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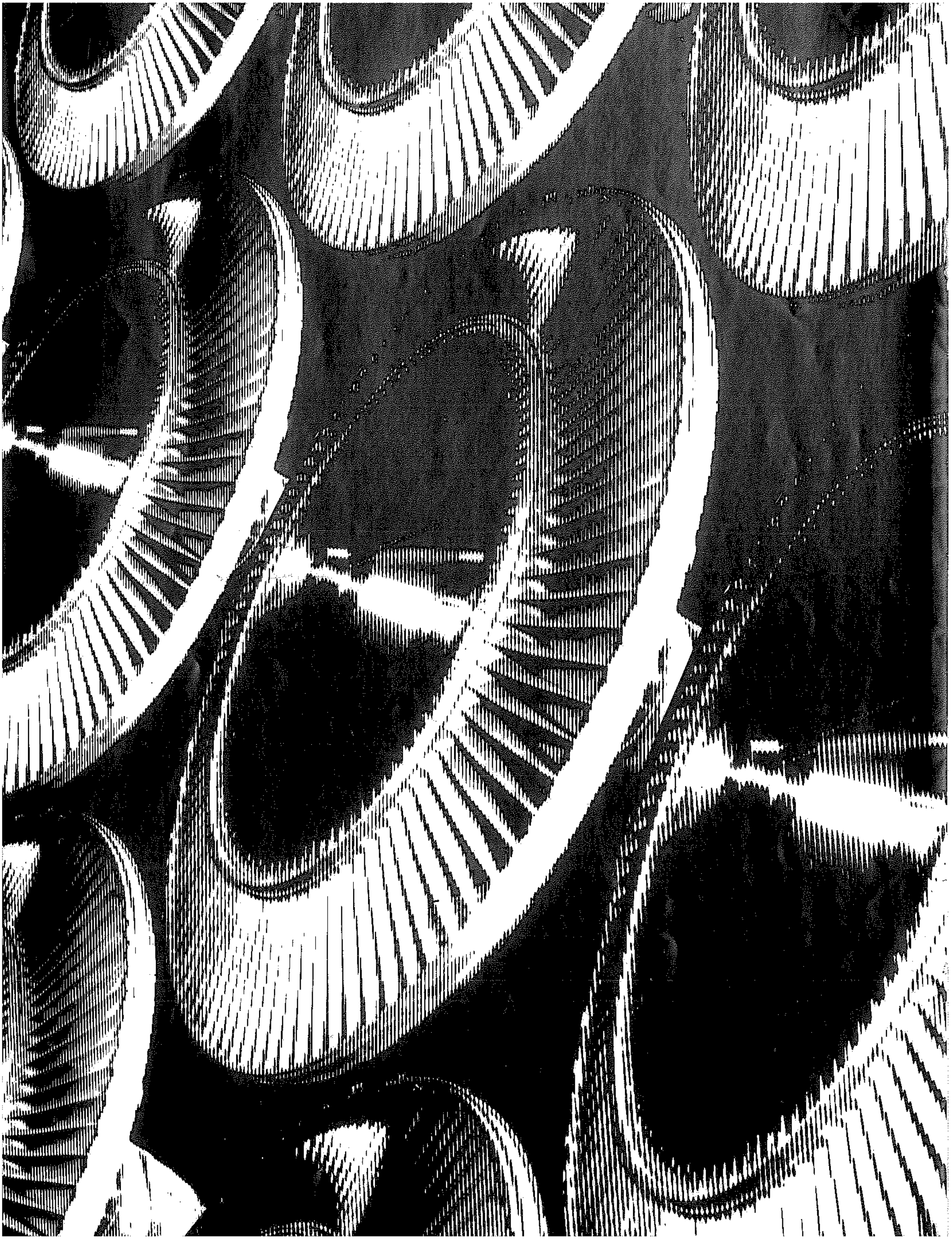
Reprinted from Technology Review,
Volume 79, Number 7, June, 1977

Cambridge, Massachusetts 02139



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Far from hindering economic growth, a policy of strict energy conservation proves an exceedingly wise investment.

Energy Conservation and a Healthy Economy

It is only too well known that we are exhausting our finite store of fuels at an alarming rate, especially the gaseous and liquid forms. It's also painfully clear that we are investing more and more for new energy supplies and obtaining less and less for our money. International fuel prices have increased much faster than the prices of other commodities because of this scarcity of petroleum and natural gas and the high cost of new energy sources. Most indications are that this gap will keep widening for many decades to come. Fortunately, is is quite certain that we can re-optimize each energy-consuming task to achieve the same result at equal or lower cost, and use far less energy. In this paper we will show the firm technical and economic bases that underlie this seemingly bold assertion. We will show that there is an enormous opportunity for reduced energy consumption per unit of product in every sector of the economy; and if we do not take advantage of this opportunity, our economic well-being and security will be endangered.

Re-optimizing energy end-uses will, of course, require long-term commitments involving significant restructuring of all sectors of society. This restructuring cannot happen automatically, because of many institutional barriers and many distortions of the free market system introduced by past decisions. But these barriers and distortions are not insurmountable. They can be largely eliminated if we attack them with a comprehensive energy policy, such as the accelerated conservation policy we propose.

Technical Room for Conservation

The laws of thermodynamics give us a most convincing technical basis for estimating the possibilities for energy conservation. Specifically, the second law of thermodynamics affords a yardstick that is universally applicable to all fuels and all processes. The second law implies that energy has a "quality" about it and that this quality can only be degraded as energy is consumed to perform useful tasks. The "available work" in a system is a quantity that takes into account both the quality and the quantity of energy *(see "The Potential for Fuel Conservation" by Marc H. Ross and Robert H. Williams, February, 1977, pages 48-57)*. This "available work" concept has been used in several studies to measure the efficiencies of various energy-using processes in our society, as a function of the task to be performed, rather than the particular device used to perform that task. Some of the efficiencies estimated in these studies are:

— Residential and commercial space heating: 6 per cent,
— Residential and commercial water heating: 3 per cent,
— Air conditioning and refrigeration: 5 per cent,
— Automobile propulsion: 10 per cent,
— Steel production: 21 per cent,
— Petroleum refining: 9 per cent,
— Cement manufacturing: 10 per cent,
— Paper production: less than 1 per cent.

The total amount of fuel used in these applications is about 60 per cent of all U.S. energy consumption. The average efficiency of utilization, obtained by weighting each efficiency by the amount of fuel used for the purpose, is only 8.3 per cent. Moreover, the figure of about 8 per cent is believed to be fairly representative of the overall energy effectiveness throughout the economy. The 10 per cent efficiency given for automobiles actually overstates their performance considerably, since this calculation takes into account only the efficiency of converting fuel energy to tractive effort at the driving wheels. It is extremely difficult to specify auto efficiencies precisely because of various non-technical factors affecting the vehicle design, such as add-on hardware to enhance convenience, safety, comfort, etc.

We're not suggesting that energy efficiency will ever approach 100 per cent for real devices or processes, even in the remote future. We wish to emphasize, however, that the present low values of efficiencies indicate the enormous opportunity for energy savings and that no fundamental scientific barriers exist to prevent substantial improvements in energy end-use effectiveness. Even a modest improvement, for example from 8.3 to 9.3 per cent efficiency, represents a saving of almost 10 "Quads" per year at the 1975 consumption level (where a Quad equals 10^{15} Btu's). This is the energy equivalent of 4.6 million barrels of petroleum per day.

Some analyses mistakenly associate large energy savings with reduced economic activity. In 1972, for example, an analysis for the Chase Manhattan Bank stated almost fatalistically that "analysis of the uses of energy reveals little scope for major saving. The great bulk of the energy is utilized for essential purposes, . . . Conceivably, the use of energy for such recreational purposes as vaca-

More efficient turbine rotors such as these produced at Westinghouse will enable significant improvements in the efficiencies of turbines, with no economic penalties. So little research has been done on improving the energy efficiency of industrial processes, say the authors, that a huge untapped potential for energy savings may exist. (Illustration: Judy Richland) tion travel and the viewing of television might be reduced — but not without widespread economic and political repercussions. There are some minor uses of energy that could be regarded as strictly nonessential — but their elimination would not permit any significant saving."

More correctly, a report by the Energy and Environment Division of the Lawrence Berkeley Laboratories answered that "more informed studies of energy use contradict this analysis. Especially misleading is the subjective phrase *essential purposes,* which obscures the whole question of efficiency. Careful analysis of energy use has revealed an enormous potential for energy conservation. The most recent forecasts from the Energy Research and Development Administration suggest that U.S. energy needs in the 1990s could be 20 to 40 per cent below what was previously expected, as higher energy prices and new end-use technologies help Americans squeeze more economic and personal well-being from every Btu."

The process known as cogeneration offers an impressive example of the energy savings obtainable using only current technology. Cogeneration — the combined production of electricity and industrial process steam — offers an opportunity for conservation because steam for industrial processes is produced at relatively low pressure and temperature and, hence, does not make good use of the high-temperature heat available from fuel combustion. The common practice of producing low-pressure process steam in a fuel-fired boiler is therefore thermodynamically inefficient. The practice can be made much more effective by first producing high-pressure steam in a boiler, then expanding this steam through a turbine to generate electricity and then exhausting the steam at the appropriate pressure level needed for the desired process.

The electricity thus produced is obtained at an additional fuel consumption rate less than half that achieved by the most efficient central station power plant. Since over 40 per cent of industrial energy — or about 16 per cent of all the nation's energy — is used in the form of process steam, the potential savings are enormous. In West Germany, cogeneration accounts for over 18 per cent of electrical needs, compared to only about 5 per cent in the U.S. A recent study by Thermo Electron Corp. for the Federal Energy Administration revealed that in just three industries — papermaking, chemicals, and petroleum refining — there exists the opportunity to produce over 34 per cent of all the nation's electricity by means of cogeneration and waste heat recovery.

While long-term dramatic improvements in end-use efficiencies can probably be made throughout the economy there will be a significant capital cost involved, unlike the case with many of the simple measures already implemented in response to rising energy prices. Such conservation actions, involving the trade-off of energy cost savings against initial capital costs, deserve the most careful attention in formulating a new U.S. energy policy.

Skyrocketing Supply Costs

To understand just how economically sound conservation measures really are, we can compare capital requirements for various supply and conservation measures.

On the supply side, diminishing fossil fuel resources have necessitated the investment of enormous amounts of capital per unit of energy production capacity. True, Middle East reserves are still readily accessible. However, most new petroleum or natural gas production areas —such as the U.S. outer continental shelf, North Sea, Alaska, etc. — require anywhere from $10,000 to $15,000 for each barrel per day of equivalent fuel energy provided. This translates into a capital demand of about $4.5 to $6.8 billion for every Quad per year of energy delivered. Synthetic gas and oil obtained from coal will be even more capital intensive, probably requiring more than $10 billion per annual Quad.

New coal supplies are still obtainable at a capital cost of $1.5 billion to $2.0 billion per annual Quad. However, coal mining, processing, and combustion produce serious environmental and safety problems which may ultimately limit the rate of coal consumption, or at least cause increases in the cost of supply. Moreover, coal cannot be as flexibly used as oil and gas. The industrial sector could undoubtedly substitute more coal to produce steam, for example, but increasing our reliance upon coal will depend mainly upon its greater use by electric utilities or the development of economical gasification methods.

Electricity as a form of energy requires a much higher capital investment. For every Quad per year of delivered electricity, the capital investment in facilities for fuel supply, generation, transmission, and distribution will range from $45 billion for coal-based systems to about 1.5 times as much for nuclear generation. We cannot directly compare electricity costs with those for coal and petroleum fuel resources, because electricity has far greater flexibility of usage than does raw fuel. Even so, the capital cost of coal-based electricity is about $15 billion per annual Quad of coal converted to electricity, or more than eight times the capital cost of raw coal supply, itself.

Despite its high capital cost, electricity occupies a unique and vital place in the spectrum of energy forms. Many tasks exist that can be performed only by energy of the highest thermodynamic grade, such as electricity. So electricity is an essential part of a balanced energy supply system. Electricity should be recognized, however, as having both special properties and high capital intensity, and therefore should not be used as a convenience fuel, as for home heating.

The enormous and growing capital required to develop new energy supplies could injure the entire economy. According to even highly optimistic projections of economic growth and capital formation, the U.S. economy is unlikely to produce more than $2.7 trillion for all purposes over the next decade. Assuming that the long-standing ratio between business and residential investments prevails, about $1.8 trillion will be available for all business investments for both new capacity and replacement purposes. A New York Stock Exchange report estimated that, of that capital, the energy supply industry would require more than $800 billion.

It is an alarming prospect that we might have to allocate almost half of all business capital to energy supply investments alone. In the recent past, the energy industry has consumed only about one-fourth of total U.S. business capital, and even this fraction had created growing stresses in the capital markets. Unless this trend is reversed, we will soon be devoting so much of our scarce capital resources to energy production that other business needs will suffer a severe lack of investment funds.

A Bargain in Conservation

In contrast to the rising expenditures needed to develop diminishing fuel reserves, conservation can be put to effective use with substantially smaller capital commitments.

For example, for only a modest investment we could reap large improvements in the energy efficiency of the common window air conditioner. Data published by the Federal Council on Science and Technology showed that three commercially available room air conditioners with exactly the same 5,000-Btu-per-hour cooling capacity had the following initial costs and energy consumptions:

— $120 for a 4.58 Btu/watt-hour unit;
— $140 for a 5.80 Btu/watt-hour unit;
— $165 for a 8.70 Btu/watt-hour unit.

As you can see, by investing only $45 in additional first cost — 38 per cent more — one can obtain an efficiency improvement of 89 per cent.

Since the air conditioner is likely to be used only 500 hours per year, or about 6 per cent of the time, the energy saving will be 258 kilowatt-hours per year. However, its usage is likely to coincide with the period of highest summer electrical demand. Hence, the $45 increment for conservation can be viewed as a direct substitution for more than one-half kilowatt of expensive utility system peak generation and distribution capacity, having a value of at least $200.

Unfortunately, user benefits do not reflect the same degree of advantage indicated by the capital cost comparison. In fact, the consumer would save only about $18 per year for 500 hours of use, yielding a gross payback of about four years. Even this moderately attractive return can be illusory when the ultimate consumer does not participate in the initial purchase decision, for instance if he lives in a rental apartment or housing equipped by the builder rather than by the owner.

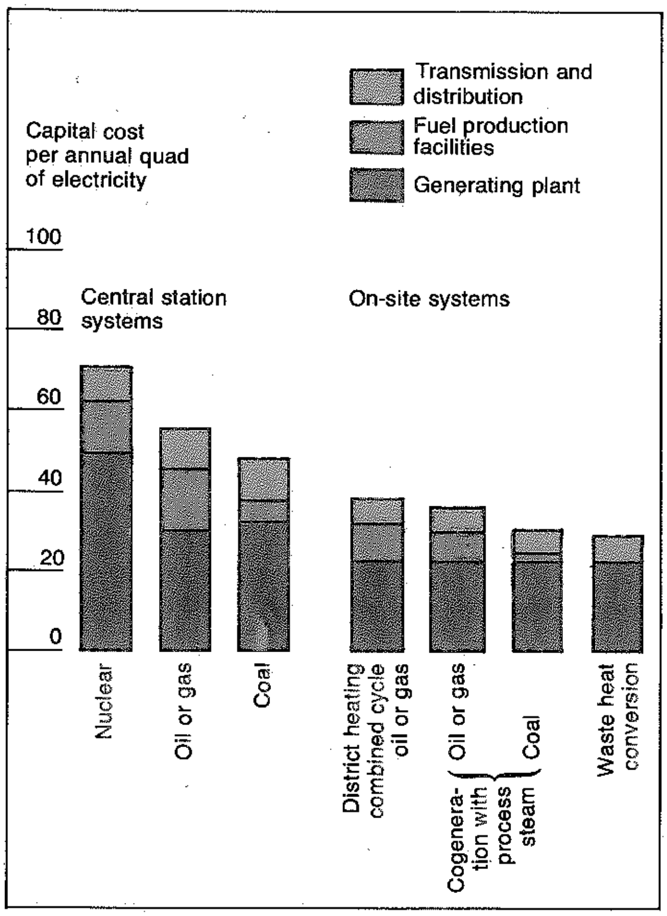
Another example of high return on conservation investment is the case of waste heat recuperators. Recuperators can provide fuel savings of at least 25 per cent on most high-temperature furnaces used for controlled-atmosphere metal processing. The cost of such recuperators is about $1,300 for each combustion burner on a radiant tube furnace, with fuel savings amounting to about 125,000 Btu per hour per recuperator. Under normal plant operating schedules, this represents capital cost investment of $1.5 billion per annual Quad of fuel saved, compared to the $6 billion per annual Quad cost of new domestic gas supply.

With the recent sharp rise in industrial gas prices, the payback period for recuperators has shortened to about three to four years, a range that is still only marginally attractive to most industrial firms whose capital budgets can barely cover essential or "main-stream" business investment needs.

The generation of electricity from waste heat also represents an excellent investment opportunity. A recent engineering study conducted for a major cement manufacturer revealed the opportunity for producing 4,700 kilowatts of electricity by capturing waste heat from the exhaust of the company's cement kilns using a steam-electric bottoming cycle system. The cost of the system was $2.7 million.

If that 4,700 kilowatts were to come half from a new coal plant and half from a new nuclear plant a capital investment of more than $7 million would be required for fuel supply facilities, generating apparatus, and transmission and distribution equipment. In terms of energy capital effectiveness, the waste heat recovery system costs less

Capital costs are significantly less to construct on-site power generation systems at industrial facilities than to build large central station systems.



than $25 billion per annual Quad of electricity, or less than half that of the average investment required for new coal and nuclear utility capacity.

It is noteworthy that in this particular case the conservation equipment was not installed, and the cement plant continues to purchase its electricity at 2.5 cents per kilowatt-hour. Allowing for operation and maintenance of the steam-electric bottoming cycle, the savings would have been $775,000 per year; i.e., the energy conservation investment would be recovered in about 3.5 years. Since this payback did not meet the company's requirements for discretionary investments, the proposal was rejected. As a result, the failure to implement this one conservation measure in one cement plant causes a continuing loss to the nation of 180 barrels per day equivalent petroleum. In general, capital investments for on-site generation of electricity by various schemes are smaller than those for central power stations, as shown in the chart at the left.

These few examples have only scratched the surface of conservation investment possibilities for industry. We have identified numerous examples of energy conservation investments in the steel, aluminum, oil refining, paper, chemical and other industries that significantly outperform corresponding investments in new energy supplies. In other sectors of the economy cost effective opportunities might include:

— Substitution of diesel engines for gasoline engines in light trucks, which would require less capital per unit of fuel saved than does new petroleum supply capacity.

— Weight reduction in automobiles through material substitution, which can actually decrease total capital cost.

Reducing passenger space is also cost-effective, but this type of energy conservation involves changing life-style and consumer tastes rather than improving technical efficiency, which is the focus of this discussion. It is important to clarify the distinction between these two different kinds of conservation, and to dispel the popular misconception that conservation is equivalent to belt-tightening. Such actions, usually taken in response to immediate crises, tend to obscure the real and lasting benefits of conservation through improved end-use effectiveness.

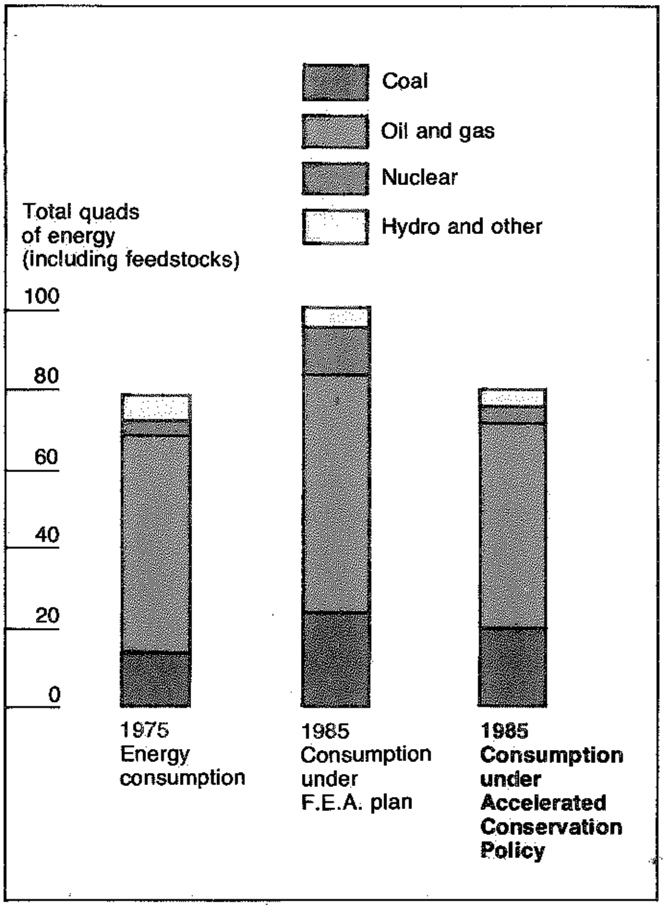
Some Barriers to Conservation

Because of their economic attractiveness, one might expect capital investments in conservation to proceed at a faster rate in the industrial than in the residential or other sectors of the economy. After all, in industry energy users are likely to have a greater awareness of first-cost versus operating-cost tradeoffs. However, industry has not significantly outpaced other sectors in improving its energy efficiency. Where industrial conservation investments have been made, the decision has often been influenced by factors other than simple economics; for example, the threat of outright curtailment of production due to fuel interruption.

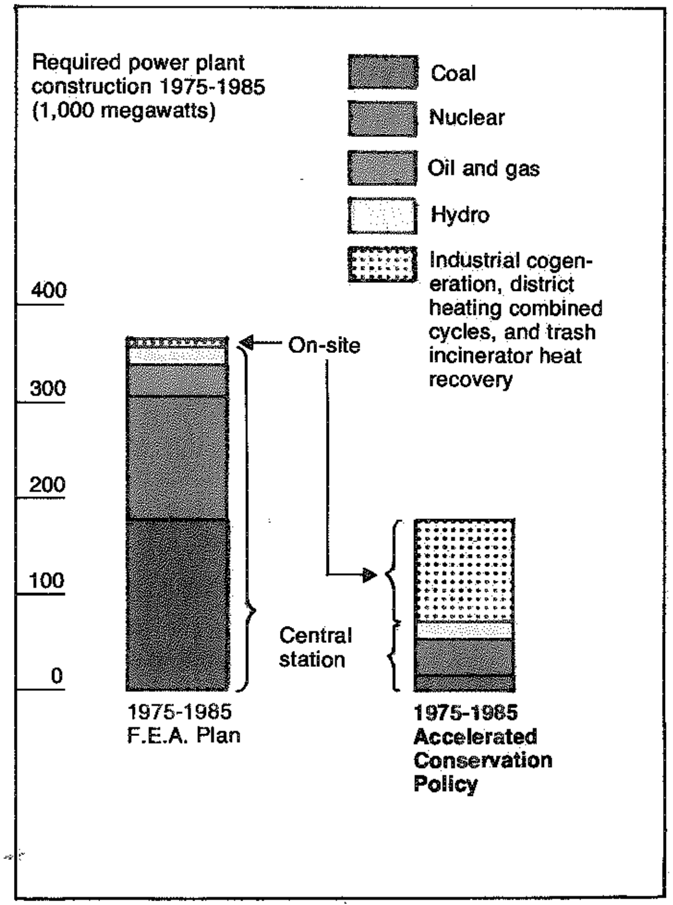
We've identified several reasons behind industry's reluctance to invest in energy-efficient equipment:

— Most energy-user companies must maintain conservative debt-to-equity ratios because of uncertainty about the future availability and cost of financing. Conservation investments, therefore, do not usually command high priority in the competition for limited capital funds.

The authors' Accelerated Conservation Policy would essentially bring energy demand after a decade to the same level as the 1975 consumption, at the same time allowing a normal economic growth. This demand is smaller than that forecast in a Federal Energy Administration plan which relies primarily on prices.



A conservation policy would drastically reduce the required utility investment in central station electrical generation capacity, from $391 billion to $91 billion. An additional $61 billion increment of power generation capacity would be spent for generation capacity at the site of use.



These funds must first be reserved for essential mainstream business purposes, such as tooling new products and expansion of capacity to meet market conditions.

— Criteria for investment payback are more stringent for manufacturing companies than for regulated utilities whose risks are lower.

— The pricing of industrial electricity and fuel is largely based on average, rather than incremental costs of supply.

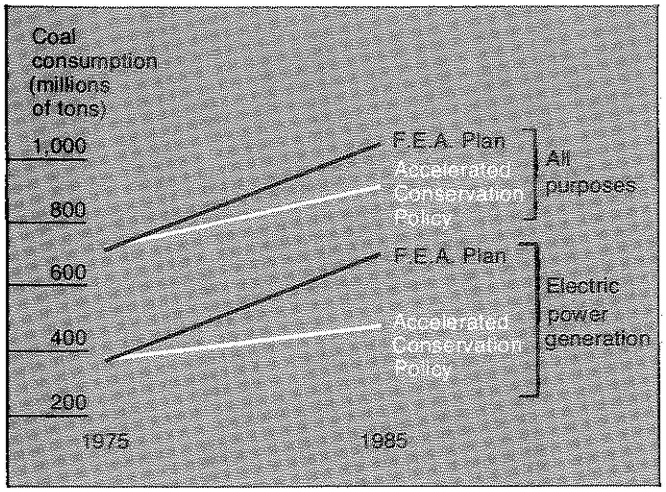
— These factors tend to create a major distortion in the deployment of scarce capital resources to achieve the optimum balance between investments in new energy supply and in energy conservation.

A Plan for Accelerated Energy Conservation

A new government policy stressing energy conservation could produce major changes in our energy usage patterns in a relatively short time and without impairing economic expansion. By comparing energy demand estimates, with and without an accelerated conservation approach, one can really see the important differences that might be anticipated during the next decade.

For our scenario of life *without* accelerated conservation, let us examine a 1975 report by the Federal Energy Administration (F.E.A.) entitled, "National Energy Outlook." In its ten-year forecast for U.S. energy production and usage the F.E.A. predicted that higher energy prices alone could cut 1985 consumption from an unconstrained demand level of 123 Quads to about 107 Quads. Demand would be restricted further, to about 101 Quads, by some additional conservation measures which were not specified.

Under the F.E.A. plan, electrification was to increase



Coal consumption under the conservation policy would not rise nearly as precipitously as under the F.E.A. plan.

from 1.93 trillion (24 per cent of all 1975 energy input) to 3.35 trillion kilowatt-hours (more than 34 per cent in 1985). Thus, with the real G.N.P. expanding at about 3 per cent per year (34 per cent over the decade), total energy was to grow by 2.8 per cent per year and electricity by 5.5 per cent per year. The plan was expected to produce almost no change in the distribution of energy by the end-use sectors relative to the pattern existing in 1975: residential and commercial would still comprise 37 per cent of consumption; transportation, 24 per cent; and industry, 39 per cent.

The F.E.A. projected a shift in energy resources, with coal rising from 18 per cent in 1975 to 22 per cent in 1985, nuclear energy rising from 3 per cent to almost 10 per cent (accounting for over one-fourth of electricity generation), and oil and gas declining from 74 per cent to 63 per cent (the major reduction occurring in electric utility consumption of these fuels).

To provide a framework for evaluating these forecasts we have devised an alternative plan which stresses conservation measures. Based upon the same growth in real G.N.P. as assumed in the F.E.A. plan — approximately 3 per cent per year — the alternative approach postulates no substantial social changes or curtailment of living standards. This "Accelerated Conservation Policy" is by no means the only plan that might be considered, but it illustrates some of the benefits realizable by more effective energy end-use.

A key element of the conservation policy is the transfer of a major portion of the capital now marked for new energy supplies into investments in energy conservation in each of the end-use sectors. An important result of this transfer will be a major reduction in the total amount of capital required for all energy investments.

The Accelerated Conservation Policy calls for sharp curtailment in the rate of growth for electricity, the most capital intensive form of energy. It also calls for certain specific measures to improve end-use efficiencies, including:

Enforce the mandatory automobile fuel economy standards already enacted by Congress. Impressive progress is being made toward meeting the 1980 criterion of 20 miles per gallon (m.p.g.), particularly by General Motors. The 1977 GM fleet average is projected to be 18.4 m.p.g. compared to 12.3 m.p.g. in 1974. Much of this improvement was accomplished through improved design and weight reduction, with little or no sacrifice in interior space or comfort. Planners should also consider a stepwise introduction of post-1980 standards, perhaps at a linear rate from 20 m.p.g. to the mandated 27.5 m.p.g. in 1985. This staged progression will insure that the improvements in average fuel economy continue without interruption for the turnover in overall population of 100-million-plus vehicles. The 27.5-m.p.g. goal is a difficult one, but there are strong indications that this level can be achieved by such strategies as the wider use of stratified charge or diesel engines, or both, improvement in transmissions, further weight reductions, etc. Some flexibility on the part of Congress with respect to emission levels of nitrogen oxides may be desirable to reach the optimum balance between fuel economy and exhaust pollutants.

Construct alternative electric generation capacity in lieu of 103,000 megawatts (Mw) of planned central station capacity. This alternative capacity would include cogeneration of electricity with industrial process steam (64,000 Mw); generation by district plants producing both electricity and space heating for buildings (32,000 Mw); and burning trash to generate electricity (7,000 Mw). Together, these electricity sources would contribute 24.5 per cent of all U.S. electricity. To stimulate this substantial shift away from central station utilities to the far more efficient systems identified above, several actions will be required, such as mandatory rules for purchase of surplus industrial electricity by utilities; a restructuring of backup or demand charges originally designed by utilities to discourage on-site generation; provision of direct government loans to industries and apartment or commercial complexes to finance investments in on-site generating capacity; special taxes on industries and commercial businesses which do not take advantage of proven cogeneration opportunities; and changes in federal, state and local rules regulating utilities.

Establish efficiency goals for all energy-intensive industrial processing equipment and systems; examples are blast furnaces, paper-making machines, refinery and chemical plants, heat-treating equipment, etc. In setting such goals consideration should be given to the efficiencies being attained in foreign countries where conservation technology has progressed further than in the United States.

Enact mandatory heating, insulation, and lighting standards for new residential and commercial construction. Standards should provide for optimum utilization of passive solar measures such as window and roof overhang design. We might also prohibit certain practices such as electric resistance space heating, and limit heat pump electric heating to those regions having moderate winter temperatures.

Enact progressively stricter efficiency standards for all major energy consuming appliances, such as water heaters, refrigerators, air conditioners, home furnaces, etc.

Phase out natural gas as a fuel, either for central station electricity generation or for process steam applications in industry. This could mean either a direct ban on such use, or a steeply progressive tax on gas fuel that is so misused. Sufficient gas must be reserved for residential space heating and for direct-fired high-temperature industrial processes to avoid excessive growth in electricity demand.

Provide direct government loans and other economic incentives to finance the retrofitting of houses with conservation equipment, including insulation, storm windows, improved furnaces, and other cost-effective systems. This program should be continued until every structure in the nation has been modified to an extent commensurate with the capital cost of incremental new energy supply. These measures probably won't be completed until well beyond 1985, and our projections assumed less than one Quad of savings per year.

Collectively, these and several less important actions would reduce energy consumption over the next decade to 80 Quads per year, a saving of 21 Quads relative to the F.E.A. plan. In effect, energy growth can be almost halted over the ten-year span while economic activity can still expand by 3 per cent per year. Moreover, the costly electrical sector would increase to only 2.53 trillion Kwh, a growth rate of 2.8 per cent per year relative to 1975. The fraction of total energy converted to electricity, 29 per cent, is higher than in 1975, but still well below the 34 per cent figure projected by the F.E.A. plan.

In the Accelerated Conservation Policy, distribution of energy by end-use sector differs from that of the F.E.A. plan, with transportation accounting for only 20 per cent, and industry rising slightly to 42 per cent. Sources of energy would change somewhat (*see page 35*) with nuclear fuel contributing only 7 per cent instead of 10 per cent of all energy. The fraction for oil and gas is about the same for both plans — 63 per cent — but the contribution of coal rises from 22 per cent to 24 per cent under the accelerated conservation alternative.

Major contributions to the 21 Quads of total energy saved under the conservation policy are due to:

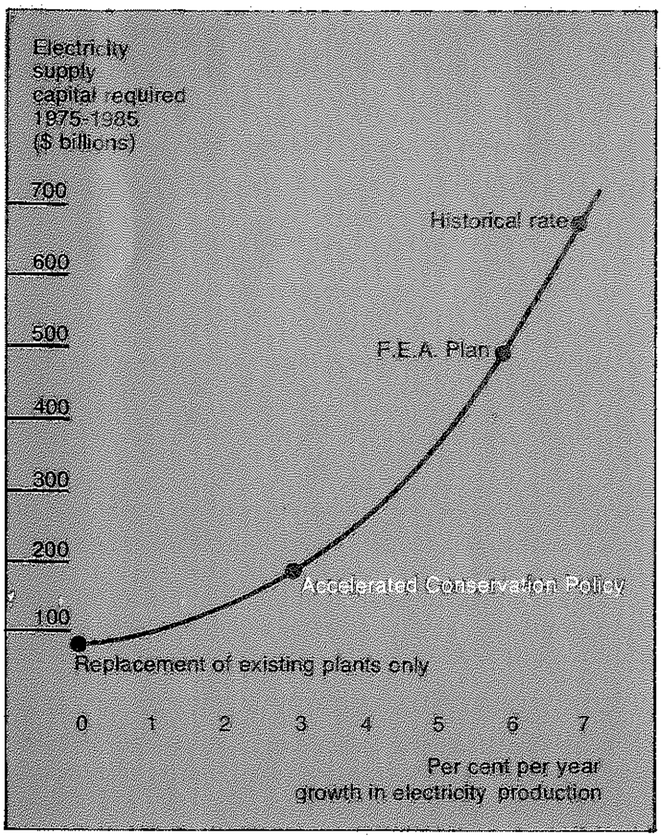
— Automobile fuel economy standards (5.6 Quads),
— Alternative methods for electricity generation (2.9 Quads),
— Improved efficiencies in industrial processes (4.5 Quads), and
— Appliance efficiency standards (2.5 Quads).

The remaining 5.5 Quads of savings result from improved insulation standards for all new buildings, increased retrofitting of insulation in existing structures, some modest usage of solar-assisted water and space heating, and greater efficiency in trucks due to wider use of diesel engines, improved scheduling practices, drag reductions, etc.

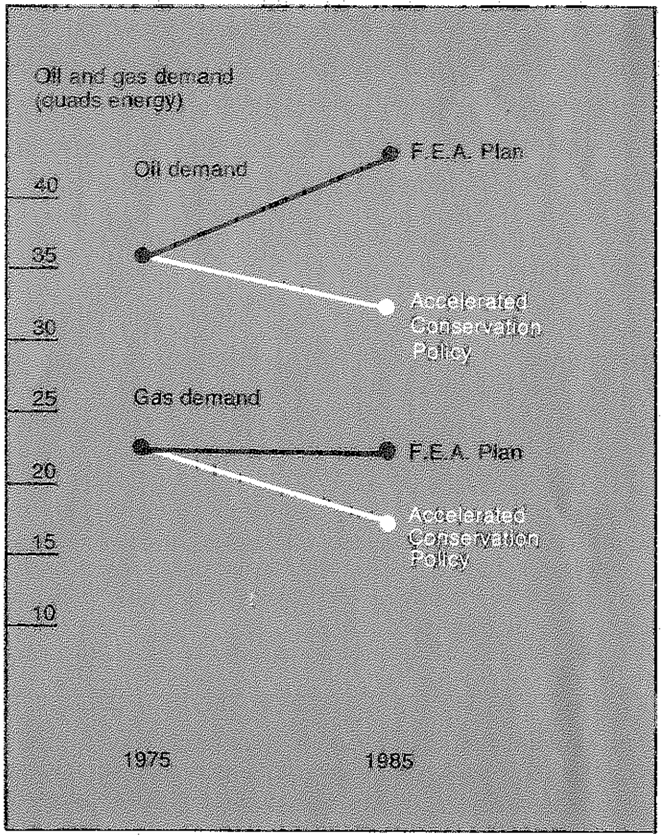
None of the measures we've proposed, except for far-term automobile efficiency improvements, requires unproven technology. Moreover, the overall improvement represents only a modest aggregate gain in the absolute efficiency of devices and processes. In fact, under our policy the average efficiency of energy utilization increases to 10.9 per cent — only 2.6 percentage points over the 8.3 per cent we mentioned earlier. Approximately one-third of this gain is attributable to automobile fuel economy improvements alone.

What Cost Conservation?

The most striking difference between the Accelerated Conservation Policy and the F.E.A. plan is the amount of capital needed to implement these alternative programs. Over the 1975-to-1985 decade the F.E.A. plan would require $570 billion for energy supply and $78 billion for energy conservation, for a total investment of $648 billion. In sharp contrast, the Accelerated Conservation Policy would require $61 billion for supply and $157 billion for conservation, for a total of only $218 billion — *less*



Because of the slower growth of electrical demand, capital investment requirements for generation capacity, transmission and distribution, and fuel production facilities will be far less.



The greatest dividends of an Accelerated Conservation Policy occur because of sharply reduced oil and gas demand. In effect, accelerated conservation measures become the second most important energy source in 1985.

than half the F.E.A. capital requirements.

These enormous capital savings are due in large part to sharply lower central station electric generating capacity. Less generating capacity investment is needed, not only because of reduced total electrical demand, but also because of the lower cost of alternative combined-cycle generating equipment, such as cogeneration. As you can see on page 35 and following, the conservation policy will thus result in significant savings on nuclear and fossil generating plant construction, and on coal, oil and gas consumption.

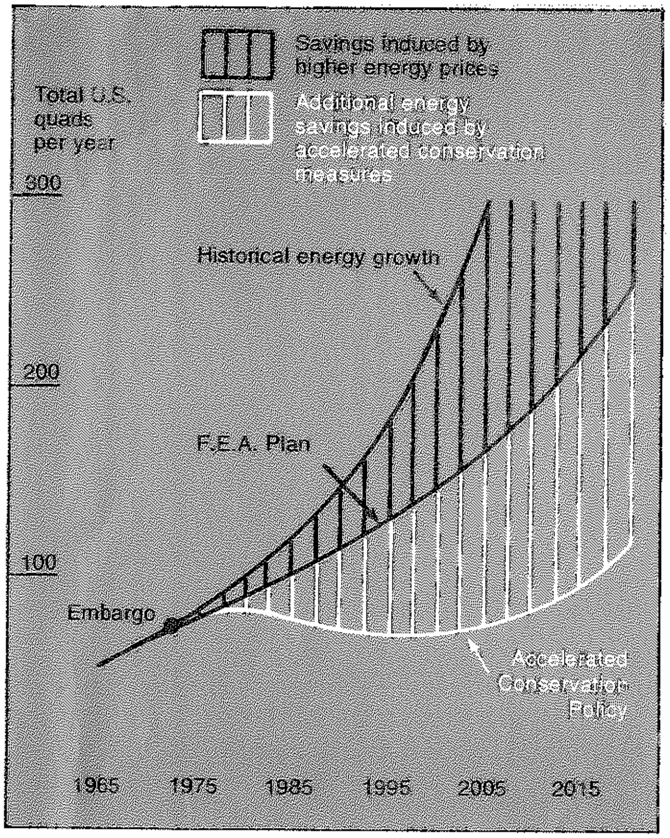
Savings on petroleum consumption will have a dramatic effect on imports. Accelerated conservation policies produce a net surplus or reserve of 4.5 Quads per year of natural gas by the end of the decade as is shown by comparisons of F.E.A. projections of maximum natural gas supply with our calculations of demand under a conservation policy. Required petroleum imports will be only 5.3 Quads or 2.4 million barrels per day — about one-third the present level of imports. Even if natural gas price controls were continued, the Accelerated Conservation Policy would curtail usage enough to almost exactly balance F.E.A.'s domestic supply forecast of 17.9 Quads for price-controlled supply. In contrast, the previous F.E.A. plan with complete price deregulation achieves zero imports in natural gas, but still requires the import of about 6 million barrels per day of petroleum — over 13 Quads.

There are clear and compelling economic advantages to the nation for conserving more energy. Before this can occur, however, we must resolve the differences between two different sets of economic assessments that ultimately determine how we balance energy conservation. The problem is that investment decisions on conservation are generally made by a completely different group than that responsible for capital investments in energy supply. These two groups operate under substantially different ground rules for return-on-investment and access to capital markets. For example, the return-on-investment for energy conserving equipment required by energy users in industry is much higher than that for electricity plants achieved by regulated utilities, and the debt-to-equity ratio of manufacturing industries is much lower than that of utilities. Thus, it is totally unrealistic to suppose that the so-called "free market" approach will produce an optimal allocation of the nation's scarce capital resources among energy supply and conservation options.

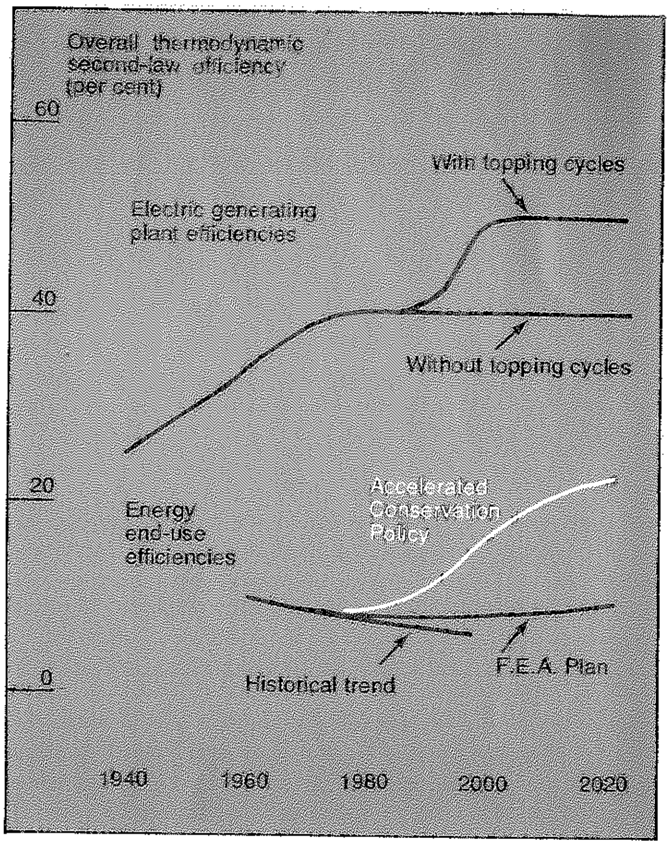
Nothing resembling a free marketplace exists today, given the fact of cartel pricing for petroleum, and considering the long history of massive federal subsidies to the energy supply industry — research and development grants, depletion allowances, guaranteed return on utility investments, etc. This fact has often been obscured by those who promote price deregulation as the only means for a comprehensive energy policy.

Strong Regulation Needed

Our proposed policy for accelerated energy conservation depends heavily upon mandatory measures to improve



An Accelerated Conservation Policy which increased energy efficiency in our society by only about one percentage point every two-and-a-half years could allow an uninterrupted growth of three per cent per year in G.N.P., with little or no increase in energy demand.



An enormous untapped potential for conservation, discovered as we proceed along the conservation road, could well allow continued economic growth with no more energy than we use today. The efficiency improvements proposed by the authors may seem ambitious, but they are still less than those accomplished in the electric power industry.

end-use efficiency. This approach will inevitably raise arguments aginst tampering with the so-called "free market." Direct intervention must be considered, however, because price alone cannot provide sufficiently strong motivation for accelerated conservation.

Price increases are limited as a conservation stimulus even for the industrial sector, because energy cost still averages well below 10 per cent of value added for all manufacturing. Thus, even large additional rises in fuel prices will not necessarily place overwhelming conservation pressures upon manufacturers.

Congress has recognized this aspect of energy policy, and has acted wisely in passing the mandatory automobile fuel economy legislation. By forcing the desired trend in new car efficiency, this measure will mean a continuing reduction in gasoline consumption throughout the next decade and beyond. Moreover, the law can reduce gasoline consumption without the need for decontrolled gasoline prices.

The transition to a conservation plan requires nothing short of a massive restructuring of the priorities for deployment of resources, both capital and technological. This shift must take place in a relatively short period so that we won't exhaust our capital resources in marginal ventures.

Only the Beginning for Conservation

A conservation strategy could actually have more profound far-term implications than near-term. Current technology can clearly provide the 21 Quads of incremental annual savings over the next eight to ten years. But considering that overall second-law fuel efficiency would still be less than 11 per cent at that point, aggressive research into end-use efficiencies could almost certainly advance the technology still further. A concerted effort in this area has not even begun, and the untapped potential for improvement may well exceed anything on the horizon among the various alternative energy supply options. If, for example, we were able to continue improving energy efficiencies by about one percentage point every two and a half years, we could sustain an uninterrupted growth in real G.N.P. of 3 per cent per year for the next three decades, and still consume no more energy than we do today (*see above left*). Even then, our overall end-use efficiency would be only 20 per cent, about equal to that of the steelmaking process today.

The improvements in energy end-use efficiency that we postulate are, in fact, not all that remarkable. As you can see from the graph at the right above, they are still less than that accomplished over a comparable number of decades in improving electric generating plant efficiencies. The latter process, of course, has been subjected to enormous and continuing commitments of technological resources —the same prescription that is suggested here for energy end-use processes.

Some progress has already been made in overcoming the notion that the conservation of energy is synonymous with decreased economic activity. There is a growing awareness that capital investments in energy-saving devices can often yield greater dividends than comparable investments in new supply. Given appropriate stimulus, then, it is quite likely that the U.S. economy will make substantial progress toward more efficient end-use of energy over the next ten years. Unfortunately, there is little appreciation of the fact that conservation can play a major role in our long-term energy future. This misconception must be changed so that we can focus attention upon the task of developing the new conservation technology needed to insure continuing reductions in energy consumption in the period beyond 1985.

Perhaps the most decisive of all arguments in favor of conservation is the dividend that such a policy can buy in terms of time — the time needed for a thorough, searching, and balanced investigation of all possible energy supply alternatives, including the complete costs of their environmental and safety impacts.

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This article is based on long-standing work being done at Thermo Electron Corp. on energy conservation technology and energy policy issues.