Energy Needs: Projected Demands and How to Reduce Them

Historically, energy has been an inexpensive and readily available commodity in the United States. Indeed, the cost of energy in most forms has declined relative to overall price indices in the period since World War II. But there is evidence that a new era in energy use is beginning, ushered in by growing shortages of the traditional fuels and characterized by rising prices for energy. Last year, for example, marked the first time that the average price of electricity (measured in constant dollars) has increased since 1946. Some observers have speculated that, by the end of the century, the cost of electricity might double, the cost of gas (natural and synthetic) might triple, and the costs of petroleum, coal, and uranium might increase substantially.

The demand for energy has sometimes been regarded as independent of its price, and many projections of future energy needs continue to be made on that assumption. Many economists, however, believe that higher prices will slow the growth in the use of energy and, because of energy's central role, may even retard the growth of the economy as a whole. The desirability of slowing economic growth is still a controversial subject. But damping the demand for energy is beginning to receive serious consideration in the federal and state governments as a potential means of dealing with (i) the environmental problems caused by energy production and use, (ii) the supply problems caused by shrinking domestic reserves of gas and oil, and (iii) the international economic penalties of importing ever larger amounts of these fuels. Promoting the conservation of energy might significantly ease these problems. Higher prices, tax incentives and subsidies (or their removal), changes in building codes, restriction of advertising that encourages energy use, and even rationing have been proposed as measures toward that goal.

The demand for electricity has grown more rapidly than that for other forms of energy in the last two decades, and the need for electricity (and for more power plants) has occasioned considerable debate. The Federal Power Commission (FPC) estimates that the demand will double from about 1.5 trillion kilowatt-hours in 1970 to 3 trillion in 1980 and will almost double again by 1990; similar estimates are that demand will continue to grow at that rate until the end of the century. The FPC estimate and others like it are based at least implicitly on extrapolations of previous trends in overall economic and population growth, and not on any detailed model of the manner in which these and other variables that affect the demand for power might change. Hence these estimates are likely to be accurate only to the extent that past trends continue essentially unchanged into the future.

Rising Prices May Restrict Demand

More sophisticated studies of the demand for electricity under a variety of alternative assumptions about the future are beginning to appear. In a 2-year study funded by the National Science Foundation's program of Research Applied to National Needs (RANN), for example, D. Chapman and T. Mount of Cornell University and T. Tyrrell of Oak Ridge National Laboratory evaluated the relations between variables that might influence the growth of demand and the actual demand for electricity, state by state, for each class of consumers—residential, commercial, and industrial (*1*). Their econometric analysis indicates that the price of electricity is the most important determinant of growth in electricity use for all types of consumers, followed by population growth, personal income, and the price of natural gas. Thus substantial cost increases and reduced population growth, according to the Cornell–Oak Ridge study, would significantly reduce the demand for power in the long run.

The downward trend in the relative price of electricity has apparently begun to reverse itself, and prices may well rise sharply as fuel scarcities, the rising cost of power plants, and pressure to incorporate the social and environmental cost of energy production in its price tag make their impact felt. The population growth rate appears to be declining, because of decreases in both the birth rate and the fertility rate—which in recent months has fallen to about 2.08 children per woman, below the "zero population growth" replacement rate. Whether these trends will continue is uncertain, predictions about the future being what they are, but it is possible to calculate the demand for power that would result from particular assumptions about the future. Chapman and his associates, using their econometric model, find that variations in the price of electricity and to a lesser extent in the rate of population growth can cause as much as a fivefold reduction in the electricity needs projected by the FPC.

If the relative cost of electricity doubles by the end of the century, the model projects a demand for about 2 trillion kilowatt-hours, only 33 percent more than that used in 1970. If the cost of electricity increases only slightly (in constant dollars)—which the FPC believes will occur—Chapman finds a demand of about 3.5 trillion kilowatt-hours. Constant prices for the next 30 years would increase the demand still further, according to the model, but a 50 percent decrease in the cost of power would be necessary to maintain a doubling of the demand every 10 years. Hence Chapman believes that the FPC projections are seriously in error and that plans based on those projections will be unrealistic.

Similar evidence comes from a detailed case study of the demand for electricity in California, a study conducted by the Rand Corporation for the California Resources Agency with support from NSF (*2*). The Rand researchers found that past methods of estimating demand varied from one utility to another, but amounted in most cases to an extrapolation of past trends. They developed a forecasting model to test these estimates against projections calculated on the basis of consistent statewide demographic and economic assumptions. They present five alternative scenarios for California's future, including (i) a "high growth" situation that assumed a new population boom, vigorous economic growth, and the continued availability of cheap energy; (ii) an intermediate situation comprised of an assumed continuation of economic growth at about 3 percent per capita per year but with increasing energy prices; and (iii) slowed economic and population growth coupled with markedly higher prices for all forms of energy.

Use of electricity has been increasing at a rate of about 8.5 percent per year in the nation's most populous state. The Rand study finds that even under the most ambitious assumptions the demand for electricity is unlikely to grow faster than 6.3 percent annually between now and the year 2000, and that, if energy prices increase, the growth might easily slow to a 4.7 percent annual increase. Under the most limiting assumptions, higher energy prices combined with an economic decline would slow the growth in the demand for power to as little as 3.4 percent per year. None of the scenarios would significantly alter the need for more electricity until the 1980's, but because of the long times necessary to gain approval for and construct power plants, planning for that period is already under way within the utility industry and in governmental agencies.

Other investigators of the influence of prices on the demand for power have found qualitatively similar results, and, while the precise estimates depend on the particular econometric model used, it seems likely that rising prices will significantly reduce the need for electricity below that indicated by simple projections of past trends. Slower growth rates could alter the prospects for new methods of generating electricity, decrease the urgency with which near-term options—such as the breeder reactor—need to be pursued and buy more time to examine other unconventional sources of power.

Slower growth rates for all forms of energy consumption might mitigate the environmental damage associated with energy production and use and ease the shortages of gas and oil that are now expected. Studies of the demand for gas and other fossil fuels which are comparable to the econometric studies of electricity demand are lacking; but Chapman believes that for gas, at least, rising prices will have similar effects. Significantly, both the Cornell–Oak Ridge group and the Rand group found little evidence that gas prices would influence the demand for electricity despite the fact that these are competing sources of energy in many markets, implying that rising prices for one would not cause a major switch to the other.

If the growth in the demand for energy and particularly for electricity might abate somewhat because of higher prices, deliberate conservation policies would undoubtedly reduce demand still further. Indeed, the econometric studies suggest that raising prices to reduce the demand may be an exceedingly effective means of promoting the conservation of energy.

Promoting Energy Conservation

One method of reducing the demand for power and promoting its efficient use which has attracted considerable attention consists of doing away with rate structures that provide incentives for high volume consumers. In most states, high volume consumers receive such large discounts on the price of electricity that small users effectively subsidize large users. Because the industries and commercial interests that benefit from this discount would be the first to reduce their use of power when faced with higher prices, the method appears to many observers to be a particularly appropriate one. An analysis, conducted by economists associated with the Environmental Defense Fund (EDF), of the price-sensitivity of the demand for power in Wisconsin, led the EDF to intervene before the state utility commission in hearings on proposed rate increases for electricity. The EDF claims that by pricing power in proportion to the true cost of supplying each customer, the demand for electricity in Wisconsin would be sufficiently decreased to obviate the need for several projected power plants. The environmental group plans to challenge electricity rates in other states on similar grounds.

Others have proposed more drastic changes in the cost of energy and in the tax system as a means of slowing the exploitation of energy resources. Walter Heller of the University of Minnesota, for example, believes that large depletion allowances, capital gains shelters, and special tax deductions should no longer be allowed for energy-producing industries: "Here is another case where the believers in the market-pricing system ought to live by it. The public is subsidizing these industries at least twice—once by rich tax bounties and once by cost-free or below cost discharge of waste and heat" (*3*). The principle put forward by Heller and other critics of the existing financial incentives is that the cost of energy should reflect the environmental and ultimately the social costs of producing it. Policies such as these, whatever their other effects, would result in higher prices for energy and hence greater incentives for its conservation.

In addition to tax policies designed to raise prices for traditional sources of energy, tax incentives to encourage more efficient building design, more efficient appliances, and the use of solar energy have been proposed. The conservation of energy in buildings and appliances might also be mandated by regulatory policies that avoid direct financial incentives or disincentives. Federal guidelines and state building codes, for example, could be changed to require more insulation in houses and heat-reflecting glass in office buildings. Requiring appliances to bear labels that make explicit the efficiency of the device and the estimated operating costs would allow consumers to make more informed decisions. Many of these proposed policies would not discourage economic growth—a criticism frequently made by those who oppose efforts to reduce the demand for energy; others, such as requiring that the cost of promotional advertising by electric utilities could not be counted as a business expense (as at present) but must rather be deducted from profits, might have economic side effects.

Just how feasible are such policies and how much might they reduce the demand for energy? Very little research has been directed to these questions, but a second Rand study (*4*), conducted for the California state legislature, claims that such measures would be very effective. By the year 2000, use of electricity in the state might be reduced by as much as 430 billion kilowatt-hours annually through conservation policies, a 50 percent reduction in the demand projected by conventional methods; these savings would reduce the need for new power plants from an estimated 127 to 45 or less. Environmental damage due to power generation would be consequently reduced, the study concludes, but only relatively minor economic dislocations would occur and the growth of the state's economy would not be affected. This finding has led some federal officials to question whether increasing energy use and economic growth are necessarily correlated, as is often assumed. The Rand study recommends an early introduction of conservation measures.

Research on methods of improving the efficiency of energy use and on means of implementing these improvements is just beginning, and more is needed. But it seems likely that from now on energy will always cost more and that expensive energy will induce some consumers to do with less and others to use it more efficiently. As a result, energy needs in this country may well be grossly overestimated. Moreover, it seems clear that in the long run energy needs could be reduced still further through effective conservation policies.

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References

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Cyclic AMP in Brain: Role in Synaptic Transmission

The task of investigating the function of an organ as complex as brain is enormously difficult, but it promises proportionate intellectual and practical rewards. The ultimate goal—the explanation of human behavior in terms of cellular biochemistry—may not be achieved in the foreseeable future. Nevertheless, as an increasing number of investigators devote their time and talents to the neurosciences, they are beginning to accumulate clues to how the intricate circuitry of the central nervous system transmits and integrates nerve impulses. One area of research that has experienced explosive growth in the last 5 years concerns the role of 3′,5′-adenosine monophosphate (cyclic AMP) in brain. Although the story is by no means complete, the formation and degradation of cyclic AMP have been shown to be regulated, at least partially, by the same factors that affect impulse conduction by neurons. In addition, some central neurons appear to transmit their messages to other nerve cells by releasing chemicals, called neurohormones, that diffuse across the synapses and stimulate the production of cyclic AMP by the target cells.

Since Earl W. Sutherland, who is now at Vanderbilt University in Nashville, Tennessee, discovered cyclic AMP and elucidated its role as the "second messenger" for the hormones epinephrine and glucagon, this ubiquitous chemical has been shown to play a central role in numerous cellular and hormonal activities (*1*). Theodore Rall, at Case Western Reserve University in Cleveland, Ohio, collaborated with Sutherland on the earlier research. According to Rall and Sutherland, brain is an unusually rich source of adenylate cyclase, the enzyme that catalyzes the synthesis of cyclic AMP from adenosine triphosphate (ATP), and also of phosphodiesterase, the enzyme that inactivates the cyclic nucleotide.

Rall and his colleagues are currently investigating the factors that regulate cyclic AMP synthesis and degradation in brain slices. They have found that stimuli known to cause depolarization of neurons produce increases in the cyclic AMP concentrations of the slices. As a result of depolarization, neurons either fire or become more responsive to subsequent stimulation. The stimuli they are studying include putative neurohormones—like norepinephrine, serotonin, and histamine—and electrical stimulation. Rall thinks that the neurohormones bind to receptors on the cell membrane and thus stimulate the activity of adenylate cyclase. Electrical stimulation, on the other hand, probably acts indirectly by causing the release of adenosine.

Role of Adenosine

Adenosine, which is not thought to be a neurohormone, produces striking increases in the cyclic AMP concentrations of brain slices. According to Rall, adenosine stimulates adenylate cyclase by binding to a specific membrane receptor that is not affected by the neurohormones. He can distinguish the adenosine receptor from the others by use of the chemical theophylline. In most systems, theophylline potentiates the observed increases in cyclic AMP concentrations because it inhibits the activity of phosphodiesterase; however, it prevents the increases elicited by both electrical stimulation and adenosine, presumably by blocking the adenosine receptor.

John W. Daly and his colleagues at the National Institute of Arthritis, Metabolism, and Digestive Diseases in Bethesda, Maryland, are also interested in the factors that control cyclic AMP formation and degradation in brain slices. They have observed that complex chemical depolarizing agents like ouabain, veratridine, and batrachotoxin enhance the conversion of ATP to cyclic AMP. These chemicals also cause the release of adenosine from the slices. Because the adenosine release parallels the enhanced formation of cyclic AMP and because theophylline antagonizes the effects of the depolarizing agents, Daly has postulated that these agents also act indirectly through adenosine.

According to Daly, adenosine and adenosine-dependent depolarizing agents interact synergistically with the neurohormones, histamine, serotonin, and norepinephrine, to produce a much greater enhancement of cyclic AMP formation than would be caused by either kind of stimulus acting alone. He has speculated that this type of synergism may help to regulate or modulate the activity of neurons in the brain. Informational input to the same neuron from two or more sources could cause a much greater cyclic AMP response than that caused by a single source. Evaluation of this hypothesis requires a better understanding of the subsequent biological functions of cyclic AMP in the brain.

Although brain slice techniques are valuable for studying the regulation of cyclic AMP metabolism, they entail two major problems for the investigator. The slices, even of a restricted area of the brain like the brainstem or cerebellum, are composed of several cell types. These include the neurons that actually transmit impulses, glial cells, whose functions are not well understood at all, and the cells of connective tissue. The investigators have not yet been able to determine which cell types are responsible for the observed changes in cyclic AMP concentrations in brain slices, and thus they have little information about cyclic AMP's function there. The second problem is that there is no way to correlate these biochemical changes with the behavior, including learning and memory processes, of the living animal.

In order to solve the first problem, several laboratories have directed their efforts to the study of brain cells in culture. For example, Alfred G. Gilman, first with Marshall Nirenberg at