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Project Summary

An Assessment of Central-Station Cogeneration Systems for Industrial Complexes

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This project assesses the potential for central-station cogeneration system development based on an analysis of the economic, environmental, energy efficiency and social impacts of such systems. In this study the cogeneration system consists of a utility-sized power plant which supplies both the electrical and steam needs of a number of nearby industries. Such a system can result in increased energy efficiency, reduced pollutants, and reduced overall cost. A number of methodological approaches, including environmental impact analysis, cost-benefit analysis, and social impact analysis were used to investigate issues relevant to cogeneration system development.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The type of cogeneration system considered in this report is one in which a large utility power plant supplies both electricity and steam to a group of local industries. The industries are located within a few kilometers of each other. The study compares such a system with one in which electricity and process steam are supplied from separate energy sources. The latter, decentralized energy supply system, is called a "conventional energy system"

Figure 1 shows two hypothetical systems which were compared in depth in this project. Six, 909 Mg/day (1000 TPD) chlorine-caustic soda plants are to be supplied with a total of 660 MW of electrical power and 363 kg/sec (2,880,000 lb/hr) of steam at 303 kPa (30 psig) and 288 °C (550 °F). In the conventional energy system this energy is supplied by a 1100 MW(e) power plant and six industrial boilers. In the cogeneration system most of the electricity and all of the steam is supplied from the power plant, while additional electricity is supplied from another power plant in the utility's grid. (The dashed lines in the Figure bound those parts of the cogeneration system which are located in close proximity.)

The idealized industrial complex which was analyzed in depth in the project consists only of chlorine-caustic soda plants. Pulp and paper mills, textile mills and phosphoric acid plants, were originally considered for possible inclusion. The most important characteristics of these industries are the quantity and quality of steam required. In general, these industries use large amounts of electrical energy, as well as steam at pressures below 3450 kPa (500 psi). Although the study focussed on coal-fired utility power plants, the economic and social impacts of using nuclear power were also considered. Industrial boilers were assumed to be coal-fired.

The energy analysis included comparing the total energy consumption of the cogeneration system and the conventional energy systems. A computer model was developed to calculate the significant operating parameters of both systems. The energy system included boilers, turbines, generators and piping. Energy use by the air pollution control system employed on coal-fired boilers was also included in the analysis.

A cost-benefit analysis determined the economic viability of the cogeneration system. A computer program called Model for Assessment of Integrated Energy Systems (MAIWS)*, was used to compare costs of the cogeneration and conventional energy systems. A sensitivity analysis on factors which effect the cost of system energy production was also made. The factors included power plant and industrial boiler capacity, fuel type, nuclear reactor type, fuel costs, and steam transport distance.

The study considered the following environmental impacts for industrial boiler and coal-fired power plants: (1) air emissions, (2) water consumption, (3) solid waste production, and (4) water quality. The costs of different types of air pollution and water pollution control systems were also compared.

An analysis was made to determine how wastewater treatment costs could be reduced in industrial complexes which incorporate several different types of industries. The recycling of wastes, as well as using wastes from one industry to treat those from another was considered. The study determined both capital, and operation and maintenance (O & M) cost savings for these two options.

The study identified the institutional constraints on developing and operating a central-plant cogeneration system and analyzed the socioeconomic impacts which would occur from such concentrated industrial development. Major impacts that would be caused by demographic changes in the host community during the construction and operation of a cogeneration system were estimated. (For example, the influx of construction workers and their families may put a strain on the local school system.) The study also identified general policies and siting considerations which might mitigate undesirable impacts due to large demographic changes.

*Previously developed by Oak Ridge National Laboratories.

Since this study considered a hypothetical system, the quantitative results are not directly applicable to other cogeneration systems. However, the methodology used to analyze these hypothetical systems should be applicable to real ones and the observed trends lead to important general conclusions about the benefits and drawbacks of cogeneration development.

Findings and Conclusions

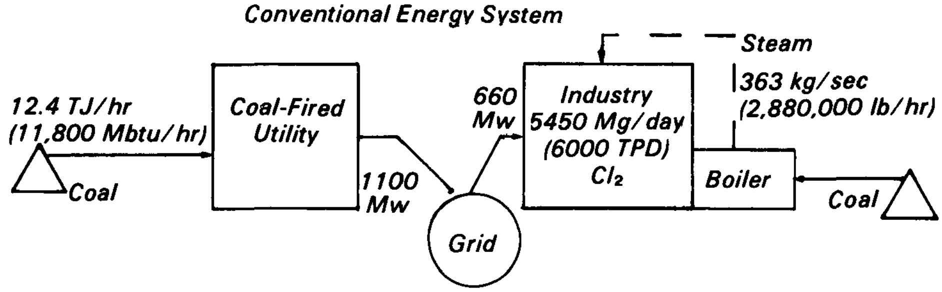
Both benefits and problems were found with central-station cogeneration systems. But with proper design, most significant problems can be overcome.

Energy Efficiency Impacts

As expected, fuel savings occurred when switching from the conventional to a cogenerating energy supply system. For the case study considered here, fossil fuel consumption was reduced by 15 percent (assuming that industrial boilers in the conventional energy system operate at 80% efficiency). The efficiency of the central-station power plant increased from 32% to 57% when it was converted to the cogeneration mode. Energy production efficiency of the whole system (including supplementary utility capacity) increased from 46% to 54%.

Economic Impacts

Costs for construction, O&M, and fuel for the conventional energy and cogeneration systems were evaluated. Table 1 presents the capital costs and the first year O&M and fuel costs for both systems. Fuel savings achieved by using cogeneration offset the incremental costs of the cogeneration system



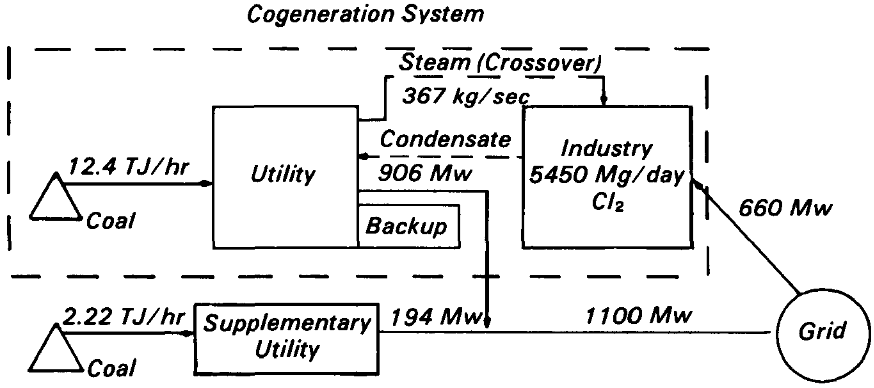


Figure 1. *Hypothetical energy systems compared in study.*

Table 1. *Comparison of System Costs (Millions of 1977 Dollars)*

Cost component	*A Conventional System*	*B Cogeneration System*	*Net B − A*
Capital	*538.2*	*560.8*	*22.6*
First year O&M	*21.9*	*22.0*	*0.1*
First year fuel	*129.8*	*109.1*	*−20.7*

after less than 2 years of operation. In terms of 1977 dollars, the 30-year life cycle net present value (NPV) of choosing the cogeneration system was $234.5 M, or approximately ten times the additional capital costs.

The economic sensitivity analysis showed that final costs and discount rates have the greatest influence on NPV of the cogeneration system. Next in importance are the capital and O&M costs of utility power plants and industrial boilers. Capital and O&M costs of cooling towers, piping, and pollution control equipment have much less influence on NPV.

Environmental Impacts

Reduced coal consumption in industrial complexes which have central-station cogeneration systems reduces the production of environmentally harmful residuals, and has the potential for reducing pollution control costs. However, high emission densities may occur at the site of the industrial complex causing local environmental problems.

For the cogeneration system analyzed in this report, substantial reductions in criteria pollutant emissions occurred from those generated by the conventional energy system. Pollutant reductions are listed in Table 2. Total reduction in air pollution control costs was approximately $7M.

Compared with a conventional system, a cogeneration system reduces water consumption because of its increased efficiency. Total water requirements for the industrial complex will depend on the industries located there. From a national viewpoint, significant amounts of water can be saved. However, there is the possibility that water demands from a particular cogeneration system and industrial complex will be so high that significant demands on the local water supply will occur.

Coal-fired cogeneration systems will use substantial amounts of land for disposal of solid waste. However, land devoted to the disposal of solid waste is reduced in comparison with a conventional energy system by the percentage increase in efficiency. If flue gas desulfurization is used for control of sulfur oxides emissions, the reduction in land required is important because the land committed for disposal of flue gas desulfurization solid waste cannot be used for any other purpose until the land has been properly reclaimed.

Table 2. *Annual Residual Reductions (Kg/Yr)*

Air Pollutants	
Particulates	8.2×10^5
Sulfur Oxides	3.6×10^6
Nitrogen Oxides	3.2×10^6
Carbon monoxide	8.6×10^5
Hydrocarbons	4.1×10^5
Solid Waste*	
Ash and flue gas desulfurization (FGD) sorbent	1.8×10^8
Ash and fluidized bed combustion (FBC) sorbent	2.7×10^8

**Reduction in solid waste was calculated for each of two different SO_2 reduction options*

The advantages of centralizing wastewater treatment facilities are an important indirect impact of cogeneration which result from the close proximity of different industries. The financial benefits are small compared to the savings from energy efficiency improvements; however, they are significant when compared to pollution control costs. For instance, combining wastewater treatment facilities of a 909 Mg/day (1000 ton per day) pulp and paper mill with a 189 Mg/day (208 ton per day) carpet mill would result in $980,000 in capital cost savings and $495,200 in annual O&M costs (1977 dollars). Four other similar combinations of industries were analyzed in the report to determine the financial benefits of combined wastewater treatment.

Institutional and Social Impacts

The social impacts of cogeneration are inversely related to the size of the host community. Large host communities have a greater capacity to accommodate the cogeneration system needs than small communities. A cogeneration system located in a sufficiently large community would induce a moderately positive rate of economic growth. Changes in small host communities arising from cogeneration system construction may be so large and so sudden that the changes will be detrimental.

One factor which was an important determinant of social impacts on communities of any size was the degree to which industrial and power plant construction were coordinated. A properly phased construction schedule can reduce peak adverse impacts by 20% to 50%.

Only slightly larger social impacts arising from demographic changes will occur if a nuclear plant is constructed instead of a coal-fired plant. This difference is principally due to higher labor demands during nuclear power plant construction.

Recommendations

Cogeneration System Planning and Design

Energy efficiency is optimized when industries locate as close as possible to utility power plants. The power plant should maximize the amount of low pressure steam extracted for industrial use. Industrial processes should be designed with process steam requirements which easily interface with the cogeneration system.

Steam extracted for industrial use should not exceed 6.9 MPa (1000 psi) or 430 °C (800 °F). The minimum pressure of transported steam should be 700 kPa (100 psi) and at saturated conditions. Industries should require large quantities of low pressure steam to obtain maximum system efficiencies. The industries should condense the steam and return it to the power plant for reuse.

In-plant generation of steam would be an economically better approach when distances between industries and utilities exceed several kilometers. The specific distance depends on technical and economic factors of each individual system.

Centralization of other facilities (e.g. air pollution control and wastewater treatment) should be undertaken when possible. Industrial cositing should be particularly sought when opportunities exist for waste products from one industry to be used as raw materials for another.

The host community for the cogeneration system in this study should have greater than 30,000 employees in a population of 100,000 to avoid significant negative social impacts. The construction schedule should be closely managed in order to reduce the extra demands on public facilities. In particular, manpower planning should minimize the need for new workers. Strict housing regulations should be used to control short-term housing problems.

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Further Research and Program Development

Cogeneration systems have the potential for producing energy savings and environmental benefits which coincide with federal energy and environmental goals. However, each proposed system must be analyzed on a case-by-case basis. The authors of the study recommend the development of programs to provide incentives and guidelines for environmentally safe cogeneration systems.

Site-specific impact analyses of hypothetical cogeneration systems located in communities with different characteristics could be conducted using ambient air quality modeling, social impact analysis, and institutional barrier identification and evaluation. Two areas which are particularly in need of further study are: (1) reduced cost of pollution control through centralized treatment facilities which utilize process or power plant waste heat, and (2) land use impacts of pollution control alternatives (e.g. fluidized bed combustion) which produce large quantities of solid wastes. Although the impacts of each system will be site-specific, a series of case studies should be made to obtain impact trends.

An overall environmental study should be performed to examine the impact of environmental regulations on cogeneration development and to study the impact of formulating environmental standards which encourage proper siting of cogeneration systems. The use of extracted heat for industrial processes, and the use of cogenerated heat for district heating and cooling, and for agricultural and aquacultural applications could be incorporated in any future research and environmental policy development. A detailed guidebook on the use of power plant or process waste heat for wastewater treatment is also recommended.

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The complete report, entitled "An Assessment of Central-Station Cogeneration Systems for Industrial Complexes," (Order No. PB 82-232 372; Cost: $18.00, subject to change) will be available only from:

National Technical Information Service
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