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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

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

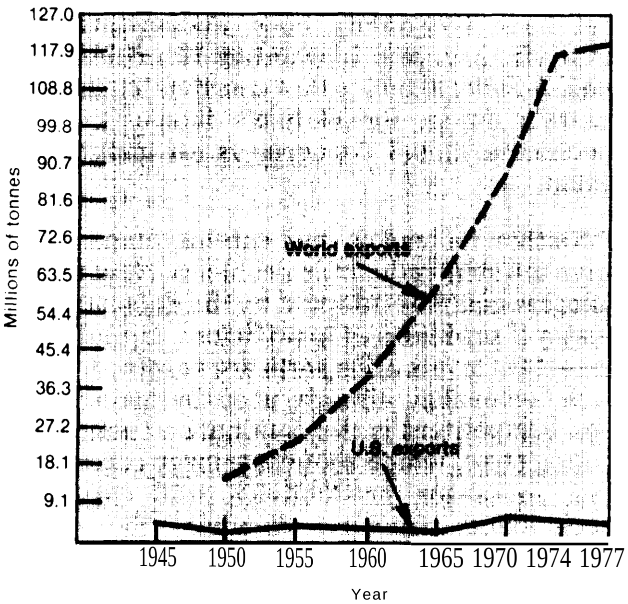
blast furnace iron, may be developed commercially within the next 5 to 15 years. Potential advantages include reduced capital costs, reduced pollution, and increased use of coal.

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.)

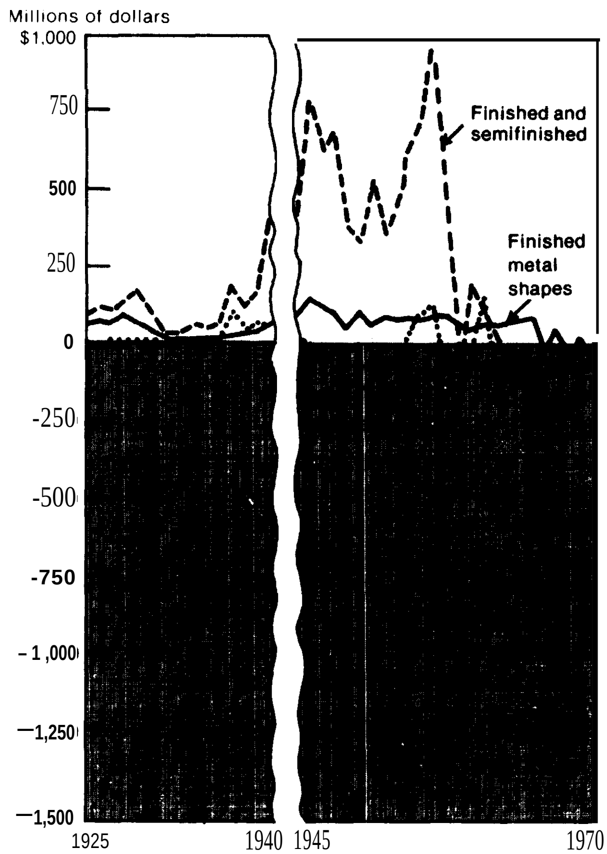
Figure 1.—U.S. Exports—Share of World Steel Trade, 1945-77



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.

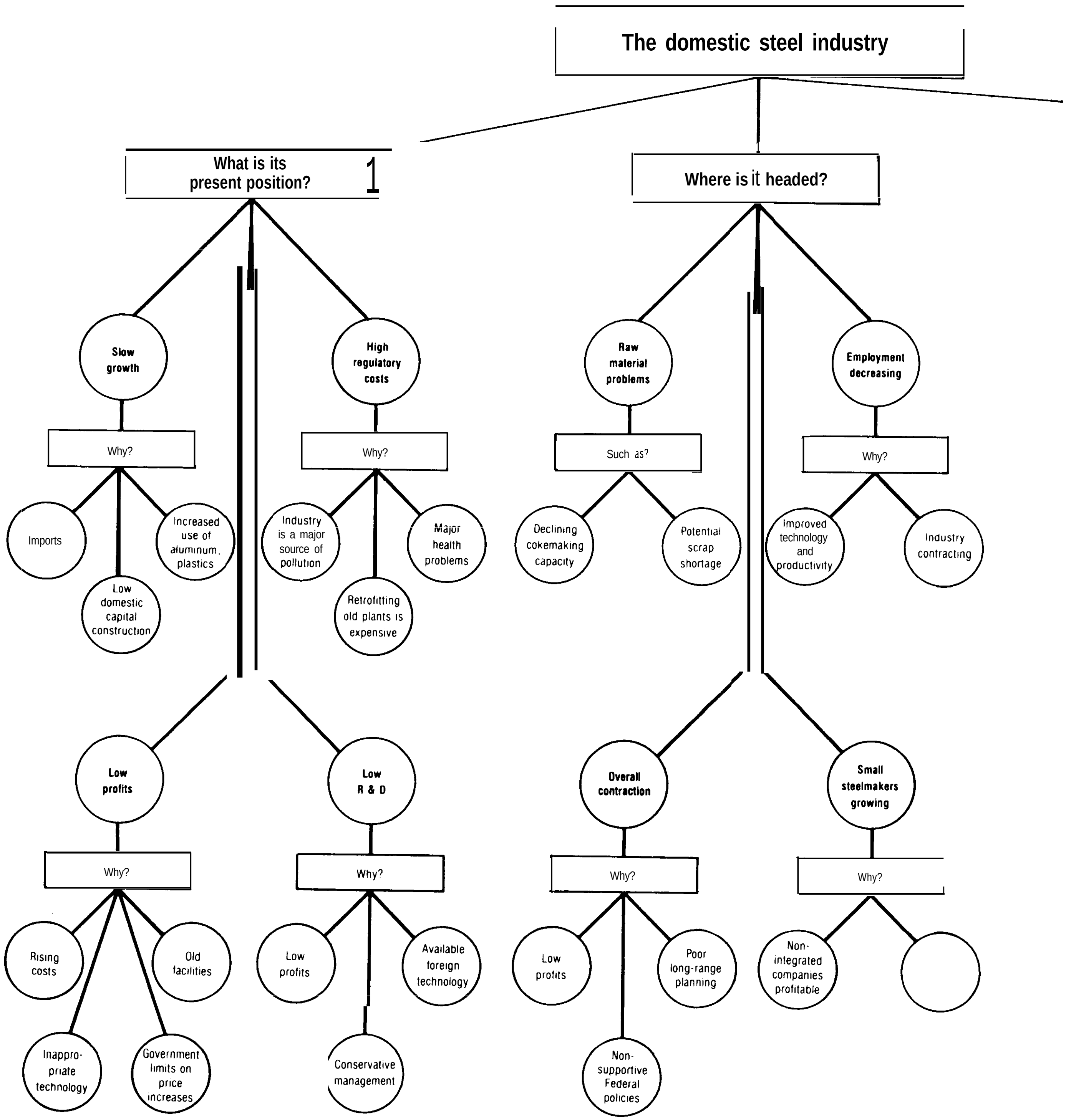
Predictions of future supply and demand for steel products are uncertain, but high steel demand and barely adequate world capacity are possible by the mid- to late 1980's. Under those conditions, if domestic capacity is replaced with modern facilities, the U.S. industry can claim its share of increased 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,

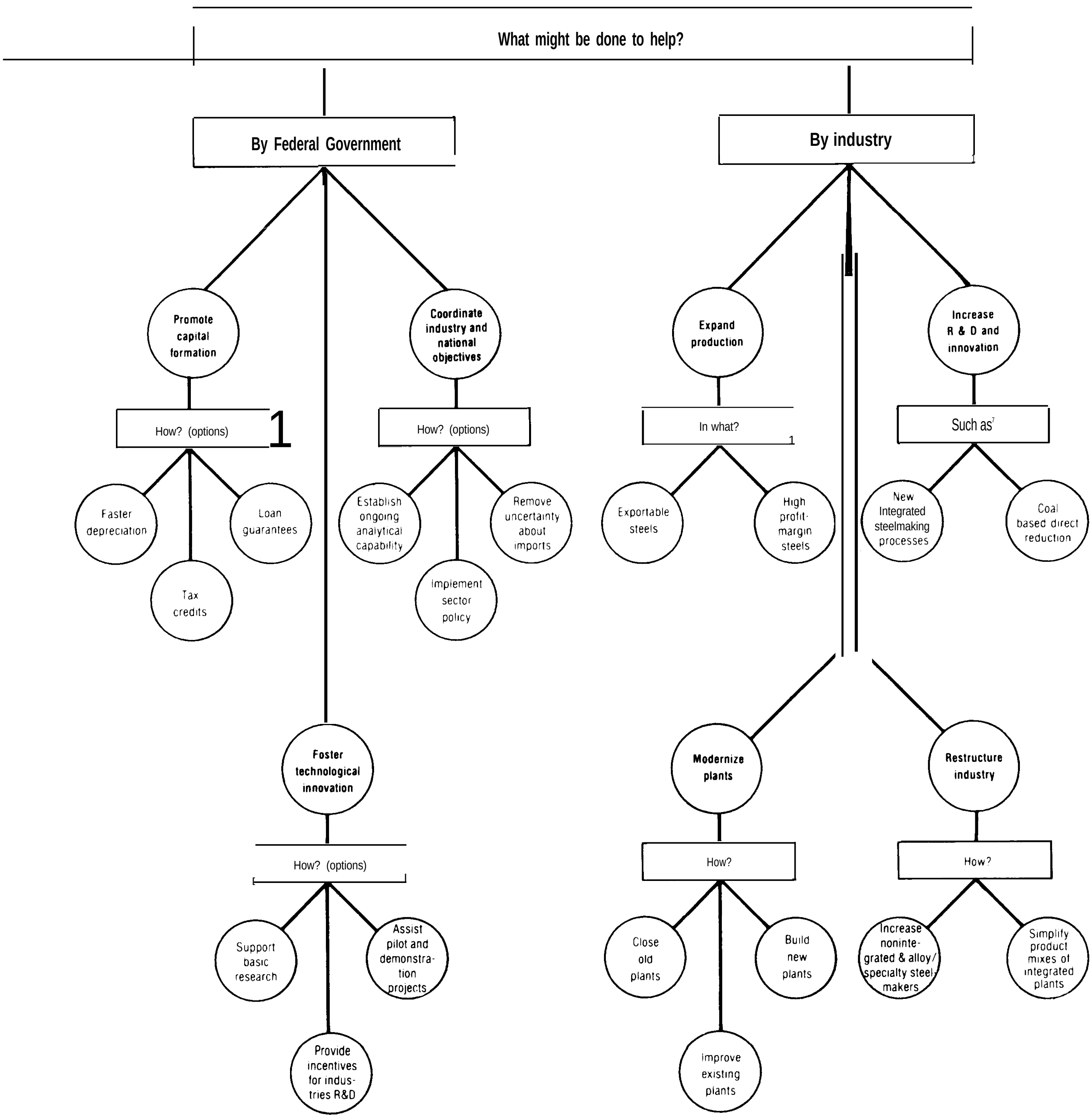
Policy Options

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
Coordinate industry and national objectives
How? (options)
Establish ongoing analytical capability
Implement sector policy
Remove uncertainty about imports
Foster technological innovation
How? (options)
Support basic research
Provide incentives for industries R&D
Assist pilot and demonstration projects
By industry
Expand production
In what?
Exportable steels
High profit-margin steels
Increase R & D and innovation
Such as[7]
New Integrated steelmaking processes
Coal based direct reduction
Modernize plants
How?
Close old plants
Improve existing plants
Build new plants
Restructure industry
How?
Increase noninte-grated & alloy/specialty steel makers
Simplify product mixes of integrated plants

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.

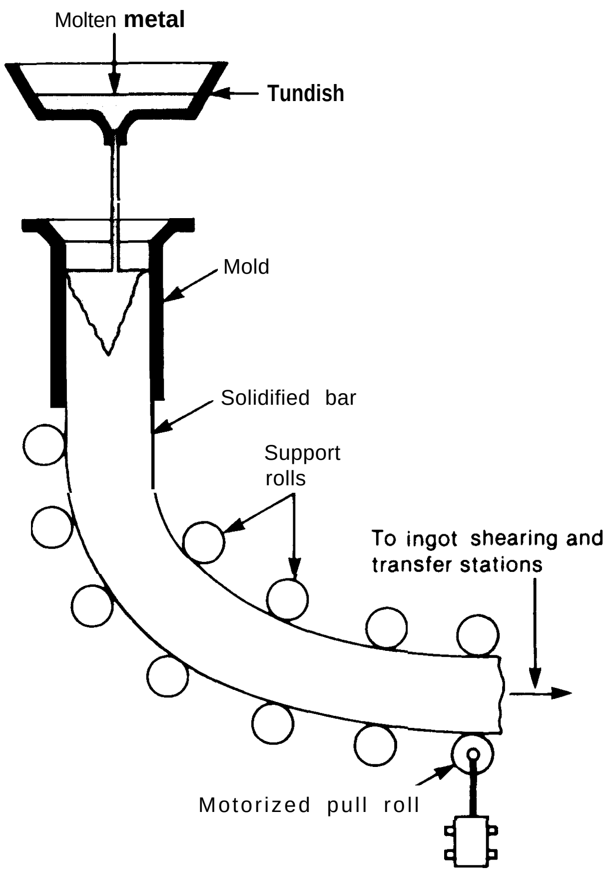
Thus, perhaps the greatest need is for a careful examination of the costs and benefits of a Federal policy for the steel sector that would first establish a set of goals consistent with national and industry needs and then a set of coordinated, reinforcing actions that would effectively and efficiently 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.

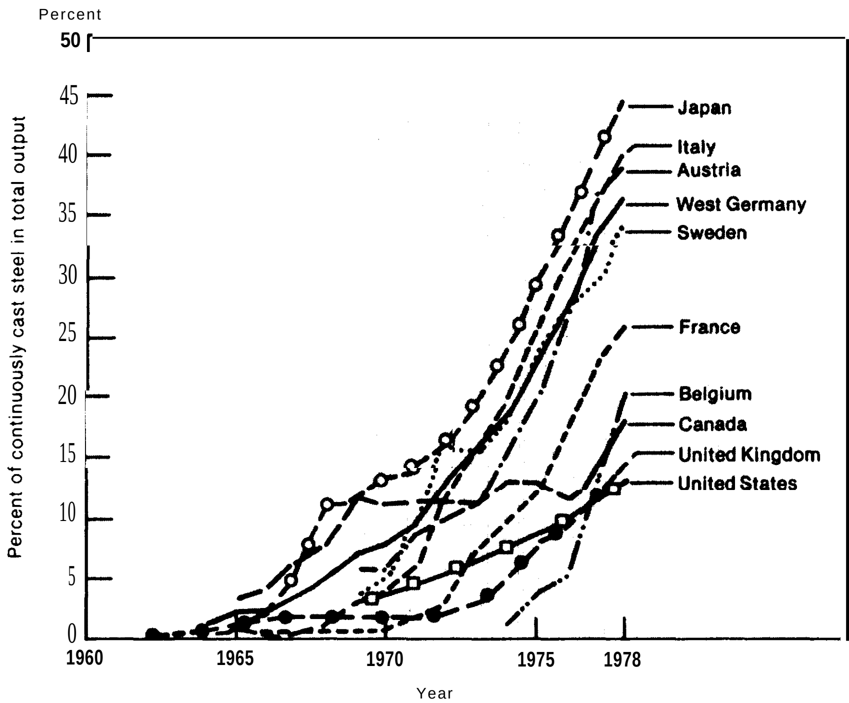
These advantages are not being fully exploited by the domestic steel industry. Although domestic adoption of continuous casting is increasing, the United States has fallen behind almost all other steel-producing nations in the extent to which this process is used. (See figure 4.) For example, in 1978, 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.

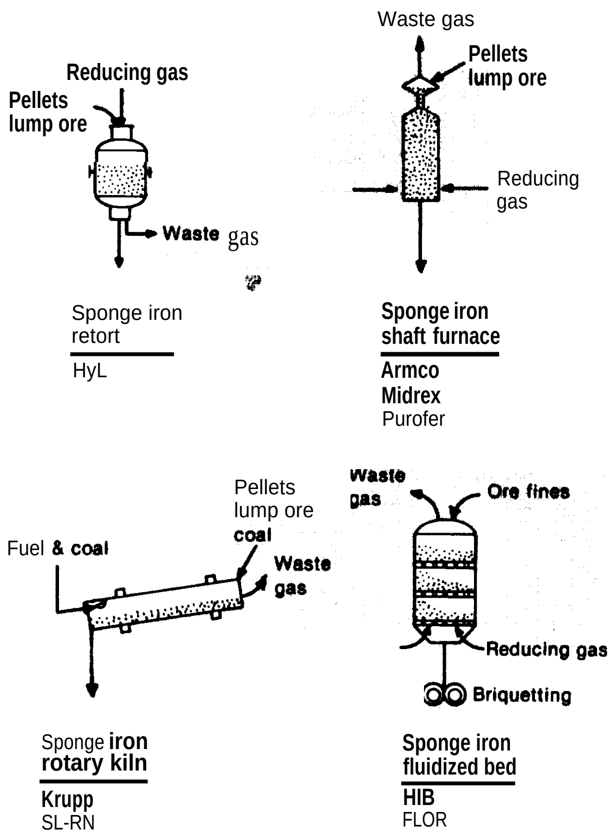
The OTA analysis indicates that, on balance, the overall economic benefits of continuous casting justify increasing its use, although recent economic conditions have to some extent justified industry's short-term focus, which has not favored investments in continuous casting. A key question is how much 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	o.o
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,

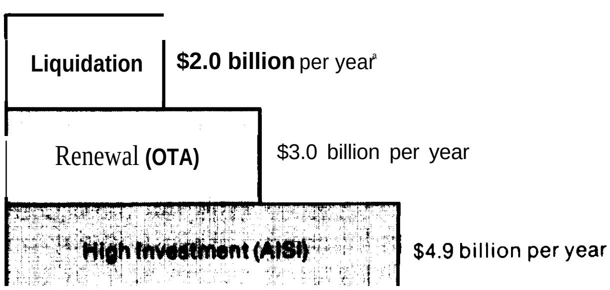
There are three routes to revitalizing the technological base of the industry: 1) modernization and replacement; 2) expansion of existing facilities; and 3) greenfield (new plant) construction. OTA's analysis of the minimum modernization and expansion needs for the coming decade indicates that the most 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)



aRepresents a continuation of capital Investment trend for the past 5 to 10 years

SOURCE Off Ice 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.

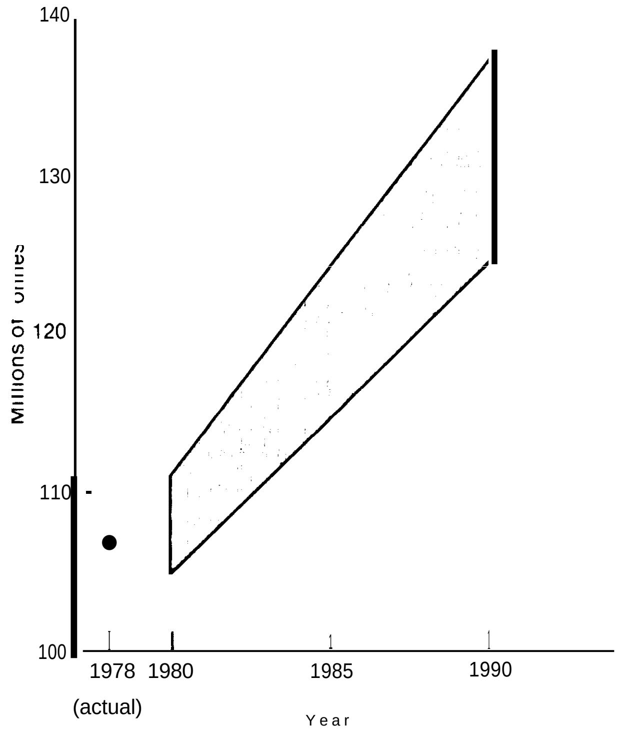
Steel Use and Future Demand

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.

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 manu-

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

facturing 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[a]		
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		Capability change 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 Ford ham 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.