of the alloy/specialty companies. The information gathered was used to examine the adequacy of prevailing levels of education and training, technical manpower use patterns, and present and future technical personnel needs.

About 10 percent, or 16,000 employees, of the integrated companies are technical personnel. The greatest use of technical personnel by integrated steel companies is made by large plants with advanced technological bases. For the other two industry segments, the percentage of technical personnel ranges between 3 and 4 percent (table 148).

These figures are consistent with data on the profitability y of the three segments (see ch. 4): the low employment costs of nonintegrated producers contribute to their greater profitability, and the same appears true for the alloy/specialty producers. The most likely explanation for this pattern is that these two segments are largely free of the need for technical personnel in the primary, ironmaking stages of the industry; moreover, there is evidence that these two segments have made greater use of equipment suppliers for much of their technical support, particularly in the development of steelmaking furnaces.

The employment figures are also consistent with the lower capital costs for modernization and expansion in nonintegrated versus integrated plants (see ch. 10). As a result, OTA's Renewal scenario, with its emphasis on the nonintegrated segment, would have lower technical personnel requirements than the High Investment scenario, and its lower capital costs would be paralleled by lower employment costs.

Education

Compared to other manufacturing industries, the steel industry employs small numbers of technically trained personnel. Based on its total work force, the industry employs only about 60 percent as many scientists and engineers as the average manufacturing industry. This compares to 220 percent for petroleum refining, zoo percent for chemical and allied products, and 130 percent for electrical equipment.

The steel industry also relies more heavily on scientists and engineers with 1 to 3 years of college than is typical of manufacturing in-

Table 148.—Steel Industry Technical Personnel: Proportion in Total Work Force; Tonnes per Technical Personnel, 1979

	Integrated carbon steel	Non integrated carbon steel	Alloy/specialty	Total
Percent of technical personnel in total work force.........	**9.60/.**	**3.3%**	**3.60/.**	**8.71%**
Tonnes per technical employee	*2,256.3*	11,947.2	*2,131.8*	*2,352.3*

SOURCE: OTA contractor report by F A Cassell, et al, dustries in general.[2] For example, about 5.4 percent of the aluminum industry's work force has completed a 4-year college education in science or engineering, but this is the case with only 3.9 percent of all steel industry employees. Technical personnel with undergraduate degrees make up three-fourths of the steel industry's technical staff. They are well represented in production, but less so in engineering, R&D, and administration. Only 12 percent of all technical employees have graduate degrees—mostly at the Master's level. Larger companies tend to have more personnel with graduate degrees (table 149). Significantly, slightly more than 4 percent of technical employees have nondegree technical training.

The largest numbers of technical employees in the steel industry are mechanical and electrical engineers and material scientists (including metallurgists). A much smaller number are chemists and chemical engineers, and even fewer mining engineers and physicists work for the steel industry. In recent years, steel companies have brought in computer specialists, electronic engineers, and pollution engineers (table 150). With the exception of researchers, nearly all technical personnel are recruited upon graduation from college.

For steel-related technical input, the steel industry also relies heavily on domestic equipment manufacturers and engineering-construction firms, many of which are associated with foreign engineering firms and increasingly with foreign steel companies and equipment manufacturers. Domestic equipment companies have rather limited R&D programs. They tend to promote from within and maintain stable engineering groups, although their blue-collar work force may fluctuate

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[2] Bureau of the Census, *1970 Census of the Population: Industrial Characteristics*.

Table 149.—Technical Personnel; Degree and Work Assignment

	Engineering R&D	Administration	Sales/ marketing	Production	Quality control	Other	Total		Employees in top management	
							Number	Percent	Number	Percent
Integrated										
Ph. D	222	12	3	15	8	5	277	3.1	26	9.4
M.S./M.A. .	382	104	43	199	53	64	845	9.5	71	8.4
B.S./B.A.	1,041	807	377	4,480	502	347	7,564	85.0	321	4.2
Associate ...	11	10	1	65	3	—	90	1.0	—	—
Nondegree	11	8	–	99	3	3	124	1.4	3	2.4
Total. . .	1,667	'94 1	424	4,858	569	419	8,900		421	
Percent of total	(18.70/~)	(10,6°/0)	(4.80/~)	(54.60/')	(6.5°/0)	(4.7°/0)			(4.7°/0)	
Nonintegrated										
Ph.D.	—	—	—	l	—	—	1	0.5	1	100.0
M.S./M.A, ...	4	2	–	3	3	4	16	7.8	8	50,0
B.S./B.A. .	21	25	9	23	12	31	121	58.7	20	16.5
Associate	3	—	3	4	—	10	20	9.7	—	—
Nondegree . . .	5	1	—	20	3	18	48	23.3	1	2.1
Total.	33	28	12	50	18	81	206			
Percent of total	(16.0°/0)	(13,6°/0)	(5.8°/0)	(24.3°/0)	(8.7°/0)	(39.3°/0)			(1 4.%₀)	
Alloy/specialt y										
Ph.D.	23	1	2	1	1	1	29	2.6	6	10,7
M.S./M.A.	24	5	5	10	5	5	54	4.8	2	3.7
B.S./B.A.	137	123	101	190	122	19	692	61.8	51	7.4
Associate	20	9	9	25	5	3			—	—
Nondegree . . .	18	62	69	69	45	11	274	24.5	1	0.4
Total.	222	200	186	295	178		1,120			
Percent of total	(19.8%)	(17.9%)	(16.6°/0)	(26.3%)	(15.9°/0)	(3.5%)			(5.4%)	

SOURCE. OTA survey, 1979 The sample represents close to 60 percent of the Integrated producers, almost one. fourth of the non!ntegrated producers, and more than one.third of the alloy/specialty producers

Table 150.—Technical Personnel by Degree and Field

	Mat. sci.	Chem.	Comp. sci.	Physics	Chem. eng.	Elect. eng.	Mech. eng.	Ind. eng.	Mining eng.	Other	Total
Integrated											
Ph. D.	85	64	–	14	19	6	17	4	6	**60**	277
M.S./M.A. . . .	99	80	15	18	81	70	93	79	34	**276**	845
B.S./B.A. .	704	514	57	106	523	1,065	1,271	597	158	**2,569**	7,564
Associate .	2	6	9	–	1	16	7	—		**49**	90
Nondegree	6	12	11	2	4	16	12	**6**		**55**	124
Total. .	896	676	92	140	628	1,173	1,400	686	198	3.009	8,900
Nonintegrated											
Ph. D.	1	—	—	—	–	—	—	—	—	—	1
M. S./M.A. . . .	2	2	—	—	—	1	4	2	—	**5**	16
B.S./B.A. . . .	18	7	9	–	–	13	20	17	1	**36**	121
Associate . .	—	—	8	–	–	6	1	1	—	**4**	20
Nondegree .	—	—	14	–	—	—	5	3	—	**26**	48
Total. . .	21	9	31	“ –	–	20	30	**23**	1	**71**	**206**
Alloy/specialt y											
Ph. D.	19	3	–	1	—	—	1	—	—	**5**	**29**
M.S./M.A.	19	4	—	1	—	2	7	**2**	—	19	54
B.S./B.A. . . .	139	34	9	11	22	64	108	**65**	16	223	692
Associate .	3	1	3	1	—	20	8	**5**	—	30	71
Nondegree .	22	6	17	—	—	6	6	**2**	—	215	274
Total. .	202	48	29	14	22	**92**	130	74	16	492	1,120

SOURCE OTA survey, 1979 The sample represents close to 60 percent of the integrated producers; almost one-fourth of the nonlntegraled producers, and more than one-third of the alloy/specialty producers

with changing business conditions. Many engineering-construction firms have broadly trained staffs, skilled in developing, organizing, and executing major projects from planning to startup. These staffs are well informed about new technological developments in steel and they know how such developments can best be incorporated into existing or new plants.

Technical Manpower Use

Production and Quality Control.—The steel industry employs slightly more than half of all its technical personnel in production and quality control (table 149). The industry's orientation toward engineering and product improvement as important means of responding to market needs gives these two functional areas great importance. Employees with responsibilities for technological problems tend to spend most of their time in the role of "firemen, " responding to particular problems at particular shops or plants that are beyond the capability of local operating and engineering managers to solve. Steel industry technical personnel are generally well trained to perform in the existing environment, which emphasizes incremental engineering and product improvements rather than major innovations based on new scientific or engineering knowledge.

Research and Development.—About 18 percent of all technical personnel in the steel industry is employed in engineering and R&D (table 149). There has been no growth in the number of research personnel during recent years. This may be attributed to a real dollar decline in steel R&D expenditures and to the virtual standstill in new plant construction. Not all steel companies even have R&D departments; in some cases, consulting firms are used instead of in-house technical R&D staff.

Steel industry research has been focused for the most part on cost improvement and on new products and alloys, and the development of new processes has been undertaken mostly to achieve these ends. A considerable amount of process research is carried out jointly by several steel companies, the entire industry, or by equipment manufacturers.

Sometimes research personnel undertake specific studies for the purpose of designing new equipment, but more often they function as troubleshooters in defining and solving problems that occur in the course of production with existing equipment. According to industry sources, approximately 20 percent of R&D staff works on meeting environmental requirements. For instance, U.S. Steel estimates that 12 percent of its scientists and 25 percent of its engineers are currently engaged in environmental control activities. The proportion of R&D personnel working on energy-related technologies is unknown.

The industry's orientation towards incremental, market-oriented R&D is generally reinforced by a reward structure that does not encourage independent and creative research. Although R&D and engineering personnel of steel companies may reach management positions by promotion in those units, a more typical route to higher levels of management is for a scientist or engineer starting in an R&D or engineering department to move first into other areas, such as marketing and production, where there are greater opportunities. Thus, competent researchers may not stay in R&D because they are more likely to reach higher salaries and more prestigious positions through other departments. The main disadvantage of drawing directly from R&D staff for management is that technical personnel may not have appropriate expertise for business and policy work. An advantage, however, is that such promotions will lead to greater awareness at the management level of the technological base of the company and a more effective use of technical feedback for process improvement and market development.

Of the steel industry's major international competitors, only the Japanese steel industry has an R&D program that is as strongly market-oriented as that of the United States. France, England, and West Germany have more diversified steel R&D activities, ranging from basic to applied research, than is the case in either the United States or Japan. Foreign steel producers are often the beneficiaries of publicly supported steel-related R&D, and they are also involved to a much greater extent in the sale of steelmaking equipment. All of these conditions combine to make R&D less subject to short-term fluctuations in the business cycle and to create more numerous long-term intellectual opportunities for R&D personnel than is the case in the United States.

Top Management.— Only 5 percent of all technical personnel in the entire industry have top management positions (table 149). Some steel industry analysts and customers argue that the overall influence of accounting and financial executives in the steel industry is far stronger than in the past; others disagree. If this is indeed the case, it is likely a reflection of declining profit margins in the industry and a resulting interest in tighter, more formal budgeting and proposal evaluation. Nevertheless, top executives of many of the most profitable and technologically competitive firms do have technical backgrounds. Although not heavily represented in top management, research department personnel regularly participate in the planning, conceptualization, and specification stages of capital proposals, Their primary functions in this role are to help anticipate technological changes and to evaluate the technological feasibility of various equipment features.

Technological change per se is generally not a primary concern of steel executives. Managers usually make an investment decision on the basis of the general necessity or wisdom of making such an investment, calculated or at least justified in terms of the profits and rate of return to be realized. Financial considerations are given priority, operating considerations are secondary, and technology is at best ranked third. *

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*Important factors encouraging new investment are growth in markets, followed by considerations about the price level of steel. Still another factor affecting the decision to invest in new facilities is the rate of payoff from alternative investment opportunities outside steel. Tax factors also affect the extent and timing of investment in new facilities. The degree of technological change as it affects expected rates of return and risk also has considerable impact on the kind of equipment being acquired, but less so on the extent of investments being made. (D. L. Hiestand, High Level Manpower and Technological *Change in the* Steel *Industry, New* York, Praeger, 1974, pp. 29-30.)

Research personnel are sensitive to the reluctance of steel company executives to adopt new technologies. The receptivity of particular steel companies towards new technology largely depends on the top executives themselves. If top management creates an environment that is receptive to ideas and risk taking, those below them will be innovative; if adventurous planning, operating, and engineering managers are penalized or their suggestions discouraged, they will hold back.[3]

Differences Between Industry Segments

The major industry segments—integrated, nonintegrated, and alloy/specialty companies—show some interesting variations in their use of technical personnel (see table 149). On the whole, these differences are related to the greater complexity of integrated steelmaking and the greater emphasis on quality control and marketing in the alloy/specialty segment of the industry. The most significant differences are in the educational level of the technical staffs and in the way technical personnel are used.

Differences in Educational Level.—In general, lower level technicians are more prevalent in the nonintegrated and alloy/specialty segments of the steel industry, while integrated companies tend to require technicians with undergraduate and graduate degrees. Only about 2.5 percent of all technical employees in integrated companies have limited technical training rather than full degrees. By comparison, almost 35 percent of the technical staffs of nonintegrated companies and about 30 percent of those in alloy/specialty companies do not have baccalaureate degrees. Of those who do have degrees, about 3 percent of those in integrated companies, 8 percent in nonintegrated companies, and 7 percent in the alloy/specialty companies have advanced graduate degrees. One-third of all R&D technical employees in integrated companies have graduate degrees, compared with one-fifth for alloy/specialty companies and only one-tenth for nonintegrated companies.

Differences in Use of Technical Personnel.—Nonintegrated and particularly alloy/specialty companies employ a somewhat larger percentage of technical personnel in administration (14 and 18 percent, respectively) than do integrated producers (11 percent). Of greater interest, alloy/specialty companies use proportionately more technical employees in marketing and quality control than do the other segments (30 percent as opposed to 10 and 15 percent for integrated and nonintegrated firms). Alloy/specialty firms use about three times more of their technical personnel in marketing than do the nonintegrated producers. This is a reflection of the relative importance of product quality and marketing to alloy/specialty producers.

Integrated producers use more than half (about 54 percent) of their technical employees in production, twice the level for the other two segments (about 25 percent). To some degree this difference occurs because integrated companies use more processes than the others, so the technical side of production plays a more important role in their operations.

Although the nonintegrated companies have the smallest number of technical employees in relation to total production, they use a greater fraction of them in top management than do companies in the other steel industry segments. Fifteen percent of all technical personnel in nonintegrated companies are in top management, compared to about five percent for the other segments. Nonintegrated companies thus appear to encourage greater coordination between the economic and technological dimensions of management. One result of this may be the apparent rapid adoption of new technology made available by equipment manufacturers (foreign and domestic) and the constant attempt to reduce costs through technological change.

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[3] D. L. Hiestand, High Level Manpower *and Technological Change* in the Steel Industry, New York, Praeger, 1974, pp. 29-30.

Employment and Continuing Education

Most steel companies have tuition support programs for undergraduate and graduate education. There is generally much less support for publishing in professional journals and for sabbaticals at domestic and foreign universities. Technical personnel in R&D are given some opportunity to attend meetings and conferences, but technical people in other departments tend to have few such opportunities, There is some criticism of the industry because the training and development of technical staff are geared to managerial and executive development rather than to ongoing education in technical specialties. These are the areas viewed by management as the industry's backbone, an orientation reflected in mobility patterns that generally reemphasize R&D.

The steel industry draws only small numbers of technical personnel from high-technology industries, such as aerospace, computers, and electronics, or from similar types of process industries such as chemical, glass, and aluminum. There appears to be a trend among steel technicians toward retiring to Government and university jobs; there is little flow of personnel in the opposite direction. The U.S. steel industry also lacks strong links with other industries, universities, or the Government with respect to midcareer employment or training, This limits the industry's ability to draw on technological ideas originating in other areas or to otherwise strengthen the professional background of its technical personnel. In Europe and Japan, on the other hand, there are opportunities for intersectoral training and mobility of technical manpower; in West Germany, there is much greater opportunity than in the United States for technical talent to move back and forth between Government and industry and between basic and applied research. The underlying goal is to provide industrial activities oriented towards the international market with a strong science and engineering basis. Clearly, this approach allows and even encourages considerable training and technology transfer between different sectors of the economy.

Present and Future Manpower Needs

The steel industry claims that it does not have problems in meeting its current technical personnel requirements. The industry's ability to attract technical personnel in sufficient numbers is in part related to improvements in steel industry pay scales during the 1970's. Starting salaries have become more competitive with those of other industries. Many steel executives make the following manpower assumptions:

- Most or all of the necessary manpower, with the required skills, is already present in the organization.
- If not already available, the necessary skills can be acquired by present employees through training, experience, or other means quickly enough to avoid hindering a project.
- If there are no present employees who can acquire the needed skills quickly and easily enough, trained personnel can be attracted from elsewhere either to meet fully the company's needs or to help develop existing employees.
- If all of the above are inadequate, some other organization can be engaged on contract to meet all of the company's needs or to develop the manpower required.'

Other industry representatives, particularly college recruiters, are concerned that more growth-oriented industries may be attracting the best technical talent. Clearly, the ability to meet personnel requirements does not fully lay to rest the question concerning the performance of the industry's technical personnel—particularly when more sophisticated equipment or processes are involved.

Occupational projections by the Department of Labor show that demand for steel industry professional technical personnel will

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'Ibid., p. 38

increase by 5.6 percent between 1976 and 1985.[5] The use of lower level technicians in control and monitoring of production promises to enlarge. However, most growth and replacement demand is expected to be for chemical, civil, electrical, and sales engineers. This is the result of an ongoing emphasis on the development and application of existing steelmaking technologies.

Research activity in mining and metallurgical engineering is virtually nonexistent; this represents a national weakness in the preparation of sufficient numbers of such personnel. In addition to the lack of manpower, funding is a problem. Given the growing demand for high-performance steels and the growing use of computers in steelmaking, additional shortage areas are likely to include material scientists and electrical engineers familiar with both the industry and process control technology. Anticipated shortages of mining and metallurgical engineers and of process control experts will make it difficult for the steel industry to meet its needs for cost reduction, energy economies, and environmental compliance.

The future availability of technical personnel must also be viewed in terms of alternatives to present industry strategies. Current investment strategies entail leadtimes from concept to installation of new capacity that provide technical personnel with sufficient opportunity to learn what needs to be known about the improved technology. Should the industry decide to shift to a more extensive research program involving a greater emphasis on basic research and accompanied by a vigorous investment program in new steelmaking technology, it is uncertain that present staff would be fully capable of making the transition. Familiarity with fundamentally new technological concepts and completely new skills could be required, and most steel technicians are not now equipped to deal with such new skill requirements. Furthermore, the steel industry could face difficulty in recruiting some types of personnel. Unlike the highly regarded government-supported steel industries in other countries, the U.S. steel industry could have problems in attracting capable domestic technical personnel who now are inclined to work in higher technology, more R&D-intensive, and higher growth industries than steel.

Labor

Generally, steel industry employees in the labor category have not impeded technological change. However, the job classification system and local union work practices, as well as limited familiarity with new technologies, are potential constraints on the flexibility needed to introduce new steelmaking equipment and processes.

Apprenticeships and Retraining

The median age of steel industry employees is higher than the all-manufacturing average.* Nevertheless, a number of companies provide programs for the training or retraining of workers for jobs made more complicated by new technologies.** At one company, a program has been in effect since 1962 to retrain electrical workers for efficient main-

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[5] F. A. Cassell, *The Use of Technical Personnel in the Steel Industry Including Comparison With Japanese and German Industries*, contractor report for OTA, 1979.

*In 1970, the median age for steel industry employees was 43.9 years, compared to the all-manufacturing average of 39,9 years. (Department of Commerce, Bureau of the Census, 1970 Census of Population: Industrial Characteristics, table 32.) Because of declining steel industry employment, it is likely that the industry's median age has increased at a faster rate during the past decade than the all-manufacturing average.

**Entry into apprenticeship training does not guarantee subsequent employment in a craft. Training may be terminated upon a substantial reduction in the number of required craftspeople within specific crafts as a result of technological changes in steelmaking process, practices, or equipment, (Agreement Between U.S. Steel and the USWA, 1977, p. 205.)

tenance of modern electrical equipment and controls. These updating and upgrading programs consist of classroom and laboratory training of up to 5 years. Most companies conduct some form of apprenticeship program to meet their maintenance requirements. There are such programs for about 20 different crafts in the steel industry, usually of 3 to 4 years duration, consisting mainly of shop training and classes.' Apprenticeship training provides companies with the growing number of craft workers that are needed in today's plants. An industry-labor committee develops educational attainment and work achievement standards for the various types of apprenticeships.

There is some concern, however, particularly among members of the academic community familiar with the steel industry, that these apprenticeships and retraining programs are inadequate because the instructors themselves may lack sufficient familiarity with new steelmaking technologies.

Job Classification

Generally, production processes and operating procedures in the steel industry have changed slowly over the years. Nevertheless, gradual technological and operational changes in steelmaking have created shifts in job content and occupational requirements for employees in the industry. During the 1950's and 1960's, the industry made major investments in blast furnaces, basic oxygen furnaces, and computer-controlled processes. A number of open hearths were gradually phased out. These technological changes reduced the need for unskilled workers and increased the need for craft workers and process-control specialists. Fewer workers are now directly engaged in production processes, and more nonproduction workers are needed. *

When such shifts in occupational requirements occur, job classifications may change too. The job classification system used in the steel industry describes skill requirements for 12 major job categories. These descriptions are developed and agreed upon by separate industry and union committees. A major overhaul of the job classification system took place in 1971 to bring job categories in line with gradually changing skill requirements.

Local Work Practices

Changes in skill requirements and declining steel industry employment levels** may require modifications of established work practices. These practices evolve from management policy, supplementary agreements with local unions, arbitrary decisions, and verbal understandings. Specific local practices cover such issues as job content, workload, crew size, seniority practices, and coffeebreaks. By their very nature, local practices may vary from plant to plant across the country.

A number of work practices go back many years in origin and during World War II a considerable number of local practices were added, either unilaterally by management or by agreement with local unions. At the height of the postwar economic boom, plants were operating at maximum rates and domestic market conditions were such that potential labor instability could be more counterproductive to the industry than limited protection for existing work rules. Local practices were given formal recognition by the well-known "local practices" (z-B) clause in labor's agreements with the major steel companies. Most, but not all, companies now have this provision in their contracts; a few

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'Bureau of Labor Statistics, "Labor Productivity of the Steel Industry in the United States, " BLS report No. 310, 1966, p. 23.

*A 1969 Bureau of Labor Statistics study of the manpower implications of computer process control in blast furnaces, steel works, and rolling mills found that the major impact was a change in job duties rather than a change in the number employed. Job changes among operators generally consisted of a shift from manual to automatic control of dials, levers, and other control devices, Nevertheless, unskilled jobs are being eliminated wherever possible as labor-saving devices are adopted. For example, more efficient blast furnaces using processed ores eliminate many unskilled jobs. (Bureau of Labor Statistics, "Technological Change and Manpower Trends in Five Industries," Bulletin 1856, 1975,)

**Steel industry employment levels have decreased by 21.4 percent since 1960 as a result of limited growth and improved productivity. (See ch. 4.)

companies are bound by a weaker version of 2-B. The 2-B clause regulates unilateral management changes in local work practices. It requires management to maintain local practices unless change is required by contractually defined “changed conditions, ” such as technological innovations, or by union agreement with proposed changes. *

As time passes, the gap between current conditions and those for which the local practices rule was originally established may grow wider. With the introduction of new steelmaking technologies, there has been a sudden surge in the number and gravity of labor issues. During the late 1950’s, for instance, the various effects of automation on employment, job content, and organization of work dominated collective bargaining.

Work rules may become dysfunctional from a productivity point of view, although they may continue to serve the best interests of individual workers. Herein lies the potential for disagreement about the value of specific rules. It is often difficult to determine which local rules are inefficient, make-work rules. The U.S. Supreme Court has generally taken the position that because make-work practices sanctioned by union-management agreements are intended to protect labor, they are allowable. Most disagreements on local work rules are settled by arbitrators, and over the years a sizable body of formal understanding has developed from arbitration alone.

Regulations concerning the size of whole crews are the local practice usually held responsible for inefficiency. Management made unsuccessful efforts during the 1959 steel strike to have the 2-B clause removed from contracts in order to increase flexibility when using new technology such as fully automated equipment. Instead, the 1960 settlement of the steel strike provided for establishing a joint committee to study local working conditions.[7] This committee never became effective because the parties were unable to agree on a neutral chairman. Nevertheless, labor-management discussions continued on the subject, During the 1965 contract negotiations, the union made an unsuccessful demand for stronger union control over eliminating or changing job duties because of technological change. Finally, the 1974 Experimental Negotiating Agreement, the “no strike agreement, ” retained the union’s right to strike and management’s right to lock workers out at a particular operation over local issues unique to that operation. *

Contractual changes relating specifically to 2-B continue to be made at the plant level during formal bargaining on local issues. These talks coincide with industrywide contract negotiations held every few years. Arbitrators have in general interpreted the local practices section in such a way as to give management a free hand in introducing technological changes and new equipment. Substantial changes in production methods have also been held to justify eliminating local practices. An accumulation of small changes over a reasonable length of time has been held to have the same effect as a single substantial change. When such changes occur, arbitrators have upheld management’s unlimited right to make a fresh start in crew assignments rather than to be held to assignments in proportion to former workloads. Clause 2-B has been held to apply in many contract areas, but it has been narrowly applied in most cases. Most 2-B cases have been decided in management’s favor. In part, this is because unions have failed to screen arbitration cases, and in part because charges of violation of 2-B have tended to be thrown into cases in which local working conditions are at best a peripheral issue. These arbitration

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*“The Company shall have the right to change or eliminate any local working condition if, as the result of action taken by Management under Section 3, the basis for the existence of the local working condition is changed or eliminated, thereby making it unnecessary to continue such local working condition. Management’s action is subject to the grievance procedure. ” (Section 2-B, paragraph 4, of the basic steel industry agreement.)

“’Featherbedding and Union Work Rules, ” in Editorial Research Reports, vol. H, R. M. Boeckel (cd.), 1959, pp. 815, 824-828.

*The agreement aims to stabilize steel production and employment in a cyclical economic environment faced with growing import penetration by labor agreeing not to strike during industrywide bargaining in return for cooperative contract negotiations.

decisions have encouraged most companies to consider local working conditions no longer a major barrier to eliminating inefficient work practices and certainly no barrier to introducing new technology.’

Companies differ in their ability to eliminate work rules that are inappropriate for new, modern equipment. * Only in a few companies or plants do employee pressures prevent the effective and efficient adoption of new equipment.[9] Successful companies wisely attempt to make new equipment more attractive to their employees: they develop wages and other incentives that reward highly productive operation and that cover a large proportion of their work forces. Established local practices do not prevent management from making unilateral changes in local practices such as reducing crew sizes if “conditions change” as specified in 2-B. The installation of new equipment, for instance, makes it possible to change local practices and improve productivity, although the 2-B clause makes it difficult to extend such changes to adjacent production areas that are not directly involved with the new equipment. *

“G. L. Magnum, “Interaction of Contract Administration and Contract Negotiation in the Basic Steel Industry,” Labor Law Journal, September 1961, p. 856.

*Nonunionized companies, such as smaller nonintegrated steelmaker (“minimills”), are not bound by the 2-B contract provisions. They have much greater latitude in changing local work rules, regardless of whether such changes result from the use of new technology or new operating procedures. However. such companies might also be fared with informal resistance on the part of individual employees.

[9] In conversation with Milton Deaner, vice president, National Steel Corp.

*The following arbitration issue illustrates justifiable and unjustifiable management actions under 2-B:

While introducing a new incentive plan in a butt mill, management installed cooling table synchronization and reduced the crew size in the process. At the same time, for purposes of the incentive program, management reduced the spell time and crew size at a welder station on the same production line not affected by the changed mechanical condition.

The arbitrator upheld the first action but reversed the second, [J. Stieber, “Workrules Issue in the Basic Steel Industry, ” Monthly Labor Review, March 1962, pp. 267-268.)

Conclusions

The training and skills of steel industry employees and their execution of responsibilities on the whole have not impeded the development and use of new technologies. The industry has successfully developed and marketed new products, although its record of process development is less strong. Nevertheless, there is room for improvement with respect to technical education and training, the use of R&D personnel, and local staffing practices,

The proportion of technical employees in the steel industry’s work force is lower than the all-manufacturing average, and their educational attainment is somewhat lower than for other basic industries, Continuing education is generally adequate, although extensive career changes by means of sabbaticals or exchanges with universities and Government are not very common. Insufficient instructor familiarity with new steelmaking technologies appears to be a constraint in apprenticeship and retraining programs. Assuming that steelmaking technologies continue to grow in complexity and that product quality requirements continue to increase, then it appears that a future manpower shortage in mining engineers, metallurgists, electrical engineers, and computer scientists is likely.

Prevailing manpower use patterns are functional in that they reflect the industry’s concern about production capability. The great majority of technical personnel employed by integrated producers work in this area. The technical staffing patterns of alloy/specialty companies place a greater emphasis on quality control and marketing. Only about 18 percent of all steel industry technical personnel are engaged in engineering R&D; an even smaller proportion is in steelmaking R&D because of considerable engineering work and environmental R&D being conducted by R&D staff.

Job classification schedules appear to have incorporated most changing skill requirements associated with technological change. Staffing flexibility at the plant level appears to be constrained, however, by the fact that local unions must approve changes in past staffing practices in production areas adjacent to those where new equipment has been installed.

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