Photo credit: Sun Oil Co.

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Chapter 1
Summary and Findings

Virtually every function of industry uses energy. Efficient use of this energy is affected by, among other things, available technology, capital investment, and the cost of energy. Since 1973, the cost of premium fuels such as petroleum distillates and natural gas has increased over a factor of three in real terms. In response, the industrial sector has taken numerous steps to reduce its energy use per unit of output. However, many opportunities still exist to use energy even more efficiently. OTA examined those opportunities to determine why they were not being exploited and to see if legislative policies could encourage faster improvements.

The OTA study focused on the four industries that use the most energy: paper, petroleum refining, chemicals, and steel. These industries were examined in detail for three reasons. First, it was assumed that if conservation and the more efficient use of energy had any role to play in U.S. manufacturing, it would be most apparent in these four industries. In 1981, these industries used nearly 10 quadrillion Btu (Quads) of final energy* (about 43 percent of all energy used by the industrial sector). Thus, these industries are likely to be the leaders in increasing energy efficiency.

Second, to the extent public policies have an effect on energy use, that effect should be greatest and most apparent where energy use is greatest. Such policies could result from a desire to reduce oil imports, to forestall depletion of domestic supplies of energy resources, and, perhaps most importantly, to improve the Nation's overall economic health.

Finally, by examining the operations and decisions of these industries and their constituent firms, it should be possible to evaluate progress in energy conservation and the impacts of legislation as they would most likely occur. Each of these four industries explicitly considers energy in management activities and investment planning because energy use accounts for a significant share of each industry's production costs.

OTA examined the technical options available to each industry and the factors that guide investment decisions about energy efficiency improvements. A principal part of the analysis was a series of case studies of both large and small companies in each of the four industries. In addition, a series of engineering consultants knowledgeable about industry and its operations were asked to make independent appraisals of each industry and case-study firm. At workshops, industry representatives, consultants, OTA staff, and others integrated the results.

For the repot-t, OTA identified the technical and economic potential for energy conservation and also for switching from high-cost and insecure premium fuels to lower cost domestic fuels in each industry. Both changes were seen to improve energy efficiency because they decrease the cost of energy per dollar of production. As a necessary part of its analysis, OTA examined the manner in which capital budgeting decisions about energy efficiency-improving projects were made. **OTA** also examined and identified the barriers that prevent efficient use of energy and assessed the likely effects on each industry of a selected list of Government policy initiatives on energy use and capital funding. The policies included the accelerated depreciation provisions of the 1981 Economic Recovery Tax Act, broadened and expanded tax credits for energy investments, imposition of energy taxes on premium fuels or equivalent price increases, and increased capital available for investment.

* This number values electricity at 3,412 Btu/kWh. It is final demand

U.S. INDUSTRIAL ENERGY USE

In 1981, U.S. industry used over 23 Quads* of energy-bearing materials, mostly as fuel, but also, in some cases, as feedstock. * * Manufacturing accounted for about 75 percent of that total; mining accounted for another 12 percent; and agriculture and construction, another 6 percent. The four manufacturing industries studied in depth by OTA accounted for about 57 percent of the total energy used in manufacturing, including 74 percent of the oil and 60 percent of the natural gas.

Between 1972 and 1981, American industrial energy use declined by over 2 Quads, and energy efficiency improved by almost 18 percent per unit of production. Even more noteworthy than the drop in absolute energy consumption was the decline in the rate of energy use compared to the rate from the previous decade. if growth rates of that decade had continued, industrial energy use would have reached nearly 40 Quads by 1981.

While this decline might initially be considered purely a gain in energy efficiency, analysis carried out by the Department of Energy (DOE) suggests that it is the result of a more complex process in which a changing product slate and a general decline in the growth of manufacturing output over the 1970's combined with energy efficiency to reduce overall energy use.

Industrial energy efficiency gains between 1972 and 1981 are notable in that they have occurred at the same time the rate of economic expansion declined. Given that capital has been severely restrained because of high interest rates and depressed sales, management has been less able to purchase new fuel-efficient capital stock than it could have if the economy were expanding at 1960-72 rates.

Domestic energy prices have greatly increased (in real dollars) over the past decade, leading to significant changes, both in the absolute amount of energy and in the mix of energy used in industry. Prices for distillate petroleum products have more than tripled over the past 12 years, while the cost of natural gas has risen by nearly four times. The overall average price of energy has increased from $1.86 to $3.69 (in 1972 dollars) per million Btu.

The change in the amount and mix of energy used by the industrial sector is shown in figure 1. Use of petroleum products increased from a 1951 level of under 5 Quads to a 1979 high of 10.3 Quads. It has since declined to almost 1970 levels. The use of coal has declined from a 1951 level of over 6 Quads to a 1981 level of 3.2 Quads. Natural gas use is down by over 1.0 Quad since 1971, while electricity use has increased by 1 Quad.

In the pulp and paper industry, total energy use has risen slightly since 1972. However, the industry is more energy self-sufficient, and energy use from purchased fuels has declined. The integrated mills that convert trees to pulp and then to paper are almost 25 percent more efficient now compared to 1972. Mills that convert purchased pulp to paper are almost 20 percent more efficient. Much of this energy efficiency has shown up in decreased use of residual fuel oil* (down 40 percent since 1972). Overall, the paper industry has exceeded its voluntary goal of 20-percent improvement by almost 5 percentage points.

The petroleum refining industry has decreased its overall energy use per unit of output by 20.8 percent, primarily by reductions in natural gas use (down 37 percent since 1972) and distillate and residual fuel oil use (down 62 percent and 31 percent, respectively). Based on 1972 production levels, the industry exceeded its voluntary goal of a 20-percent energy savings.

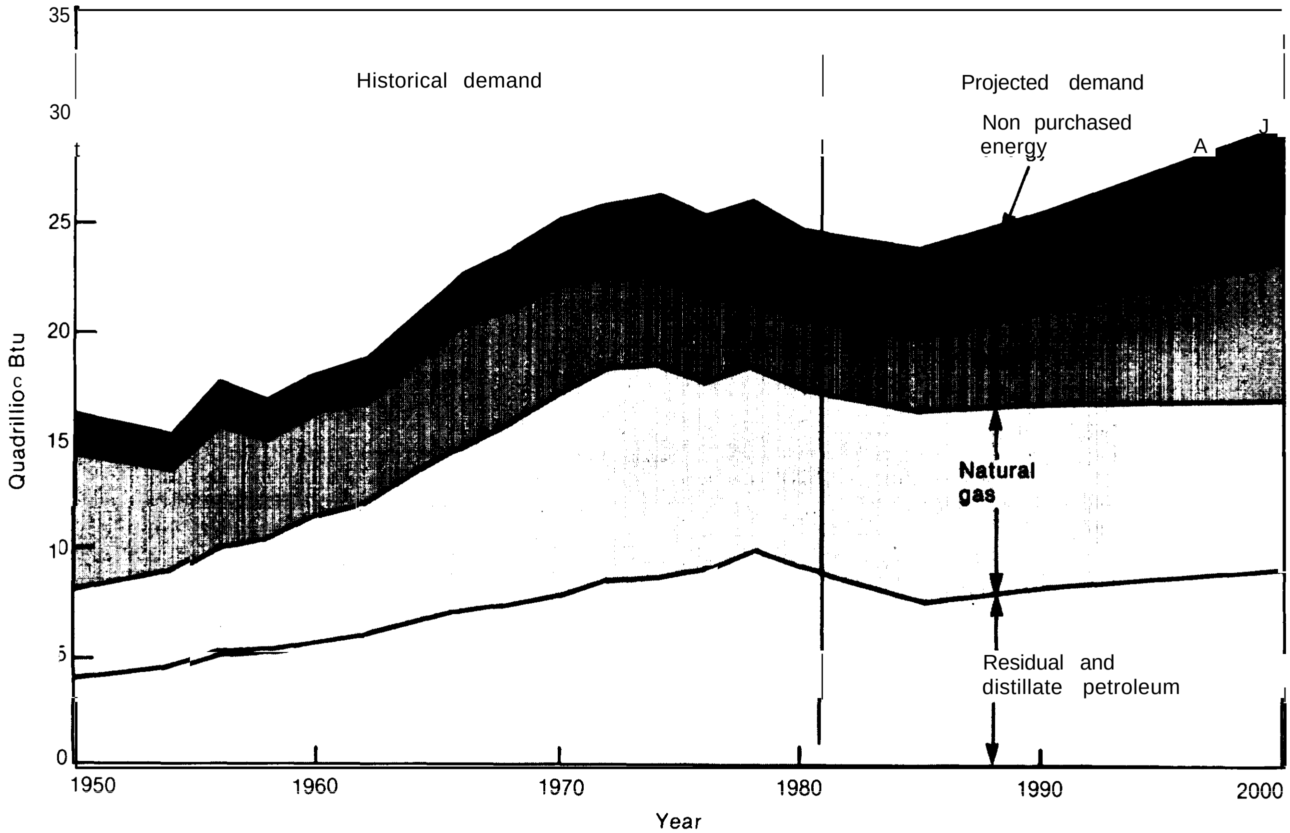
In the chemicals industry, energy use per unit of output has decreased by 24.2 percent since 1972 through decreased use of natural gas (down 24 percent) and residual fuel oil (down 42 per-

"Quadrillion Btu. This is final demand, for which electricity use is computed at 3,412 Btu/kWh. It Includes petroleum products, natural gas, coal, and nonpurchased fuels such as biomass. Including conversion losses in producing the electricity, industry can be said to have used over 29 Quads of primary energy,

* *Feedstocks are raw materials, natural or manmade, used in production,

* Residual fuel oil is the heavy hydrocarbon material remaining after crude 011 is distilled; distillate fuel oil is the lightweight hydrocarbon material derived from crude 011 via distillation.

Figure I.—Industrial Energy Demand, 1950-2000



SOURCE: Energy Information Administration and Office of Technology Assessment.

cent). Compared to 1972 production levels, the industry exceeded its 1980 industry improvement goal by more than 10 percentage points.

The steel industry has decreased its use of energy per unit of output by 17 percent, mostly through decreased use of bituminous coal (down 35 percent) and metallurgical coke (down 36 percent).

ENERGY CONSERVATION

Energy efficiency improvements can be classified into four categories: 1) improved housekeeping; 2) equipment retrofit; **3)** shifts to new process technologies (usually as a result of capacity expansion) to make existing products; and 4) shifts to new, less energy-intensive, product lines (see table 1). By and large, investments in (1) and (2) involve relatively small commitments of capital, whereas more is required of **(3)** and (4). OTA finds that housekeeping procedures, by and large, have been or are being done. Managers in energy-intensive American corporations seem keenly aware of the cost of energy and therefore of the need to minimize its use. Housekeeping is one way to accomplish this task rapidly and inexpensively. Retrofits to existing equipment, however, are not as common. Given the existing economic environment—with high interest rates, depressed capacity utilization, and, in some cases, declining sales—retrofit additions

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Table 1.—Categories of Energy-Related Capital Investment

Definition	cost	Payback period	Example
Housekeeping			
Substitution of labor and management effects for energy	Very low	Very short	Setting up routine procedures to check, clean, or replace steam traps; manually adjusting and optimizing boiler controls, monitoring building for air leaks, and the like
Equipment retrofit			
Addition of new parts; substitution of existing parts on functioning capital equipment	Usually moderate	Months to several years	Installation of computerized boiler control for maintenance of optimum burner efficiency; installation on process stream lines of additional heat exchanger surface
Process shift			
Building of new facilities to manufacture existing products with new processes	Often quite high	Many years	Building new minimill for production of steel from scrap metal; manufacture of linear low-density polyethylene at low pressure using new catalytic system
Product switching			
Undertaking the production of a new series of products	Moderate to quite high	One to many years	Switching from production of bulk commodity chemicals to that of biotechnology chemicals

SOURCE: Office of Technology Assessment

are often perceived as strategically unjustified. OTA has found that most retrofits have very short payback periods; i.e., the projects pay for themselves through decreased energy costs in less than **2** years.

Investment in new equipment is very likely to be the most effective means of increasing energy efficiency. As of 1975, 57 percent of all capital equipment in manufacturing was 25 or more years old. Much of this equipment was built wherever space permitted at existing industrial sites and with little regard for minimizing energy losses. In new plants, final products can usually be made with less energy. However, investments in new processes and process equipment, especially in the 1981-82 economic environment, have been rare, a situation that also existed throughout the late 1970's in some industries. Capital costs are now very high, and in the present investment climate, risks seem great. Many consider it better management to delay investments rather than risk damaging the economic health of their companies.

Another trend, the shift to less energy-intensive products, will also contribute to increasing energy efficiency per economic output. This phenomenon accounted for about 10 percent of the total reduction in industrial energy in 1981 relative to a continuation of the 1950-73 trend. Product mix shifts will occur within specific industries and will also result from one industry growing while another declines. Product shifts can also result from the introduction of new or improved products that provide a given service but require less energy to manufacture than do the products they replace. Product shifts are driven by changing demand patterns, international competition, and increasing production costs (including energy costs) .

To assess technical and economic opportunities for improving energy efficiency, OTA projected industrial energy demand based on assumptions about future energy prices, product demand, interest rates, and the use of a range of technologies available for increasing energy efficiency. Table 2 presents the energy price assumptions. Table 3 presents a summary of energy growth rate pro-

Table 2.—Average Industrial Fuel Prices Assumed **in OTA Modeling**[a] (1980 dollars per million Btu)

	1980	1985	1990	2000
Gas	3.0	5.0	6.3	9.0
Residual oil	5.0	5.0	6.2	9.0
Distillate oil	6.7	6.6	7.7	10.5
Coal	2.1	2.2	2.3	2.4
Electricity (at 3,412 Btu/kWh)	12.6	13.8	13.7	13.8
Steam	5.5	5.9	6.3	7.4

Assumptions
Gas —Price follows Natural Gas Policy Act (Public Law 95-621) deregulation scenario
Residual oil —Follows Energy Information Administration's (EIA) projected refinery acquisition crude 011 price (steady at $32 through 1987, then up to $58 by 2000)
Distillate oil —Commanding a high premium over crude 011 because of growth in demand
Coal —Follows EIA forecast of low growth in mine and transportation prices
Electricity —Follows 011 and gas prices in 1960's, then shifts to those of coal
Steam —Price affected by boiler/cogenerator mlx and natural gas/coal fuel demand

[a]OTA's modeling effort actually uses a range of fuel prices that reflects the quality of fuel and the different energy prices in various geographical regions of the United States

SOURCE Off Ice of Technology Assessment

jections and their relationship to overall production in the entire industrial sector and in the case-study industries.

Two major conclusions may be drawn from the data in table 3. First, from the standpoint of the entire industrial sector, including mining and manufacturing, available technology and expected energy price changes* will allow industrial output to grow at a much faster rate than that of energy use. **OTA projects that for the next two decades industrial energy use can grow at a rate of not more than 1 percent per year, with a 2.7 percent per year average growth rate in the gross national product (GNP).** This compares to an energy use growth rate of 3.1 percent per year from 1950 to 1973 relative to a GNP growth rate of **3.8** percent per year. Moreover, the output growth projected here will occur with virtually no increase in the use of the two premium fossil fuels–natural gas and oil–because coal and electricity (generated from coal or nuclear fuels) can provide the energy needed for growth. Dependence on premium fuels will still be high and industry will remain sensitive to oil and gas prices. Figure 1 shows the projected changes in energy used by industry.

Second, in three of the four major industries closely examined by OTA, **the two** major alter**natives for improving energy efficiency, product and process shifts, will bring about greater improvement than will retrofit and housekeeping measures.** However, product and process shifts are by far the most expensive investments and depend on a strong product market to make them economically attractive. These large investments, however, do more than save energy; they increase overall productivity by reducing the costs of all factor inputs and by improving product quality. Indeed, the latter are the primary goals of such investments, and without productivity improvements, energy efficiency gains will be considerably less.

An important point to note is that these investments are long term, for the most part; i e., their major effects will not show up until the 1990's. Furthermore, these efficiency improvements will continue past the year 2000 as new

*Although OTA has not modeled fuel price sensitivity in detail, higher price Increases are expected to cause even greater efficiency gains, and a lower energy growth rate.

Table 3.—Relative Energy/Output Growth Patterns for Years 1980-2000 (percent per year)

	Paper	Petroleum	Chemicals	Steel	Total sector
Product output growth rate[a]	2.9	**-0.3**	**4.0**	1.2	2.7
Change in energy growth from:					
Product/process shifts	-1.0	+ 0.5	-1.7	-2.0	-1.7
Improved efficiency from existing processes and machines	-0.7	-1.2	-0.6	-0.4	}
Results in:					
Energy demand growth	1.2	-0.7	1.7	-1.7	1.0

[a]In this projection, the industrial sector includes the activities of mining, construction, and agriculture as well as manufacturing, Growth in industrial output was projected by the Mellon Institute, using the macroeconomic models of Data Resources, Inc , and Dale Jorgenson Associates, Inc. In terms of these two models of the U S economy, a 2 7-percent growth in Industrial output is consistent with a similar rate of growth for the gross national product, For further discussion of macroeconomic assumptions and analyses see *Final Report' Industrial Energy Productivity Project,* Energy Productivity Center, Mellon Institute, September 1982, pp. 11-24.

SOURCE: Office of Technology Assessment.

processes and process technologies become a larger share of total production and as production of less energy-intensive products becomes a larger portion of overall industrial output. **For the 1980's, increases in efficiency will be largely the result of retrofit and housekeeping measures and investments in new equipment made during the 1970's.**

Investment Considerations

In setting overall priorities among different product lines and production facilities, firms place energy efficiency in the context of a larger strategic planning process. * In all cases analyzed, industry was found to make investment decisions that affect energy efficiency on the basis of a strategic planning process that considers not only energy costs, but also a number of other factors. The most important of those factors are:

1. **Perception of product demand:** In particular, energy conservation projects in product lines that are declining are not considered good investments, even at very high rates of return. On the other hand, energy conservation projects in product lines whose markets are expanding will be undertaken at even moderate rates of return.
2. **Perception of competition:** Competition can arise either from a technological basis, such as the challenge of electronic mail to the paper industry, or from foreign competitors within the same industry, because of lower labor costs, lower capital costs, and so forth.
3. **The cost of capital:** Corporation managers invest their money in projects related to one of the four investment categories or in some type of revenue earning account. Funding required beyond that available within a company comes primarily from borrowing. Given the economic circumstances of 1980 and 1981, one of the major barriers to investment in energy conservation projects is the very high cost of capital, Also, because banks, insurance companies, and other financial institutions are reluctant to commit funds to organizations with large debt loads, many firms find themselves with capital funds constrained by debt-related factors. As a result, companies are forced to limit their investment in new projects, and many high-return, energy efficiency-improvement investments are foregone.
4. **The cost of materials and labor:** A project may be energy efficient yet still economically undesirable if it requires more expenditure of labor or uses more material than is presently used. For instance, it is possible for integrated paper manufacturers (i.e., those who produce both pulp and paper, rather than purchase pulp to make paper) to become even more energy self-sufficient by burning more of their wood feedstock. However, this practice would result in less pulp available for other uses. At current energy prices, this trade of material for energy would be unacceptable.
5. **Government policy,** or lack of certainty about Government policy. Government policy can address investment in general or be targeted specifically to energy. Of major importance are those policies that affect the entire economy, since investment can be particularly constrained during periods of depressed economic activity.

When all capital projects being considered by a corporation are examined, the investment menu can be divided into mandatory and discretionary categories. OTA has found that mandatory projects are by far the most numerous. Discretionary capital funds are those that remain after mandatory investments have been made. Mandatory projects such as pollution control equipment and projects needed to support a capital expansion are generally not affected by energy costs and the five factors just listed above.

Discretionary capital investments, however, are subjected to the corporation's strategic planning process, which is guided by the six (including energy costs) factors. In some companies, the decision to invest in discretionary projects comes only after a very formal process. In other firms examined by **OTA,** the process seems less formalized, but still subject to the perceptions of

*There are, of course, many small investment opportunities, some energy-related, which may not be subjected to exhaustive strategic analysis. Funds for such projects are usually allocated by a supervisor or plant manager from a small discretionary pool of funds in the annual budget.

managers about growth potential of a product; market and technological competition; and use of capital, labor, and materials.

Energy efficiency investments fall within the discretionary category. All firms regard **energy efficiency as one more item in which they could invest, not as a series of projects that are different from other potential investments.** In no case has OTA found companies that accord energy projects independent status. Rather, energy-related projects are part of the general strategy governed by the factors listed earlier. These projects must contribute to the corporate goal of increased profitability and must enhance a corporation's competitive position.

While ideas for energy conservation can arise from anywhere, even outside a company, the approval process can often be complex and the project analysis, exhaustive. OTA found that technical decisions tend to be separate, and subservient to, corporate financial decisions. Plant engineers are usually not participants in detailed financial assessments.

In general, individual project financing is not considered when a large list of projects is being evaluated for their technical merits, despite the fact that when returns (i.e., energy savings) are high and a project is highly leveraged (i.e., much of the money used to buy the equipment is borrowed), the individual returns for each dollar invested can be very high. Large corporations consider borrowing funds only at the highest decisionmaking levels and when **all** projects have been evaluated. At that time, the decision to borrow is guided by the strategic considerations listed earlier and depends not only on the returns of an individual project, but on such corporate-wide parameters as debt-equity ratio, debt-service load, and bond rating. **Because project economics and corporate finance are treated separately by corporations, a Government policy which is designed to promote energy efficiency by influencing only project economics, but fails to affect corporate finance, will be ineffective.**

Case= Study Industries

Investment decisionmaking by the case-study industries illustrates the importance of the several investment factors and indicates the technology choices being made.

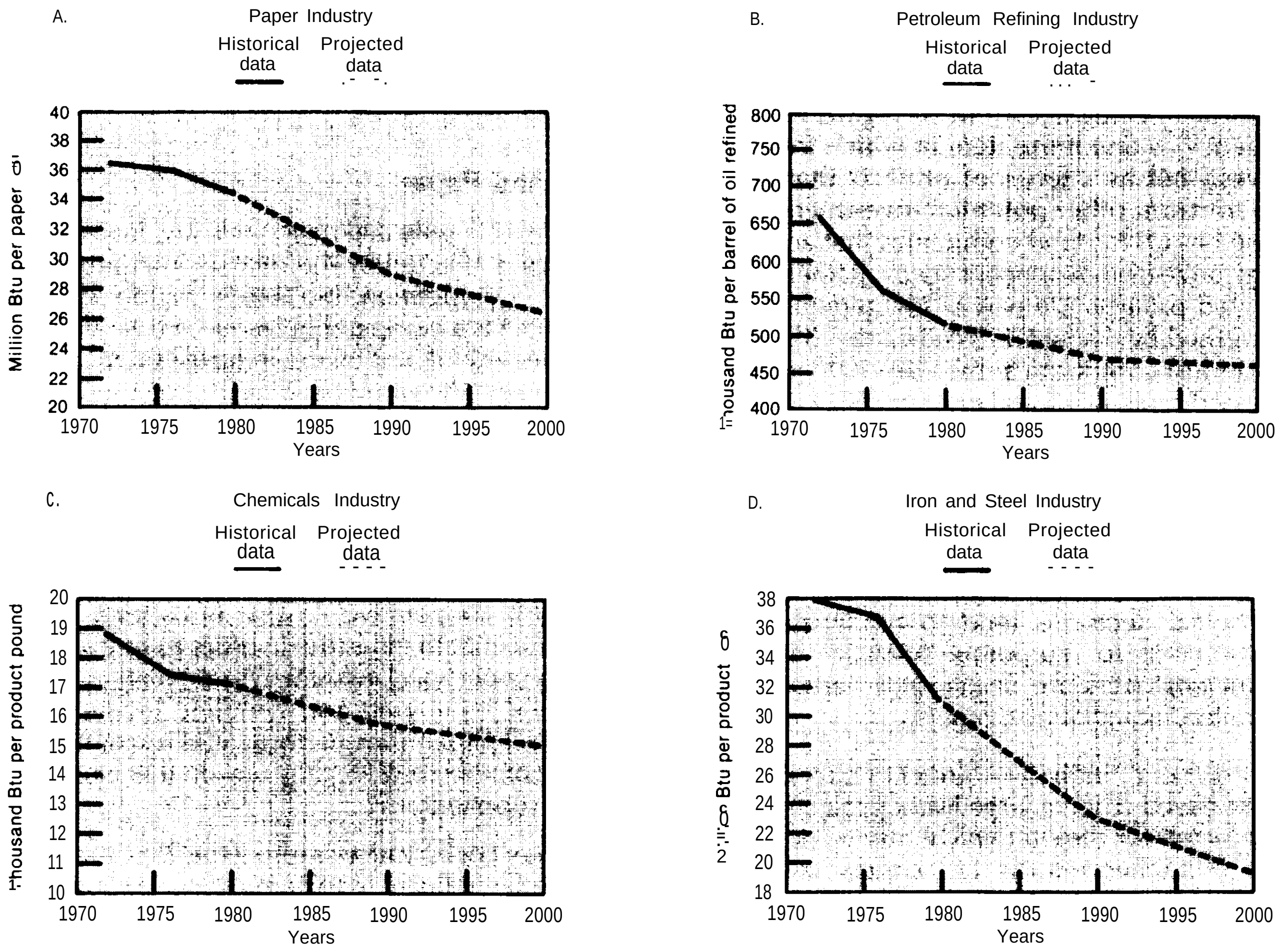
Pulp and Paper

In the U.S. pulp and paper industry, investment strategy is affected by the relative freedom from import competition (no other nation except Canada has a comparable resource base of marketable timber) and by the industry's close association with the wood building products industry. The absence of import competition and the presence of significant export prospects have been major factors in keeping profits and investments high. The paper industry's special relationship with the wood building materials industry is competitive in that they share the same resource base; it is also cooperative, in that firms tend to be engaged in both industries in order to spread risks and to pool capital investments in timberland and in wood harvesting and handling technology. Pulp and paper firms perform little research and development; instead, they rely on that of equipment suppliers.

Energy conservation improvements in the pulp and paper industry have come about through improved housekeeping measures and increased capability to recover energy from waste. In the latter case, the industry moved from supplying 41 percent of its energy needs from self-generated sources in 1972 to 50 percent by 1981.

OTA projects that the energy intensity of paper production—i.e., the energy required to produce a ton of product-will decline by nearly 18 percent by 2000 (fig. 2A) because of specific process changes anticipated for each of the papermaking steps and from changes that should occur in overall energy production and use in the paper industry. In particular, major economic opportunities exist for cogeneration, Also, pulping energy demand will likely decline, owing to the increased use of continuous digest-

Figure 2.–Energy Intensity Projections, 1970-2000



SOURCE Office of Technology Assessment

ers (as opposed to batch processing). In addition, projected secondary fiber pulping–i.e., recycling of wastepaper such as newsprint—will contribute to the decline. Energy savings can also be expected in the bleaching process by displacing energy-intensive chemical bleaching with oxygen-based bleaching, assuming technological risks of equipment failure and plant downtime can be minimized. In the papermaking process, energy can be used more efficiently if computerized process control and new technology can be employed. Also, if natural gas prices continue to go up, this industry can be expected to substitute electricity for gas in its paper drying processes.

Overall, the pulp and paper industry mirrors aggregate industrial trends, except that its oil use will decline rapidly as number **6** residual oil is displaced in boilers by coal and biomass fuels. This industry is unique in its long history with biomass fuel (primarily wood) because of its dependence on biomass feedstocks. The biomass fuel alternative will look more attractive in the future as fossil fuel prices rise. Over the next 20 years total energy per ton of paper shipments should decline by over 25 percent, while purchased energy should drop by 42 percent. The difference reflects an anticipated increase in the industry's use of biomass fuels.

Petroleum Refining

The domestic petroleum refining industry is dominated by vertically integrated firms that produce crude oil here and abroad and sell petroleum products to final consumers. Since petroleum production has been and should continue to be profitable, investment in domestic refining will be limited by available funds only in the sense that refining activities must compete with exploration and drilling.

The domestic refining industry is getting smaller because of the reduction in demand caused by the rising prices of petroleum-based fuels relative to prices of all other fuels and other goods and services in general. This situation has led to the substitution of other products for petroleum products and hence has reduced the demand for refinery outputs. In 1981, the refinery utilization rate was only 65 percent of capacity. At the same time, the refinery product slate was shifting away from regular, leaded gasolines to unleaded, higher octane products and to a steadily declining fraction of residual fuel oil. Also, there was a shift in crude oil away from the more easily refined light, low-sulfur crude oils toward heavier, high-sulfur crude oils.

The OTA projection presented in table 3 shows energy use in petroleum refining operations to decline 0.7 percent per year. This reduction is primarily the result of retrofit and housekeeping measures. The shift to heavier, high-sulfur crude oil feedstocks, combined with the market requirements of high octane, unleaded motor fuels, necessitates a growth in energy use of 0.5 percent per year to accommodate these product and process shifts.

Of the four industries studied by OTA, petroleum refining is the only industry in which product or process shifts are not projected to lead to less energy use. Nonetheless, overall energy efficiency, as reflected in the decline of energy intensity in refinery operations, can be expected to improve, as shown in figure 2B. The average energy intensity is projected to decline by nearly 10 percent from 1980 to 2000. This reduction will be the result of a number of anticipated technological changes in refinery operations, primarily in distillation and cracking.

In distillation, energy can be conserved through improved efficiency in distillation heaters, extensive use of vapor recompression and waste heat boilers to maximize the recovery of heat content from waste streams, and the use of computerized process controllers to optimize plant operations. New process technologies should be available to convert undistilled residual oil (called residuum) to middle distillate products suitable for further refining and, at the same time, produce steam for plant process use. Thus, while use of fossil fuel for heaters is expected to grow slightly as the economy expands, demand for steam from boilers will decrease. Overall electricity use will grow because of the use of vapor recompression. In the cracking processes, increased efficiency from the use of vapor recompression and process control will be partially offset by the increased need for energy to perform hydrocracking operations on the heavier, more sulfur-laden, crude oil feedstocks.

Regarding shifts in refinery fuel, the projection of existing trends indicates that there will be a substitution of coal for gas in fuel boilers and as a source of hydrogen in reforming. But the extent of both changes will depend primarily on the price of natural gas. Gas price also affects substitution of gas for oil. If natural gas prices increase sufficiently, oil could be substituted for gas in direct heating.

Chemicals

The chemicals industry is the most dynamic of the four industries examined by OTA. It makes the most diverse set of products. The greatest portion of its energy use occurs in the production of commodity chemicals such as ethylene, polyethylene, benzene, and the like. The proportion of energy use is less in intermediate and final consumption chemicals, such as pharmaceuticals and agricultural pesticides.

The chemicals industry uses the largest amount of energy-bearing materials of the four industries examined by OTA. Its use of both total energy and premium fuels—i. e., oil and natural gas—is larger as well. **The energy intensity of the chemicals industry over the next two decades is projected to decrease by about 9 percent** (fig. 2c), resulting from a combination of retrofit equipment and technical innovation in new processes; e.g., vapor recompression, process controls, and heat recuperators and exchangers that will all be used to improve thermal efficiencies. In addition, there is a distinct trend in this industry toward increased use of electricity and coal and away from premium fuels. For instance, as processes for producing ammonia and methanol from coal come onstream in the next two decades, less natural gas will be required and more coal will be used. The OTA projection indicates natural gas use will go from 45 percent of the total energy used in the chemicals industry in 1980 to 19 percent in 2000, while coal will increase its share from 6 to 29 percent.

For chemicals, probably the most important source of improvement in energy intensiveness is shifting the product mix. This shift-from energy-intensive commodity chemicals to higher value pharmaceuticals, pesticides, and other consumer products—is occurring for two reasons. First, profit margins on commodity chemicals are low, while margins are higher for lower volume, higher valued products. Demand for the latter is growing much faster, so that these less energy-intensive products are attracting the bulk of investment in the United States. Investments in processes for manufacturing chemicals such as ammonia and ethylene are low because large supplies have recently come on the international market from OPEC and other energy-rich nations that view the production of commodity chemicals as the best way to increase revenues and to expand industrial employment.

Steel

Among the four key energy-using industries, steel now suffers the most from declining domestic sales. In addition, older, large-scale, integrated firms also suffer from competition from domestic minim ills that can produce steel at much lower costs. investment strategies vary a great deal between the older, integrated firms and the newer minim ills. The former have been forced into triage, sacrificing older mills to husband resources for their most efficient and highest profit operations. Even for the latter, many energy-related projects cannot be undertaken because of limited funds or because of abnormally low use of existing capacity. At minim ills, capital availability does not now appear to constrain investment in energy efficiency or for any other objective as long as target hurdle rates* for returns on investment are achieved.

OTA projects that energy use by the steel industry could decline at a rate of 2 percent per year, while output would grow at an annual rate of about 1 percent. The major source of this energy efficiency improvement will be process change—in particular, the replacement of ingot casting by continuous casting and the substitution of the electric arc furnace production (using scrap metal feedstocks) for the blast furnace/basic oxygen furnace combination (using iron ore feedstocks). The latter change will also result in the substitution (in the form of electricity) of steam coal for metallurgical coal.

OTA projects a decline in energy intensity of about 39 percent from 1980 to 2000 (fig. 2D). This decrease will result from the decline of the integrated production of steel and from the continued improvement in the amount of steel produced by electric arc facilities and continuous casting. Growth in mini mill steel production will result in a decline in hot metal production from open hearth or basic oxygen furnace operations and a decline in coke production and coke use. With continuous casting, there will be significantly more energy saved than with batch operations.

*An investment hurdle rate is defined as the minimum return a project must have to be acceptable to a firm.

POLICY OPTIONS

To assess the effects of a range of incentives on energy use in industry, OTA selected a set of policy initiatives directed at energy or corporate investment. These options include the following:

- Option 1: Removal of the accelerated cost recovery system (ACRS) provisions of the 1981 Economic Recovery Tax Act.
- Option 2: Addition of a 10-percent corporate income tax credit for investments in energy efficiency-improving equipment.
- Option 3: Imposition of a premium fuels tax of $1.00 per million Btu on petroleum fuels and natural gas.
- Option 4: Lowered interest rates as a surrogate for capital availability.

In addition, OTA attempted to determine how these policies would most affect the operation of a corporation. While the analyses can be used to project absolute energy use in each policy option case, their primary benefit is to allow a comparison of each legislative option to the reference case.

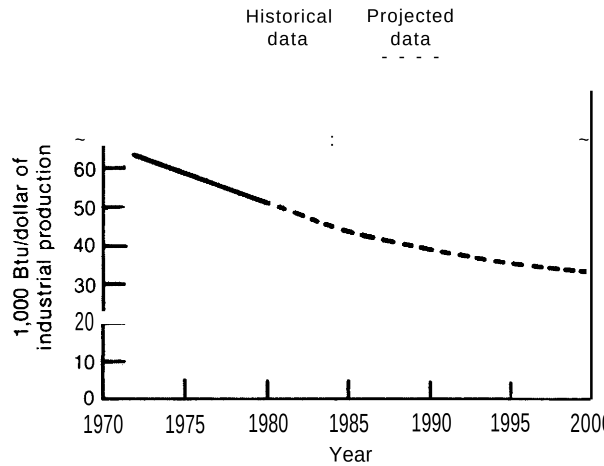
REFERENCE CASE

The Current Economic and Legislative Environment, Including the 1981 Economic Recovery Tax Act

projections of total industrial energy demand and fuel mix for the reference case have been shown previously in figure 1. These projections were based on the energy price assumptions shown in table 2 and on the economic growth rates shown in table 3. I n figure 3, OTA projects industrial sector energy intensity between now and 2000. Given the reference case, with its assumption of the current legislative environment, including ACRS depreciation, purchased energy use per dollar of industrial output should decline from a 1980 level of over 50,000 Btu per dollar to under 35,000 Btu per dollar by the end of the 1990's.

Two points should be. made about the projections presented. **First, improvements in energy efficiency are due primarily to investments in new processes and process equipment.** These investments and the demand for energy, however, depend greatly on future profitability and, therefore, on economic growth.

Figure 3.—Industrial Sector Energy Intensity Projection, 1972-2000

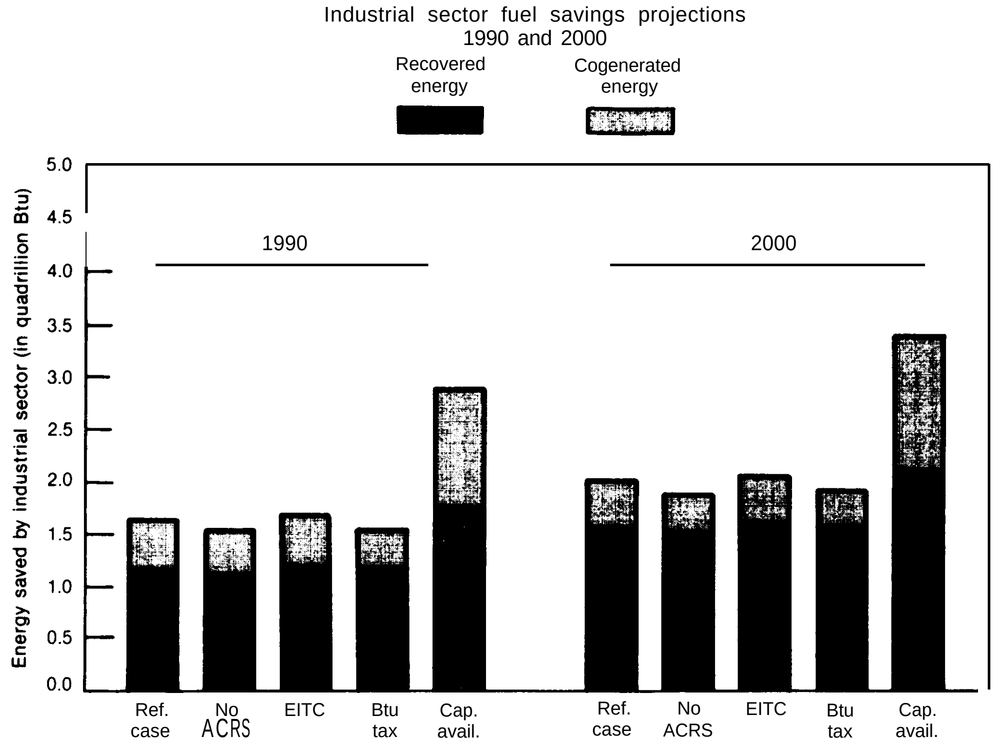


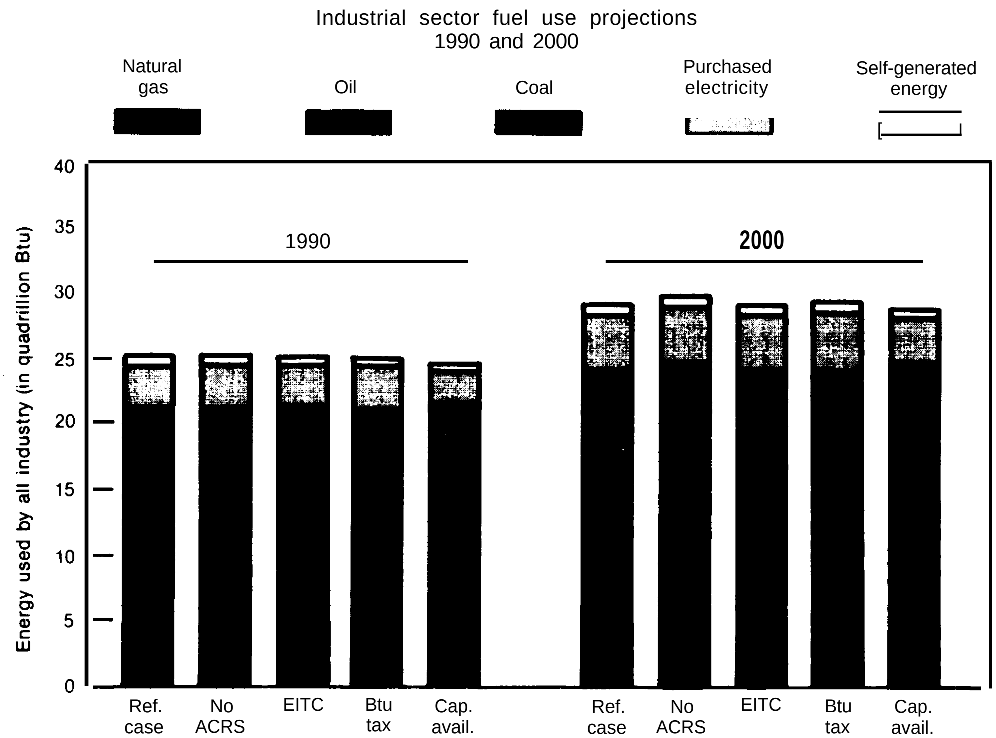
SOURCE: Office of Technology Assessment

Second, projections of the four major sources of industrial energy indicate that natural gas and oil use will remain more or less steady, electricity use will grow at about the same rate as total product growth, and coal use will grow at twice the rate of electricity. The projected, relatively rapid growth of coal results from the expectation that virtually all new large industrial boilers will be coal-fired. However, depending on the price of natural gas and on whether it will compete on the margin with residual oil or coal, the future paths of oil and gas could be reversed. The less expensive that gas is, relative to oil, the more likely it will be that existing oil heating will be converted to gas heating. Finally, electricity use will keep pace with final product demand. Efficiency improvements in electric motors will be offset by increased use of electric drying. Depending on the price of purchased electricity and the environmental restrictions on industrial cogeneration, a large share of this growing demand for electricity may be supplied by onsite generation.

Figure 4 presents a comparison of energy use in 199o and 2000 under the reference case and under each policy option. It also presents a chart showing energy saved in 1990 and 2000 (corn -

Figure 4.—industrial Sector Projections





SOURCE. Office of Technology Assessment

pared to a 1976 base) under the reference case and under each policy option. Following figure 4 is a discussion of each policy option, its impact, and the energy projected to be used if it were effected.

OPTION 1

Removal of Accelerated Depreciation

The ACRS can be a stimulus for investment, provided industry is profitable. Under these circumstances, the ACRS would likely accelerate investment and, as a result, there would be a corresponding acceleration of energy efficiency improvements as old equipment is replaced. Consequently, removal of the ACRS would slow the rate of improvement in energy efficiency, but only if economic conditions improve so that substantial and sustained investment were relatively unconstrained. **Currently, however, factors such as high interest rates, high debt/equity ratios, and low to moderate product demand, are the factors limiting investment decisions. Under these conditions, the absence or presence of the ACRS will have little effect on industrial energy efficiency.**

Under a condition of restrained product growth, the most significant shifts in energy use arising from the removal of the ACRS would involve cogeneration and capital-intensive conservation technologies. OTA projects that market penetration of these two categories of equipment would be restricted if depreciation periods reverted to pre-ACRS schedules. A decrease in cogeneration would cause a decline in the self-generation of electricity and in waste heat energy recovery. Additional requirements for boiler-generated steam, to make up for the loss of steam for cogeneration, would cause an increase in coal use above that used in the reference case in each of the four industries.

Finally, both the ACRS and the energy investment tax credits, discussed next, create situations where third-party financing for tax shelter purposes can be attractive to individual investors who wish to shelter personal income. Such situations can create opportunities for investments that can lead to increased energy efficiency, particularly cogeneration. However, uncertainty about the Internal Revenue Service's approval for these arrangements has prevented many of them from occurring.

OPTION 2

Targeted Energy Investment Tax Credits

Energy investment tax credits (EITCs) at a 10-percent level have little direct influence on capital allocation decisions in large American firms, and thus have little influence on energy conservation. These credits appear to be too small to exert any change on the returns on investment of most projects or on the cash flow of a company. A firm has an overall objective of increasing productivity, and therefore profitability, when it makes an investment in energy-using equipment. Energy is just one of many factors determining productivity of a given process, and a targeted incentive, such as the EITC, is diluted to the degree energy efficiency must compete with other factors of production for investment priorities.

In particular, the shift of 2 to 4 percentage points in a typical **20-to** 30-percent return on investment on a project brought about by a 10-percent EITC is usually not enough to cause a firm to reorder the priorities of its capital allocation plan. In some industries, OTA found that case-study firms claimed only 1 percent of the dollar amount for EITCs compared to that claimed for the general investment tax credit, an indication of the dilution that exists when targeting just one of several factors of production compared to targeting the entire investment. In this connection, **tax credits applied to cogeneration are more effective, particularly to third parties whose only objective is the production of cogeneration equipment.** Under these conditions, such credits can make the difference between going ahead with the investment or not.

A further barrier to the EITC is the decisionmaking structure of the firm. In some case-study firms, OTA found that the technical staff who decide on the engineering merits of a particular project often have no authority or responsibility for the financing considerations of the project. Such arrangements as third-party leasing and leveraged capital purchases are the responsibility of the financial offices. Therefore, the management staff that has the final decision on whether or not to undertake energy-related projects may not be the staff that is aware of all the technical opportunities that exist in an industrial facility. OTA's survey of firms in the energy-intensive industries indicates that economic calculations for individual projects are carried out on the basis of IOO-percent equity financing, the rationale being that this is the only way projects can be accurately compared. Only when considering the finances of the entire corporation, such as its debt load and debt-to-equity ratio, is leveraging (i.e, borrowing) considered.

In the steel industry, there is support for tax credits, but only from the standpoint of cash flow. That is, industry representatives agree that tax credits do little to move energy projects ahead of other possible investments; instead, they provide additional money from the energy projects that are taken on (and would have been taken on anyway), that can be used in general corporate operations. OTA projects that even if extending the EITC caused a slight increase in waste energy recovery in the iron and steel industry, the impact on the entire industry in terms of overall increased energy efficiency would be negligible.

The response of the chemicals industry to EITCs ranges from active support in one case, to neutral indifference i n most cases, and corporate antipathy in a few others. Some chemical firms suggest that modest EITCs serve as indicators to the manufacturing sector of the value the Government places on energy efficiency improvements. However, it appears that a 10-percent EITC is less effective than are existing and anticipated energy prices in heightening corporate managers' awareness about energy conservation. As with steel, the impact of the modest 10-percent EITC on the overall energy use in the chemicals industry is projected to be negligible. For petroleum refining, the principal effect is projected to be a small increase in cogeneration, reflecting the higher leverage these credits have on energy production projects.

OTA has been unable to find any projects throughout all the case-study firms where a decision to undertake a project hinged on gaining a lo-percent tax credit. overall, the impact of a 10-percent EITC on the total industrial sector is judged to be minimal. For the EITC to be effective, it would have to be substantially increased, probably to above 40 percent.

OPTION 3

Tax on Premium Fuels

Taxes at a rate of $1 per million Btu on natural gas and petroleum fuels—equivalent to about a 25-percent tax, or to $6 per barrel of crude oil—would change the fuel use mix in industry and would cause energy efficiency to improve slightly. In the case of coal, a premium fuels tax would only add to an already large price differential, and therefore the economic incentive to switch to coal would not be significantly increased. For electricity, the tax would be more important in terms of relative prices, but the limited existence of new technologies that efficiently use electricity to replace petroleum or natural gas will constrain conversion to electricity for several years.

Efficiency improvements that result from the premium fuels tax would be a few percent greater than those of the reference case. There are two major reasons for this small increase. First, the overall total cost of energy, despite a 25-percent increase in the price of premium fuels, will be considerably less than 25 percent, since gas and oil account for about 60 percent of total industrial fuel use. The net price increase will not greatly accelerate the incentive industry already has to invest in new process technology. Second, a tax just on premium fuels would provide an incentive to switch fuels, which would not necessarily increase overall energy efficiency.

The tax would have different consequences for each of the industries investigated. Within the pulp and paper industry, a premium fuels tax would accelerate the industry toward more energy self-sufficiency through use of biomass, and would increase their use of coal. A number of firms are considering replacing their oil-based, steam-generating facilities with fuel-flexible or coal-based ones. Such a tax would accelerate this change. A premium fuels tax is projected by OTA to decrease natural gas consumption in the pulp and paper industry by 5 to 10 percent. Much of this decrease would result from a cutback in cogeneration, with the result that the amount of electricity purchased from utilities would increase.

Since coal is the dominant fuel in the steel industry, a premium fuels tax would have a small impact. In 198?, the steel industry derived only 4 percent of its energy from petroleum sources, and less than 25 percent from natural gas.

The petroleum refining industry might be affected by a premium fuel tax in two ways. First, the tax would cause some reordering of energy-related projects to positions ahead of other capital projects. In particular, coal use for refinery operations would increase, while use of natural gas and cogeneration would likely decrease. Second, the fuel tax would undoubtedly decrease the industry's earnings through a general decrease in demand for its products.

The domestic impact of a premium fuels tax on the chemicals industry is less foreseeable. The largest effect of a premium fuels tax on the chemicals industry would likely be the negative impact on the ability of the chemicals industries to export products because of the resultant: 1) higher prices on U.S.-produced goods in overseas markets; and 2) the increased cost advantage for foreign firms to sell their products, both in the United States and throughout the world. OTA projects the direct impact of a premium fuels tax would be an increase in the use of coal and a decrease in the use of natural gas. As with the other industries, cogeneration, using natural gas, would also decrease relative to the reference case. Finally, the tax would probably cause a slight reordering in project priorities.

OPTION 4

Lowered Interest Rates as a Surrogate for Capital Availability

Corporations have a strong motivation to invest in new production equipment to maintain or improve their market share. If these corporations also perceive energy prices to be high and believe they will go higher, they have considerable incentive to make sure those investments increase energy efficiency. Therefore, low interest rates affect energy efficiency to the extent that lower rates may allow a company's cash flow to go further, its debt service to be less burdensome, and its ability to take on more debt to increase. In all cases, low interest rates increase the effective availability of capital and therefore allow more projects to be undertaken. Even with an attractive interest rate, however, investment will be restrained unless there is a perception of profitability and increased capacity utilization.

In this connection, if interest rates were to fall considerably, automobile sales, house sales, and the like would improve; capacity utilization rates would rise; and corporate capital funding would expand. However, even under these circumstances, especially for firms in the four energy-intensive industries examined by OTA, some companies cannot borrow funds because they have already reached the debt ceiling imposed by their desired bond rating. In these cases, the size of corporate debt load, not the interest rate, is the problem.

OTA finds that the availability of low-cost capital would result in the most significant shifts in total sector energy use from that of the reference case. In this situation capital-intensive technologies, such as cogeneration and heat recovery devices, would be significantly more attractive and would find greater use. Coal use would be greater because of increased penetration in both process and boiler applications. An apparent anomaly would occur in natural gas use, where the consumption figure for 2000 would actually be 3 percent higher than that in the reference case. This increase would be entirely attributable to the projected increased use of natural gas in cogeneration. The impact of increased penetration of conservation technologies and of greater numbers of energy-efficient processes in the low-capital-cost case would be a decrease in total energy use that would equal a full percentage-point drop in 1990 and half a percentage-point drop in 2000.

In the pulp and paper industry, OTA projects a shift to more self-generated energy, with natural gas and oil use down, but cogeneration increasing relative to the reference case. A low-interest cost of capital should bring about a 5- to 10-percent decrease in energy intensity.

The chemicals industry is somewhat unique in that OTA projects for it a slight increase in energy used per unit of chemical output if the cost of capital were lowered. Low capital costs would permit a large cogeneration effort, which would increase natural gas use in this industry. However, electricity demand from utilities would decrease, and the sum of energy used by the utility and the chemicals industry would be lower.

EFFECTS OF POLICY OPTIONS ON THE INDUSTRIAL SECTOR

For the entire industrial sector, under the conditions of the reference case, energy intensity is projected to fall from its current level of approximately 51,000 Btu per dollar of industrial output to a low of 33,000 Btu per dollar of output by 2000. The curve in figure **3** illustrates this as well as the long-term nature of the investments made by industry that would result in increased energy efficiency. The rate of decline in energy intensity will be less during the 1990's than in the 1980's. This decline should continue well past **2000** as the fraction of capital stock replaced by new processes and process equipment continues to grow. **During this period, the use of coal should increase from 5 percent of the total energy consumed to almost 18 percent as coal becomes a major fuel for process heat and steam boilers. In addition, the amount of purchased electricity should nearly double.** This effect should be balanced by decreases in the use of natural gas, while use of petroleum-based fuels should remain about the same.

OTA has found that investments in new technology are driven principally by judgments about future profitability. This, in turn, is affected by increased product demand, productivity, and a change in product mix. Where product demand is expected to grow, as in the pulp and paper and the chemicals industries, investment in expansion will be large and, consequently, energy efficiency improvements will be extensive. Where large changes in production technology are necessary to avoid a substantial loss of market, as in the steel industry, expansion of the industry will not occur, but investment in new technologies will still be large, The technologies in which steel will invest—primarily continuous casting and electric arc minimills—will also provide enormous increases in energy efficiency. Finally, where product demand is declining but a product mix shift will occur, as in the petroleum industry, investment will be needed to account for different product slates. In the case of petroleum, the changing characteristics of the crude oil feed stock and shifts away from heavy fuel oil and gasoline are the major factors. Again, efficiencies will result, although to a lesser extent than with other industries because investment will be less.

The policy options investigated by OTA do not affect perceptions of profitability nearly as much as do product mix shifts. The policy options are primarily aimed at accelerating investment, once a decision has been made, or targeting certain aspects of that investment, in this case, energy. They are most effective for those capital-intensive items that are primarily concerned with energy, such as cogeneration. Even here, however, the attention to product demand and mix is so dominant that none of the options, with the exception of lower capital cost, changes the decision pattern of manufacturing by a great amount. **Given a healthy economy and reasonable access to capital, however, industry will make investments over the next few decades that will increase productivity and profitability and will have a positive effect on energy efficiency. This improvement can take place without additional Federal incentives.** The key is stable economic growth, without which even much larger incentives than OTA has considered will not be of much value.