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ANL/CNSV-TM-37

MASTER

INDUSTRIAL COGENERATION CASE STUDY #2:
AMERICAN CYANAMID CHEMICAL COMPANY,
BOUND BROOK, NEW JERSEY

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Energy and Environmental Systems Division
Argonne National Laboratory
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PREFACE

The project reported here was directed and conducted by James H. McElroy. Nirmal Kotamraju worked and consulted on all of its aspects and provided particularly valuable service in his organization and management of the data development. Richard Peppin contributed to and participated in the early stages of project development; Barbara Coates performed much of the data manipulation; and Leila Snyder typed the manuscript drafts. Thanks are due Charles Leatham of Gilbert Commonwealth Engineers for his expert consultation on many of the technical aspects of cogeneration and to Jack G. Faucett for his consultation on the intricacies and complexities of interest, capital depreciation, inflation, and investment decision making.

Special thanks go to the people of American Cyanamid -- at headquarters, to Mr. L. T. Longbridge who initially coordinated the JFA contacts; and at Bound Brook, to James A. Feeney who authorized the study project, and, particularly, to William Mitchell, utilities plant superintendent, Laura Liebermann, power plant engineer, and Charles McCann, power plant accountant, whose cooperation, active support, insights, and patience in responding to our many inquiries made the project possible.

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1 INTRODUCTION AND BACKGROUND

Argonne National Laboratory, under the sponsorship of the Department of Energy's Office of Industrial Programs, has financed a project to do case studies of cogeneration at five industrial establishments. Six reports, one on each of the five individual case studies and a summary synthesis report, document the total case study project.

This chapter describes the objective of the project, the general methodology of site selection, and the selection of the subject Cyanamid plant in particular. The chapter concludes with a brief discussion of the case study methodology employed and the report organization used for documenting the results.

1.1 PROJECT OBJECTIVE

The main objective of the Industrial Cogeneration Case Study Project, which this report partially documents, is to improve understanding of cogeneration through case studies on the actual operation of functioning cogeneration facilities at establishments.

Much has recently been written and said about the energy-saving potential of co-locating facilities that generate electric power with facilities that consume large quantities of lower grade process heat. Thereby much of the by-product heat of electric generation that is traditionally thrown away (often as a thermal pollutant) can be used productively. If properly designed and operated such cogeneration can save large amounts of fuel and capital. (Capital savings are achieved through not having to provide equipment to convert the saved fuel into energy that is to be discarded.)

To fill the gap between theoretical and practical knowledge, DOE/Argonne National Laboratory have commissioned two sets of case studies of cogeneration operations in the U.S. The first set of studies explored the issue at a number of commercial and residential apartment facilities. The other set, which constitutes the scope of the present project, explores cogeneration at five large industrial establishments located in five widely separated locations.

The earlier case studies were of relatively small-scale operations that primarily provided electricity and space conditioning energy for mostly commercial, residential, and service sector establishments. With one exception, the operations studied had electric power capacities of 5000 kW or less, and most used diesel prime mover technology and had requirements for relatively low grade by-product heat. They all operated on oil or natural gas and were of fairly recent (since 1960) vintage. In addition, most, at best, were only marginal economic and energy-saving successes and, at worst, total failures in both aspects.

In contrast, the case studies of this project are of much larger scale operations, 12,000-29,000 kW of electrical capacity, with large additional amounts of motive power cogenerated in some cases. The industrial

cogeneration operations serve process heat requirements that are much more diverse. For example, steam is frequently needed at more than three different enthalpies (temperature and pressure) and the process heat usually needed must be of a much higher grade than is typical for space conditioning. (Sometimes fairly high grade heat, 400 psi superheated steam, is required.)

The five establishments of this project use steam-turbine, prime-mover technology. Fuel use, on the other hand, is diverse. All of the electric generation is 30 years of age, or more, with some dating back to the first two decades of this century. The cogeneration operations studied are the result of long histories of incremental plant changes, additions, and refinements. Only one of the facilities even remotely resembles the originally designed and installed cogeneration operation; the others have grown and evolved into operations quite different from those initially installed.

1.2 SITE SELECTION METHODOLOGY AND CRITERIA

For this case study project the Department of Energy was interested in cogeneration in five industries -- (1) food processing, (2) textiles, (3) pulp and paper, (4) chemicals, and (5) oil refining. In selecting sites for study, Jack Faucett Associates (JFA) used a cogeneration data base they developed that identifies and categorizes most of these establishments. From this array, JFA selected some from each industrial category, based on a number of specific considerations and factors, and began requesting their participation and cooperation in this project.

In general, sites ultimately selected were those that would provide the widest possible variety of information about the actual practice of industrial cogeneration in the U.S., particularly on those factors operating near the economic margin that can make the difference between successful and unsuccessful cogeneration operations. The case study candidates were not selected according to scientific sampling principles. Rather, JFA's experience and knowledge gained in doing other case studies, especially one on cogeneration, and in developing and analyzing its cogeneration data base, were used as bases for selections.

1.2.1 Size of Electric Generation Plant

A prime objective of this study was to investigate the economics of operating cogeneration plants. In that regard, the most interesting plants are those with electrical generation in the 10,000-30,000-kW range. As cogeneration candidates in the future, the smaller operations are less numerous and are expected in general to be less attractive; whereas the larger ones, being major beneficiaries of the economies of scale available from electric generation technology, are expected to be clearer winners. As to the very large operations, however, the number of industrial applications where they are practical is small. For example, there are no large (greater than 30,000 kWe) cogeneration plants in the food and textile industries. The five industries studied constitute the bulk of U.S. manufacturing capacity and thus the bulk of the market for cogeneration, which lies in such medium-to-large-sized plants as those selected for study.

1.2.2 Facility Location

Facility location was an important choice criteria for two reasons:

1. The overall project's usefulness is enhanced by case study experience provided from a large variety of geographical locations.
2. Selected individual establishments should be in locations that are generally attractive to industry -- out-of-the-way locations were avoided. For example, pulp and paper mills in remote and isolated locations in the states of Maine, Oregon, and Washington were not contacted. The participation of paper mills closer to the industrial heart of the country was preferred.

Additionally, it was desired to have sites located in as many different states and regulatory environments as possible. Facilities selected are in five states; New Jersey, South Carolina, Tennessee, Illinois, and California.

1.2.3 Facility Fuel Use

Case study candidates were chosen with major consideration given to the type of fuel used. The widest possible variety of fuel use was sought; the sites selected use petroleum, natural gas, coal, refinery by-product oil and by-product gas, and paper mill by-product black liquor. An aspect related to fuel used by these sites is the fuel-use mix of the electric utility that serves them.

In effect, onsite electric generation competes in part with the local electric utility, since industrial plant managers typically have the choice of making power onsite or buying it from the utility. To varying degrees, this decision has been made based on the comparative economies involved. Because a large and growing share of the cost of purchased power (as well as onsite generated power) goes for fuel purchase, the kind of fuel used to generate utility-produced power is an important consideration. If the onsite cogeneration uses the more expensive oil and gas fuels and the electric utility uses the same, onsite cogeneration can be expected to be much more cost competitive with the purchased power option than would be the case if the relatively inexpensive coal and nuclear fuel generated the utility's power.

Fuel usage aspects for 1978 of the five onsite generating facilities selected for the entire case study project are:

1. The American Cyanamid plant in New Jersey (the subject of this report) uses oil and natural gas and competes with the Public Service Gas and Electric Company whose base-load electric generation was about 50% oil, 25% nuclear, and 25% coal fueled.

2. The Celanese plant in South Carolina uses coal and competes with Duke Power Company whose baseload electric generation was 66% coal and 33% nuclear fueled.
3. The Mead Paper plant in Tennessee uses purchased coal and by-product black liquor and competes with Appalachian Power Company whose baseload electric generation was nearly 100% coal fueled.
4. The AMOCO plant in Illinois uses natural gas, refinery gas, by-product fuel oil, and residual fuel oil and competes with the Illinois Power Company whose baseload electric generation was more than 90% coal fueled.
5. The C&H Sugar plant in California uses oil and gas and competes with Pacific Gas and Electric Company whose baseload electric generation was 48% natural gas and 49% oil fueled, with the remaining 3% provided by geothermal energy.

1.2.4 Prime Mover Technology

Case study candidates were chosen with consideration given to the type of engine used as the prime mover. Analysis, however, of JFA's cogeneration data base revealed that not much variety existed in the kind of technology used for large cogeneration prime movers. One listing of large industrial cogeneration facilities showed that out of 380 facilities, 349 were powered by steam turbine, 17 by internal combustion (diesel), and fewer than 20 by gas turbine. The fact that all of the sites selected use steam-turbine technology resulted because of limitations in the number of case studies performed plus the application of other important site selection criteria.

1.2.5 Motive Power Cogeneration

The most common perception of cogenerated power is that of electric power. Technologically, however, there is no reason to accept that limitation. A more general and proper notion of cogeneration conceives of power in both mechanical and electrical terms. In selecting sites for this study, the primary focus was on onsite electric generation with recovery and use of by-product heat, but sites also were sought for the project where significant motive power was generated so that the relationship between motive and electric power cogeneration could be examined. It turned out that all of the sites have some motive power generation. The American Cyanamid site, however, has only a small quantity of it, less than 1000 kW.

1.2.6 Varied Institutional Environment in Which the Cogeneration Plant Existed

An initial criteria for case study site selection was varied institutional arrangements in which cogeneration existed. Sites of particular interest were those where cogenerators:

1. sold excess electricity to the electric utility that serves their area;
2. bought additional power above and beyond what they produced;
3. wheeled onsite generated power over electric utility lines to remotely located consumers; and
4. were provided with back-up demand capacity without a requirement for a minimum purchase of electricity.

While the objective of studying a variety of relevant institutional arrangements was pursued, contacts with industrial cogeneration managers revealed that all of the candidate sites reviewed were similar in that they had connections with their local electric utility to import power. None of the sites contacted were isolated from the grid; all purchased electricity in addition to making it; and none had excess power they wanted to sell to the electric utility or wheel over the electric utility's lines. While other institutional arrangements do sometimes exist, a finding of this project's site selection process was that other arrangements or (historically) the need for them is rare.

1.3 SELECTION OF THE AMERICAN CYANAMID'S BOUND BROOK PLANT

American Cyanamid was selected as a representative chemical industry plant. The Bound Brook, New Jersey, site, chosen largely for its location, is in one of the most heavily industrialized regions of the United States, almost midway between New York City and Philadelphia. In addition, both city and state are locations where electric generation is heavily dependent on oil for fuel. In the past coal fulfilled most of the area's fuel needs, but air pollution considerations now have forced a shift to cleaner natural gas, oil, and nuclear power for industrial and electric utility use. While coal fuels some of New Jersey's electricity generation, the actual generation takes place at plants in nearby Pennsylvania.

The Cyanamid plant too, which was built to use coal, was similarly forced in the 1960s to shift to oil and natural gas. Coal handling facilities have been removed and coal is no longer used. A return to its use is neither contemplated nor could be accomplished without major expense. This cogeneration operation is medium sized and relatively simple. Condensing is not used in the production of electricity and little motive power cogeneration is carried on.

1.4 REPORT OVERVIEW

In the three chapters remaining, Chapter 2 describes the plant and discusses the evolution of its onsite generation to its present state. Chapter 3 details cogeneration at the Cyanamid Bound Brook plant, and in Chapter 4, its energy characteristics and economics are evaluated by com-

paring them with those of the electric utility power that would be required in the absence of onsite generation.

2 AMERICAN CYANAMID'S BOUND BROOK PLANT

American Cyanamid is a major United States chemical manufacturing company. The firm has 11 major divisions with facilities located primarily in the eastern United States. In 1977 corporate sales totaled \$2.4 billion.

The Bound Brook plant is in the Organic Chemicals Division and is the largest and most diversified chemical manufacturing facility within the American Cyanamid Corporation. The plant initially was built and put into operation during the 1915-1918 period as the Calco Chemical Company, and was taken over by American Cyanamid in 1929. Since then it has grown from an employment level of 400 employees to one of 2400.

It occupies 150 buildings on a 600-acre site and produces 1000 products. Among its output are pharmaceuticals, fine chemicals, agricultural chemicals, elastomers, rubber chemicals, dyes, chemical intermediates, organic pigments, and plastics additives. Its annual expenditure for labor, materials, supplies, utilities and taxes is in the \$140 million range.

The plant is located on the Raritan River, which is the source of its water needs, and has its own water purification and wastewater treatment facilities. As do most chemical manufacturing plants, the facility operates around the clock, 365 days a year. Because of the continuous nature of many chemical processes, reliable uninterrupted continuity of plant operations is essential for profitable operations.

2.1 ENERGY OPERATIONS

Energy needs of the plant are supplied by purchased residual fuel oil, natural gas, and electricity. Residual fuel oil is trucked to the plant daily. Natural gas is supplied on an interruptible basis by Public Service Electric and Gas (PSE&G), which also supplies the purchased electricity that enters the plant from two different points on the PSE&G system. Having two locations for electrical connection provides increased reliability of supply.

The plant's central energy facilities include two high pressure operating boilers (aggregate capacity of 425,000 lb/hr) and one low pressure standby boiler (capacity 210,000 lb/hr).

Steam from the high pressure boilers is expanded through back pressure turbines to generate electricity and is exhausted at 125-psi for distribution to plant processes. (A small amount of 125-psi steam is also used in the powerhouse for steam driven air compressors, air conditioners, and steam driven powerhouse auxiliaries.) The steam is also expanded through pressure-reducing valves to 450-psi for about 15% of the plant's process heat needs that require that pressure.

The plant has three turbine generators -- two operate on 750-800-psi, high pressure steam and one, on 450-psi. The two modern high pressure units

provide essentially all of the onsite electricity generated. The seldom used 450-psi turbine generator is an old unit that regularly provided power before the two high pressure units were installed, but now is there for backup only.

The powerhouse auxiliaries and air compressors are the only steam driven machines at the Cyanamid plant. All other plant motors are electrically driven. These steam drives exhaust at about 5 psi and the exhaust steam is used to heat the make-up feed water. The plant has almost no condensate return. Powerhouse steam generation and electricity production are governed entirely by plant demand for the 450- and 125-psi process steam. Electricity needs beyond those provided by powerhouse generation are satisfied by the PSE&G connections.

2.2 ONSITE ELECTRIC GENERATION EVOLUTION

When the Bound Brook plant initially was built and then expanded in the 1915-1920 period, four 150-psi, 20,000 lb/hr, coal-fired boilers and two 300-kW turbine generator (TG) sets were installed. This initial electric generation equipment used condensers for heat sinks and process steam was provided directly from the boilers. The system was not cogenerational, as there was no recovery of heat that would otherwise be discarded. During this early time it was conventional industrial practice for plants with significant power needs to meet them with onsite generation. This practice made economic sense because industrial generators could operate nearly as efficiently as the central stations of the times, and reliable electric power distribution systems of large capacities were not yet in existence. It is doubtful that PSE&G could have provided the plant with the large quantity of reliable electric power needed as economically as the power could be generated onsite. The plant did have a small tie with PSE&G for nighttime lighting and priority loads at that time, but the bulk of its power was made onsite.

In 1929, after being acquired by American Cyanamid, the plant went to cogeneration. This move was accomplished by adding a 100,000 lb/hr, 450-psi boiler and a 1500-kW noncondensing, back-pressure TG that exhausted at 125 psi to serve process heat needs. At about this time the tie with PSE&G was disconnected.

During the thirties the plant continued to grow and add steam generators and electric generation equipment. In 1934 and in 1939, each, a 100,000-lb/hr boiler was added along with a 2400-kW, noncondensing back-pressure TG. Between 1939 and 1941 yet another TG set was added. This time it was a 1250-kW extracting condensing TG set that extracted 5-psi steam for use in producing anniline and heating feed water. This unit served another purpose, which was to provide electricity with condensing -- electricity made in excess of that made with cogeneration.

This type of production became desirable because of a growing imbalance between the demand for electricity and that for process steam. Due to changes in some of the plant processes, particularly the increased use of electric driven refrigeration units, more and more electricity was being consumed for each unit of steam consumed. The plant needed more

electricity relative to steam, and Cyanamid determined that an appropriate stop-gap means for increasing its relative electricity production would be to install an extraction/condensing TG unit. Installing additional condensing capability, however, provided only a temporary solution. Plans were made and implemented in 1941 to install an 800-psi, 220,000 lb/hr steam generator and a 5400-kW noncondensing TG. Moving to this new higher pressure from 450 psi allowed for a new balance between electricity and 125-psi process steam production in which more electricity per unit of process steam was produced.

From the 1949s through the 1950s, production continued to grow. Also during this period, the use of refrigeration and other electricity-intensive processes grew relatively more rapidly than did processes requiring heat. Consequently, by the late 1950s another high pressure (800-psi) boiler (220,000 lb/hr) and another (8800-kW) noncondensing TG were installed. These new additions allowed a further increase in the amount of relative electricity produced. Moreover, the increasing use of relative electricity was continuing to such an extent that even with 800-psi steam, not enough electricity could be made to satisfy demands. Thus, in the early 1960s a substantial electric tie with PSE&G was established to purchase electricity. Initially this tie was not synchronized with onsite generation. In the early 1970s the necessary synchronization electric switch gear was installed, and Cyanamid onsite generators and PSE&G now run in parallel. Parallel operation allows the plant to continually adjust its onsite generation so that it makes and purchases an optimum mix of electricity. Since the tie was established the purchased power share of all its electric needs has grown to about 50% of total annual electrical consumption. Moreover, the large recent fuel price increases have reinforced this trend. It appears that the fuel price increases have caused a relatively larger reduction in process steam needs than in those for electricity. Thus rising fuel prices have caused increasing consumption of central station electric power by the Cyanamid Bound Brook plant.

During the whole period from the 1920s until the conversion to natural gas and oil in 1969-1970, the old boiler and electric generation equipment was left in place as new equipment was added, so that in the late 1960s the plant had over 20,000 kW of connected electric generating capacity and more than 700,000 lb/hr of boiler capacity. On the average, over the years, about 60% of the additions made to boiler and electric generation facilities was for capacity and about 40% of the new capacity was for modernization and upgrading of gear to enable the plant to convert an ever-growing share of the steam it generated into electricity.

Cyanamid ended the 1960s with over 300,000 lb/hr of obsolete steam generation capacity and nearly 7000 kW of outdated and seldom used electric generation capacity. Most of this gear was removed in the late 1960s and early 1970s, leaving the plant that now exists.

Fuel Usage. From the time the plant was built, over 60 years ago, to 1970, coal was the primary fuel used at the site. Until 1958 anthracite from the nearby anthracite-producing areas of Pennsylvania was used exclusively. In 1958 capability for using bituminous coal, as well as its use, was added to the plant.

In 1969 and 1970 due to air pollution from its coal burning and resultant pressure on the plant for cleanup from the New Jersey State Department of Health, Cyanamid began to convert from coal to natural gas and oil. The conversion was completed in 1970 at a reported cost of over \$3 million, and the plant no longer has coal-burning capability, relying entirely on natural gas and fuel oil.

3 COGENERATION AT CYANAMID

There are three outputs of the cogeneration system at the plant. These are: (1) process steam generated to meet the thermal industrial requirements; (2) mechanical power provided directly to drive air compressors and powerhouse auxiliaries; and (3) electricity generated as a by-product.

Approximately 50% of the plant's total electrical requirements are met through onsite generation and the other 50%, through electricity purchases from the Public Service Electric and Gas Company (PSE&G) of New Jersey.

The cogeneration system is discussed in two sections. The first, provides a description of the equipment and the manner by which process steam, mechanical power, and electricity are generated, along with the relationship among the outputs. The second, describes the performance and reliability of the system in providing these outputs.

3.1 COGENERATION EQUIPMENT, PROCESSES, AND OUTPUTS

3.1.1 Description of Equipment

A schematic of the cogeneration system is shown in Fig. 3.1. The major components of the system are: boilers, turbine generators (TGs), and steam driven compressors. In addition to this equipment, there are certain other steam driven machines (such as feedwater pumps and fans) located in the powerhouse.

The system consists of two boilers* (capable of burning either natural gas or fuel oil), two turbine generators,** and six steam driven compressors. Boiler capacity is 440,000 lb/hr and the total normally used electrical generating capacity is 14,200 kW. The combined power of the compressors is less than 600 hp.

The boilers generate steam at 800-psi, with boiler No. 8 providing steam at 700°F and boiler No. 9 providing steam at 760°F. Steam from boiler No. 8 drives TG No. 7, and steam from boiler No. 9 drives TG No. 8. In addition, steam from boiler No. 8 is passed through a desuperheater to serve process steam needs at 450-psi. The technical specifications of the boilers are shown in Table 3.1.

Turbine generators No. 7 and No. 8 are driven by the 800-psi steam and exhaust at 125-psi. Turbine generator No. 8 is run as closely as

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*A third boiler was installed in 1971 to supplement the supply of 125-psi steam from the turbine generators. The demand for 125-psi steam has decreased substantially since 1971 and can be met entirely through the exhaust of the turbine generators. Therefore, the boiler is no longer used.

**A third turbine-generator is not now in use as the process steam and electrical generation requirements can be met by the other two turbine generators.

Figure 3.1 Components of the Cogeneration System at Cyanamid

Table 3.1. Characteristics of Boilers at Cyanamid

Boiler No.	No. 8	No. 9	No. 10
Manufacturer	Riley	Babcock & Wilcox	Erie City
Capacity (lb/hr.)	220,000	220,000	210,000
Pressure (psi)	800	800	125
Temperature (°F)	700	760	420
Feedwater Temp. (°F)	230	230	230
Fuel Type	oil/gas ^a	oil/gas ^a	oil/gas
Date of First Use	1941	1957	1971
			(currently not in use)

^aOriginally coal fired

possible to its capacity, with TG No. 7 being used to supplement it. Both of the TGs are noncondensing units and consequently no heat is lost through condensing. Hence, their thermal efficiency is very high -- 95% or more. The characteristics of the turbine generators are shown in Table 3.2.

The compressors are driven by 125-psi steam and exhaust into the 5-psi header. The aggregate rated power output is 600 hp.

3.1.2 Description of Cogeneration

The cogeneration system is governed to meet the thermal demands of the industrial processes, with electricity being generated as a by-product. Process steam production and the generation of electricity and mechanical power are discussed in this section.

Process Steam. Process steam is required at 450 and 125-psi. The 450-psi steam is generated by reducing the pressure of the steam output of the boilers from 800-psi by passing the steam through a desuperheater. Since no mechanical energy is generated in the process this activity is not cogeneration. Process steam is provided at 125-psi from the exhausts of

Table 3.2. Characteristics of Turbine Generators at Cyanamid

Turbine-Generator No.	No. 4	No. 7	No. 8
Manufacturer	Westinghouse	G.E.	Westinghouse
Capacity (kW)	2,400	5,400	8,800
Date of First Use	1934	1941	1957
<u>Steam Inlet</u>			
Temperature (°F)	600	700	760
Pressure (psi)	450	800	800
Flow Rate (lb/hr)	120,000	195,000	225,000
<u>Steam Exhaust</u>			
Temperature (°F)	420	420	420
Pressure (psi)	125	125	125
Flow Rate (lb/hr)	120,000	195,000	225,000

the turbine generators (TGs). (See Fig. 3.1.) When the 800-psi steam generated by the boilers is passed through the TGs, its pressure is reduced and it is extracted at 125 psi. The TGs thus serve as pressure-reducing stations in the supply of process steam.

Electricity. The quantity of electricity generated is dependent upon the demand for 125-psi process steam and, to a small extent, upon the steam demand of the compressors and powerhouse auxiliaries. Steam to satisfy both of these demands is provided entirely by the exhausts of the TGs. Therefore, electricity is generated as a by-product when the pressure of the steam generated by the boilers (800-psi) is reduced to the 125-psi level. The No. 8 TG is run as much as possible with TG No. 7 being used to supplement it.

Mechanical Power. Mechanical power is required for both the compressors and the powerhouse auxiliaries, driven by steam exhausting from the TGs at 125-psi, which then exhausts into the 5-psi header. The enthalpy (heat energy) of the steam is lowered by converting a portion of it into mechanical energy (hp-hr), which then drives the machines.

3.2. PERFORMANCE AND RELIABILITY OF THE COGENERATION SYSTEM

Process Steam. To provide the 450- and 125-psi process steam required respectively, the steam generated by the boilers is passed through a reducing valve and through the turbine generators (TGs). The reliability of the supply of process steam thus depends on the operating reliability of the boilers, TGs, and desuperheaters.

Boilers. Each of the two boilers has a generating capacity of 220,000 lb/hr. Peak demand for process steam usually does not exceed 360,000 lb/hr. Therefore, if one of the boilers is inactive, sufficient steam for a peak need cannot be generated. However, boiler No. 10 (presently inactive) can be used in conjunction with another boiler to provide the required 125-psi steam. Thus, even with one boiler inactive, Cyanamid can generate enough steam to meet its needs (see Fig. 3.1).

Turbine Generators. There are two TGs at the plant with individual flows that can be as high as 195,000 and 225,000 lb/hr. The average demand for steam at 125 psi exceeds the amount that can be provided by any single TG. Thus, if one is inactive, boiler No. 10 or the 800/125-psi desuperheater must be put in operation (see Fig. 3.1).

Desuperheater. The 800-psi steam generated by the boilers is passed through a desuperheater to produce the 450-psi process steam required. Since the desuperheater is the only means by which 450-psi steam is provided, its operating reliability is essential to assure a steady supply.

The use of desuperheaters to provide the 450-psi steam is inefficient in that no mechanical energy (and, in turn, electricity) is generated when the 800-psi steam is reduced. The 800-psi steam is at a temperature of 700°F with an enthalpy of 1335 Btu/lb and the 450-psi steam is required at a temperature of 600°F with an enthalpy of 1300 Btu/lb. The 35-Btu/lb differ-

ence is the heat loss in desuperheating. The steam flow through the desuperheating valve averages about 30,000 lb/hr, and with this level of steam flow approximately 300 kW of electricity could be generated. The electricity could be generated if the TGs had an extraction point at 450 psi, but the cost of such equipment exceeds the benefits that could be derived from the small additional quantity (300 kW) of electricity to be derived.

Electricity. Onsite electric generation provides approximately 50% of the total electrical requirements with the remaining 50% being met through purchases from PSE&G.

The three TGs available (with generating capacities of 2,400, 5,400, and 8,800 kW) have a total generating capacity of 16,600 kW. In addition, up to 20,000 kW of electric power can be purchased from PSE&G. Thus a maximum of 36,600 kW can be provided to the plant and since peak electrical demand usually never exceeds 25,000 kW, an ample supply of electricity is readily available. The onsite generating capacity of 16,600 kW cannot, in itself, meet the peak electrical demand (25,000 kW) of the plant. In the event of an outage of the tie-line from the utility, some plant operations would have to be curtailed to compensate for the shortfall. Two separate feeders from the utility guard against such an occurrence.

There is very little flexibility in the onsite electrical generation system, since its output is almost entirely dependent on the demand for process steam. No electricity is generated through condensing, and while this feature conserves energy, the supply of electricity provided is slightly less reliable in the event of outages.

Mechanical Power. The total rated output of the compressors is about 600 hp or about 450 kW. This output amounts to less than 3% of onsite electric generating capacity. The compressors are located inside the powerhouse and their operation is monitored by powerhouse personnel.

4 ECONOMIC AND ENERGY EFFICIENCY OF COGENERATION AT CYANAMID

In this chapter, the actual economics, fuel usage, and characteristics of cogeneration are evaluated through comparison with those of a hypothetical alternative under which the plant purchases electricity from the Public Service Electric and Gas (PSE&G) Company.*

The evaluation is presented in four sections. The first section shows the costs and fuel consumption associated with onsite electric generation for the 5-year period from 1974 through 1978. The second, presents those associated with the purchased power alternative. The third, makes a comparison of the costs and fuel consumption of onsite electric generation with those of the purchased power alternative; and the fourth, makes a second comparison. The comparison in the fourth section is made using capital costs that have been adjusted to reflect the costs that would have to be charged to onsite generation as if the capital equipment required for electric generation had been purchased in 1972. This supposition was made in order to provide more current estimates.

4.1 ONSITE ELECTRIC GENERATION

The fuel consumption and costs associated with onsite generation presented here were computed from detailed monthly data obtained from the accounting records of Cyanamid. These data were aggregated to yield annual totals for the years 1974 through 1978.

4.1.1 Onsite Electric Generation Fuel Consumption

Fuel consumption for onsite generation was calculated in the following manner: (See data presented in Table 4.1.)

1. The quantity of electricity generated (in kWh) in each of the years 1974 through 1978 was obtained from the accounting records of Cyanamid.
2. The fuel-to-electricity heat rate (in Btu/kWh) -- the quantity of fuel required to generate one kWh of electricity -- was obtained. An internal study conducted by Cyanamid determined the fuel-to-electricity heat rate to be 4450 Btu/kWh. Their two turbine generators (TGs) are noncondensing and, therefore, no condensing losses are associated with them. Thus, the only losses are boiler and TG losses. Thermal efficiency of the boiler is about 80% and that of the TGs, about 95%. If the system were 100% thermally efficient, it would take 3412 fuel Btu to generate one kWh.

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*This alternative is hereafter referred to as the purchased power alternative.

Table 4.1. Cyanamid Onsite Electric Generation Fuel Consumption

Year	On-Site Generation	Fuel-to-Electricity Heat Rate	Fuel Consumption				
	(kWh, thous.)	(Btu/kWh)	Total (Btu Billions)	Natural Gas (Btu billions) (Cubic Feet millions)		Fuel Oil (Btu billions) (Gallons thousands)	
1974	76,538	4,450	341	139	134	202	1,390
1975	70,185	4,450	312	187	179	126	867
1976	68,178	4,450	303	86	83	217	1,450
1977	65,849	4,450	293	148	143	145	998
1978	67,045	4,450	298	50	48	249	1,716
Total 1974-1978	347,815	4,450	1,547	610	587	939	6,421
Annual Average	69,563	4,450	309	122	117	188	1,284

3. The heat rate (in Btu/kWh) was multiplied by the quantity of electricity generated (in kWh) to yield the fuel consumed (in Btu) in the generation of electricity.
4. The fuel consumption was allocated between natural gas and fuel oil. This allocation was made in such a way as to charge to electric generation the monthly incremental cost for fuel. Since electricity is a by-product that results from adding extra enthalpy to the steam, which is then removed in the electric generation process, the fuel charge for the electric generation must be that for the incremental fuel. Thus if both low priced gas and high priced oil were used by Cyanamid in a given month, electric generation would be charged for fuel oil.

The data on fuel consumption shows that:

- Between 1974 and 1978 fuel consumption for electric generation amounted to 1.5 billion Btu, with consumption averaging 309 billion annually (see Table 4.1).
- Of the 309 billion Btu of annual fuel consumption, 122 billion were supplied by natural gas, with the remainder by fuel oil (Table 4.1). Fuel consumption is weighted towards fuel oil because steam generation at Cyanamid, and consequently electric generation, is highest during the winter when natural gas supply is curtailed and fuel oil use increases.
- Electric generation decreased by 13% between 1974 and 1978, with fuel use decreasing from 341 billion Btu in 1974 to 298 billion in 1978, due to a reduction in process steam demand during the period (Table 4.2).

4.1.2 Onsite Electric Generation Costs

A review of onsite generation costs shows that:

- Onsite electricity generation costs to Cyanamid average 13.5 mills/kWh (see Table 4.3), or \$936,000 per year. Of this amount, \$606,000 (65%) was estimated for fuel; \$257,000 (27%), for operation and maintenance of the electrical generating equipment; and \$73,000 (8%), for capital payments.
- The unit cost of generating electricity rose from 10.4 mills/kWh in 1974 to 15.9, in 1978. This 53% increase in unit cost is a result of an approximated 34% increase in total costs (from \$797,000 in 1974 to \$1,069,000 in 1978) and a 13% decrease in the quantity of electricity generated. The 34% increase in total costs resulted in turn from an approximated 43% increase in fuel costs and

Table 4.2. Cyanamid Steam Production and Onsite Electric Generation

Year	<u>On-Site Generation</u>	<u>Steam Production</u>
	(kWh, Thous.)	(Btu, billions)
1974	76,558	3,248
1975	70,185	2,599
1976	68,178	2,856
1977	65,849	2,648
1978	67,045	2,523
Total 1974-1978	347,815	13,874
Annual Average	69,563	2,775

Table 4.3. Cyanamid Onsite Electrical Generation
Total Costs

Year	<u>On-Site Generation</u>	<u>On-Site Electric Generation - Costs</u>				<u>Costs per unit of Electricity Generated</u>
	(kWh, thousands)	Fuel (dollars, thousands)	Operation and Maintenance (dollars, thousands)	Capital (dollars, thousands)	Total (dollars, thousands)	(mills/kWh)
1974	76,558	496	223	78	797	10.4
1975	70,185	518	243	76	837	11.9
1976	68,178	636	257	73	966	14.2
1977	65,849	668	271	71	1,010	15.3
1978	67,045	710	291	68	1,069	15.9
Totals 1974-1978	347,815	3,028	1,286	366	4,680	13.5
Annual Average	69,563	606	257	73	936	13.5

a 30% increase in fuel costs and a 30% increase in operation and maintenance costs (see Table 4.3). Since capital costs are less than 10% of total costs, their small decline had little impact on total costs.

4.1.2.1 Onsite Electric Generation Fuel Costs

Fuel costs (in dollars) of onsite generation were determined by multiplying fuel consumption (calculated in Btu) by a weighted average unit fuel cost (obtained in dollars per Btu). (See Tables 4.4(a) and 4.4(b).)

They represented, as stated above, about 65% of the costs, averaging about \$606,000 per year. Of the 13.5 mills/kWh spent for onsite generation, 8.7, were for fuel. (See Tables 4.3 and 4.4(a).)

They rose from \$496,000 in 1974 to \$710,000 in 1978, an increase of 43%, which is due to a 64% increase in the unit cost of fuel, from \$1.455 per million Btu in 1974 to \$2.383 in 1978 (see Table 4.4(a)).

4.1.2.2. Onsite Electric Generation Operating and Maintenance Costs

This section provides the costs of operating and maintenance labor and materials for onsite electrical generation. These costs accounted for approximately 27% of the costs of onsite electrical generation.

The cost data, obtained from the accounting records of Cyanamid, showed considerable monthly variation. The fluctuations were due to accounting procedures and large periodic maintenance expenditures. Since the benefit of large maintenance operations extends into periods other than the period in which maintenance is done, operation and maintenance costs were averaged over the entire period of the study, with variations in cost attributable only to inflation.

Annual expenditures for the labor and materials required for the operation and maintenance of the electric equipment also were obtained from the accounting records of Cyanamid.* These expenditures were then deflated to a common base (1974 dollars) through the application of GNP deflators and summed to yield a total expenditure for the 5-yr period under consideration. The average annual expenditure (in constant 1974 dollars) was then inflated (using GNP inflators) to yield a current dollar expenditure for the years 1974 through 1978.

An analysis of the data on operating and maintenance costs shows that:

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*American Cyanamid breaks down its total operating labor expenses into costs incurred in the operation of both the steam and electric equipment. The breakdown is based upon the percentages of man-hours spent on operating each type of equipment. The percentages were developed by American Cyanamid and were the result of internal studies.

Table 4.4.(a) Onsite Electrical Generation Fuel Costs

	<u>On-Site Generation</u>	<u>Energy Consumption</u>	<u>Unit Cost of Fuel</u>	<u>Fuel Cost</u>	<u>Fuel Cost per Unit of Electricity</u>
Year	(kWh, thousands)	(Btu, Billions)	(\$ per Million Btu)	(dollars, thousands)	(mills/kWh)
1974	76,558	341	1.455	496	6.5
1975	70,185	312	1.660	518	7.4
1976	68,178	303	2.099	636	9.3
1977	65,849	293	2.280	668	10.1
1978	67,045	298	2.383	710	10.6
Total 1974-1978	347,815	1,547	1.957	3,028	8.7
Annual Average	69,563	309	1.957	606	8.7

Table 4.4.(b) Onsite Electrical Generation
Fuel Use and Costs by Fuel Type

Year	<u>Natural Gas</u>			<u>Fuel Oil</u>			<u>Total</u>		
	(Btu billions)	(\$ per million Btu)	(thousands of dollars)	(Btu billions)	(\$ per million Btu)	(thousands of dollars)	(Btu billions)	(\$ per million Btu)	(thousands of dollars)
1974	139	1.683	95	202	1.985	401	341	1.455	496
1975	187	1.064	199	126	2.532	319	312	1.660	518
1976	86	1.570	135	217	2.309	501	303	2.099	636
1977	148	1.839	287	145	2.628	381	293	2.280	668
1978	50	2.660	133	249	2.313	576	298	2.383	710
Total 1974-78	610	1.392	849	939	2.319	2,178	1,547	1.957	3,028
Annual Average	122	1.392	170	188	2.319	436	309	1.957	606

- These costs account for 27% of the expenses for on-site generation and averaged about \$257,000 per year. Of the 13.5 mills/kWh spent for onsite generation, 3.7 mills/kWh were spent on equipment operation and maintenance. (See Tables 4.3 and 4.5.)
- About 20% of the \$257,000 was spent on operating costs and the remaining 80%, on maintenance (see Table 4.5).

4.1.2.3 Onsite Electric Generation Capital Costs

Capital costs are the third cost element of onsite generation and account for 8% of total costs. These costs are low because the equipment used was purchased in the 1940s and 1950s and has been almost fully depreciated.

Annual capital costs were calculated in the following manner.

1. Capital costs were estimated by engineering consultants* to this project for a facility with an onsite generation capability equivalent to that of Cyanamid's Bound Brook plant. The cost of such a facility is estimated at \$5,507,000 in 1980 dollars. (This cost is the incremental cost for the electric generation plant.)
2. Capital expenditures were obtained for the facility as if construction had taken place in 1951, determined as the mean construction date of the electrical generating facilities. The expenditures were computed by deflating the costs (in 1980 dollars) to 1951 by applying GNP deflators obtained from the U.S. Department of Commerce. The 1951 current dollar construction cost was determined to be \$1,824,000.
3. Annual capital costs for 1974 through 1978 were determined using an interest rate of 4% and an annual rate of depreciation of 3-1/3%. (The equipment was assumed to have a useful life of 30 years and was depreciated on a straight line basis.) The 4% interest rate is about what Cyanamid had to pay for bond money in the early 1950s.

The results are presented in Table 4.6. An analysis of the results shows that:

- Capital costs account for only 8% of the costs of onsite electric generation and averaged about \$73,000 per year. Of the average 13.5 mills/kWh spent for 1974-1978, 1.1 mills/kWh were spent on capital. (See Tables 4.3 and 4.6.)

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*The Engineering consultants were Gilbert Commonwealth Associates of Jackson, Michigan.

Table 4.5 Onsite Electric Generation Operating and Maintenance Costs

Year	<u>On-Site Generation</u>	<u>Operating Costs</u>		<u>Maintenance Costs</u>		<u>Total Costs</u>	<u>Cost per Unit of Electricity</u>
	(kwh, thousands)	Labor (dollars, thousands)	Materials (dollars, thousands)	Labor (dollars, thousands)	Materials (dollars, thousands)	(dollars, thousands)	(mills/kWh)
1974	76,558	36	6	69	111	223	2.9
1975	70,185	40	6	76	122	243	3.5
1976	68,178	43	6	80	128	257	3.8
1977	65,849	46	6	85	136	271	4.1
1978	67,045	49	6	91	146	291	4.3
Total 1974-1978	347,815	214	30	401	643	1,286	3.7
Annual Average	69,563	43	6	80	129	257	3.7

- Capital costs decrease only slightly from 1974 to 1978. (See Table 4.6.) For any given five-year period, they vary by only a small amount as a result of the low rate of interest (4%) and the 30-yr depreciation of the equipment.

4.2 PURCHASED POWER ALTERNATIVE

The preceding section shows the costs and energy consumption associated with onsite electrical generation. In order to evaluate the energy-saving and economic advantages of onsite generation, these costs must be compared with the alternative under which electricity is purchased from the local utility. In this section, the energy consumption and costs associated with purchasing electricity under the hypothetical situation, hereafter referred to as the purchased power alternative, are presented. In the next section the economic and energy saving aspects of onsite generation are compared with that alternative.

4.2.1 Purchased Power Alternative Fuel Consumption

Fuel consumption under the purchased power alternative is discussed in this subsection. Data on fuel consumption, shown in Table 4.1, were determined in the following manner:

1. The quantity of electricity Cyanamid generated (in kWh) in each of the years, 1974 through 1978, was obtained from their accounting records. Under the alternative, equivalent amounts would be purchased from PSE&G.
2. The heat rate in Btu/kWh (the quantity in Btu of fuel required to generate one kWh of electricity using baseload equipment) was calculated from data obtained from annual reports submitted to FERC by PSE&G. The method for calculating the heat rate is discussed below.
3. The heat rate (in Btu/kWh) was multiplied by the quantity of electricity generated (in kWh) onsite to yield the fuel (in Btu) that would have been consumed by the utility in replacing that quantity.
4. The energy consumed for electric generation was distributed by fuel type based upon the fuel consumption profile of PSE&G's baseloaded plants discussed below.

The heat rate and fuel distribution were calculated as follows:

1. The plants under PSE&G that are baseloaded are identified.

Table 4.6 Onsite Electrical Generation
Capital Costs

Year	<u>On-Site Generation</u> (kWh, thousands)	<u>Capital Costs</u>			<u>Capital Costs Per Unit of Electricity</u> (mills/kWh)
		<u>Annual Depreciation</u>	<u>Annual Interest</u>	<u>Total</u>	
		(dollars, thousands)			
1974	76,558	61	17	78	1.0
1975	70,185	61	15	76	1.1
1976	68,178	61	12	73	1.1
1977	65,849	61	10	71	1.1
1978	67,045	61	7	68	1.0
Total 1974-1978	347,815	305	61	366	1.1
Annual Average	69,563	61	12	73	1.1

Table 4.7 Purchased Power Alternative
Fuel Consumption

Year	<u>On-Site Generation</u> (kWh, Thous)	<u>Purchased Power Fuel-to- Electricity Heat Rate</u> (Btu/kWh)	<u>Fuel Consumption</u> (Btu, Bil)	<u>Fuel Type</u>		
				<u>Coal</u> (Btu, Bil)	<u>Nuclear</u> (Btu, Bil)	<u>Oil</u> (Btu, Bil)
1974	76,558	11,132	853	349	0	503
1975	70,185	11,288	792	277	167	348
1976	68,178	11,265	768	276	176	315
1977	65,849	11,205	737	251	132	354
1978	67,045	11,168	748	225	187	337
Total 1974-1978	347,815	11,207	3,898	1,378	662	1,857
Annual Average	69,513	11,207	780	276	132	371

2. Their heat rate (in Btu/kWh), electric generation (in kWh), and fuel consumption by type (in Btu) also are identified.
3. A weighted average of the heat rate in (Btu/kWh) is then obtained.
4. The fuel consumption (in Btu) under the purchased power alternative is determined by simply multiplying the heat rate (in Btu/kWh) by the quantity of electricity generated (in kWh).
5. The fuel distribution is obtained by distributing energy consumption according to the fuel distribution of the baseloaded plants.

The heat rates for baseloaded plants were selected because Cyanamid's demand from PSE&G would be relatively constant and would be provided by the baseload capacity of PSE&G. The heat rates were adjusted to reflect line losses of 7%.

The data on energy consumption of the purchased power alternative showed that:

- o Between 1974 and 1978, energy consumption for electric generation would have amounted to 3,898 billion Btu with consumption averaging 780 billion annually (see Table 4.7).

By contrast, energy consumption for onsite generation averaged about 309 billion Btu annually. (A comparison between onsite generation and the purchased power alternative is made in the next section.)

- o The average annual heat rate for the purchased power alternative would have been 11,207 Btu/kWh. On the other hand, the average annual heat rate for onsite generation was 4,450 Btu/kWh, which is only 40% of the purchased power alternative. Thus, it readily can be seen that onsite generation is significantly more energy efficient (see Tables 4.1 and 4.7).
- o Of the 780 billion Btu consumed at the utility each year, 276 billion (35%) of coal, 132 billion (17%) of nuclear fuel, and 371 billion (48%) of fuel oil are consumed averagely (see Table 4.7).

4.2.2 Purchased Power Alternative Costs to Cyanamid

In order to make an evaluation of the economics of onsite generation, its cost must be compared with the cost of electricity under the purchased power alternative. The method of obtaining the cost of electricity and

a discussion of the results are given in this section. The economic comparison is made in the next section. It is important to realize here that the cost to Cyanamid is based on purchased power prices rather than utility costs. Since PSE&G does not use marginal cost pricing, Cyanamid's costs are not precisely the economic costs of the power.

The plant now meets its electricity requirements partly through onsite generation and partly through purchases from PSE&G. Under the purchased power alternative the plant would purchase all of its electricity from PSE&G. Therefore, the incremental cost of the purchased power alternative -- the cost of purchasing an amount equivalent to the quantity of electricity generated onsite -- is the difference between the cost of meeting total electricity consumption and the cost of electricity being purchased. The cost of electricity under the purchased power alternative was calculated as indicated below (data is shown in Table 4.8):

1. An electric bill for purchasing all electricity used (both electricity generated onsite and that purchased) was calculated, as described later.
2. The cost of electricity purchased was obtained from the plant's accounting records.
3. The incremental cost of electricity under the purchased power alternative was obtained by subtracting the cost of electricity purchased from the bill that was calculated as if all power were purchased.

The electric bill for Cyanamid's total consumption was calculated with the aid of rate schedules obtained from PSE&G. There are three charges for electricity purchases under their billing system. These are: demand, energy, and fuel adjustment.

The demand charge is based on the maximum rate of electricity demand (i.e., maximum kW draw on the line); the energy charge, on the total consumption (kWh) of electricity; and the fuel adjustment charge, upon actual fuel cost deviation from the expected fuel costs.

The demand charge is effectively the charge for the plant's peak electrical consumption. The peak consumption was assumed to be the sum of the current peak demand from the utility (obtained from electric bills) and the current peak draw* from the onsite electrical generation system (obtained from plant records). The demand charges were then calculated by applying the demand rates obtained from the rate schedules.

The energy charges and energy adjustment charges were obtained by applying the rates obtained from the rate schedules to Cyanamid's total kWh consumption. The demand, energy, and energy adjustment charges were then summed to the total charge for electrical consumption.

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*Based on conversations with plant engineers at Cyanamid, it was determined that the peak draw and the average draw from the onsite electrical generation system were almost the same.

Table 4.8 Purchased Power Alternative Costs

Electricity Consumption				<u>Purchased</u> <u>Power Cost</u> <u>If all</u> <u>Electricity</u> <u>Were</u> <u>Purchased</u>	<u>Cost of</u> <u>Electricity</u> <u>Actually</u> <u>Purchased</u>	Purchased Power Alternative	
<u>Year</u>	On-Site Generation (kWh, thousands)	Purchased (kWh, thousands)	Total Generated Plus Purchased (kWh, thousands)	(dollars, thousands)	(dollars, thousands)	Purchased Power Cost of On-Site Generated Electricity (dollars, thousands)	Unit Cost (mills/kWh)
1974	78,558	64,426	140,984	3,342	1,615	1,727	22.6
1975	70,185	56,767	126,952	3,401	1,606	1,793	25.5
1976	68,178	67,478	135,656	3,627	1,908	1,719	25.2
1977	65,849	69,523	135,372	4,082	2,198	1,884	28.6
1978	67,045	73,930	140,975	4,416	2,420	1,998	29.8
Totals 1974-1978	347,815	332,124	679,938	18,867	9,758	9,119	26.2
Annual Average	69,513	66,425	135,988	3,773	1,950	1,824	26.2

An examination of the incremental costs of electricity under the purchased power alternative shows that:

- Between 1974 and 1978, the plant would have purchased electricity under the alternative for an average annual unit cost of 26.2 mills/kWh (see Table 4.8). During the same period it actually generated electricity at a cost of 13.5 mills/kWh. (A detailed economic comparison between onsite generation and the alternative is shown in the next section.)
- The unit cost of purchased electricity rose from 22.6 mills/kWh in 1974 to 29.8 mills/kWh in 1978, an increase of approximately 32% (see Table 4.8).
- Between 1974 and 1978, the corporation would have had to pay a total of \$9.1 million for 347 million kWh, or about \$1.8 million annually.

4.3 COMPARISON OF ONSITE GENERATION WITH THE PURCHASED POWER ALTERNATIVE

An evaluation of the cost and energy-saving effectiveness of onsite generation is made in this section. The actual energy consumption and costs associated with onsite generation are compared with those under the hypothetical situation where electricity is purchased from PSE&G. Both of these situations were discussed individually in the preceding sections.

4.3.1 Energy Consumption of Onsite Generation Compared with the Purchased Power Alternative

A comparison of the energy consumption associated with onsite electrical generation with energy consumption under the purchased power alternative shows:

- Fuel consumption (in Btu) for electric generation under the alternative to be more than two and a half times that of onsite generation. Cyanamid consumed an average of 309 billion Btu each year to generate 69.5 million kWh, and PSE&G would have consumed 780 billion Btu to generate an equivalent quantity (see Table 4.9).
- The difference in energy consumption between onsite generation and the purchased alternative is a result of the difference between their respective heat rates. Electricity was generated at Cyanamid for 4450 Btu/kWh. The PSE&G would have generated electricity at an average heat rate of 11,207 Btu/kWh (see Tables 4.1 and 4.7). The difference in heat rate arises from the fact that the utility generates its electricity through condensing, which results in the latent heat of vaporization in the steam being discarded. Onsite generation, by contrast, uses the latent heat for process purposes.

Table 4.9. Fuel Consumption Comparison, Cyanamid Onsite Generation vs. PSE&G Purchased Power Alternative

<u>Electricity Produced</u> <u>On-Site</u>		<u>On-Site Generation</u> <u>Actual Fuel Use</u>			<u>Purchased Power Alternative</u> <u>Hypothetical Fuel Use</u>				<u>Cogeneration Savings</u>				
Year	(kWh, thousands)	Natural Gas	Oil	Total	Coal	Nuclear	Oil	Total	Natural Gas	Coal	Nuclear	Oil	Total
		(Btu, billions)			(Btu, billions)				(Btu, billions)				
1974	76,558	139	202	341	348	0	503	853	-139	349	0	301	512
1975	76,165	187	128	312	277	167	348	792	-187	277	167	222	468
1976	68,178	86	217	303	278	176	315	769	-86	276	176	98	465
1977	65,849	148	145	293	251	132	354	737	-148	251	132	209	444
1978	67,045	50	249	298	225	187	337	748	-50	225	187	-62	450
Total 1974-1978	347,815	610	939	1,547	1,378	662	1,857	3,898	-610	1,378	662	918	2,351
Annual Average	69,513	122	188	309	276	132	371	780	-122	276	132	184	470

- o For the 5-yr period studied, onsite generation resulted in a savings of 1378 billion Btu of coal, 662 billion of nuclear fuel and 918 billion of oil. These savings were achieved at a fuel cost of 610 billion Btu of natural gas

It is evident that onsite vs electric utility generation of electricity can realize considerable savings of energy.

4.3.2 Comparison of the Costs of Onsite Generation with the Purchased Power Alternative

A comparison of these costs shows that:

- o Between 1974 and 1978 Cyanamid generated electricity onsite for about 13.5 mills/kWh. If it had purchased its electricity from PSE&G, it would have had to pay about 26 mills/kWh, nearly twice that amount (see Table 4.10).
- o Between 1974 and 1978, the annual savings of onsite electric generation changed very little.
- o The constant dollar rate of return of onsite generation increased from 109% in 1974 to 197% in 1978 (see Table 4.11). The rapid rise and the magnitude of the rate of return is a result of the vintage of the electric generating equipment. The book value of the equipment is small (nearly zero), and the return is relatively very high.

It is evident that the onsite generation of electricity has proved to be economical for Cyanamid. A major reason for its current attractiveness lies in the fact that its capital costs again are almost negligible because of the vintage of the generating equipment. In order to examine its economic effectiveness today, the costs incurred by a relatively new facility must be analyzed and compared with the costs of purchasing electricity. The cost of generating electricity at a hypothetical new (1974) facility is analyzed in the next section.

4.4 COMPARISON OF THE COSTS OF ONSITE GENERATION FOR A HYPOTHETICAL NEW FACILITY WITH THE PURCHASED POWER ALTERNATIVE

In this section the estimated costs associated with onsite electrical generation for a new (1974 start-up) facility are compared with the costs under the hypothetical purchased power alternative. The method of determining the capital costs is discussed first, followed by a comparison of the total costs with the purchased power costs.

The capital costs of onsite generation were determined in the following manner:

Table 4.10. Cost Comparison Cyanamid Onsite Generation
vs PSE&G Purchased Power Alternative

Year	<u>Electricity Produced</u>	<u>On-Site Generation Cost</u>		<u>Purchased Power Alternative Cost</u>		<u>Cogeneration Savings</u>	
	(kWh, thousands)	Total Cost (dollars, thousands)	Unit Cost (mills/ kWh)	Total Cost (dollars, thousands)	Unit Cost (mills/ kWh)	Total Savings (dollars, thousands)	Unit Savings (mills/ kWh)
1974	76,558	797	10.4	1,727	22.6	930	12.2
1975	70,185	837	11.9	1,793	25.5	956	13.6
1976	68,178	966	14.2	1,719	25.2	753	11.0
1977	65,849	1,010	15.3	1,884	28.6	874	13.3
1978	67,045	1,069	15.9	1,996	29.8	927	13.9
Total 1974-1978	347,815	4,680	13.5	9,119	26.2	4,439	12.7
Annual Average	69,513	936	13.5	1,824	26.2	888	12.7

Table 4.11. Rate of Return of Onsite Generation
on Undepreciated Value of Capital

Year	<u>Undepreciated Value of Capital</u>	<u>Savings due to On-Site Electric Generation</u>	<u>Constant Dollar Rate of Return</u>
	(thousands of 1951 dollars)	(thousands of 1951 dollars)	(per cent)
1974	421	469	109
1975	360	431	120
1976	299	322	108
1977	238	353	148
1978	177	349	197

1. The cost estimates (in 1980 dollars) of onsite electrical generation equipment (referred to earlier), were deflated to 1972 by applying deflators obtained from the U.S. Department of Commerce.*
2. An annual rate of depreciation of 3-1/3% (equipment life of 30 years) was assigned to the equipment.
3. A rate of interest of 7.5% was assigned to the cost of borrowing the capital required for the construction of the facility. The rate of interest is based upon an examination of the rates of interest that Cyanamid pays for the retirement of their long-term debt (obtained from Moody's Industrial Manual).

Capital costs were then added to the fuel, operating, and maintenance costs to yield the cost of onsite electric generation for a new facility. The results are presented in Table 4.12.

An analysis of the capital costs shows that:

- If the plant had installed new electrical generating equipment in 1974, electricity would have cost an average of 15.9 mills/kWh for the five years -- a cost that is 18% higher than the current cost of 13.5 mills/kWh (see Tables 4.3 and 4.12).
- Capital costs for a new facility average about \$241,000 each year. On the other hand, capital costs for the current facility average about \$73,000 per year (see Tables 4.6 and 4.12).

A comparison of the costs for onsite electric generation with the costs of the purchased power alternative shows that:

- Under the alternative, the plant would have to pay an average of 10.3 mills/kWh more each year for electricity. Between 1974 and 1978, it would have generated electricity onsite at a new facility at an average annual loss of 15.9 mills/kWh. If it had purchased the electricity from PSE&G, it would have had to pay an average of 26.2 mills/kWh, a cost that is 65% higher (see Table 4.13).
- The constant dollar rate of return of onsite electric generation ranged from 21-29% between 1974 and 1978 (Table 4.14). The rate of return, while still positive, is not as high as the rate of return (109-197%) on the current capital investment at Cyanamid because of the relatively recent acquisition of the equipment.

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*U.S. Department of Commerce, Industry and Trade Administration, Construction Review, Table E-1 - Construction Cost Indexes, column entitled "Electric Light and Power," (May 1979).

Table 4.12 Onsite Electrical Generation Total Costs (Capital Costs are for a new, 1974, facility)

Year	<u>On-Site Generation</u>	<u>On-Site Electrical Generation - Costs</u>				<u>Costs per unit of Electricity Generated</u>
	(kWh, thousands)	Fuel (dollars, thousands)	Operation and Maintenance (dollars, thousands)	Capital (dollars, thousands)	Total (dollars, thousands)	(mills/kWh)
1974	76,558	496	223	253	972	12.7
1975	70,185	518	243	247	1,008	14.4
1976	68,178	638	257	241	1,134	16.6
1977	65,849	668	271	235	1,174	17.8
1978	67,045	710	291	229	1,230	18.3
Totals 1974-1978	347,815	3,020	1,236	1,205	5,518	15.9
Annual Average	69,513	606	257	241	1,104	15.9

Table 4.13 Cost Comparison (New Facility)^a
Cyanamid Onsite Generation vs
PSE&G Purchased Power Alternative

Year	<u>Electricity Produced</u>	<u>On-Site Generation Cost</u>		<u>Purchased Power Alternative Cost</u>		<u>Cogeneration Savings</u>	
	(kWh, thousands)	Total Cost (dollars, thousands)	Unit Cost (mills/kWh)	Total Cost (dollars, thousands)	Unit Cost (mills/kWh)	Total Cost (dollars, thousands)	Unit Cost (mills/kWh)
1974	76,558	972	12.7	1,727	22.6	755	9.9
1975	70,185	1,008	14.4	1,793	25.5	785	11.1
1976	68,178	1,134	16.6	1,719	25.2	585	8.6
1977	65,849	1,174	17.8	1,884	28.6	710	10.8
1978	67,045	1,230	18.3	1,996	29.8	766	11.5
Total 1974-1978	347,815	5,518	15.9	9,119	26.2	3,601	10.3
Annual Average	69,513	1,104	15.9	1,824	26.2	720	10.3

^a Capital costs are for a hypothetical facility comparable to Cyanamid's with a centroid of construction in 1972 and whose first year of operation is 1974.

Table 4.14 Rate of Return of Onsite Generation
on Undepreciated Value of Capital
(New Facility)

Year	<u>Undepreciated Value of Capital</u>	<u>Savings due to On-Site Electric Generation</u>	<u>Constant Dollar Rate of Return</u>
	(thousands of 1972 dollars)	(thousands of 1972 dollars)	(per cent)
1974	2,234	651	29
1975	2,154	618	29
1976	2,074	437	21
1977	1,994	500	25
1978	1,914	502	26

From the above analysis it is evident that three cost factors -- fuel, capital, and purchased electricity -- must be taken into account when the economics of onsite electrical generation are considered. All three can be expected to rise in the future but the manner in which they rise relative to each other will determine the relative economics of onsite generation.