84

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Capital investment to save energy

Installation of energy-efficient processing equipment would conserve as much as 25% of U.S. industrial demand projected for 1985

G.N. Hatsopoulos, E.P. Gyftopoulos, R.W. Sant, and T.F. Widmer

At a cost of about 50% less than the cost of new energy supplies now planned or under development, U.S. manufacturers could furnish themselves with a fuel source that equals the amount of energy consumed by automobiles in the United States today. How? Through investment in energy-efficient plant and equipment, say the authors of this article. Higher energy efficiency could be achieved by combining processes and by recovering heat that now is wasted when it escapes to the environment. The authors explore the conservation possibilities in the raising of process steam, direct-combustion heating of materials, and use of electric motors. Unfortunately, they say, many manufacturers set too high a rate of return for these investments—higher than that for their regular capital projects—which may lead to uncompetitive positions in their markets.

George N. Hatsopoulos is president of Thermo Electron Corporation, which makes process equipment and provides services to energy-intensive industries. Elias P. Gyftopoulos is Ford Professor of Engineering in the Department of Nuclear Engineering, Massachusetts Institute of Technology. Roger W. Sant, former assistant administrator for energy conservation and environment in the Federal Energy Administration, is director of the Energy Conservation Policy Center, Carnegie-Mellon Institute of Research. Thomas F. Widmer is vice president of engineering at Thermo Electron.

In November 1976 the manager of a cement plant in a southeastern state presented to corporate headquarters a proposal to install a 4,700-kw generator powered solely by waste heat from cement-making kilns. The turnkey price was $2.7 million. Top management turned down the proposal for having a rate of return lower than the hurdle rate for this kind of investment. The cement plant continues to buy electricity from the local utility.

In generating the electricity that the rejected unit would have produced, the utility consumes 188 barrels of oil a day. Had the cement company installed the heat recovery unit, the electricity produced would have replaced not only an equal amount of new fuel supply facilities but also a corresponding amount of new generating capacity needed for expansion. The coal- and nuclear-based systems that would have been replaced cost $5 million and $8 million respectively—two to three times the cost of the energy-saving proposal.

In late 1975 a paper company considered a proposal to install in a mill a system for recovering waste heat from papermaking. The system would have cost $316,000. The recovered energy, to be used for paper drying and space heating, would have saved $185,000 per year in fuel costs. The investment was not approved.

In early 1977 executives of a major steel manufacturer debated whether to spend $1.2 million to retrofit two slab-reheat furnaces with recuperators and the required new burners and controls. The annual gas saving would have amounted to $400,000. The executives decided, however, not to purchase the recuperators.

The history of these proposals illustrates a cost-saving opportunity that many manufacturers are passing up: energy conservation. It also raises two questions: Are the criteria used by manufacturers for investments in energy efficiency appropriate in their competitive environments? What energy and cost savings could be expected from more efficient use of energy in manufacturing? We have studied these questions and have identified four factors that should be taken into account in energy conservation decisions:

1
Although the average price of energy has now fallen well below the still rising replacement cost of energy supplies, this condition is likely to be only transitory. Recognition of this likelihood may reduce the cost of transition for some companies.

2
Because the rate of return on investment required by energy-using industries is higher than that granted to regulated utilities for comparable-risk new power plants an opportunity to attract new special-purpose capital from investors exists.

3
Most companies set the expected rate of return from energy-saving investments at a level about twice as high as that for mainstream business investments. As a result, capital spending is concentrated on the latter while higher energy costs are passed on to consumers. Revision of that priority may represent a chance to increase market share for some companies.

4
Federal, state, and local regulations restrict the generation of electricity by many manufacturers. But these regulations are in the process of being revised, and appropriate presentations to authorities could result in advantages for some manufacturers.

If these factors were taken into account, we estimate that cost-effective investments (in which the total cost of the energy saved is equal to or less than the replacement cost of the fuel or the electricity saved) could save about 25% of the industrial energy that will be in demand by 1985 and thereby do much to offset higher energy costs. Available technology could be used, and no curtailment in production would be necessary. The energy saved would be huge–equivalent to the energy consumed by all the automobiles in the United States today.

The conservation measures we identified would entail a capital cost of less than $126 billion over the next seven years. To obtain the same amount of fuel and electricity through new energy supply investments (from source to consumer), an expenditure of at least $170 billion would be necessary. The weighted average total cost of fuel and electricity saved would approximate $2.50 per million Btu versus $5.10 per million Btu for the same mix of energy supply.

Factors affecting conservation

Some of the factors affecting investments in energy efficiency are purely economic; others are behavioral and institutional.

In the past few years, one fundamental economic factor has emerged–the large disparity between the price of energy and the cost of its replacement. From 1950 to 1970, energy prices and replacement costs declined annually in real terms at a rate of 1.7%. Electric utilities were building larger and more efficient plants, and energy suppliers were using more sophisticated methods of discovering, producing, and distributing natural gas and oil. In those days, all forms of replacement energy, even regulated natural gas, had costs equal to or less than the price of supplied energy.

Just before the oil embargo, however, replacement costs started to climb sharply. From 1971 to mid-1973, prices rose to their real 1950 level. For the first time in our history, the replacement cost of all energy sources jumped above the average price paid by consumers. The postembargo oil price increases have accelerated this trend; as *Exhibit I* shows, the replacement cost for the mix of energy consumed by industry in mid-1977 exceeded the price of supplied energy by about 37%. The cost disparity in September 1977 was the most for natural gas (59%)–it would be even higher if Alaskan gas, liquefied natural gas, or synthetic fuels were used as replacement fuels–and the least (0%) for coal.

The example of the waste-heat-powered electric generator illustrates this disparity. The southeastern electric utility cited at the start of this article charged the cement plant 2.6 cents per kilowatt hour (kwh). This price was based on the utility's aftertax return on assets of almost 8%. The utility's rate structure, however, represents an average of the cost of new

Exhibit I
Average price and replacement cost of energy used in industry

Energy form	Percent of industrial use (1977 to June)*	Dollars per million Btu of delivered energy (September 1977)		Ratio of replacement cost to average price
		Average spot price†	Replacement cost‡	
Coal	19.0%	$1.05	$1.05†	1.00
Petroleum	34.0	2.41	2.88*	1.20
Natural gas	34.5	2.08	3.30*	1.59
Electricity	12.5	9.00	12.90§	1.43
Weighted average		$2.86	$3.93	1.37

Monthly Energy Review, U.S. Department of Energy, November 1977.
†*Energy,* November 4, 1977, p. 2.
‡Cost of new energy if investment decision is made today.
§Charles L. Rudasill, "Comparing Coal and Nuclear Costs," *EPRI Journal,* October 1977, p. 14.

plant and equipment plus older, less expensive facilities. If the electricity was to be produced exclusively from new facilities, the 2.6-cent price would bring a return of only 5.5%. If the utility charged the cement manufacturer a rate reflecting the cost of new facilities, the price per kwh would be about 4.1 cents rather than 2.6 cents.

This disparity cannot last, because eventually new energy will supply much of the demand and replacement costs will reach a new plateau. The costs of synthetic fuels, and perhaps of electricity from the sun and the nuclear breeder, approximate 1.5 to 2 times current replacement costs. The abundance and partial renewability of these supplies should cause prices to plateau. Furthermore, it is politically unrealistic to doubt that deregulation will come; the question is, Over what period of time? Investment decisions that reflect these realities may provide the manufacturer with a competitive edge.

Different ROI criteria for utilities and manufacturers produce another economic disparity. Had the cement producer used the utility's 8% rate of return as his investment criterion, the cost of the electricity generated by the waste-heat recovery system would have been only 1.2 cents per kwh. Thus, assuming the same capital costs, we find that electricity from new plants costs about 3.5 times more than electricity from waste heat–4.1 cents versus 1.2 cents.

Both houses of Congress have passed a 10% additional investment tax credit to partly overcome this disparity. If the credit is enacted, it clearly deserves use by manufacturers for marginal projects. It may also be possible to overcome the balance of the disparity through new forms of financing that reflect the low risk of energy conservation projects and make them competitive with new forms of energy supply.

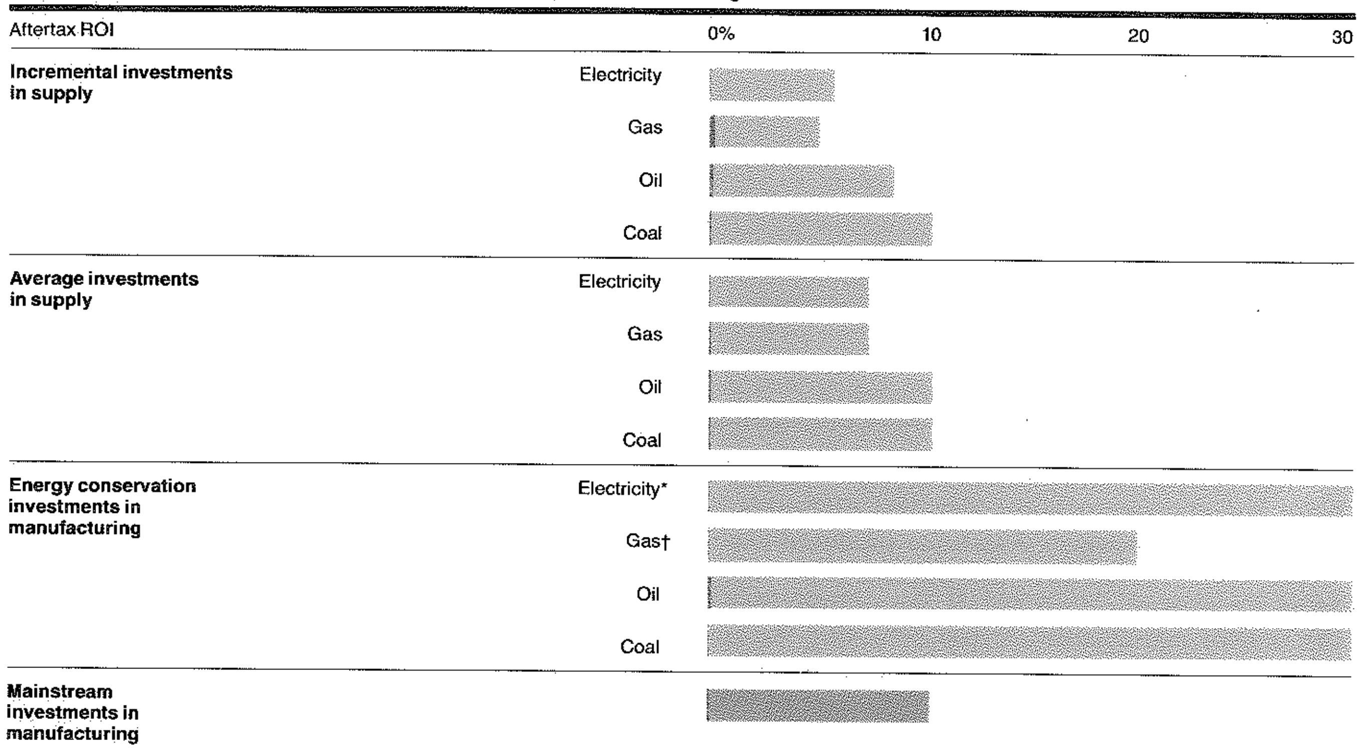
Top management of the cement company assessed the plant manager's proposal on the basis of 2.6 cents per kwh of purchased electricity. This analysis resulted in a projected aftertax ROI of 22%, considerably less than the 30% expected from the discretionary investments that did not increase production. Although the company's typical ROI criterion was only about 15% and its average return on assets only 10%, top management rejected the proposal.

If, however, the company had used the 4.1-cent replacement cost in its analysis, the generator would have earned a return well above 30%. Then management would have approved the project.

This kind of situation often prevails in our economy. While utilities are making incremental investments in new facilities that yield only 8% on assets, energy users are turning down investments in conservation equipment (yielding an equivalent amount of electricity) if the projected annual return from the outlay falls below 30%.

Similar but less dramatic disparities exist in uses of other forms of energy (see *Exhibit II*). The difference in investment returns, calculated on average versus replacement costs, is about 1.6 percentage points for petroleum and about 2.9 percentage points for natural gas. Only for coal is there virtually no difference. Recently, manufacturers' required return on gas-saving investments appears to have dropped to about 20% (based on a three-year payback) from 30% (based on a two-year payback), probably because of fear of curtailment. This means that gas

Exhibit II
Estimated prevailing returns on investment in energy supply and manufacturing



*Two-year payback with ten-year declining balance depreciation compounded monthly.
†Three-year payback.

users are now more inclined to regard conservation investments as essential than risky.

Electric utilities realize an average return of less than 8% on total capital, while manufacturers' returns are 10% on total capital.[1] Market forces, of course, cause the difference. Because they are regulated monopolies, utilities neither raise nor lower their average return on capital by scheduling more or less profitable incremental investments.

Because they are relatively unregulated and highly competitive, manufacturing enterprises seek investments that promise an above-average rate of return. So they evaluate electricity-saving projects with roughly a 22% additional handicap relative to utilities' evaluation of electricity-generating projects.

Factors other than market forces often create great differences between what manufacturers expect for return rates through conservation and what utilities expect for new power plants. Classical economists would argue that there is no reason to give higher priority to expansion of production capacity than to cost-reduction or energy-conservation projects using known technology. Yet expansion was the cement producer's priority, and scarce capital is going to expansion projects at the expense of conservation projects. Because of the new realities in energy, however, at some point competitors will find a way to undertake both expansion and conservation—for instance, through special-purpose financing packages.

The disparity between the criteria for these two types of investment is larger now than a decade ago. Business executives' uncertainty concerning the reliability of projects and the future availability and cost of capital seems to account for this disparity. The low price-earnings ratios in the stock market probably cause more concern than the high interest rates on debt. If corporate executives perceive more abundant capital at hand, the gap between the criteria for discretionary investments and those for mainstream investments will disappear.

Finally, a number of institutional barriers prevent the adoption of energy conservation measures. For example, various federal, state, and local power commissions regulate the generation and sale of electricity. These regulations are currently under review. If manufacturers wishing to generate by-product electricity participate in the review process, they might influence it to their advantage.

In summary, energy-efficiency investments are not being undertaken as fast as economic circumstances and anticipated developments warrant, primarily because they are evaluated on an unequal basis in comparison with investments in new energy supplies. In the foreseeable future this practice will erode competitive strength. Companies recognizing that energy prices will eventually rise to their next replacement-cost plateau can seize the opportunity to use energy efficiency as a means of increasing market share.

Conservation & capital needs

How much saved energy could be produced through cost-effective technology? After studies of various industries, we estimate that approximately 25%—the equivalent of 4.5 million barrels of oil per day—of projected 1985 energy usage in manufacturing could be saved through conservation measures whose capital and total costs would be equal to or less than those needed to obtain comparable amounts of new energy supply.

One-fourth of the energy saving could be achieved with cogeneration—that is, the generation of electricity in combination with the raising of process steam, with direct-fired, high-temperature furnaces, or with direct-fired, low-temperature applications. The estimated capital cost would be $76 billion, whereas for equivalent new coal- and nuclear-fired central power stations it would be $105 billion. Using the utilities' 8% return on investment, we estimate the total cost of the cogenerated electricity to be 2.8 cents per kwh versus a national average of 4.4 cents for electricity from new central power plants.

Another one-fourth of the saving could be obtained through energy recycling and waste-heat recovery by means of economizers, regenerators, recuperators, and waste-heat boilers. Its capital cost would be about $9.5 billion, and its total cost 80 cents per million Btu versus $14.0 billion and $2.70 per million Btu, respectively, for new fuel supply.

One-tenth of the energy saving could be achieved through the increased efficiency of electric motors, electrolytic processes, and lighting. These measures would cost about $10 billion—about one-half the capital cost of an equivalent amount of new electricity supply. The cost per kwh of the electricity saved would be 1.7 cents.

The remaining energy saving (40%) would result from measures particular to each manufacturing process. Assuming that savings would be distributed among the various fuels in the same proportion as the present usage pattern, we estimate the capital requirement to be less than $30 billion versus about $32 billion for new fuel supplies. The cost per million Btu would be $1.30 for saved energy versus $3.20 for replacement energy.

Because of wide differences in the efficiency of current practices, particular industries deviate substantially from the average 25% energy saving. In addition, particular industries have different mixes of energy-saving opportunities with regard to fuel types —that is, the fractions of savings that can be achieved in coal, oil, gas, and electricity.

A summary of our estimates appears in *Exhibit III.* By 1985, the equivalent of 4.5 million barrels of oil daily—about three times as much as the supply of the Alaskan pipeline—could be saved at a 25% reduction in capital cost ($126 billion versus $170 billion) and an overall 50% reduction in the unit cost of energy ($2.50 versus $5.10 per million Btu).

Measure of efficiency

The estimated energy saving is only a fraction of the existing potential. Assessment of this potential requires a reliable and practical yardstick for measuring the effectiveness of energy usage in manufacturing. Such a yardstick could be used not only by managers to set goals for improvement but also by market planners and product developers to provide direction for new business opportunities.

The laws of physics and thermodynamics give us an absolute measure of efficiency of any process that transforms a material from one form to another. This measure accounts not only for the amounts of energy required and consumed in the process but

1. "Annual Survey of Corporate Balance Sheets: 1977," *Business Week*, October 17, 1977, p. 72; "Survey of Corporate Performance: Third Quarter, 1977," *Business Week*, November 14, 1977, p. 105.

Exhibit III
Summary of energy savings and costs projected for 1985

Energy-saving technology	1985 Energy savings (in millions of barrels of oil per day)		Capital cost		Energy total cost	
	Fuel	Electricity	Conservation (in billions of dollars)	Energy supply (in billions of dollars)*	Conservation (in dollars per 10^6 Btu)	Energy supply (in dollars per 10^6 Btu)
Cogeneration of electricity with:						
Process steam	0.68	0.55	$54.0	$73.0	$8.40†	$12.90†
High-temperature processes	0.16	0.16	3.5	7.0	4.10†	12.90
Low-temperature processes	0.18	0.06	18.5	24.5	8.90†	12.90
Energy recycling	1.12		9.5	14.0	0.80	2.70
Electric motors and other electrical processes	0.46	0.15	10.5	20.0	5.00†	12.90
Process modifications:						
Electrical	0.23	0.08	Less than 10.0	10.0	7.80†	12.90
Nonelectrical	1.67		Less than 20.0	21.5	1.00	2.70
Average					$2.50	$5.10
Total	4.50	1.00	Less than $126.0	$170.0		

*Based on $60.0 for electricity, $6.8 for oil, and $2.0 for coal, all in billions per annual quad.
†Energy in the form of electricity.

also for the quality of that energy. One way to describe the measure is to use a formula in which efficiency equals:

$$\frac{(\text{quality of required energy}) \times (\text{required energy})}{(\text{quality of consumed energy}) \times (\text{consumed energy})}$$

Quality is an important characteristic because, of course, an amount of energy at a high temperature is more useful and more valuable than an equal amount at a low temperature. Its value can be calculated by means of standard thermodynamic techniques. For example, the quality of natural gas is about 1.0, and that of waste heat at 1,000°F is 0.42. The quality of energy required for heating steel parts at 1,500°F is 0.53, and that for raising saturated steam at 200 pounds per square inch is 0.33.

Today, we estimate, the average efficiency of the U.S. manufacturing sector is about 13%. By 1985, the energy saving that we have discussed could raise the level to 17%—still leaving a large margin for further improvement. Of course, we do not suggest that efficiency can ever come close to 100%. Nevertheless, we are convinced that the potential is so large that it deserves manufacturers' careful consideration.

Values of efficiency can be calculated for complete processes like the transformation of wood into a particular type of paper or of iron ore into a special steel. The results differ widely, even for slight variations of the same product, such as hardened steel versus steel ingots. For this reason, efficiencies of complete processes are impractical for setting goals for improvement.

It *is* possible, however, to determine values of efficiency for manufacturing stages or functions like steam raising under specified conditions or heat treating at a given temperature. For certain functions, the results are almost independent of the product and uniquely related to the equipment in question and its function. Therefore, efficiency values for these functions can be very helpful to plant managers and engineers.

The function-related efficiency can be evaluated either for a single piece of equipment or for several pieces collectively. It can also be applied to equipment processing various materials and being powered by various forms of energy. The overall efficiency of the equipment is the sum of the energy quality terms of the different outputs divided by the sum of the energy-quality terms of the different energy inputs.

The ratio of required energy to consumed energy is often used as a measure of efficiency of industrial processes. Though well defined, this ratio neither reveals the enormous opportunities for energy saving nor addresses the real causes of inefficiency. For example, the average value of this ratio for all U.S. manufacturing is about 75%.

If that were the efficiency of manufacturing, little room for improvement would exist. But the average value of the correct efficiency is a mere 13%, which suggests great opportunities for improvement. (It should be noted that the efficiency of the buildings and transportation sectors is even less.)

Exhibit IV
Major energy-consuming functions in manufacturing

Function	Approximate portions of primary energy usage
Raising of process steam	40%
Direct-combustion heating of materials:	
Low-temperature processes (less than 800° F)	12
High-temperature processes (more than 800° F)	10
Electric motors	17
Total	79%

Better energy efficiency

The primary sources of energy inefficiency in manufacturing are burning of high-grade fuel to produce low-temperature process heat, loss of high-grade waste heat to the environment, and use of certain manufacturing processes. Inefficiencies of processes can be attacked only through systematic analysis of the operations particular to each industry—a task that requires intimate and detailed knowledge of the technologies involved.

The first two sources of inefficiency are common in industry and can be reduced with technology applicable to many industries. These inefficiencies, which are found in fuel-fired kilns, furnaces, ovens, and dryers, can be reduced through various process rearrangements, including recycling of waste energy and recovery of waste energy.

Even without consideration of specific products, we can identify a major part of the potential savings in industry merely by referring to processes employed by most manufacturers. These functions, listed in *Exhibit IV*, account for almost 80% of the energy used in manufacturing. In the next few pages we discuss the energy-saving modifications of these functions that are possible with currently available technology.

Steam raising

The energy used in the raising of process steam accounts for about 40% of the energy consumed in manufacturing, an account exceeding the fuel consumption of all U.S. automobiles. Such steam is generally used at relatively low pressure and temperature (50 to 150 pounds per square inch and 300°F to 350°F). The normal method of raising process steam in fuel-fired boilers is very inefficient because the product is relatively low-temperature steam although the combustion of the fuel generates much higher-temperature heat.

An average-size residual-oil-fired boiler costs, installed, about $8 per pound of steam per hour. By including units that recycle waste heat, a manufacturer can increase the boiler efficiency by 10% at an added investment of about $2 per pound per hour. Retrofitting such units on existing boilers can be done for about $3 per pound per hour. If equipment usage averages 6,000 hours a year, these investments in recycling units for new and existing boilers would be 53% and 29% less than the investment in new petroleum supply, respectively. These percentages are based on the estimated capital for new oil-producing facilities of $15,000 per daily barrel.

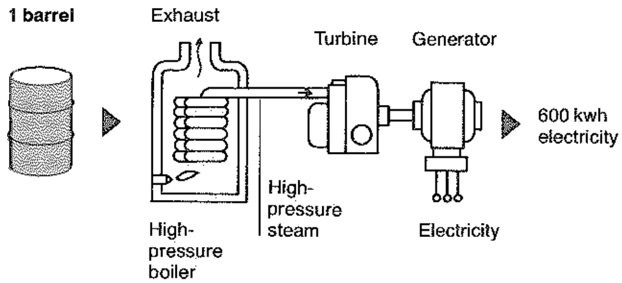
The recycling of waste heat alone takes less than full advantage of the opportunity to curb inefficiency in process steam production. To realize significant energy savings, the manufacturer can make better use of the high-temperature heat created by fuel combustion. Generation of motive power or electricity in combination with steam raising—that is, cogeneration—can accomplish this.

Part A of *Exhibit V* illustrates how a back-pressure steam turbine can effect cogeneration. By exploiting waste energy from the turbine instead of consuming raw fuel, the combined process produces the same amount of steam as a low-pressure-fired boiler does. The combined approach also generates 600 kwh of electricity. Separately, the two units consume the equivalent of 2.75 barrels of petroleum;

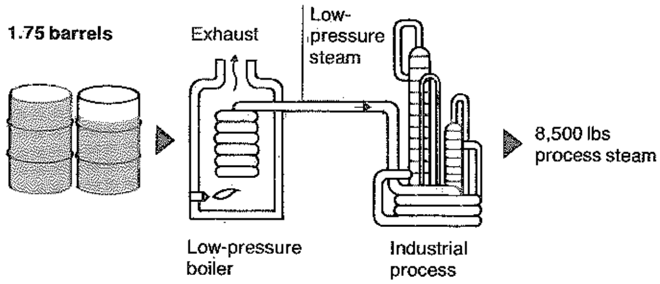
Exhibit V
Modifications of three power-consuming manufacturing functions to conserve energy

Part A

Electricity only

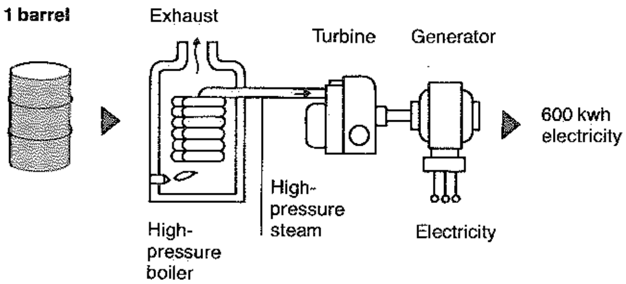


Process steam only

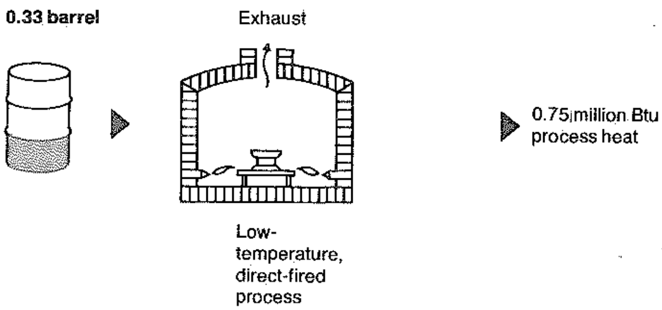


Part B

Electricity only

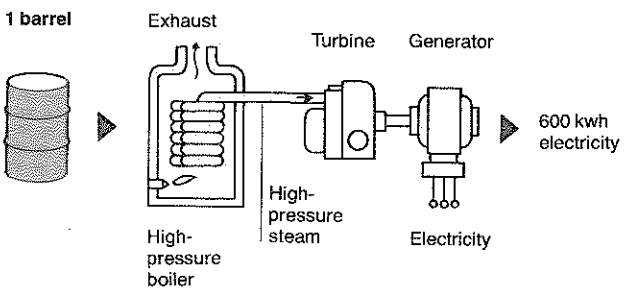


Process heat only

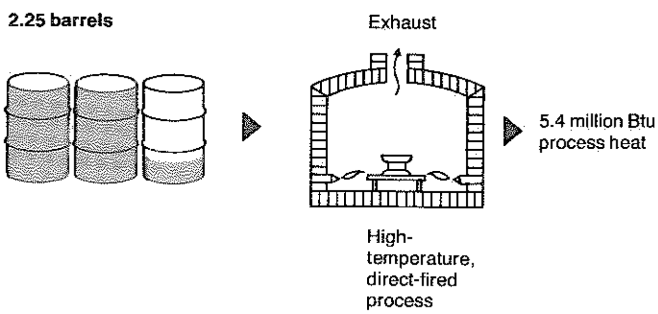


Part C

Electricity only

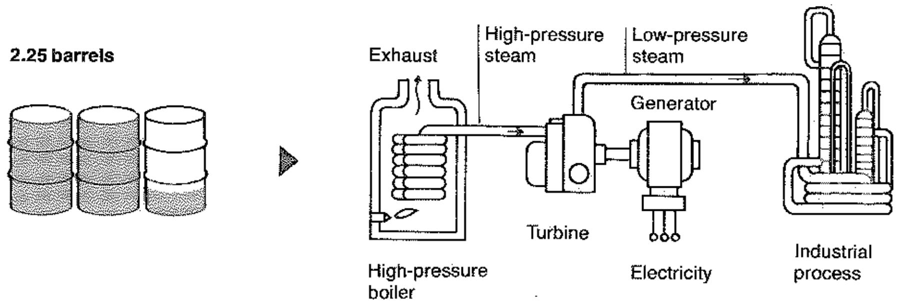


Process heat only



Electricity and process steam

2.25 barrels

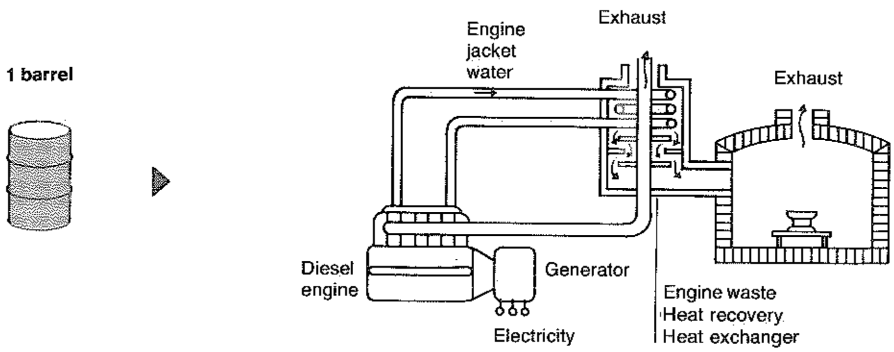


+600 kwh electricity

8,500 lbs process steam

Electricity and process heat

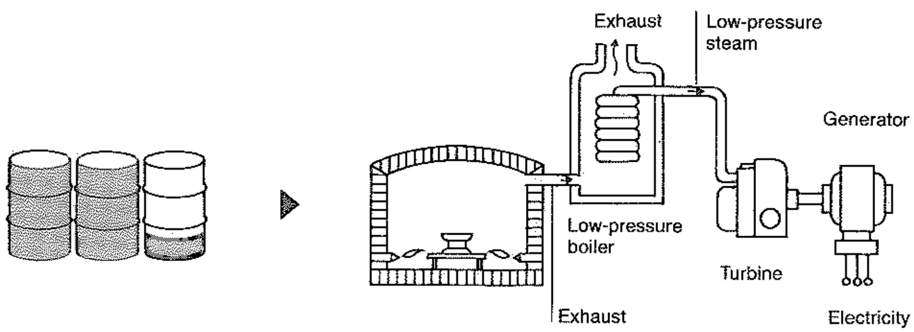
1 barrel



+600 kwh electricity

0.75 million Btu process heat

Electricity and process heat



+600 kwh electricity

5.4 million Btu process heat

but in cogeneration, 2.25 barrels. (Looking at it another way, cogeneration produces 600 kwh of electricity for half the one-barrel expenditure of a modern central station plant.)

Considerable latitude exists for varying the ratio of electricity to steam. Steam-turbine engines normally yield up to 70 kwh for each million Btu going to process steam. With diesel engines, electricity production rises to as much as six times that of steam turbines. The incremental fuel consumption of steam-turbine engines is about 5,000 Btu per kwh and of diesel engines, 6,800. Both amounts are less than the rate of 10,000 Btu per kwh of utilities' generating plants.

In our projections for conservation by 1985, we included only about one-third of the potential because by then only that amount of electricity could be cogenerated with process steam with cost effectiveness.

Heating processes

The energy used in the direct-combustion heating of materials accounts for about 22% of that consumed in manufacturing. Inefficiencies can be reduced by a variety of methods.

Low-temperature units

Inefficiencies in low-temperature processes—required temperatures lower than 800°F—like baking, drying, and curing occur because the manufacurer uses high-quality-fuel heat to accomplish a task that requires only low-grade energy. When the temperature requirement is very low, say 200°F to 300°F, diesel or steam-turbine engines can be used for cogeneration of electricity, as in steam raising. *Part B* of *Exhibit V* illustrates the combined process.

For intermediate temperatures, opportunities exist for using waste heat derived from the exhaust of a high-temperature furnace (metal heat treating, for example) or from a gas turbine cogeneration unit. It may also be possible to recycle a portion of the low-temperature furnace exhaust to preheat materials or incoming process air.

In processes like drying textiles or food grains, the addition of a diesel engine to cogenerate electricity not only yields a dramatic increase in efficiency—by almost a factor of four—but also permits the substitution in the heating operation of low-grade residual oil for scarce natural gas.

The dryer provides an excellent illustration of the advantages of fuel substitution in most low-temperature industrial heating processes. It is often claimed that natural gas is absolutely necessary to fuel ovens, kilns, and crop dryers, where clean heat is required. But there is no reason that the manufacturer cannot use a separate combustion system, burning "dirty" fuel like coal or almost any other fuel to heat clean air (through an exchanger) for delivery to the oven or dryer.

The best solution, of course, is to use a diesel engine with a heat exchanger in its exhaust. In this way, the manufacturer retains the clean process environment, eliminates gas usage entirely, and improves efficiency.

Obviously, the diesel engine costs far more than a simple once-through system using only a gas burner with air dilution ports. But, even so, this conservation measure will yield much more energy per dollar of capital invested than will comparable investments in new energy supply.

Theoretically, as much as 250,000 megawatts (Mw) of electrical generating capacity could be achieved through conversion of all low-temperature processes to cogeneration with diesel engines. Since many low-temperature processes are small in scale and operated only intermittently, we have included only 20,000 Mw of this cogeneration capacity in our projections for 1985. Much of the remaining conservation potential could be obtained by means of heat exchangers to recycle process heat and thereby reduce fuel requirements by 15% to 30%.

High-temperature units

Many heating processes in the manufacture of metals, ceramics, glass, and cement require high temperatures in furnaces, sometimes in excess of 2,000°F. As the temperature rises, the inefficiency due to cooling of combustion gases becomes less significant. Efficiency loss occurs, however, in other ways. Insulation loss generally rises with temperature. More important are the losses "up the stack" in the form of high-quality energy contained in exhaust gases and in materials leaving the furnace.

A variety of conservation measures can be employed to improve the efficiency of high-temperature furnaces. In addition to the obvious one of reducing heat loss with better insulation, the manufacturer can recycle exhaust heat to preheat the air used in combustion, recover heat from material leaving the furnace to preheat material entering it, employ exhaust heat for steam raising or other process-heat purposes, or cogenerate electricity from exhaust heat by means of turbines. (See *Part C* of *Exhibit V* for a diagram of this last method.)

One can appreciate the magnitude of the potential energy saving from these measures by examining a typical example of high-temperature industrial processing—the hardening and tempering of alloy steel parts such as gears, shafts, and bearings. The process consists of three operations: heating steel parts to 1,650°F, quenching parts in oil at 350°F, and tempering parts at 700°F.

About 1,400 Btu of gas fuel are consumed for each pound of material undergoing treatment. New furnaces with improved insulation are now being installed for some hardening and tempering operations. As *Exhibit VI* shows, there are at least four other conservation measures available that improve efficiency. All these measures rely on waste-heat recovery or waste-heat recycling to overcome losses in the furnaces.

By 1985, the theoretical potential for cogeneration with such furnaces approximates 30,000 Mw of generating capacity. We have included only about 5,000 Mw in our projections because cogeneration will compete with other conservation measures. Capital equipment for recovery of waste heat for direct use tends to cost less than that for cogeneration.

Electric motors

Now consuming about two-thirds of the electricity used in manufacturing, electric motors afford one of the simplest opportunities to improve efficiency. By 1985, they are expected to account for about 710 billion kwh of electricity consumption, or about 17% of the total energy consumed in manufacturing.

Such motors now cost about $40 per horsepower. Increasing the amount of copper and magnetic materials used and making certain design improvements could raise efficiency by about 10% at a cost of about $10 per horsepower.

If all new motors purchased by industry incorporated this better design, the annual energy saving by 1985 would amount to about 2% of industrial electricity consumption. The capital cost penalty for motors used in new installations, $10 per horsepower, represents an incremental investment of $300 million over the next seven years.

Exhibit VI
Efficiency improvement options for the hardening and tempering process

Conservation measures	Gas fuel used per pound of parts heat-treated (in Btu per pound)	Percent of fuel saved	Percent of efficiency
Present practice	1,400	Baseline	12.6
Improved insulation; reduced radiation, penetration, and transfer losses	1,258	10.0	14.0
Improved insulation plus recuperators on hardening and tempering furnaces	1,000	28.6	17.7
Improved insulation plus total process regeneration	821	41.4	21.5
Improved insulation plus bottoming engine for electricity	1,258 (−302)*	32.0	22.2

*Fuel saved because the electricity generated by the bottoming engine need not be produced by a utility.

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The cost of using high-efficiency motors in all new and existing industrial installations (at $50 per horsepower) amounts to $6.3 billion and translates into an electricity cost of 1.2 cents per kwh. In the absence of such an investment, the operation of less efficient motors through 1985 will require the generation of new electricity at a capital cost of about $13.8 billion and a total cost of 4.4 cents per kilowatt hour.

Opportunities for action

Our analysis indicates that manufacturers would benefit from the investment of about $126 billion over the next decade in more energy-efficient plant and equipment. The result would be an enormous additional fuel source at a total cost about 50% less than that of new energy supplies currently under development.

Does this capital spending make sense to industrial management according to traditional practice? It probably does not, at least to the extent of $126 billion. Yet investments in energy efficiency must somehow be evaluated on an equivalent basis with investments in new energy supplies. Otherwise, the cost of transition to the new energy era will be too disruptive.

National policy recommendations

1
Continue to allow the prices and rates for all forms of energy to adjust as rapidly as equity considerations allow, so that prices fully reflect the current costs of new supplies rather than "rolled in" or average prices.

2
Restructure the special conservation-oriented investment tax credit recently enacted to provide increasing tax credits up to 30% as projected rates of return on projects drop below 15% and approach 8%.

3
Provide cost-sharing grants for projects using energy-saving technology that has not been previously installed in the particular industry or process.

To overcome some of the disparities we have described, we make several recommendations for national public policy in the ruled insert shown above. But more important, we suggest that managers recognize these matters:

□
In the foreseeable future, replacement costs of energy are likely to continue upward to a new plateau, probably twice their current level. Regardless of what that eventual level is, energy prices will ultimately move toward their replacement costs. Managers who recognize this trend in their conservation investment decisions may achieve higher market shares.

□
The 10% additional investment tax credit already passed by both houses of Congress deserves full use if enacted. As we have indicated, 10% is not enough fully to overcome the existing investment disparity between utilities and their customers; but it will provide some assistance in justifying reconsideration of some previously marginal conservation projects.

□
An opportunity may exist for manufacturers to package conservation projects in a form that would demonstrate to the financial community their attractiveness relative to new supply options. Once investors understand the saving in cost per unit of energy, they may be willing to give the manufacturer more favorable terms.

□
Manufacturers may obtain a competitive advantage by reassessing priorities for conservation projects. Many companies have saved more than 30% of their energy costs since 1974 and have thus gained a significant advantage on product costs. In those companies that have achieved substantial savings, top management attention has always seemed to be present.

□
The energy bill in congressional conference (as this article was being written) directs various power commissions to raise the price of surplus cogenerated electricity and the purchase of backup power to a level equal to the power it replaces. This policy, if enacted, may substantially increase the attractiveness of cogeneration projects. Consultation with local utility commissions may be required to complete this action.

One may reasonably choose to blame the confused energy picture on bureaucrats and politicians and do very little about energy productivity until that picture clears up. However, it may be just as reasonable and substantially more competitive to conclude that, regardless of national policies, the facts of the energy situation are clear enough to warrant high-priority attention—now, not later.

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