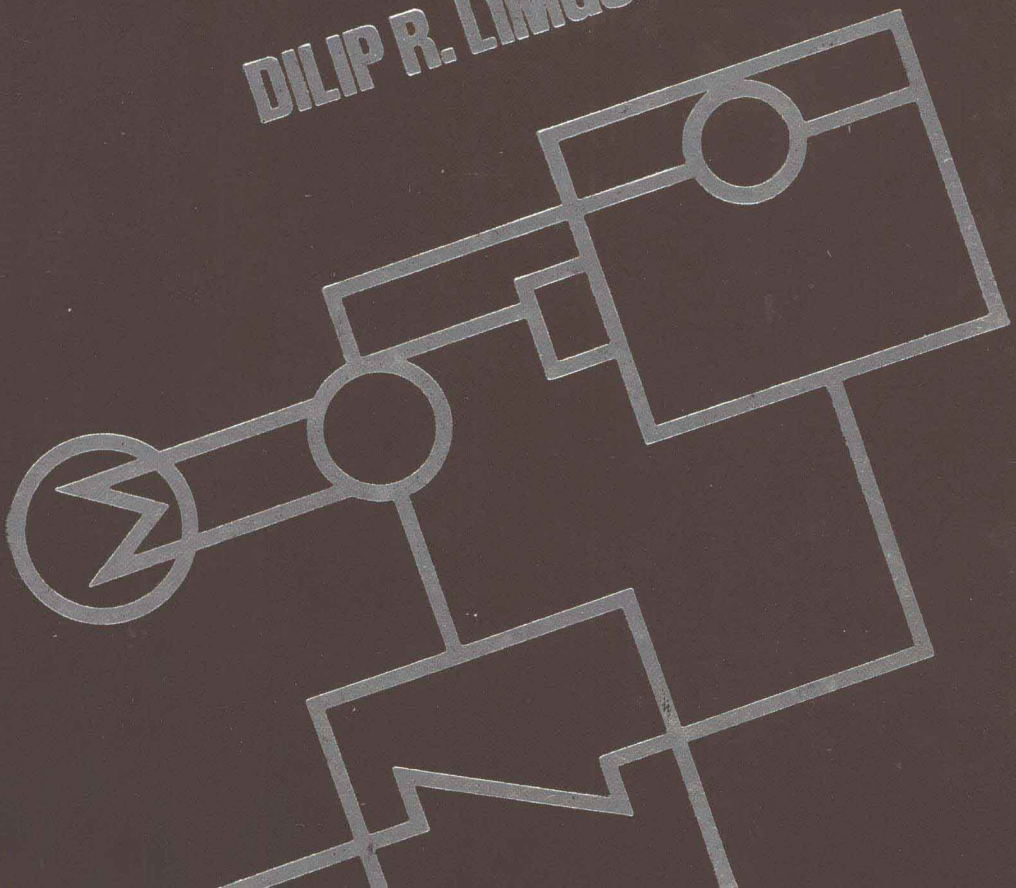
PLANNING COGENERATION SYSTEMS

DILIP R. LIMAYE



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Foreword

Cogeneration represents a classic case of how changing economic conditions can give an old technology new life. It has been practiced since before the turn of the century, but had declined steadily in importance for decades. The dramatic events of the 1970s placed energy efficiency in a new light and have led to a great resurgence of interest in the last few years. Cogeneration will continue to increase in importance in the coming years because it makes good economic sense and it helps to meet important national energy conservation goals.

An early example of cogeneration was at the Dow Chemical Company's Midland, Michigan plant. Herbert H. Dow founded the company in 1897 to extract bromine and chlorine from brine using a new electrolysis process. Initially he generated his own power with wood-fueled steam engines without recovering the waste heat from the engines because there was little need for steam in the original plant. Then in 1910 he developed a new chlorine process which required the concentration of brine in massive vacuum evaporators.

At the time Dow's powerhouse engines exhausted steam at 150°F after generating power. Since the new process required great quantities of heat, Dow routed the wasted steam to the brine evaporators, allowing him to save fuel and to avoid the cost of installing a separate boiler. Cogeneration, as this practice has come to be known, has been utilized continuously by Dow Chemical since that time. Today the company is probably the world's largest cogenerator.

Around the turn of the century most industrial electricity users, like Dow Chemical, generated their own power. At the time electric

utility service was unreliable, expensive, and not widely available, so on-site generation was usually a better alternative. In the early 1900s over half of all the electricity used in the United States was self-generated, much of this from cogeneration systems.

However, the relative importance of power generation by industry declined steadily through the late 1970s. The primary reason was the improvement in service by electric utilities. As electric generation technology advanced, larger and more efficient power plants were built, which lowered the cost of power. As the electric utility industry grew, more and more industrial plants were served by utilities. In the 1920s and 1930s electricity generation became a regulated business, and on-site generators could be regulated as a utility if they sold any excess power. These many factors combined to cause cogeneration to decline greatly in significance, reaching a nadir of only 3% of the total electrical power generated in the U.S. around 1980.

In the last few years, though, there has been an enormous resurgence of interest in cogeneration. The most important factor in this development has been the huge escalation of energy prices over the last decade. The oil shocks of 1973 and 1979 caused fuel prices to skyrocket. Likewise, electric rates escalated greatly due to technological limits on the maximum size of power plants, environmental regulations, nuclear problems, and higher fuel prices.

Cogeneration has always been able to save fuel, but as long as energy prices were cheap, spending capital to save energy could not be economically justified. With today's high prices, cogeneration can represent one of the best investments that an energy user can make. Future price trends, as electric rates continue to rise and finite resources of fossil fuels are depleted, will make cogeneration increasingly attractive.

The passage of the Public Utilities Regulatory Policy Act in 1978 and the favorable decision by the Supreme Court in 1983 also played a critical role in cogeneration's renewal. PURPA removed most of the institutional obstacles to cogeneration, which had previously caused many potential cogenerators to disregard it despite excellent economics. Cogenerators can now count on fair treatment by the local electric utility with regard to interconnection, back-up power supplies, and the sale of excess power.

In addition, cogenerators no longer fear being regulated as an electric utility. With PURPA it is now possible for energy users to install the most efficient cogeneration systems, especially those with high electric outputs, allowing the full potential of cogeneration to be realized on a national scale.

There have also been a number of other significant incentives to cogeneration. Improved technologies have been developed, which are more efficient or are lower in capital cost. The gas turbine combined cycle cogeneration system, first installed in the late 1960s, is now being widely implemented, whereas in the past most had been steam turbine systems.

Other parties have created incentives for cogeneration. The Federal and state governments have encouraged cogeneration to help meet energy conservation goals and to contain future electric rate increases. Many electric utilities want more cogeneration in their service territories in order to avoid spending scarce capital on expensive new power plants and to provide needed generating capacity.

Cogeneration is highly capital intensive, so its proliferation depends to some extent on the development of techniques for project financing. Cogeneration lends itself well to project financing: it generates large revenues or cost savings; substantial tax benefits are realized from accelerated depreciation and investment tax credit; the nature of the assets allows a high degree of debt financing; and there is little technological risk. Because of these characteristics, cogeneration has caught the fancy of the financial community in the last year or two, and many firms are actively seeking cogeneration projects to finance.

Yet another spur has been the development of a cogeneration industry, in which third-party project developers finance cogeneration systems and sell power and heat over the fence to large energy users. In effect, these firms serve as nonregulated utilities to the energy user, and, since they are taking advantage of the high efficiency of cogeneration, they can sell energy at a discount below the cost of alternative sources of supply.

This development will greatly increase the number of potential applications for cogeneration, making available the cost savings to energy users who lack capital or who do not want to be in the power business themselves.

The future of cogeneration is indeed very bright. The further development of industrial cogeneration capacity is well documented and will occur rapidly in the next few years. One study has estimated the market for cogeneration equipment and services at $60 billion by the year 2000. Another survey predicts a doubling of industrial cogeneration capacity by 1993.

Many new cogeneration technologies are in the developmental stage and will be commercialized in the 1980s and 1990s. Gas turbines with higher firing temperatures will increase the potential fuel savings and further improve the economics of these cogeneration systems. Fuel cells allow electricity to be generated without the theoretical limitations of thermal cycles, and the waste heat can be put to use to create highly efficient cogeneration systems on a very small scale.

Phosphoric acid fuel cells will be commercially available at competitive costs in the late 1980s, and molten carbonate and solid oxide fuel cells are likely to be available in the 1990s. Coal gasification, while not a cogeneration technology per se, will allow the most efficient cogeneration systems to burn coal-derived fuel rather than being limited to oil or natural gas, eliminating the most significant drawback of gas turbine and diesel cogeneration systems. These new technologies, combined with projected energy price trends, will further enhance the importance of cogeneration.

Most cogeneration today is practiced in large-scale, industrial plants. The recent development of low cost, prepackaged cogeneration systems in small sizes is opening up the market for relatively small energy users, with total energy bills as low as $250,000 per year. These prepackaged units can be produced cheaply since they will be manufactured in large quantities, and the economies of mass production will compensate for the loss of economies of scale resulting from the small size. They can be installed quickly, require little engineering, and are easy to service.

By reducing the size at which cogeneration becomes economic, these prepackaged systems will exponentially expand the number of potential sites for cogeneration. Prospective cogenerators will include anyone with a substantial demand for both power and heat, such as: hospitals, colleges, shopping centers, multi-family residential build-

ings, and small industry. It has been estimated that 10,000 MW or more of small cogeneration capacity will be installed in the next decade. In response to this demand, there will develop a small cogeneration industry, which will own and operate small cogeneration systems and will sell power and heat to these energy users.

The economic attractiveness of cogeneration is most dependent on the price of electricity, so it will first be widely implemented in regions with high rates, such as California and the Northeast. Other areas which are served by a utility with nuclear problems will also develop cogeneration capacity rapidly. As electric rates continue to escalate along with other energy prices, cogeneration will spread across the entire U.S. Eventually there will be few new central station power plants built, and most new electric generating capacity will consist of cogeneration systems.

The time has come when it is no longer economical for large users of electricity and heat to use power generated by conventional condensing plants. To survive in today's fast-moving world, all major energy users will eventually be forced to cogenerate to stay competitive.

Gerald L. Decker, *President*
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Winter Park, Florida
March, 1984

Gerald L. Decker was one of the principal investigators of the Energy Industrial Center Study, sponsored by the National Science Foundation. This study was the first significant analysis of the new role of cogeneration as the nation's energy future, following the Arab oil embargo.

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Chapter 1

Cogeneration in the 1980s

Dilip R. Limaye

According to the General Accounting Office, U.S. industry and electric utilities use nearly half the primary energy consumed, and the waste heat from power generation and process energy use amounts to over seven million barrels per day oil equivalent.[1] Cogeneration can offer a method to reduce the amount of waste heat by simultaneously producing electricity and useful thermal energy from a common primary energy source. Because of its potential for efficient use of energy, cogeneration is receiving increasing attention in the U.S.

The concept of cogeneration is not new. Industrial generation of electricity has been practiced for a long time. In the early 1900s, most industrial plants generated their own electricity and approximately half of this was using cogeneration.[2] On-site generation/cogeneration was more reliable and less expensive than utility generated power. However, in the 1920s and 1930s, the regulation of electric utilities, first by state agencies and then by the Federal government, resulted in elimination of unproductive competition, and consolidation and extension of utility service areas. Coupled with the availability of inexpensive fuels for power generation and technological advances in central station utility generation and transmission of electricity, industrial generation/cogeneration became economically less attractive. From the 1920s to the mid-1970s, there was a generally declining trend in the proportion of electricity cogenerated in

industry.[3] Other factors contributing to this declining trend included the following:

- Industry was hesitant to invest in generation because of the possibility of Federal and state regulation as a utility, and the related reporting requirements.
- Utilities offered very low prices for excess power sold by an industry to a utility.
- Utilities charged high prices for standby or supplemental power needed by the cogenerator.

As a result, industrial generation declined from 18% of total electric generation in 1941 to about 4% in 1977.[4]

The Changing Energy Situation

In the last decade, the energy situation in the United States has undergone a significant transition. The nation has faced increasing prices and decreasing availability of conventional energy sources, energy supply disruptions, environmental constraints to the utilization of coal, and high capital costs for expanding the energy delivery system. Efficient utilization of our energy resources has become a very high priority and cogeneration has become economically attractive. At the same time, Federal legislation has attempted to remove some of the institutional barriers to cogeneration and small scale power production. Moreover, the problems faced by electric utilities have resulted in increased interest on their part in industrial cogeneration.

The electric utility industry is beset with financial problems of unprecedented magnitude. New generating plants committed in the 1968–1974 time frame, when demands were forecast to grow at an annual rate of 7–10 percent, have been mostly deferred or cancelled. The basic problems faced by the utilities include:

- High costs of new capacity
- High interest rates
- Escalating fuel costs
- Environmental/siting constraints

- Increased customer resistance to rate increases
- Regulatory lag.

These problems, coupled with slower load growth, have led to lower revenues than forecast, while the capital requirements for new capacity have continued to escalate rapidly. Utilities have therefore been forced to borrow large amounts of money at very high interest rates. Utility earnings have been depressed, and it is becoming difficult to offer new stock (except at prices below book value) *and* to cover the interest costs of new borrowing.

Power Generation in the 1980s

Many utilities, looking ahead to the late 1980s, see their best prospects in (a) completing plants now almost completed, and (b) to some extent discouraging increases in load growth with the expectation that a two percent annual growth rate will be manageable, allowing time for their economic situation to stabilize before having to undertake another new plant. As part of this basic approach, all utilities would find it advantageous to flatten their system load curve, and to reduce or eliminate use of expensive peaking generation requiring use of high cost fuels in relatively inefficient power plants. Cogeneration could contribute significantly in this approach. In addition, utilities may be able to raise capital through innovative financing schemes such as joint ventures or third-party arrangements to build new capacity for cogeneration.

Until recently, few utilities actively encouraged or participated in cogeneration. In a recent survey of utilities, conducted by EPRI as a part of case studies of industrial cogeneration,[5] utilities expressed concerns regarding the potential loss of baseload, reliability and maintenance of cogeneration equipment, interconnection costs, the availability of cogenerated power when needed by the utility, and the need for standby capacity.

The significant changes in the economic and institutional aspects of power generation, which occurred in the 1970s and are expected to continue in the 1980s, have created a trend towards increased interest in and acceptance of industrial cogeneration by utilities. These changes have led utilities to consider industrial cogeneration in their

planning for future capacity needs, and have also resulted in the growing recognition of cogeneration systems as a utility business opportunity. Cogeneration ventures, owned and operated by a utility, can be highly complementary to traditional utility operations, and possibly offer a potential for higher profits than the traditional utility business. Utilities are therefore increasingly interested in examining opportunities for participation in industrial cogeneration projects.[6]

It appears that the changing economic and institutional environment will lead electric utilities in the 1980s towards a gradual redefinition of their traditional role. In the future, utilities are likely to be seen as "energy service companies" rather than merely as suppliers of electricity. In this new role, utilities may embark upon a number of new types of business ventures, some of which have already been undertaken by utilities in the past several years. Thus, utilities may actively encourage cogeneration and may even participate in such projects.

Cogeneration—Old Game, New Rules

A number of significant changes have occurred in the last few years relative to the institutional and regulatory aspects of cogeneration. The National Energy Act (NEA) of 1978 contains a number of important provisions which attempt to remove institutional barriers to cogeneration. The most important provisions are in the Public Utility Regulatory Policies Act (PURPA), which provides the following for facilities that "qualify" by meeting certain operating and efficiency requirements.[7]

- Utilities must purchase any and all power that the qualifying facility (QF) wants to sell.
- The rate offered by the utility for such power purchase should be based on the "avoided cost" of the utility.
- The rates charged by a utility to a QF for standby/backup power must be nondiscriminatory.
- The QF is exempted from utility regulation under the Federal Power Act, the Public Utility Holding Company Act and state regulations related to rates and financial reporting.

A qualifying facility must not be more than 50% owned by an electric utility.

Federal Court cases in Mississippi (which ruled PURPA unconstitutional) and in the D.C. Court of Appeals (which asked FERC to reconsider the 100% avoided cost rule and the requirement for utilities to interconnect with a QF) had created some uncertainties in PURPA implementation. However, both of these rulings were appealed to the U.S. Supreme Court, which upheld the PURPA legislation and the FERC implementation rules. After the Supreme Court decision, most states have completed the implementation of PURPA rules.[8]

In addition to PURPA, three other parts of the 1978 NEA also provide incentives for cogeneration. The Powerplant and Industrial Fuel Use Act (FUA) allows cogenerators to be exempted from prohibitions on the use of oil and natural gas. The Natural Gas Policy Act (NGPA) provides an exemption from incremental pricing of natural gas to cogenerators. The Energy Tax Act (ETA) provides a 10% investment tax credit for certain property which may be used with cogeneration systems. Also, additional incentives were provided in subsequent legislation passed by the 96th Congress.[9]

Implementing Cogeneration Projects

The state regulatory environment relative to PURPA implementation has led to cooperative efforts among industry, utilities and third party investors for financing and implementing cogeneration projects.[10]

The reasons for considering such cooperative efforts are:

- Cogeneration is likely to be more capital intensive than a conventional energy system, and industry may have other uses for capital which are more attractive.
- Industry is hesitant to make major cogeneration investments because of perceived uncertainties relative to PURPA.
- Industry may not have the skilled staff needed to operate and maintain a power generation facility.
- Industry may not consider power generation a natural extension of its primary business, even when such generation is economically attractive.