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# THE PROSPECTS FOR COGENERATION IN U.S. MANUFACTURING

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# THE PROSPECTS FOR COGENERATION IN U.S. MANUFACTURING

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## INTRODUCTION

The purposes of this paper are: (1) to review the potential for cogeneration of electricity and process heat in U.S. manufacturing; (2) to estimate the energy and capital savings that cogeneration can achieve by the end of the next decade; and (3) to discuss the factors that inhibit the rapid implementation of cegeneration.

Cogeneration is the term used to describe the combined generation of electricity (or motive power) and process steam (or process heat). It can be practiced to supply the electricity and heat needs of either a community, or a manufacturing plant, or both. Usually, these two needs are supplied from different units, each generating one or the other form of energy.

In manufacturing plants, electricity can be cogenerated with low-pressure process steam, low-temperature process heat, or high-temperature process heat. Each type of cogeneration saves fuel as we can easily see by regarding the process steam as produced from the waste heat of an electricity plant, or the electricity as produced from the waste heat of a high-temperature industrial heating process.

Cogeneration saves also capital because the costs of new energy supplies (fuel replacement costs) are larger than the capital investsments in cogeneration equipment that achieves the same tasks (electricity and heat) but uses less energy.

By the end of the next decade, we estimate that cost-effective cogeneration in manufacturing could save the equivalent of up to 1 million barrels of oil per day, at a capital cost of about $25 billion less than that for equivalent new energy supplies.

The achievement of this cost-effective energy saving, however, is inhibited by several constraints, technical, economic, environmental, regulatory, and institutional. The degree to which cogeneration will be implemented depends on the policies that will be adopted to address some or all of the constraints.

## TYPES OF COGENERATION

In manufacturing plants, electricity can be cogenerated with low-pressure process steam, low-temperature process heat, or high-temperature process heat.

### Steam Raising

The raising of process steam accounts for about 40 percent of industrial energy usage. In many applications, process steam is used at relatively low pressure and temperature;

typically 50 to 150 psi and 300 to 350°F. The normal method of raising process steam in fuel-fired boilers is inefficient because the steam produced is at a relatively low temperature although the heat from the combustion of the fuel is at a much higher temperature.

The use of cogeneration can improve the efficiency. Figure 1 illustrates how cogeneration is effected by a high-pressure boiler and a back-pressure steam turbogenerator. We see that the combined process produces 8500 lbs of low-pressure process steam and 600 kwh of electricity by consuming the equivalent of 2.25 barrels of oil. If the same steam and electricity were generated in a low-pressure steam boiler and an electricity plant, respectively, they would have consumed the equivalent of 2.75 barrels of oil. In the separate processes, the two tasks consume 0.5 barrels of oil more than in the combined process. Alternatively, we can say that the 600 kwh of electricity is obtained for an incremental fuel consumption of only about 0.5 barrels, or 3 million Btu (roughly 5000 Btu per kWh) instead of 6 million Btu (10000 Btu per kWh) consumed by a modern central-station power plant.

Considerable lattitude exists for varying the ratio of electricity to steam. Steam turbogenerators normally yield about 50 to 70 kWh for each million Btu going to process steam. With diesel turbogenerators, electricity production rises to as much as 400 kWh for each million Btu going to process steam. Incremental fuel consumption is about 6800 Btu per kwh but still smaller than 10000 Btu per kWh of a central power station. With gas turbines and waste-heat boilers, electricity production is about 200 kWh per million Btu going to process steam, and incremental fuel consumption is about 5800 Btu per kWh.

For the next decade, the total potential for cogeneration of electricity and process steam is estimated to be about $1.2 \times 10^{12}$ kwh per year, or about 200,000 MW for 6000 hours per year. Because of technical and economic constraints, only up to one-third of this potential is feasible, corresponding to an addition of 50000 MW (11000 MW is already installed) and to a fuel saving equivalent to about 0.7 million barrels per day.

Direct-fired processes

Low-temperature (>800°F). Low-temperature heating processes, such as baking, drying, and curing, incur large inefficiencies because high-quality fuel is used to accomplish a task that requires only a low-grade energy supply. When the temperature requirement is very low, say 200 to 300°F, diesel or steam-turbine engines can be used to cogenerate electricity, as in steam raising. Figure 2 illustrates the use of a topping engine in the combined process, and the fuel savings in comparison to the separate processes.

By the end of the next decade, the theoretical potential for electricity produced by using diesel engines in low-temperature processes is about 250,000 MW. Since many low-temperature processes are relatively small in scale and subject to intermittent operation, we estimate that only about 17,000 MW for 7000 hours per year of this cogeneration capacity is likely to be implemented. This cogeneration will be achieved mostly with diesel engines, and to a lesser extent with gas turbines.

High-temperature processes (>800°F). Many of the heating processes required for the manufacture of metals, ceramics, glass, and cement are carried out in furnaces at high temperatures, sometimes in excess of 2000°F. Large inefficiencies occur because high quality energy is lost in the exhaust gases and materials leaving the furnace. One method of reducing inefficiency is effected by cogeneration of electricity from the exhaust gases. Figure 3 illustrates the use of bottoming engines in the combined process, and the fuel saving in comparison to the separate processes. We estimate about 5000 MW for 7000 hours per year to be cogenerated in such applications.

## SUMMARY OF ENERGY AND CAPITAL SAVINGS

Table I lists estimates of the energy and capital savings that could be effected by cogeneration in U.S. manufacturing by the end of the next decade. We see from this table that the generation of electricity in combination with the raising of process steam, with direct-fired low-temperature applications, and with direct-fired high-temperature furnaces could save the equivalent of up to 1 million barrels of oil per day. The estimated capital cost would be about $76 billion, whereas for equivalent new coal- and nuclear-fired central power stations it would be about $100 billion.

The capital investment estimates are based on the following assumptions: (a) new fossil fuel supply from source to consumer: coal $\$2 \times 10^9$ /Quad/yr, and oil $\$7 \times 10^9$/ Quad/yr; (b) new power plants (40% coal and 60% nuclear) including fuel supply and distribution: $1400/kW; (c) units for cogeneration with process steam: $850/kW plus cost of fuel supply; (d) units for cogeneration with low-temperature processes (mostly diesels): $700/kW plus cost of fuel supply; and (e) units for cogeneration with high-temperature processes: $700/kW.

Thus, if 72000 MW (50000 + 17000 + 5000) were to be installed the investment would be $101 billion. For 50000 MW cogenerated with process steam the investment would be $43 billion for about 1.5 Quad/yr of fuel supply, half coal and half oil. For 17000 MW cogenerated with low-temperature processes, the investment would be $12 billion for the topping engines (mostly diesels) plus $6.5 billion for 0.92 Quad/yr of oil. For 5000 MW high-temperature processes, the investment would be $3.5 billion for the bottoming engines and no investment for fuel.

CONSTRAINTS

The achievement of the savings listed in Table I, however, is inhibited by several constraints and uncertainties which may reduce the amount of cogeneration by a large factor. The constraints and uncertainties can be summarized as follows:

(1) Technical. Because of mismatch of the rate distributions at which electricity and process steam are required, or because of mismatch of the amounts of electricity and process steam that are required, or because of the small amounts of process steam required, some manufacturers cannot use cogeneration.

(2) Economic. Because of relatively low average electricity prices (due to historical pricing policies, to anticipated low electricity costs, to subsidies of the electricity sector, or a combination of these) coupled with relatively high fossil fuel prices, or because of differences between the rate of return (ROI) of regulated utilities and that of manufacturers, or because of alternative investments that have a high rate of return, cogeneration may not be economically attractive to some industries.

(3) Environmental. Because of environmental standards (classification of certain air pollution districts as non-degradation or nonattainment areas) cogeneration may not be possible for some manufacturers.

(4) Regulatory. Because of regulations controlling the generation and sale of electricity, and because of uncertainties about future regulations and future electricity and fuel prices, manufacturers are reluctant to engage in cogeneration.

(5) Institutional. Because manufacturers have not been in the energy supply business, or because utilities may not want to have industrial power plants connected to their grids, or because manufacturers may not want to expose themselves to regulations of public commissions, some cogeneration projects may not be constructed.

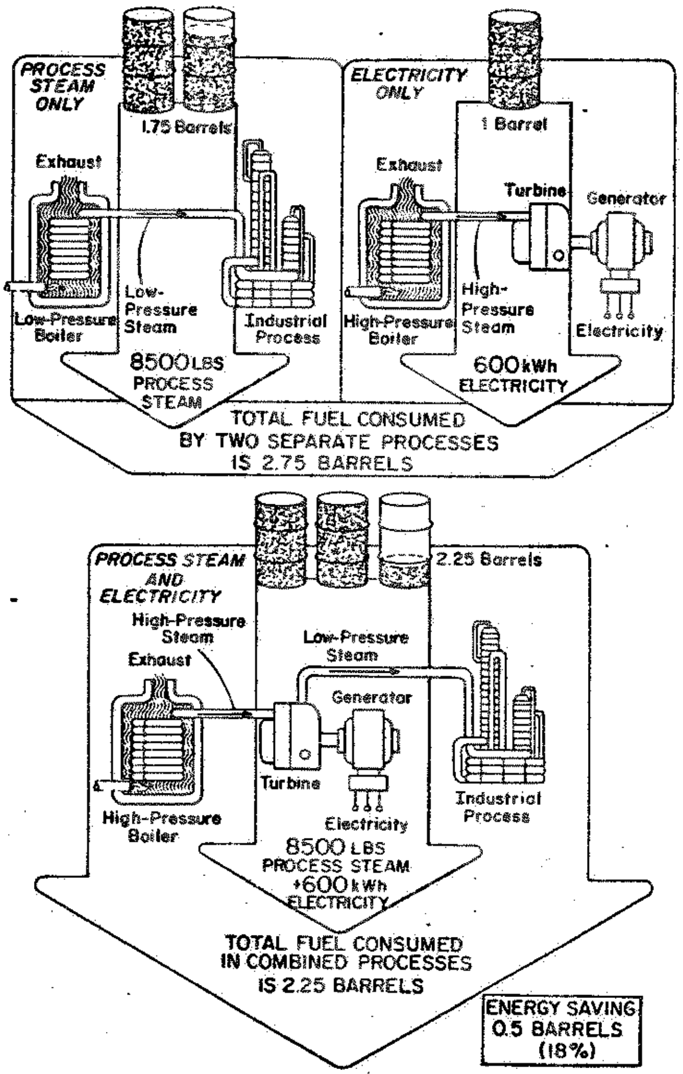


Figure 1. Cogeneration: Electricity and Process Steam

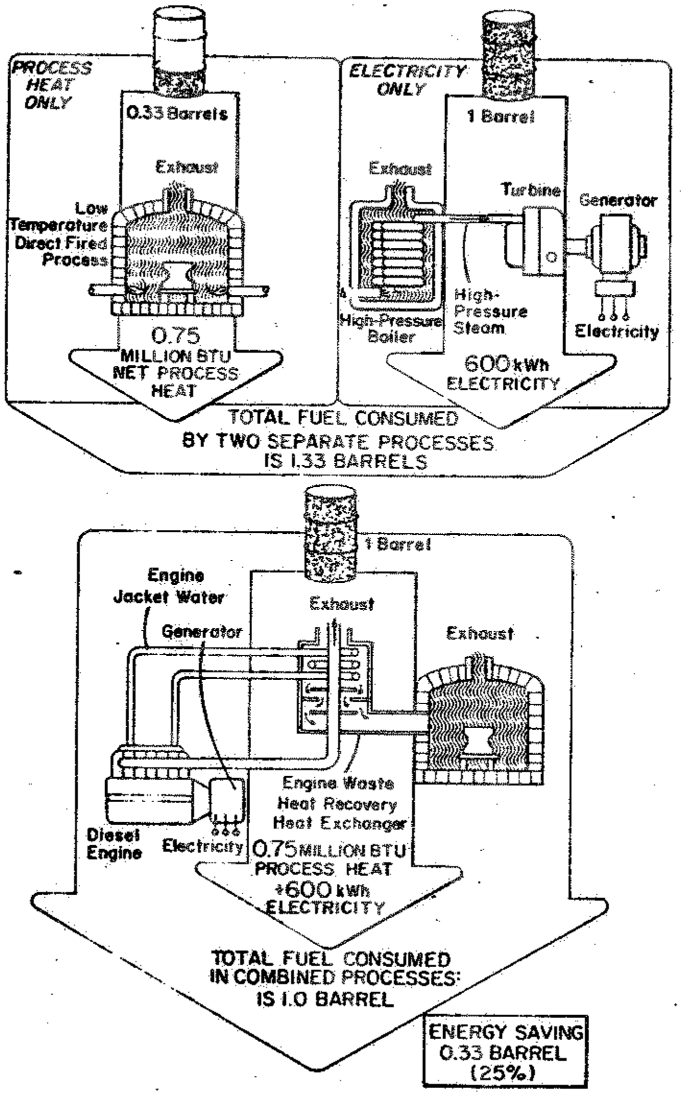


Figure 2. Cogeneration: Electricity and Low-Temperature Process Heat

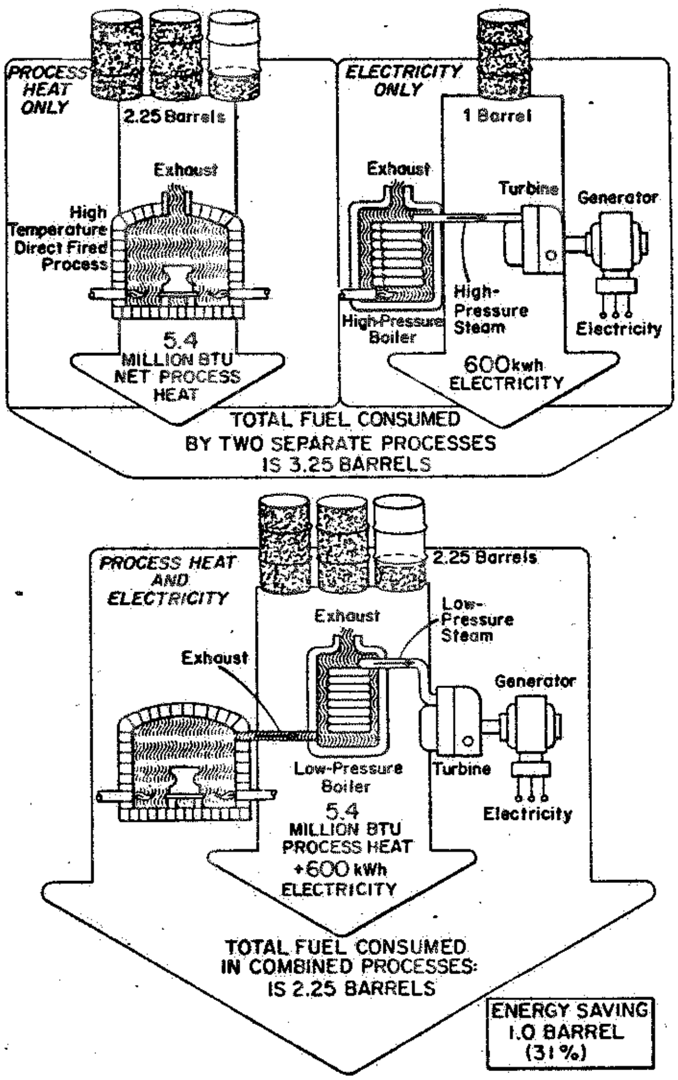


Figure 3. Cogeneration: Electricity and High-Temperature Process Heat

TABLE I

ENERGY SAVINGS AND COSTS PROJECTED FOR 1985

| Energy saving technology | 1985 Energy savings (in millions of barrels of oil per day) | | Capital cost | |
|---|---|---|---|---|
| | Fuel | Electricity | Conservation (in billions of dollars) | Energy supply (in billions of dollars) |
| Cogeneration of electricity with: | | | | |
| Process Steam | 0.68 | 0.54 | 54 | 70 |
| Low-temperature processes | 0.18 | 0.18 | 18.5 | 24 |
| High-temperature processes | 0.16 | 0.054 | 3.5 | 7 |
| Total | 1.02 | 0.78 | $76.00 | $101.00 |