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I am especially happy to have the opportunity to testify before the Subcommittee on Energy and Power of the House of Representatives on industrial energy conservation measures (H.R. 8985). Energy savings through increased end-use energy efficiency in manufacturing can make an important contribution to the energy problem and the economic well being of the nation. My testimony includes comments on the factors that make conservation possible, the magnitude of the energy and dollar savings over the next decade, and a yardstick for measuring progress in more efficient use of industrial energy.

Though opportunities exist for reducing energy demand by avoiding unnecessary and thoughtless energy waste, my remarks relate only to the special type of energy conservation that results from the use of more efficient processes in manufacturing. I believe that this type of conservation has the largest potential for reducing both energy and capital demands without changes in lifestyles, without decreases in production, and without curtailment of our economic growth.

Economic factors

Perusing the statistical abstracts of the Bureau of Census, we observe an important disparity that has developed over the past several years between fuel and capital equipment costs. In terms of constant dollars, replacement costs of industrial energy have almost doubled (see Figure 1), whereas replacement costs of capital equipment and labor have remained almost constant. The rapid increase in replacement costs of energy are primarily due to the fact that all new sources of hydrocarbons, such as Alaskan oil, deep domestic and offshore oil wells, and gasified and liquified coal require much more capital per unit of energy capacity than the sources we developed in the past and are rapidly exhausting.

Most estimates for the foreseeable future indicate that the disparity between the relative costs of energy and of capital equipment will continue and, in all likelihood, will become larger as hydrocarbons become scarcer. As a result, we see that an economic opportunity exists for replacing energy by capital equipment so as to increase the energy productivity of manufacturing processes, namely to increase the end-use energy efficiency in manufacturing.

Technical factors

It is important to recognize that U.S. industry consumes about 40% of the nation's energy, more than any other sector of the economy, but operates at an average thermodynamic or second-law efficiency of only 13%, whereas, on the same basis, the electrical utility industry converts fuel to electricity at an efficiency of about 32%. This fact is not widely appreciated even by engineers themselves because of incomplete use of thermodynamic principles for the calculation of process efficiency. As pointed out in many recent publications, including one commissioned by the American Physical Society, when the rules of thermodynamics are used correctly, energy efficiency in manufacturing is not much better than that of any other sector of the economy.

The low value of energy efficiency in manufacturing represents great technical opportunities for substantial fuel savings. In the long term, such opportunities would require development of entirely new processes.

In the short term, many analyses, including my own, have shown that the amount of fuel that can be saved in manufacturing is larger than that of all the other sectors of the economy combined. By 1985, the saving could be equivalent to 4.5 million barrels of oil per day, an amount approaching that consumed by all automobiles today. This saving can be achieved by investments in well known and well proven technology to improve efficiency. The investments, however, are about $50 billion less than those required to develop equivalent new fuel supplies such as

Alaskan oil and natural gas, nuclear reactors, and off-shore petroleum. Energy savings through increased efficiency in manufacturing is a kind of "domestic energy source" that enhances our economy, creates more jobs, decreases our dependence on foreign and unreliable energy suppliers, and reduces environmental pollution.

About two-thirds of the energy savings in manufacturing can be achieved by either recycling waste energy, or putting waste energy to good use, or both. These two energy-saving methods could reduce our energy needs by the equivalent of 3 million barrels of oil per day without affecting our lifestyles, an amount twice as large as that we will get from Alaska, and much larger than that expected from the automobile efficiency standards.

A specific example of waste energy recycling is the capturing of hot gases from a high temperature furnace to preheat the air used on the stock processed in the furnace.

Specific examples of waste energy utilization are either the capturing of waste energy from an electricity generating unit to produce steam for an industrial process, or the capturing of waste heat from a cement kiln to generate electricity. These two examples are technically referred to as processes of cogeneration, the concurrent generation of electricity and steam or heat.

Cogeneration is a method of saving energy that can be used in many large manufacturing installations because all such installations require both electricity and steam or heat for their products.

By 1985, about 400 billion kilowatt hours of electricity could be cogenerated in manufacturing plants. This electricity consumes half as much fuel as the electricity generated in central power stations, and costs about 33% less.

Despite these benefits and many warnings of energy difficulties ahead, and though it clearly serves the best interests of industry and the nation, industry is not saving fuel at a rate as fast as the circumstances require. For example, though it is economical and energy-efficient to cogenerate electricity and process steam in many industrial plants, the method has not been widely adopted.

Several factors contribute to the sluggishness of industry to become more energy efficient. For example, historically, manufacturers were not in the energy business and are uncertain whether they should enter it now. Again, as President Carter said, "The price industry pays for much of the energy it consumes is not the marginal cost of energy, but rather a "rolled in" average cost..." (see Figure 1).

The Federal Energy Administration is monitoring a voluntary program of energy conservation in industry. I believe, however, that the program is deficient, especially because of the method used to evaluate progress.

Methods of evaluation of energy efficiency

The Federal Energy Administration evaluates efficiency by means of energy per ton of product. This yardstick has an obvious simplicity and universality in that it bypasses all details of manufacturing processes. It has, however, many shortcomings that make it impractical for national policy. Some of the shortcomings are as follows.

The data collected by FEA are averages over all manufacturers of the same standard two-digit classification. As such, they cannot be used to judge whether progress is being made by all reporting plants that participate in the program. It is well known that some enlightened companies are pursuing excellent energy conservation programs, and perhaps they are masking the inefficiencies of poor performers.

Substantial differences in manufacturing processes exist. Even if the FEA data were disaggregated, it is practically impossible to make comparisons of effectiveness of fuel utilization either of a plant with another of the same type, or between plants of dissimilar products. For example, not only is the energy per ton of tissue paper different from plant to plant but it is also different from the energy per ton of Kraft paper and from the energy per ton of steel ingots.

Targets for improvement are arbitrary and lack objectivity because they are based on a particular year in the past. Energy per ton of product varies from year to year because of variations in production versus available capacity and because of variations in stockpiles. Neither of these factors are directly related to cost-effective technology for improvement of efficiency.

For certain industries, the goal of reducing energy per ton of product may be counterproductive. For example, new products may require more energy per ton but may replace and last longer than others that are more energy wasteful.

Finally, no incentives and disincentives for energy efficiency can be established and monitored because the responsibility for energy savings is collective for each industry classification.

Another yardstick that is often used by engineers is the ratio of energy out of a process or machinery over the energy into that process or machinery. This is the so-called first-law efficiency. In some applications such as generation of electricity from raw fuel, this efficiency is a sufficiently accurate description of how effectively energy is used, and of the ultimate margin for improvement.

In most applications, however, the first-law efficiency is grossly misleading because it is neither accurate nor indicative of the opportunity to save energy. We can illustrate this point by considering two examples. The first is an idealized boiler for low-temperature steam in which all the input energy goes into the water to make steam. If such a boiler were practical, its first-law efficiency would be 100%, and we might be tempted to conclude that it cannot be improved. But to raise low-temperature steam we can use low-temperature waste heat rather than raw fuel and thus save a lot of fuel. This profitable change in input energy is intuitively understandable and yet not apparent from the first-law efficiency result.

The second example is to use the same idealized boiler in combination with a turbo-generator and produce both electricity and low-temperature steam, i.e., in a cogeneration process. Here the output energy is that of the electricity and the steam. If we divide it by the energy of the fuel input we will find a result less than 100% and we might be tempted to conclude that cogeneration reduces the efficiency. But many people know that cogeneration saves energy!

Finally, if we were to evaluate the first-law energy efficiency of industry as a whole, we would find it to be about three quarters, the number reported in the National Energy Plan. This result is grossly misleading because as I already stated, the average energy efficiency of manufacturing is a mere 13%.

The 13% result for manufacturing processes is, of course, based on the so-called second-law efficiency. Experts know that this is an objective measure of efficiency that can be used in all processes, that gives an absolute value of the margin for improvement, and that reveals the true causes of inefficiency. This yardstick has shortcomings as well, especially when applied to complete processes such as the transformation of wood into paper, but its advantages far outweigh its shortcomings.

As with other general methods, the shortcomings of the second-law efficiency can be eliminated by restricting its application to specific processes, such as steam raising, and then extending it further as experience accumulates. This restriction is somewhat analogous to using miles per gallon to measure progress in energy efficiency of private automobiles and not in the entire transportation sector.

If FEA were to develop a procedure for collecting second-law efficiency data from individual manufacturing plants, I believe that many benefits would accrue: (1) many plant managers would realize that the energy efficiency of manufacturing processes is very low; for example, the efficiency of process steam boilers is more like 20% rather than 80% (as claimed); (2) process designers would recognize more vividly that substantial energy savings are achieved not only by the obvious improvements in process equipment itself but by the combination of processes, such as by cogeneration; and (3) corporate managements would appreciate that cost-effective energy savings could be larger and could be achieved faster than heretofore believed.

For these reasons, I would enthusiastically recommend that FEA be instructed to develop procedures for collecting second-law efficiency data as described in Title IV, Part A of S. 2057 which passed the Senate on September 13, 1977.

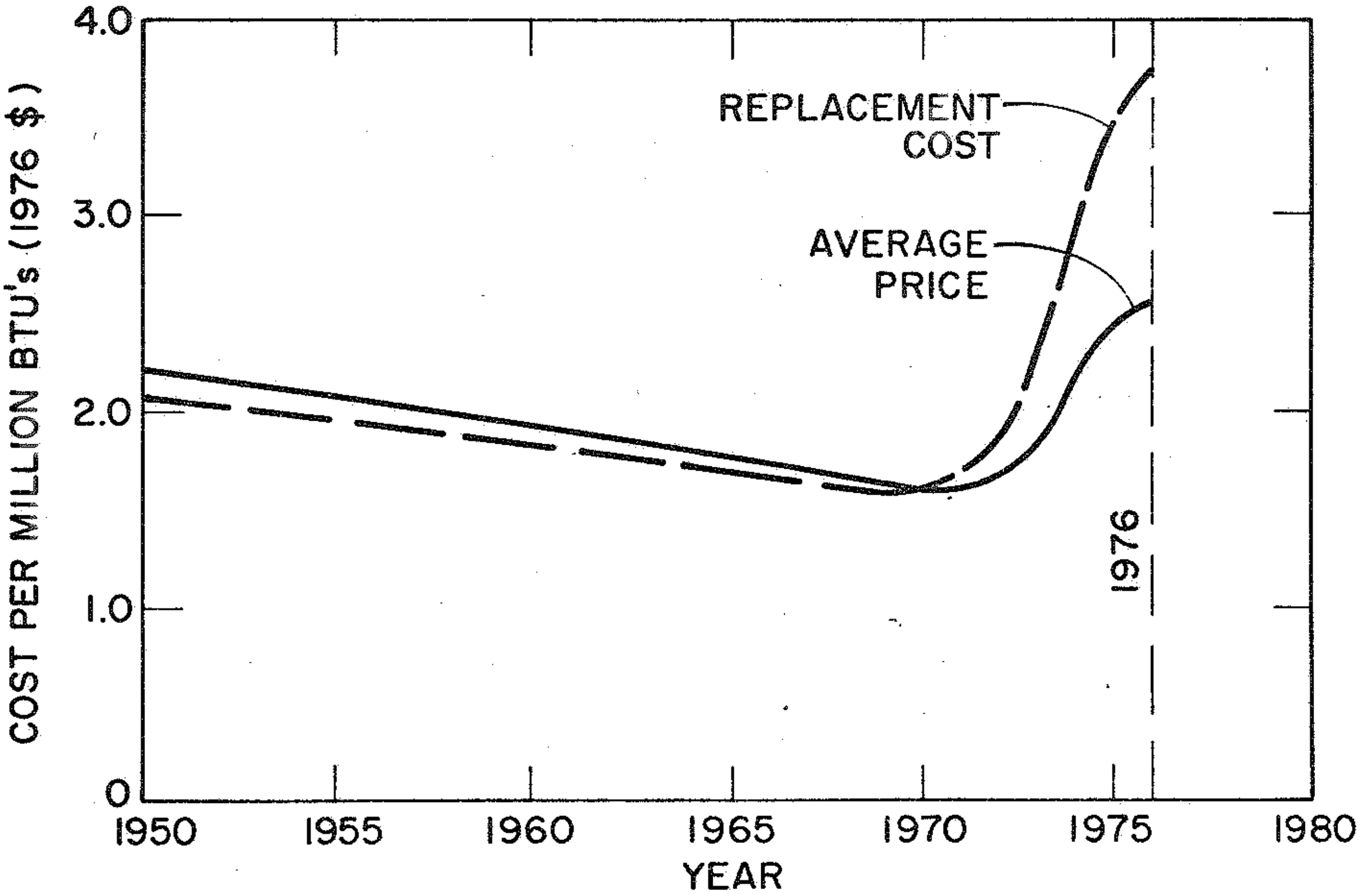

Figure 1. Aggregate cost in constant dollars of industrial energy from 1950 to 1976; (weighted according to usage of coal, oil, gas and electricity in industry).