ENERGY LABORATORY

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MANAGEMENT DECISIONS FOR COGENERATION: A SURVEY ANALYSIS

by

Robert R. Radcliffe
Dr. Richard D. Tabors

MIT Energy Laboratory Report No. MIT-EL 82-030
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ABSTRACT

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This study explores the underlying factors in the decision by private, private non-profit, and public sector facility owners to invest in cogeneration technology. It employs alpha factor analysis techniques to develop factors with maximum generalizability to the universe of variables which potentially explain the decision to invest. Data for this study come from a survey of commercial, industrial, and institutional electric energy consumers who used more than 750 KW demand in any one month of 1981 for a selected electric utility in the Boston area. There were 129 usable responses to the survey(32.2 percent).

Cogeneration is the sequential production of thermal energy and electricity at one facility. A technology advocated for its high thermodynamic efficiency compared to separate production of steam and electricity, cogeneration represents an opportunity for a facility owner to substitute capital expenditure today for future operating expenditures. For the past six years, projections of increased cogeneration of electricity and steam consistantly occurred in the literature. In reality, output of steam and electricity from cogeneration plants has declined over the past decade. In the face of contradictions between thermodynamic based projections of cogeneration potential and the reality of declining actual use, most reports offer anecdotal references to market imperfections and non-economic decision variables to justify the contradiction.

This study confirms that a number of factors other than purely economic considerations may prevent use of cogeneration technology at the present time. These factors include:

- Uncertainty caused by regulatory action
- Desire for energy self sufficiency by the organization
- Financial flexiibility
- Experience with electricity cogeneration or self generation
- Capital budget planning methods

Second, this study provides a ranking of the factors involved in the cogeneration decision explaining most variance to least variance. However, the ranking of factors provides no measure of the "importance" of these factors in the decision to adopt or not adopt cogeneration technology.

Finally, the results of this study can be used to provide a rough estimate of capacity (KW) and energy (KWH) available from potential cogenerators. This study projects a maximum potential of 106 MW and 559,000 MWH of cogenerated electrical energy in the utility service territory between 1982 and 2002.

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CHAPTER 1

COGENERATION DECISIONS

INTRODUCTION

1.1 DEFINITION OF THE PROBLEM

During the late 1970's the National Energy Act provided in Title II an incentive for energy conservation. Energy conservation is defined in most documents as an increased efficiency in energy use. One technology which fulfills the objective of increased efficiency in energy use is cogeneration of thermal energy and electricity. Cogeneration is defined as the sequential production of thermal energy--either steam, hot water, or hot combustion air--and electricity. Technologies which can be classified as cogeneration include topping cycle systems, bottoming cycle systems, and heat recovery systems, terms which are explained in greater detail in Section II. (GAO, 1975)

Since 1976, a number of federally funded research projects evaluated the cost effectiveness and nationwide energy potential of cogeneration. Salient studies include ThermoElectron (1976), Research and Planning Associates (1977, 1981), Dow Chemical (1975) and the MIT Energy Laboratory (1977, 1982). Privately funded studies also argue strongly, if not persuasively, for cogeneration. Calling cogeneration "industry's North Slope", Stobaugh and Yergin (1981, p. 159) state:

> It appears that the return on investment for many industrial firms (and for other establishments such as hospitals and shopping centers) is quite good. Furthermore, cogeneration gives companies an important hedge against almost inevitable increase in energy prices and against brownouts and other interruptions in supplies whether caused by oil producers, coal strikes, or bad weather.

While these studies projected increases for cogeneration in the U.S., the paradox of the last six years has been that reported electricity and steam cogeneration in U.S. industry has actually declined.(Pickel, 1982)

Joskow (1981, p. 4) notes that "recent discussion of cogeneration opportunities has not been entirely satisfactory for a number of reasons. Considerations of energy efficiency and energy savings have often become hopelessly muddled with broader consideration of economic efficiency. Projections of industrial cogeneration opportunities are often based on inconsistant assumptions about technical opportunities and divergent assumptions about capital costs, fuel costs and electricity prices....The wide disparity in projections and enormous difference between what has occurred and is occuring in the marketplace and what some cogeneration advocates claim should be occuring has necessarily complicated public policy decisions by state and federal regulatory agencies as well as load forecasting and system planning efforts by electric utilities."

Pickel (1982, p. I-5) points out that cogenerated electricity started to decline after the events of 1973, but cogenerated steam supply declined continually over the last 15 years.

In addition to engineering and economic evaluations of cogeneration potential, there have been numerous references in the literature to non-economic variables in the decision process affecting choice of cogeneration systems. In most reports, these non economic variables are identified by anecdote and are not empirically measured. More importantly, there has been little empirical work to determine the strength of these non-economic factors in the decision process. Typically, the non-economic variables include risk adjustments, environmental controls, regulatory uncertainty, or institutional limits such as company policy. (RPA, 1976, p. ii)

1.2 MEASUREMENT GOALS

This study draws upon disciplines other than engineering economics to identify variables in the decision process for investment in cogeneration systems. Our hypothesis is that the nature of the investment decision process used by private, private non-profit, and public organizations limits the potential penetration of cogeneration technologies in the Northeast United States. This study tests the above hypothesis by conducting a study of individual energy consuming facilities in the target utility service territory.

This study seeks to answer the following questions:

1) Are non-economic variables important in the decision to use cogeneration technology?
2) If non-economic variables are important in the decision to use cogeneration, which variables are most important?
3) What can be inferred about the prospect of cogeneration technology penetration in this utility market area from the results of this study?

If non-economic issues restrict penetration of cogeneration technology in the energy market of an utility service territory, it should be possible to find organizations who have facilities with energy use characteristics conducive to cogeneration but policies which, to date, have restricted use of the technology.

1.3 RESEARCH DESIGN

The research design for this study is a two-step procedure involving a mailed questionnaire and a follow-up telephone call or personal visit. The population of respondents is all commercial and industrial customer accounts which achieved a monthly KW demand level of 750 KW in any one month of 1981 in a particular service territory.

We obtained a list of the population from Boston Edison Company, an electric utility servicing the Boston area. Each potential respondent's organization received a telephone call to identify the correct individual's name and address to assure the questionnaire went to the proper individual. In approximately 3 cases in 10, M.I.T. Energy Laboratory staff were able to talk directly to the individual who would complete the questionnaire and encourage that person to cooperate. In this initial stage four potential respondents refused to participate.

The questionnaire was mailed April 1 and a follow-up card was mailed to all non-respondents on April 15. Selective telephone calls on incomplete responses were made up to May 30. To pursue other issues raised in conversations with respondents, a telephone interview or site visit took place with a selected group of respondents.

1.4 SUMMARY AND CONCLUSION

This chapter introduced the technology of cogeneration, briefly looked at the problem of optimistic forecasts of cogeneration in the U.S. energy supply future, and identified the primary goal of this research study. This paper focuses on the issue of non economic factors in the decision to use cogeneration systems. To accomplish this analysis, this paper uses techniques borrowed from new product development marketing research to attempt to identify the number, strength and dimensions of factors affecting the decision to adopt cogeneration technology.

CHAPTER 2

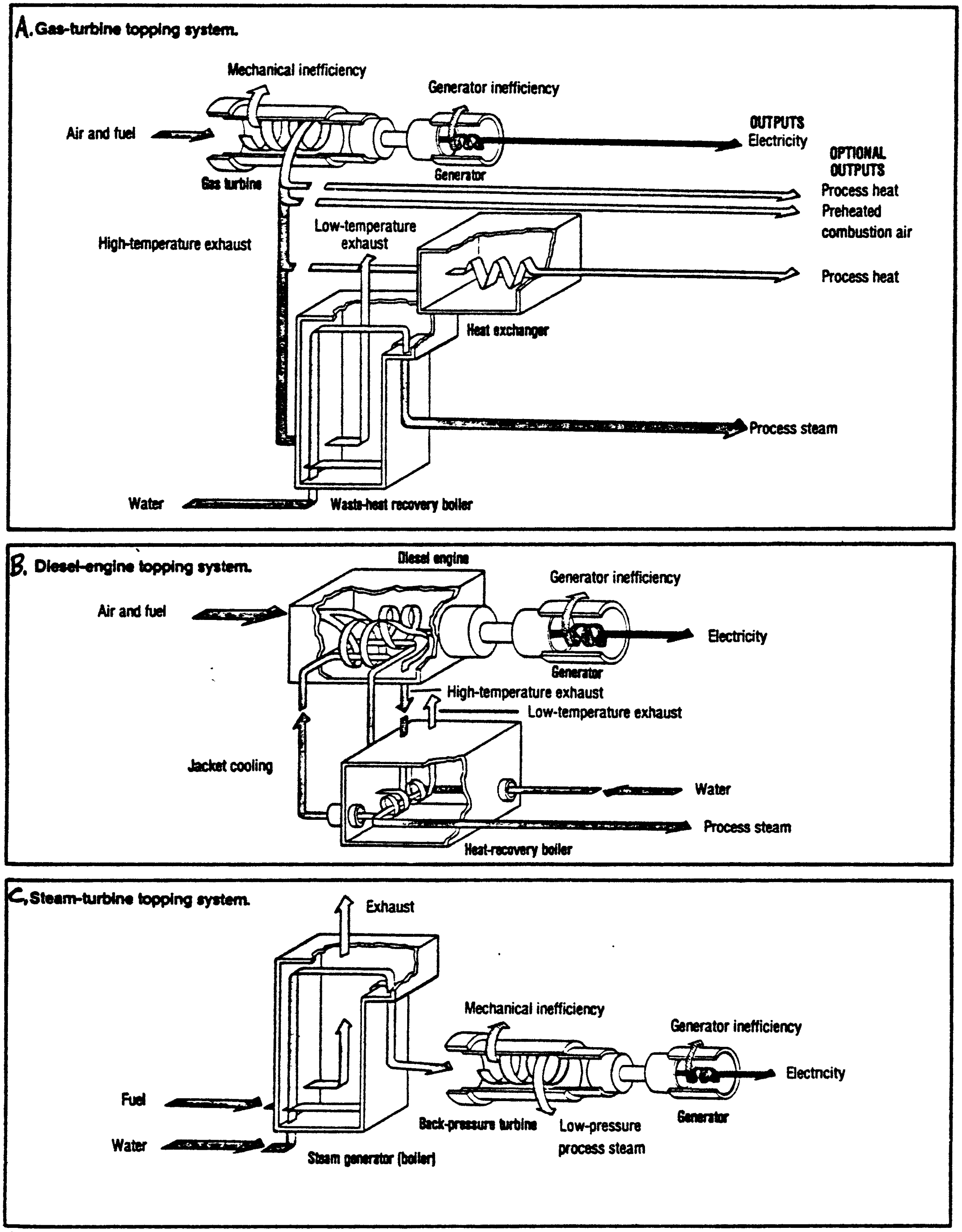
COGENERATION TECHNOLOGY

2.1 TECHNOLOGY DESCRIPTION

Cogeneration systems may be classified according to type of technology as either topping cycle or bottoming cycle. While it is not my objective to enter into a major discussion of cogeneration technology, a brief description of alternative technologies follows.

Topping cycle cogeneration is usually configured in one of three ways: steam turbine, gas turbine, and diesel. Steam turbine systems are prevalent in the United States as a matter of historical development. Fuel is burned in a boiler to produce steam. The steam turns a turbine to produce electricity by turning a generator (see Figure 2.1.C). Steam turbine systems produce relatively more thermal energy and less electricity than gas turbine systems. Gas turbine systems produce electricity first by spinning, with hot gases, a set of turbine blades. The turbine is directly connected to a generator which produces electricity. The hot gases are then used to heat a waste heat boiler to provide process steam. Gas turbines produce relatively higher proportions of electricity than thermal energy compared to steam turbine systems (see Figure 2.1A). Diesel systems operate very much like gas turbine units. The diesel engine is used to generate electricity while a waste heat recovery boiler uses the

Figure 2-1
DIAGRAM ILLUSTRATIONS OF
TOPPING CYCLE COGENERATION SYSTEMS



Source: Department of Energy-Resource Planning Associates, Inc. Cogeneration: Technical Concepts Trends Prospects, Sept. 1978 heat drawn off by a jacket cooling system to generate steam for process energy use (see Figure 2.1B) (GAO, 1976, p. 2).

The primary benefit of cogeneration systems in any configuration is the increased efficiency of energy consumed at the industrial plant location. Typically a cogeneration system will generate a kilowatt hour of electricity at an incremental heat rate (amount of added heat to produce a KWH) much lower than that of an electric utility (1000/Btu/KWH). Table 2.1 below gives typical incremental heat rates for topping cycle systems.

Table 2.1

TOPPING CYCLE COGENERATION SYSTEM

	Power/steam ratio $KWH/10^6$ Btu	Incremental heat rate Btu/KWH
Steam (Backpressure)	30-70	4500-6000
Gas Turbine	125-220	5500-6500
Combined Cycle (backpressure)	200-320	5000-6000
Diesel	400-500	650-6700

Source: Industrial Cogeneration - What It Is, How It Works, Its Potential. U.S. Comptroller General, General Accounting Office, 1976, p. 91.

2.1.2 Operation Protocols

The second element of determining if cogeneration is cost effective is the organization policy toward operation of a cogeneration plant. Belding (1982, pp. 3-5) identifies three protocols or methods of operation to be used by a cogeneration facility. These three protocols are:

1) Design a system capable of meeting plant peak load requirements which is connected to the utility grid and sells excess electricity (to the electric utility).

2) Size equipment to meet normal base load electrical requirements and purchase supplemental electricity from the utility. Supplemental thermal energy and some redundant standby equipment may be required.

3) Design a system independent of the utility grid.

Pickel (1982) and Joskow and Jones (1981) in separate works point to slightly different protocols for operation of cogeneration equipment. Pickel identifies four options for operation of a cogeneration plant:

1) Operates always
Cogeneration follows the facilities thermal load requirements

2) Never operates
All steam loads are met by a backup boiler.

3) Operates on-peak
Cogeneration system follows the site steam loads up to the system capacity during the electric utility peak electricity price periods. In off peak electic price periods the cogeneration system does not operate.

4) Operates on a time of oil basis
Cogeneration occurs following the sites steam load requirements, up to the system capacity, when oil is the utility company marginal cost fuel.

In all four operating modes Pickel assumes the cogeneration plant is sized to meet thermal requirements. Joskow and Jones (1981) focus most of their economic evaluation on thermal load following industrial systems but do look at the alternative protocol of electric load following. The conclusion they draw is that thermal load following is the most likely condition for optimal economic benefit to the cogenerator.

Thermal load following represents the most common method of sizing cogeneration equipment. In this method one chooses the type and size of a cogeneration unit to meet the requirements for thermal energy at a facility. Thermal energy includes both industrial process energy and energy consumed for space heating and cooling. Industrial process energy is thermal energy (usually steam) consumed directly in production processes for goods.

Electrical load following is a different objective which a potential cogenerator might choose to optimize. Usually, a cogenerator is an organization involved in manufacturing processes which uses more thermal energy than electrical energy. Consequently, thermal load following makes sense for manufacturing firms. However, with the trend toward a service-based economy reducing the number of manufacturing firms in New England and with significant increases in the number of educational and medical institutions, the relative amounts of steam and electrical energy consumed in an "average" New England organization change. In service industries such as commercial properties, electricity use is a larger proportion of total energy use than in manufacturing industries. Commercial property owners, therefore, may select cogeneration equipment to meet electrical energy needs. There are two complications to this view of equipment sizing and selection for cogenerators. First, a characteristic argument in favor of electric load following by a cogenerator is electric load control. Since electricity charges by an electric utility typically include a fee per kilowatt (demand charge) and a fee per kilowatt hour (energy charge) it may be possible for a cogenerator to reduce the demand charge for electricity (KW) by reducing the cogenerator's own electricity demand through producing their own electricity on site. The value of this electricity demand reduction to the cogenerator is a function of when the electricity gets generated and the price structure of electricity purchased from the electric utility. For respondents to this study, the major incentive for peak shaving (Pickel, 1982), known as a ratchet charge, is not part of the electric utilities' price structure. With a ratchet charge, a consumer of electricity is obliged to pay a fee each month for a period of eleven months, equal to the fee for some specified percentage of the highest demand charge in a given month. If a consumer uses a maximum of 100 KW of electricity for one month, the fee per KW of electricity will be, for example, 80 % of 100 KW for each of the succeeding eleven months, whether or not the consumer uses any electricity. Under this type of pricing, peak shaving by any of a number of means is an economical choice as long as the method chosen is a reliable means of reducing peak demand (KW).

The second type of price structure which would provide peak shaving incentives is marginal cost pricing of electricity. Again, none of the respondents to this study is served by marginal cost pricing tariffs although experimental marginal cost based tariffs have been evaluated . The effect of a marginal cost pricing tariff is to provide an incentive for measures taken by consumers to reduce peak electrical energy use. One measure used by some electrical energy consumers to reduce purchased electricity expense is cogeneration of electricity and thermal energy. Since marginal cost pricing is not used in the service territory subject to this study, the argument that cogeneration is a cost-effective means of reducing peak energy use and therefore the cost of electricity to an organization remains untested here.

2.1.3 Cost/Size Tradeoffs in Cogeneration Technology

According to Joskow and Jones (1981, p. 33), "It is well known that boilers and turbine/generator sets are characterized by economies of scale; unit construction costs decline as the size of the system increases. Furthermore, scale economies are likely to extend to other capital and labor costs associated with boiler generating systems. Consideration of the economics of cogeneration systems lead to some comparative statics results. (Joskow and Jones, 1981, p. 44)

1) "The more important are scale economies the larger is the plant scale at which cogeneration will be economical."

2) "The higher electric prices, the lower is the plant minimum size at which cogeneration will be economical."

3) "The higher are costs of operating for a cogeneration facility, the larger is minimum plant scale at which cogeneration will be economic."

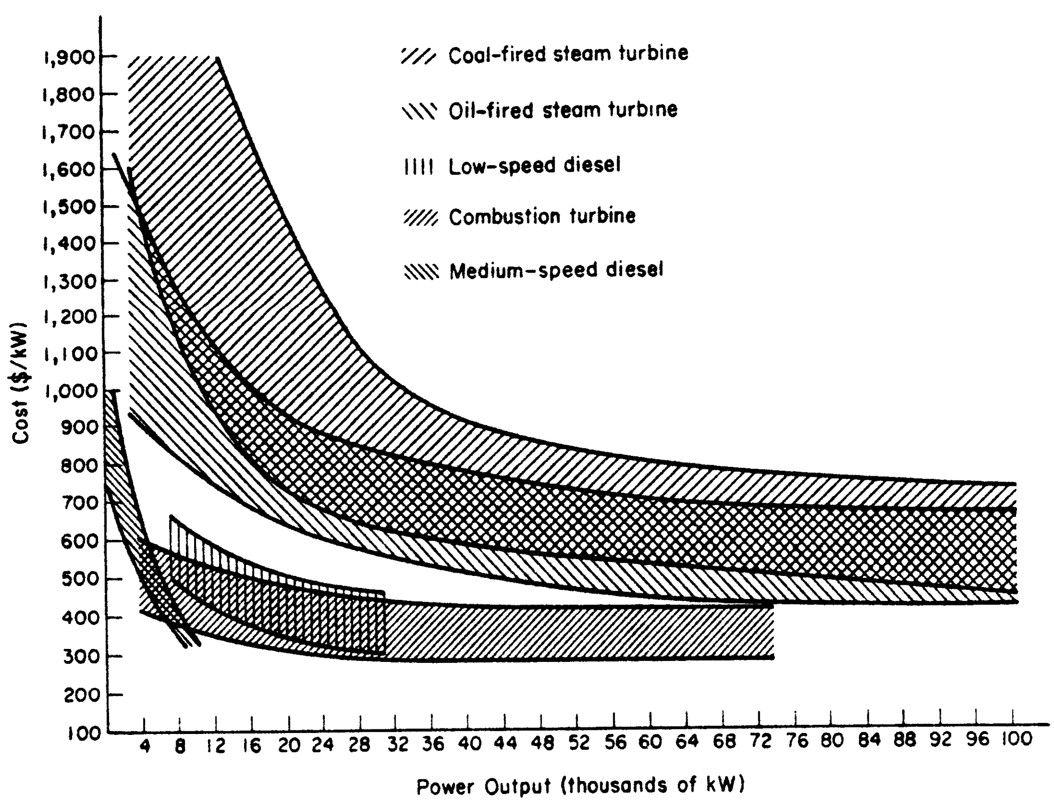
4) "The more uniform is steam load over the year, the lower will be the minimum scale at which cogeneration will be economic."

Belding (1982) developed a set of capital cost estimates for different cogeneration technologies for use in the M.I.T Industrial Energy Conservation Manual. Figure 2.2 below clearly shows the significant decline in cost as the size of the cogeneration plant increases.

Figure 2.2

ECONOMIES OF SCALE

COGENERATION PLANT CAPITAL COST



It is important to point out the extremely high capital costs involved if cogeneration occurs at low electric demand levels of 1 megawatt or less. One can infer from the graph that only medium or high speed diesel cogeneration systems may be used for very small applications. Pickel (1982, p. D-18) is a little more optimistic in his assessment of gross capital costs for units as small as 500 kW but Pickels' cost estimates for coal fired units resulted from extrapolating back a capital cost curve from larger sized coal fired facilities. For diesel and gas turbine technologies, small size systems of 1 MW and smaller are technically feasible but very capital intensive. For larger units, economies of scale indicate strongly that the cost per kW falls as system size increases.

2.2 FORECASTS OF COGENERATION POTENTIAL

Since 1975, the Federal government, state governments, a number of electric utilities, and a few private organizations studied the issue of cogeneration of electricity and steam. The strongest statement one can make about these studies is that they are diverse, and usually overstate the potential for cogeneration.

"Most studies look at cogeneration from the perspective of the firm." Pickel (1982, p. I-15) notes, "As studies are more specific geographically, they tend to be an enumeration of potential sites for cogeneration. Forecasts of cogeneration based on enumeration of sites commonly have lower estimates of cogeneration potential than studies estimated from energy use figures. Most studies limit themselves to restrictive assumptions about sizing of plant, fuel and electric prices and characteristic cogeneration plant types." Pickel cites these restrictive assumptions about plant size and operations as a main reason for the overestimation of cogeneration potential.

Of the national level forecasts of cogeneration commonly referred to in the literature, Joskow (1981, p. 26) notes the "estimated economic potential for cogeneration varies quite widely among the studies. Estimated energy saving associated with cogeneration vary by an order of magnitude. Estimates of additional electricity production and equivalent base-load generating capacity vary by more than an order of magnitude."

The conclusions of these five and other studies need to be stressed.

1) With the exception of Thermo Electro (1976), all studies either conclude or assume steam turbine cogeneration systems using coal are the most economical choice.

2) Diesel and gas turbine systems are not as economical as coal fired steam turbine systems.

3) Oil fired steam turbine systems are less economic than coal fired but more economic than diesel or gas turbines (at least in the Northeast). (Pickel, 1982)

2.3 NON-ECONOMIC ISSUES

Nearly all of the cogeneration studies raised questions about the effect of non-economic issues on the decision to invest in cogeneration. These non-economic issues are the focus of this research study. The amalgam of non-economic issues from the literature fall into nine different categories. A typology of these issues, and the reports from which the issues are derived, is listed in Figure 2.3.

The nine different classifications include:

1) Regulation - Utility

This classification is cited in at least a dozen studies as the prime disincentive for private organizations to cogenerate. The nature of electric utility regulation does, in fact, make any organization selling electricity subject to regulation in most states. In Massachusetts, for example, sale of any electricity outside of the organization makes the seller a utility under chapter 164 section 1, 2 and 3. (Massachusetts Statutes Annotated, 1978)

2) Regulation - Environmental

The same publications cite environmental control laws as a major detriment to cogeneration. The laws are voluminious and uncertain in application due to the imprecise nature of the regulations and due to their site specific application. (Demakos, 1980)

3) Utility Attitude

Sources of comments about utility attitude and cogeneration are found in eleven of the publications. Two of these appear frequently. First, utility advocacy is desired to enhance opportunities for cogeneration (Harkins, 1979). Second, utility participation is preferred, particularly by small industries and, by implication, small commercial and institutional users to allow the small firms access to qualified operations personnel without the expense of maintaining them as full time employees.

4) Line of Business

A few publications point to one corporate strategic decision which is a prerequisite for consideration of cogeneration. A company must want to be self sufficient in energy. Otherwise, "Industry management is reluctant to become involved in what is considered a highly regulated and capital intensive activity, electric generation. (Brown, 1979)

5) Uncertainty

A number of reports point to the lack of certainty about regulations, price of fuels in the future , and consistency of economic signals. (Stobaugh and Yergin, 1979) In speaking directly to the price issue Joskow notes: "Future price uncertainty (of electricity) makes future profits random variables. The more firms are risk-averse, the more they will shy away from diesel and gas turbine cogeneration in favor of steam turbine cogeneration or no cogeneration at all. (Joskow, 1981, p. 59)

6) Financial limits

Ten of the publications point to one or more elements of financial constraints upon the use of cogeneration systems. Most of the citations argue that cogeneration is alien to the industries normal line of business and therefore industry adds a discount premium to the cost of capital to account for this added risk. (Stobaugh and Yergin, 1979) Other reports focus on absolute limits to capital implicit in poor economic conditions (GAO, 1976). In either case, the implication of risk adjustment or capital limits is a higher cost to a firm wishing to cogenerate.

7) Market imperfections in pricing

Four publications specifically mention market imperfections in setting of electric utility rates as a major disincentive to cogeneration. Pickel points to "price disincentives" such as ratchet charges for KW demand used by a cogenerator as a prime problem. (Pickel, 1982, pp. II-49, II-50) Joskow and Jones (1981) argue that utility electric prices not equal to marginal cost cause equivalent problems.

8) Timing

Only two papers raised the important question of timing of cogeneration investment. In this case, the difference between the economic life of a cogeneration unit and the planning horizon of a company is listed as a significant problem preventing cogeneration. (Brown, 1979) Beyond the issue of lead time mentioned by Brown, there is an issue I would call a planning window. For cogeneration to be selected at all, it must meet all investment criteria of the organization and do so at a time when the decision to engage in physical plant expansion or retrofit is being made. (Bulpitt, personal communication) This planning window occurs within a short period of time and under somewhat constrained conditions. Intuitively, these conditions include:

a) Impending retirement of existing physical plant at the same time expansion of capacity is to occur. Cogeneration may be sized to handle both retired boiler and expansion.

b) Expansion of capacity - Cogeneration typically is sized to handle expanded capacity. (Barnett, 1981)

9) Power pool relations

Only one study mentioned relations within an electric power pooling agreement as a possible problem for cogenerators. In this case, the report recommended the utility companies in a power pool allow a cogenerator to sell power to any other utility in the pool as a way of providing the cogenerator with maximum bargaining power. (Massachusetts, 1978)

To summarize these non-economic issues into a few smaller groups of issues, there appears to be three sets of problems for a potential cogenerator to worry about. First, the organization has a large number of planning issues to confront. These include strategic questions (line of business), long range planning issues (capital limits, discount rates), and operations issues (load following protocols). Once the organization confronts its own objectives for energy, it must then reconcile those objectives with the utility company (utility attitude) and with government (environmental regulation).

2.4 CONCLUSIONS

The process of developing cogeneration for an organization obviously must be an iterative one, but the fundamental issues raised in this section have important implications for the penetration of cogeneration technology in the Northeast.

This section focused upon three cogeneration technologies commonly proposed for analysis in publications released over the past six years. These three technologies are steam turbine systems (usually topping cycle), gas turbine (topping cycle) and diesel (topping cycle).

Each of these systems may be sized to meet operation needs of the organization investing in cogeneration. Up to four operating protocols are generally considered. These protocols include:

1) Operate always
2) Never operate
3) Operate on-peak
4) Operate on time of oil

Clear evidence exists in the literature of economies of scale in cogeneration equipment. These economies of scale theoretically limit cogeneration technology to larger manufacturing firms although numerous references to commercial, institutional, or small manufacturing firms occur in the literature. While evaluations of equipment producers and consultants argue small sized cogeneration units (under 1 MW) are cost effective, the bulk of publications argue persuasively that coal fired steam turbine cogeneration systems are economically superior to either gas turbine or diesel.

National level forecasts of cogeneration penetration rates are characterized by substantial projected increases in cogeneration while the reality of cogeneration in the U.S. is that it faces a steady decline in use (Pickel, 1982). While the projections are inaccurate and in the wrong direction, (much too high), they are also characterized by a high degree of volatility in projections of both capacity and energy (Joskow, 1981).

In the face of contradictions between thermodynamic based projections of cogeneration potential and the reality of declining actual use, most reports offer anecdotal references to market imperfections and non economic decision variables to justify the contradiction. This chapter tentatively identifies nine types of non-economic or market imperfection variables which, literature asserts, limit penetration of cogeneration technologies. These types of non-economic variables include:

1) Regulation as a utility
2) Regulation of environmental impact
3) Utility attitude
4) Line of business
5) Uncertainty
6) Financial limits
7) Market imperfections in pricing
8) Timing
9) Power Pool relations

FIGURE 2.3

TYPOLOGY OF NON ECONOMIC ISSUES

ISSUE / REPORT	REGULATION		UTILITY ATTITUDE	LINE OF BUSINESS	UNCER-TAINTY	FINANCIAL LIMITS	MARKET PRICE IMPER-FECTIONS	TIMING	POWER POOL RELATIONS
	UTILITY	ENVIRON-MENTAL							
DOW (1975)	x						x		
Thermoelectron (1976)		x	x			x			
RPA (1977)	x	x	x			x	x		
EPRI (1978)	x	x	x	x			x		
Pickel (1978)									
Massachusetts Cogeneration (1978)	x	x	x						x
Brown (1979)	x	x	x		x			x	
Edelman (1979)	x	x	x	x		x	x		
Stobaugh (1979)	x	x	x	x	x	x			
GAO (1980)	x	x	x	x	x	x			
Pickel (1980)		x				x	x		
Planning and Management Assoc. (1980)		x							
RPA (1980)									
AIN (1981)	x				x				
Barnett (1981)		x							
Casten (1981)	x		x						
Joskow (1981)	x		x		x	x	x		
Joskow and Jones (1981)			x			x			
Schwartz (1981)			x						
Zimmer (1981)	x	x				x			
Belding (1982)	x	x	x						

CHAPTER 3

SURVEY INSTRUMENT

3.1 DEVELOPMENT

We selected a mailed survey method during the initial research design process of this study for several reasons.

1) The complexity of the relationship between organization policy and energy use for any individual facility required responses to a large number of questions, some of which are not quick response questions.
2) Organization complexity requires, in some cases, that more than one individual respond to different parts of the questionnaire.
3) Initial project design envisioned a survey research instrument potentially used in as many as 6 different utility service areas throughout the United States. The data reported in this research paper are limited to one utility service area.
4) The ability to follow up with questions about organization structure and essential data such as square footage and energy use required identification of respondents.

The questionnaire (Appendix A) consists of 3 clearly separate segments. Segment one is identification and screening information. Segment two is policy questions to evaluate various elements of strategic, long-range, or tactical planning. Segment three identifies physical plant characteristics and energy use for a specific facility.

The questionnaire contains four types of questions. Type 1 is identification information requiring respondents to classify the organization by function and ownership. Type 2 is screening questions to determine ownership of the facility. Type 3 questions ask the respondent to evaluate a series of policy questions related to cogeneration planning. These questions all utilize a 5-point agree-disagree scale. Question construction explores strategic, long-range planning, and tactical/operational planning issues. Type 4 questions are nominal scale variables such as energy type, physical plant type, type of calculation method used, and energy conservation activities accomplished.

3.1.1 A Note On Organization Structure, Facility Ownership, Energy Use and Research Design

Research design is a complex problem of trading off benefits of simplicity and salience against the loss of important information. This inquiry required specific and fairly accurate information on energy use, hours of operation, physical plant characteristics and discount rates. Further, this information had to be specific to a single physical location. Consequently, research design had to be modified from a theoretically optimum method such as that advocated by Dillman (1978) to accommodate problems of organization structure, facility ownership and energy use.

3.1.1.1 Organization Structure

Organization structure is a term we use to describe an organization's management hierarchy and the flow of decisions from policy to line management. (See Figure 3.1 below for a typical facility within a hierarchical management structure). Structure complicates this research design because decision making on capital budget issues such as cogeneration may occur in any one or combination of the levels of an organization heirarchy. This study's research design conflicts with this concept of capital budget decisionmaking by targeting the survey instrument to an individual physical plant operator or engineer. This study measures the respondent's perceptions of and attitudes toward organization policy.

As an example of a structural problem in the capital budget process, one respondent indicated that the City of Boston schools engage in all planning and evaluation of any investment with a greater than one year payback through the City of Boston Public Facilities Department. "The School Committee is forbidden by statute to undertake capital construction projects." Thus, the respondent for the facility could not engage in capital budgeting even if convinced cogeneration constituted a viable alternative. Recommendations for evaluation of cogeneration, however, could be made to the Public Facilities Department.

3.1.1.2 Facility Ownership and Energy Use

The effect of facility ownership issues and energy use characteristics upon the research design is substantial. Facility ownership options include a facility owned completely by respondent, joint ownership, and in some cases special provisions of long term lease arrangements. Facility occupancy may not convey the rights of ownership to engage in capital improvements. Thus, a facility may have energy characteristics which promise to be a cost effective location for cogeneration. The owner may be unwilling to act upon that potential, the leasor unable or unwilling to act and the potential for increased energy efficiency is, therefore, lost.

The question of facility ownership intertwines with the issue of who pays for the energy consumed in a facility. Commercial buildings may be owned by one organization, leased to a second organization, operated by a third, and occupied by one or more other organizations. While different lease and rental arrangements occur, characteristically the building operator of new commercal buildings is responsible for providing heat and air conditioning while the occupant is responsible for electrical energy use. Similarly, young firms, in rapid growth industries will tend to lease a building rather than purchase one outright because of the advantage of maintaining higher liquidity. In either case the lease or rental arrangement between facility owner, manager, and occupant complicates any decision to engage in physical plant changes.

Energy use within a facility is an added complication. Four issues are significant. These issues are: 1) energy type, 2) energy measurement, 3) physical characteristics of the energy conversion plant and 4) the legal arrangements to pay for energy.

For simplicity, we will discuss energy type and energy measurement together. First the research design is based on an accounting convention, the use of an electric utility user account number to define one member of a population. One electric utility account number may refer to a "facility" with no physical structure to house it (e.g., a transformer for a traction power station for a subway), part of one building (e.g., a large firm may rent 20 floors of an office building), one entire buidling, one building plus exterior lighting or a complex of several buildings.

Dr. Sharif Arab-Ismaili (1978) refers, in his development of a design for an energy management data base, to the relationship between physical structures and energy metering or measurement. Essentially, energy use within a facility is a function of physical plant growth over time. With growth and changing technology, physical plant changes allow use of different types of energy in different parts of a facility. What Dr. Arab-Ismaili pointed out so clearly, is that energy flow within a facility can overlap from building to building with multiple fuel types or multiple measurement of one fuel type (e.g., more than one electric account for a facility). Figure 3.1 graphically portrays these energy flows. The effect of these energy use and energy measurement problems on the study are difficult to

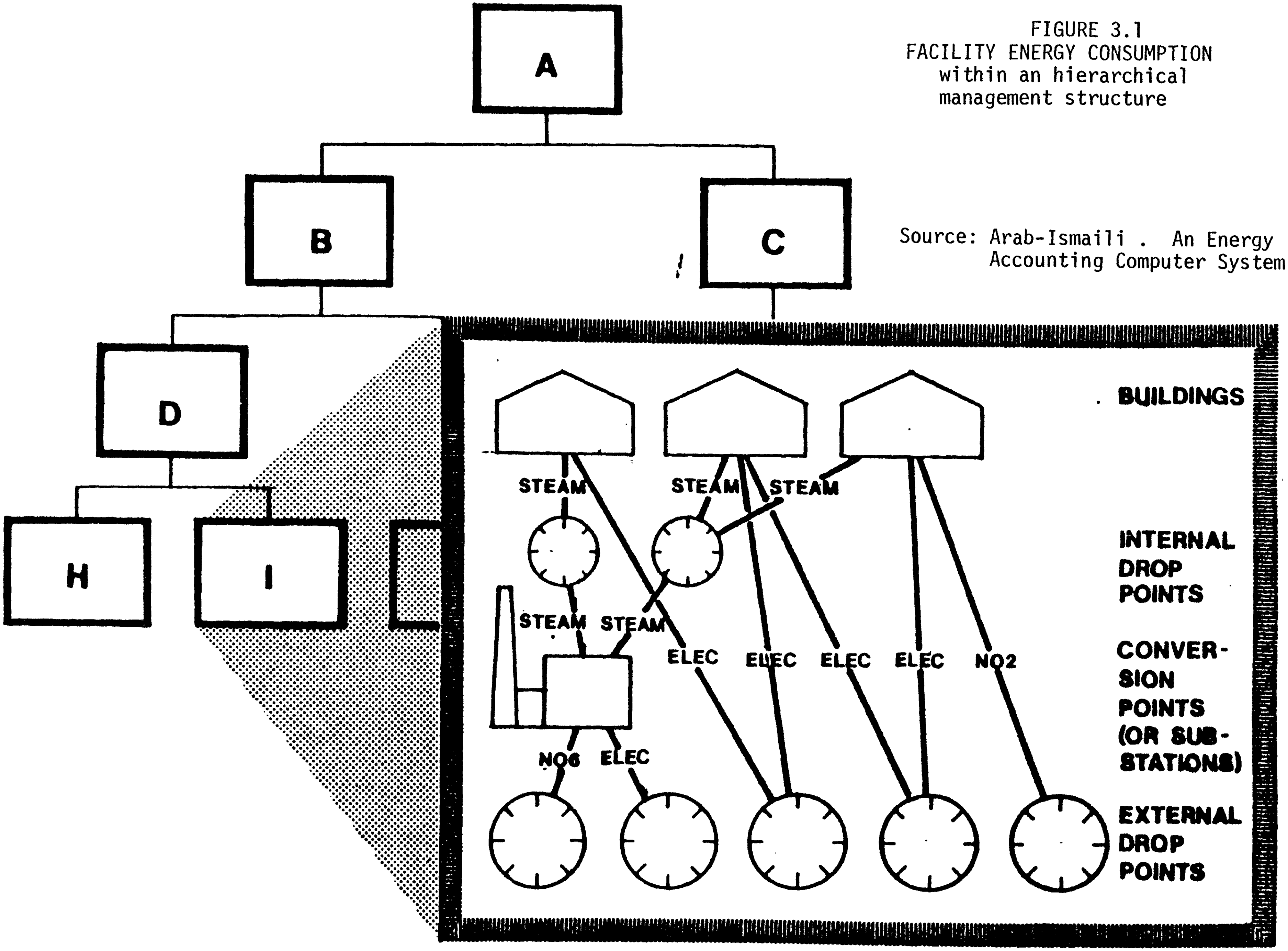


FIGURE 3.1
FACILITY ENERGY CONSUMPTION
within an hierarchical
management structure

Source: Arab-Ismaili . An Energy
Accounting Computer System

assess. The use of account numbers to define the population will overstate the number of independent facilities because of inclusion of multiple accounts for individual facilities. To reconcile this problem, this analysis attempts to differentiate between physical locations and account numbers by aggregating multiple responses for a single location into a single facility.

This decision to utilize a facility-specific analysis as the basic unit of analysis raised a number of problems. These included:

1) Determining the correct person within a facility to respond to a questionnaire.
2) Determining if the facility user, facility manager, and facility owner are all the same person.
3) Determining who, of the three decision makers in Part 2, is the prime decision maker.
4) Determining which accounts represented physically separate facilities owned by one organization.

Questions 1 through 3 were resolved by the process of telephoning organizations, explaining the nature of the research, and asking which person should be contacted. In many cases, this process required a number of telephone calls to a single organization to obtain the name of the "best" person to contact. The fourth question was more difficult to determine because the available description of the electric service account number was not always precise either in location or title of organization. To solve this problem, we engaged in a combination of inspection of account numbers, telephoning where necessary to obtain further information from an organization and cross checking these two methods with a screening question on the questionnaire.

3.1.2 Pretesting

The survey instrument went through five successive stages of revision. At each stage, members of the MIT Energy Laboratory staff, Sloan School of Management and Department of Economics, and liaison personnel from two sponsoring electric utility firms reviewed the questionnaire for content and clarity. Verbal comments from pretest individuals included:

1) Clarify definitions of cogeneration.
2) Restructure questions to better differentiate between planning and energy question groups.
3) Add questions about institutional control of capital budget decisions. The salient issue here is the determination of whether the respondent is the primary decision maker. Since I felt a respondent could be offended by a question to determine whether or not he or she is important within an organization's power structure, we did not modify the questionnaire to include questions about perceptions of control.

3.2 COGENERATION DECISION VARIABLES

There are five key types of interrelated information needed to evaluate the effect of decision variables on use of cogeneration. Within these five areas, this study developed a set of variables which measure attitudinal responses from individuals who manage a facility, descriptive variables which measure behavior and physical conditions, and variables which measure potential choice. These five types of questions cover identification variables, strategic planning, long range planning and operational planning issues, and physical plant characteristics. Within the area of long range planning, the research explores two important subsets of information. First, the study determines the method of calculating the worth of a cogeneration investment including the calculation methodologies and discount rates used. Second, it evaluates perceptions of factors which might increase risk to a firm and therefore increase cost. Within the areas of operation planning the study evaluates two important aspects of the problem. First, the method a company uses to engage in manager performance evaluation will heavily influence the managers planning of long term capital improvements. Second, the degree of efficiency in physical plant operation may heavily influence the decision to cogenerate.

3.2.1 Identification

There are seven variables used to develop descriptive information on each respondent. This identification information is used to classify respondents and to identify differences in response between organizations.

Variables include:

VAR001 - organization type
VAR002 - SIC classifcation
VAR003 - organization function
VAR004 - facility use
VAR005 - electricity account number area served
VAR006 - square feet
VAR007 - facility ownership, lease, or rental

3.2.2 Strategic Planning

Anthony (cited in Lorange, 1972, p. 4) states that strategic planning is "the processes of deciding on objectives of the organization, on changes in these objectives, on the resources used to obtain these objectives and on the policies that are to govern the acquisition, use, and disposition of these sources. The taxonomy of strategic planning commonly used today is slightly less encompassing. This study differentiates strategic planning from long range planning on the basis that strategic planning provides a sense of direction about the company and policies for evaluation while long range planning sets out realistic capital budgets to achieve those policies.

There are a number of strategic issues related to energy use at a facility. These strategic issues for cogeneration include two dimensions of energy policy (energy conservation and fuel switching) and policy on joint ventures for energy projects.

Variables include:

VAR010 - Energy independence
VAR011 - Energy independence from utility
VAR012 - Energy efficiency
VAR013 - Reduce oil imports
VAR014 - Joint funding energy projects
VAR015 - Joint funding with utility
VAR016 - Joint funding with utilty impossible
VAR017 - Energy conservation projects low priority
VAR018 - Availability of financing prohibits cogeneration
VAR019 - Economy limits cogeneration
VAR035 - Regulation as utility
VAR036 - Good utility relations limit cogeneration
VAR037 - Cogeneration viable investment
VAR038 - Scarce oil use vs. savings

3.2.3 Long Range Planning

Long range planning, management control (Lorange, 1972) and capital budgeting (Clark, 1979) are different names for the second stage of an organization's planning process. Given the goals and policy laid out in the strategic planning process, how does management implement these goals. "The components of capital budgeting analysis involve a forecast of the benefits and costs of a project, discounting the funds invested in a project at an appropriate rate, assessing the risk associated with the project, and follow up to determine if the project is performing as expected" (Clark, 1979, p. 4).

There are three main groups of questions related to long range planning for cogeneration. These questions include financial issues, timing of investment, and uncertainty about regulation. In many cases these issues interrelate so that the effect of perceptions about one issue provides input into the solution of a second issue. For example, a firm may determine a project hurdle rate, a minimum rate of return which a project must exceed to be funded. The perception that delay due to the air quality regulation approval process increases risk may be (incorrectly) evaluated by adding an interest rate premium to the hurdle rate.

Similarly, the issue of timing may prove to be significant in conjunction with the discount rate. A short planning horizon is usually associated with a high discount rate and an emphasis on short term returns. Such an emphasis on the short term works to the detriment of capital improvements because investment characteristically reduces return on investment in the early years of a project.

Variables include:

<u>Finance issues</u>
VAR018 - Financing prohibits cogeneration
VAR021 - Primary calculation method
VAR022 - Second calculation method
VAR023 - Third calculation method
VAR024 - Discount (interest) rate
VAR025 - Interest rate premium
VAR026 - Capital budget limits

Finance issues relating to cogeneration fall into two broad categories. First, does the plant manager or engineer perceive capital as a limited item. In budgetary systems, there are usually administratively imposed limits on capital budget items. The relative perception on the part of engineer or manager of capital budget limits may artificially restrict investment by ruling out in advance consideration of a captial intensive investment. The second issue of finance for cogeneration is whether the investment is "properly" valued. Two problems characteristically arise in evaluation of capital items.

1) Which calculation method is appropriate for evaluating the worth of a project

2) What rate of interest should be charged for use of funds

The calculation method used plays a role in acceptance or rejection of a capital budget item because the calculation method itself may bias results. A total of eight methods are specified in the study. The question is open ended, allowing respondents the option of entering a different method. Further, the methods are rank ordered for priority of calculation method by the respondents.

The calculation methods included in the study are listed in Figure 3.2 below and categorized by type.

Figure 3.2

CALCULATION METHODS

Judgement	Accounting	Index	Cash Flow
Experience and Judgement of Managers	Accounting Rate of Return	Payback	Net Present Value
	Return on Investment	Profitability Index	Internal Rate of Return
			Annual Capital Charge

Judgement of managers or engineers is the primary starting point for any evaluation of captial budget items. Yet it may represent the end of cogeneration consideration in many companies. While not a caluculation method per se, it is an essential issue in the evaluation and is therefore included here.

Accounting based evaluation measures are fairly common in U.S. industry. Two accounting based methods used in evaluating capital budget items are accounting rate of return and return on investment. Accounting rate of return compares annual net income, including depreciation, to the investment. Using either of two common methods (gross investment method or one half of the gross investment) the accounting rate of return calculation method is consistently incorrect because it ignores the time value of money (Anthony and Reese, 1979). Return on Investment (ROI) is a similar problem but for different reasons. ROI is an accounting calculation of a rate of return on the company's debt and equity which constitutes a one year picture of how well a company uses its invested capital. This calculation yields a percentage return which any capital project is expected to exceed to be accepted. Again, the problems with Accounting based evaluation methods are that they include no allowance for the time value of money and are dependent upon accrual accounting techniques (Clark, 1979).

Two index methods are included. These are payback and profitability index. Payback is a simple comparison of annual savings to investment cost. The resultant index number is the number of years to pay back the investment. While the time value of money may be accounted for with a discounted payback method, the primary use of payback is comparison of the number of years to payback of each project. Problems with this method usually come from ignoring what happens to cash flow after the investment is paid back. In comparison of payback periods, companies which desire liquidity or operate in a rapidly changing industry may choose high return or low payback items. Since cogeneration is a long lived investment with uncertain annual revenue, use of payback might seriously jeopardise its selection. The second index method, profitibabity index, or Benefit Cost Ratio, is a calculation of the present value of cash flows divided by the investment. This method has a number of problems if used to compare two mutually exclusive projects such as cogeneration versus steam boiler and electric purchase. Primarily, the profitability index does not take into account the relative size of a project's Net Present Value or correctly differentiate between projects which are not mutually exclusive. While some special investment cases do exist where profitability index is the preferred method of calculation, for cogeneration systems it is not preferable to Net Present Value. (Brealey and Myers, 1981)

Finally, there are the methods preferred by finance experts for calculation for capital investment which take into account the time value of money. The three methods included as options in this study are Net Present Value, Internal Rate of Return, and Annual Capital Charge. Internal Rate of Return (IRR) is defined as that discount rate which makes the Net Present Value of a project exactly equal to zero. The calculated IRR is then compared to a prespecified hurdle rate. If the calculated IRR is greater than the hurdle rate, accept the project. In the case of a relatively simple investment opportunity, IRR is satisfactory. IRR is very widely used in industry as a means of evaluating investment opportunities. However, it should not be used to evaluate cogeneration for two reasons. First, IRR gives misleading results in cases where a company compares two mutually exclusive projects. Second, as is likely with cogeneration plants, IRR will give multiple "correct" answers if the sign of the cash revenues changes during the life of the project. Therefore, if cash flows are negative in one year, IRR will be inaccurate (Brealey and Myers, 1981). Net Present Value is one of the two calculation methods preferred by finance experts for cogeneration project evaluation. It consists of a comparison of the present value of a stream of cash inflows and outflows discounted from future years to the present. This present value of cash flows is compared to investment to yield net present value. If Net Present Value is positive, the project should be accepted (Brealey and Myers, 1981). Finally, annual capital charge is a method which involves discounting all cash inflows and outflows to present value and determining the equivalent annual charge over the life of a project. This method is especially useful for evaluating expenditure alternatives that are not profit producing. (Clark, 1979)

One further aspect of the calculation for cogeneration investment needs to be mentioned. For those methods which use a discounted cash flow evaluation, the level at which the discount rate is set is an important determinant of the cost effectiveness of an investment. Two issues are important in evaluating the discount rate or cost of capital used. First, there is some theoretically optimum cost of capital which is a function of the risk of the asset. This risk applied to the asset may be different from the risk applied to borrowing of funds by the company as a whole. Arguably, therefore, the cost of capital for the company may be different from the cost of capital for a cogeneration system. This in fact is the argument used by Pickel (1982) for selection of a 5 percent real rate of interest as the discount rate to be used across all firms. To make a rough calculation of a discount rate for firms operating a cogeneration system it is necessary to use the capital asset pricing model (CAPM).

CAPM argues that the cost of capital for a firm is a function of the risk free rate of interest plus some coefficient Beta times the risk premium of the market.

$$\bar{r} = r_f + \beta(r_m - r_f)$$

where:

$\bar{r}$	= risk of firm
r_f	= risk free rate of interest
β	= measure of market risk
$(r_m - r_f)$	= risk premium on market

Using the average asset β for electric utility industry assets of 0.41 and the thirty year average risk premium on the market of 8.8 percent (Brealey and Myers, 1981), a rough calculation of project asset β for a cogeneration project can be made. The risk free rate is the present U.S. Treasury bill rate for 20 year notes which is approximately 13.8 percent (Wall Street Journal, June 9, 1982, p. 52).

$$\begin{aligned}\bar{r} &= 13.8 + .41(8.8)\\ &= 13.8 + 3.608\\ &= 17.408\end{aligned}$$

We should expect discount rates for use in discounted cash flow calculations to be in the vicinity of 17.5 percent.

Timing issues
VAR019 - Economy limits cogeneration
VAR020 - Planning horizon
VAR054 - Years to retirement

Timing issues are considered in one of three ways. First, the effect of general economic conditions on capital budget decisions is considered in variable 19. Second, the planning horizon commonly used for energy conservation capital improvements provides a fair indication of the willingness of an organization to plan long term investments. Third, the years to retirement of the main heating plant gives an indication of the planning window for selection of a cogeneration plant.

Uncertainty issues
VAR030 - Changing air quality regulations
VAR032 - Changes in air quality regulations will cause expense
VAR033 - Electricity production for own use
VAR034 - Electric sale price limits cogeneration
VAR035 - Regulation as a utility
VAR039 - Backup charges prevent cogeneration

VAR040 - PURPA Awareness
VAR041 - Cogeneration policy change due to PURPA

Uncertainty issues revolve around either the relationship between the organization which desires to cogenerate and the electric utility or between the potential cogenerator and government regulations. One added element of uncertainty in the price picture for cogeneration, and therefore for planning cogeneration systems, is the effect of the Public Utility Regulatory Policies Act (PURPA). This act is Title II of the National Energy Act of 1978 and contains two sections which directly affect the potential cost-effectiveness of cogeneration systems.

Section 201 of PURPA specifies two general criteria for a cogeneration facility. Cogeneration facilities are exempted from incremental pricing provisions of Title II of the Natural Gas Policy Act. This provision requires that interstate gas used in large industrial boilers be subject to incremental pricing. In essence, incremental pricing means that as consumption of natural gas increases, the price paid per unit of consumption increases. By voiding this provision for cogenerators, use of natural gas as a combustion fuel is less expensive. One point must be made clear. Under the provisions of the Fuel Use Act, oil and natural gas may not be used in new burners above 100 million Btu or total burner capacity of 250 million Btu. This provision effectively limits new burner fuels to coal or coal-derived fuels. While exemptions on use of oil and natural gas under provisions of the Fuel Use Act may be obtained to satisfy air quality regulations, the Act still poses a limitation to cogenerators using diesel or gas turbine technology. No clear public policy has emerged on this issue of oil or natural gas use in new equipment designed to cogenerate and technically the prohibitions of the Fuel Use Act still remain in place (Demakos, 1976).

Section 210 of PURPA provides guidelines for state Public Utility Commissions to use to develop state-level regulation of cogeneration and small power production facilities. Electric utilities are bound under these rules to purchase electricity offered for sale by the cogenerator at prices equal to full avoided costs. The electric utility must pay a price equal to avoided energy cost of producing a kilowatt hour of electricity plus some amount of avoided capacity cost. While different public utility commissions handle calculation of avoided energy cost and avoided capacity costs in different and occasionally unique ways, the effect of PURPA Section 210 has been to significantly increase the revenue potential of electrical cogeneration compared to conditions prior to PURPA (Bottaro and Radcliffe, 1982).

There are two major drawbacks to easy application of PURPA Section 210. First, in 1980, the state of Mississippi challenged the constitutionality of PURPA Section 210. The Federal District Court in Jackson overturned the provisions of Section 210 and held the law unconstitutional. While the appeal process is just completed with the federal law upheld by the U.S. Supreme Court in its decision of June 1, 1982, federal initiatives in this area were stymied for a long time (Energy Users News, June 10, 1982). However, in the utility service territory of all respondents to this survey, the provisions of PURPA or of legislation similar to PURPA but enacted at the state level are in place or considered a strong possibility by both utility and regulators alike (Massachusetts, 1982, House Bill No., 85).

Second, Bottaro (1982, p. 2) states, "the validity of these [PURPA] rules has been cast into doubt by the U.S. Court of Appeals (D.C. Circuit) in A.E.P. V. FERC (January 22, 1982) which invalidated the FERC rules regarding the requirement that rates must equal avoided costs and the requirement that utilities must interconnect with qualified facilities. The matter is currently (April 1982) under appeal."

Besides PURPA and the Fuel Use Act (FUA), potential cogenerators need to consider the Clean Air Act and Clean Water Act regulations. The Clean Air Act has two significant elements of importance to cogenerators. First, each state is required to develop and submit to the Federal Environmental Protection Agency a State Implementation Plan (SIP) which divides the state into Air Quality Control Regions (AQCR) for particulates and sulphur dioxide (SO_2) emissions (Demakos, 1980, p. 21). Once a state has air quality control regions, they must be classified as Class I, (pristine) Class II (moderate air quality deterioration permitted) or Class III (air quality may deteriorate to National Ambient Air Quality Standards levels). Where air is cleaner than ambient standards Prevention of Significant Deterioration (PSD) regulations are in effect. Since PSD rules apply to any areas designed as "attainment" for any one pollutant and almost all AQCR are in attainment of at least one pollutnat, PSD will affect almost all potential cogenerators. If PSD is required, major stationary sources whose average combined input energy is 250 million Btu per hour for all burners must use best available control technology (Demakos, 1980). Similarly, if a source of effluent falls under the new source performance standards (NSPS) of the Clean Water Act it must achieve similar stringent standards, "the greatest effluence reduction achievable through the use of the best available demonstrated control technology (Demakos, 1980, p. 50). In the face of ill defined, conflicting and sometimes obscure regulations, confusion among potential users of cogeneration is likely to occur.

3.2.4 Operational Planning

Operational planning, operational control, tactical planning, and operating budget planning, are synonymous terms to define "the process of measuring that specific tasks are carried out efficiently and effectively" (Lorange, 1972, p. 4).

The operation planning elements of the survey look at two types of information. First, there are a number of questions which measure perceived limits of cogeneration systems or operating objectives. The second group of questions comprises the final one half of the survey. These questions evaluate physical characteristics of the facility and establish operational conditions.

Variables include:

Operational
VAR027 - Personnel limits cogeneration
VAR028 - Make up water supply limits cogeneration
VAR033 - Electric production for our own use

Physical
VAR042 to VAR047 - Load diversity for a 24 hour period in four hour blocks
VAR048 - Present cogenerator
VAR049 - Proportion KWH cogenerated
VAR050 - Proportion KW cogenerated
VAR051 - Heating plant type
VAR052 - Heating fuel
VAR053 - Previous heating fuel
VAR055 - Cooling plant
VAR056 - Percent high pressure steam
VAR057 - Percent low pressure steam
VAR058 - Percent hot water
VAR059 to VAR075 - Energy conservation activities commonly available for commercial and industrial buildings
VAR076 - Heating fuel reduction since 1972
VAR077 - Electric energy reduction since 1972

Operational questions garner information about operating protocols or perceived limits to operations. Two policy questions look at production levels of electricity while two other questions focus on operating limitations of personnel or make up water.

The second group of variables may be broken into three subgroups. These are physical plant operating characterstics, physical plant description, and energy conservation activities. Physical plant operating characteristics include load diversity, steam load and hot water load. Physical plant description includes heating and cooling plant type and fuel switching in previous years. Finally, energy conservation includes the type of conservation activity accomplished and amount of energy saved since 1972.

3.2.5 Energy Use

The most important factor in consideration of traditional cogeneration systems is process energy use. However, signficant evidence exists to argue that systems may now be designed to be electric load following. With PURPA regulations, the ability to sell excess power to the electric utility provides the opportunity to take advantage of electric load following cogeneration to use greater electricity production from any cogeneration capacity.

Energy use figures for each type of fuel consumed in the facility, including KW demand, and the proportion of energy used for process, is the final segment of the study. These responses are used to calculate an additional variable for million Btu of thermal energy.

CHAPTER 4

SURVEY RESULTS

4.1 DATA PREPARATION

Returned questionnaires go though a three step procedure to prepare the responses for analysis. The three steps are data completion, data cleaning and verification, and tests for bias in responses.

Survey responses were received from organizations representing 170 accounts, 42.5 percent of the population. Of these responses, forty-one (41) were refusals to participate on the grounds that cogeneration was not applicable to the organization in question. Generally, this group of courteous, negative responses included multi-family residential units, electric power units such as traction power for subways, and total electric buildings. Usable responses for 129 accounts, 32.25 percent of the population, were evaluated for the problem of multiple account numbers serving one physical location and 12 of these responses were combined with responses from the same physical location leaving a total of 117 responses for analysis, 29.25 percent of the population.

4.1.1 Data Completion

Each questionnaire response is read for completeness prior to key-punching. Where important information is missing, a note of the missing information is appended to the response. There was a telephone follow up on significant omitted information within three weeks of response arrival. Significant information is limited to energy use, square feet, discount rates and planning horizon, fuel type, and heating plant type. All other information may be entered with missing values. In some cases, common sense allows completion of a question which otherwise would go unanswered. To provide two examples, as a cross check on the energy use table, VAR052 requests information on primary heating fuel used. Similarly, common sense dictates that the function (VAR005) of a hospital may be correctly assumed to be medicine.

If missing values occur due to non response to a question or group of questions, the data is coded as a non response. In data analyses except cross tabulations and factor analysis "missing values" for any one question are included in calculation of statistics.

4.1.2 Data Cleaning and Verification

Coding of data occurs directly on the respondents survey instrument. Each survey instrument receives a three digit identification number upon being logged in at the Energy Laboratory. Each case consists of three 80 column card image records punched onto IBM punch cards. Each card undergoes automatic verification for keypunch errors at time of punching. To back up the automatic verification, each data file update is manually checked for keypunch errors. Each survey instrument is verified by manual recoding and manual comparison with the data file.

4.1.3 Tests for Reliability

Five of the variable pairs were designed to check internal reliability of responses. One additional variable, VAR052, is used as a cross check on heating fuel type entered in the energy table. The five variable pairs and expected relationships are included in the table below.

Table 4.1

RELIABILITY TEST VARIABLES

Variable Pair	Question	Relationship Expected
VAR010	Our organization policy supports federal government policy favoring energy independence from foreign energy sources.	
BY		Positive
VAR013	Our organization actively engages in energy conservation work at this facility to reduce oil and natural gas consumption and therefore U.S. oil imports.	High Gamma
VAR012	Our organization actively engages in energy conservation work at this facility, seeking to achieve the most efficient use of energy resources.	Negative
BY		High
VAR017	An official policy of energy conservation would make no sense at this facility because we have many more important uses for our money.	Gamma

VARIABLE PAIR	QUESTION	RELATIONSHIP EXPECTED
VAR011	Organization policy strongly favors energy independence from our utility - our organization will actively seek to supply our own electrical energy needs.	
BY VAR048	Present cogenerator	Positive Low Gamma
VAR010	Our organization policy supports federal government policy favoring energy independence from foreign energy sources.	
BY VAR011	Organization policy strongly favors energy independence from our utility - our organization will actively seek to supply our own electrical energy needs	Negative High Gamma
VAR015	Assuming we were to cogenerate, we would consider a jointly funded project at this facility ONLY if our electric utility is willing to be the joint partner.	
BY VAR016	Under no circumstances would this organization engage in a jointly funded project with an electric utility.	Negative High Gamma

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Gamma is the number of concordant pairs minus the number of discordant pairs divided by the total number of pairs. The value of gamma can be taken as the probability of correctly quessing the order of a pair of cases on one variable once the ordering on the other variable is known (Nie, et. al., 1975).

$$\text{GAMMA} = \frac{P - Q}{P + Q}$$

The results of the cross tabulation tests for reliability are listed in Table 4.2 below.

Table 4.2

RELIABILITY TEST RESULTS

VARIABLE PAIR	GAMMA
VAR010 BY VAR013	0.487
VAR012 BY VAR017	-0.486
VAR011 BY VAR041	0.420
VAR010 BY VAR011	0.268
VAR015 BY VAR016	-0.240

Results of these reliability tests are mixed. The first three pairs are both high gamma scores and in the expected direction. The fourth pair, variables 10 and 11, were expected to have a high degree of discordance, but, in fact, have a low degree of concordance. Knowing that respondents favor energy independence from foreign sources will not help very much in predicting whether a respondent will seek to supply their own electrical needs. Similarly, we expected a negative relationship and high gamma score for the last variable pair, variables 15 and 16. While the direction is correct, the gamma score is lower than expected.

4.1.4 Tests for Bias in Response

The population of 400 electric energy account numbers is listed in a datafile containing the following variables. These 400 account numbers constitute the total population. Since all 400 received a questionnaire, this group also constitutes the sample for this study.

VAR001	ID NUMBER
VAR002	ACCOUNT NAME
VAR003	RESPONSE STATUS
VAR004	ORGANIZATION TYPE
VAR005	ORGANIZATION FUNCTION
VAR006	USE OF FACILITY
VAR007	KW DEMAND
VAR008	TITLE OF RESPONDENT
VAR009	GEOGRAPHIC CODE

To analyze whether responses from organizations constituted a higher or lower proportion than the population at large, this study developed descriptive statistics for these selected variables. The descriptive statistics include frequency distributions and cross tabulations.

Frequency distributions of Variables 3 through 8 describe the population. Table 4.3 below shows the ownership pattern of the population with the great majority (244) in the private sector while an additional 45 accounts are classified as private non-profit organizations. The relative frequency percent of both respondents and population is very similar. Chi square tests for independence based on relative frequency percent are not statistically significant at the .05 level with nine degrees of freedom. Calculated chi square of 3.44 is less than the expected value of 16.9.

Table 4.3
OWNERSHIP PATTERN

CATEGORY LABEL	POPULATION ABSOLUTE FREQ.	POPULATION RELATIVE FREQ. Percent	RESPONDENTS ABSOLUTE FREQ.	RESPONDENTS RELATIVE FREQ. Percent
Private	244	61.2	74	57.4
Private non profit	45	11.3	20	15.5
Local Government	66	16.3	24	18.6
State Government	13	3.3	7	5.4
Federal Government	13	3.3	4	3.1
Total	381	100.0	129	100.0

Note: Percentages are based on the original population of 399. Relative frequency percent column omits 19 cases with missing data.

Table 4.4
ORGANIZATION FUNCTION

CATEGORY LABEL	POPULATION ABSOLUTE FREQ.	POPULATION RELATIVE FREQ. Percent	RESPONDENTS ABSOLUTE FREQ.	RESPONDENTS RELATIVE FREQ. Percent
Education	47	11.8	23	18.0
Medicine	36	9.0	12	9.4
Housing	13	3.3	3	2.3
Commerce	97	24.3	21	16.4
Manufacture	149	37.3	52	40.6
Government	30	7.5	14	10.9
Other	6	1.5	3	2.3
Missing	21	5.3	--	--
Total	399	100.0	129	100.0

Table 4.4 indicates the organization function. Six (6) of the organizations classified themselves in the category other, while twenty one (21) non respondents could not be classified on the basis of organization name. The relative frequency percent of both respondents and population is very similar. Chi square tests for independence based on relative frequency percent are not statistically significant at the .05 level with thirteen degrees of freedom. Calculated chi square of 8.37 is less than the expected value of 22.4.

The majority of respondent organizations were manufacturing or commercial. Table 4.5 indicates the person or organization type to whom the questionnaire was addressed. We derived this information from the title of the peson to whom we sent the original questionnaire. This study sought to approach the energy professional in an organization, on the grounds that this person would be the "best" individual to contact. Table 4.5 demonstrates lack of

Table 4.5
TITLE OF INDIVIDUAL CONTACTED

CATEGORY LABEL	POPULATION ABSOLUTE FREQ.	POPULATION RELATIVE FREQ. Percent	RESPONDENTS ABSOLUTE FREQ.	RESPONDENTS RELATIVE FREQ. Percent
President CEO Plant Mngr.	30	16.9	26	20.3
Energy Manager Plant Engineer	140	78.7	96	75.0
Management Company	2	1.1	0	0.0
Unknown	6	3.4	6	4.7
Missing (Excluded from Δ)	221	--	--	--

complete success in this objective in the large number of people whose organizational title is unknown or missing. However, excluding the missing titles, the relative frequency percent of both respondents and population is very similar. Chi square tests for independence based on relative frequency percent are not statistically significant at the .05 level with seven degrees of freedom. Calculated chi square of 2.45 is less than the expected value of 16.9.

Finally, Table 4.6 shows the distribution of electricity demand (KW) for the population of this study. It is necessary to point out the strong decline of total numbers of organizations from the lower KW demand levels to the higher. This table is consistent with the study objectives and the definition of the study population as all utility accounts with a KW demand in at least one month of 1981 of 750 KW or greater. The relative frequency percent of both respondents and population is very similar. Chi square tests for independence based on relative frequency percent are not statistically significant at the .05 level with thirty-five degrees of freedom. Calculated chi square of 8.36 is less than the expected value of 49.8.

The key question in testing for consistency in distribution of responses between respondents and total population is whether the respondents are proportionally representative of the total population. If they are, one can be a little more assured of reasonable inference from the survey results. In this case, there are no statistically significant differences in response proportions.

Table 4.6

KW DEMAND COMPARISON

	POPULATION		RESPONDENTS	
	ABSOLUTE FREQ.	RELATIVE FREQ. Percent	ABSOLUTE FREQ.	RELATIVE FREQ. Percent
750-949 KW	142	35.6	41	31.8
950-1149 KW	64	16.0	22	17.1
1150-1349 KW	26	6.5	5	3.9
1350-1549 KW	22	5.5	7	5.4
1550-1749 KW	27	6.8	11	8.5
1750-1949 KW	13	3.3	3	2.3
1950-2149 KW	12	3.0	2	1.6
2150-2349 KW	11	2.8	4	3.1
2350-2549 KW	11	2.8	5	3.9
2550-2949 KW	5	1.3	1	0.8
2750-2949 KW	9	2.3	2	1.6
2950-3149 KW	8	2.0	4	3.1
3150-3349 KW	4	1.0	2	1.6
3350-3549 KW	3	0.8	2	1.6
3550-3749 KW	4	1.0	0	0.0
3750-3949 KW	1	0.3	1	0.8
3950-4149 KW	2	0.5	1	0.8
4150-HIGHEST KW	35	8.8	16	12.4
TOTAL	399	100.0	129	100.0

$$\text{Chi square} = \frac{(\text{Observed frequency} - \text{Expected frequency})^2}{\text{Expected frequency}}$$

4.1.5 Description of Analysis Methods

Analysis of responses uses a number of statistical analysis tools to evaluate the information contained in the surveys. These analysis tools provide three types of information. These three analysis tools are frequency distributions, cross tabulations and factor analysis.

4.1.5.1 Frequency distributions

As a means of description, frequency distribution provide numerous simple tests of a data set by scanning a set of n observations, calculating a frequency table, histogram and sample statistics such as mean, median, mode, frequency tables, cumulative frequency, and population moments. For interval data, this study uses responses to tabulate results and to evaluate selected variables for normal distributions.

4.1.5.2 Cross tabulations

Cross tabulations are joint frequency distributions according to two or more classificatory variables. The joint frequency distributions can be statistically analysed by tests of significance, the most common of which is Chi square, to determine if the variables are statistically independent. In cross tabulations, the actual frequency of responses to a variable are compared to the expected frequency of response to determine if the actual value is signficantly different from the expected value.

4.1.5.3 Factor Analysis

I use the preceding methods of analysis as a simple and quick means of data tabulation. Factor analysis, using one or more of several available methods, explores underlying relationships in the data. Rummel (1970) lists several distinguishing characteristics of factor analysis, condensed below.

1) Factor analysis can analyze a large number of phenomena.
2) It disentangles complex interrelationships among the phenomena into functional unities or separate or independent patterns of behavior and identifies the independent influences or causes at work.
3) It handles social phenomena in the situation.
4) It is applicable to a wide range of research designs and to a variety of data.
5) It has its roots in social science (psychology) mathematics, and natural science.
6) It has had wide applications.
7) The mathematical structure is related to such commonly used techniques as mutiple regression, product moment correlation economical analysis and analysis of variance.

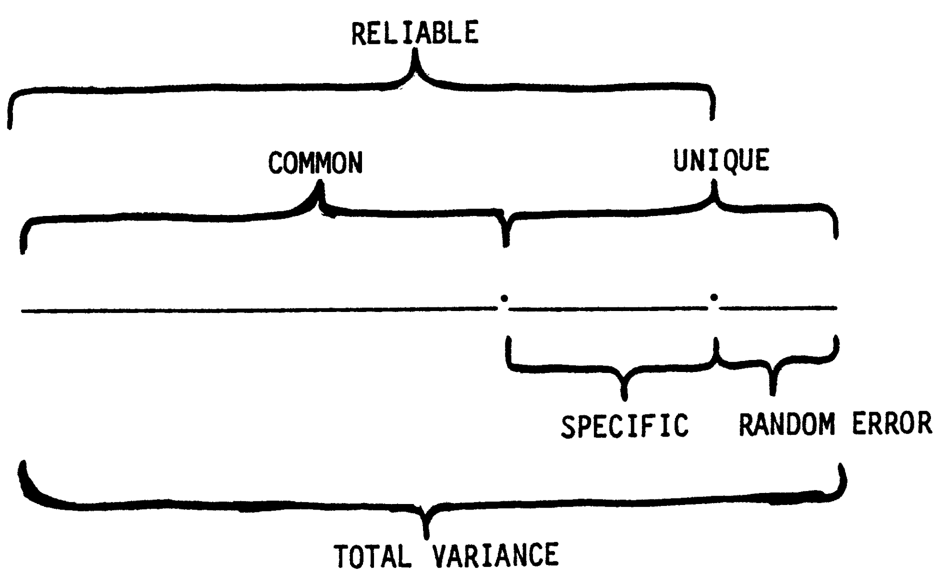
8) It yields a set of equations that can be used to describe and predict behavior. The factor analysis model can be used as a mathematical theory of behavior, and

9) Factor analysis allows a visual portrayal of behavioral relationships.

Common factor analysis is the oldest method in use and is illustrative of the mathematical theory of factor analysis. Common factor analysis seeks to explain the dimensions of the space spanning the common parts of the data vector. In factor analysis each variable may have its total variance divided into three components: common, specific, and random error. As the illustration below demonstrates, unique variance is the sum of specific and random variance.

Figure 4.1

VARIATION EXPLAINED BY COMMON FACTOR ANALYSIS



Source: Rummel (1970, p. 103)

Common variance is the variance of variable X common to the other variables.

Unique variance is that portion of variance not common to the other variables and, in principle, can be decomposed into two further components, specific variance and random error.

Specific "true" variance is that which is not shared with the other variables and random error variance. This specific component of unique variance plus the common variance determines the reliability of the variable or the proportion of total variance for a variable which is due to "true" (as opposed to random error) variance.

The common factor model is:

$$
\begin{array}{lllllll}
X_1 = \alpha_{11}S_1 & + \alpha_{12}S_2 & + \cdots & + \alpha_{ip}S_p & + \alpha_{iu}S_{iu} & & \\
\vdots \quad \vdots & \vdots & \vdots & \vdots & & & \\
X_M = \alpha_{M1}S_1 & + \alpha_{M2}S_2 & + \cdots & + + \alpha_{Mp}S_p & & & + \alpha_{Mu}S_{Mu}
\end{array}
$$

where:

S_i = a common factor

α_{ii} = a scalar weighting the contribution of S_e to the common variance x;

p = number of common factors

S_{ju} = a unique factor contributing to the unique variance of x;

α_{iu} = a scalar weight for S_{iu}

The variable S_p used in the common factor model defines p common factors present in variable x; and one factor S_{ju} unique to variable x. For each factor there is a factor loading α_{jL} which is the weight for each factor dimension. This weight measures the variance contribution the factor makes to the data vector. Finally, the elements of each factor vector S_{iL} (factor score on vector S_e for case i) comprise the factor score.

Common factor analysis has the merit of being an exploratory technique and assumes that the data have common and unique parts. In contrast, the model used for component factor analysis drops the uniqueness factor and defines dimensions of s.

The model for component analysis, known also as principal components in the SPSS package follows below:

$$\begin{array}{l} X_1 = \alpha_{11}S_1 + \alpha_{12}S_2 + \cdots + \alpha_{1p}S_p \\ \vdots \quad\quad \vdots \quad\quad \vdots \quad\quad \vdots \\ X_n = \alpha_{M1}S_1 + \alpha_{M2}S_2 + \cdots + \alpha_{Mp}S_p \end{array}$$

where:

X_1 = data for variable X

α_{11} = factor loading

S_p = dimension of component analysis

In component analysis the number of variables equals the number of dimensions. To reduce the number of dimensions, I apply the rule of thumb that no dimension (factor) will be retained if the eigenvalue is less than 1. The SPSS program for principal components allows a reduced number of factors to be specified between initial and later analyses of the factor matrix.

Finally, to find a means of generalizing a set of common factors existing in a universe of variables given a sample of variables, I used alpha factor analysis. Alpha factor analysis as developed by Kaiser and Caffrey requires "that the common factors of the sample of variables be determined so that they have maximum correlation with those in the corresponding universe of variables. The square of these correlations is α^g, a coefficient of generalizability. The generalizability factor is a linear function of the corresponding eigenvalue. For any factor F_e,

$$\alpha_e^g = \left(\frac{M}{M-1}\right) \left(\frac{\lambda_1 - 1}{\lambda_1}\right)$$

Where:

α_e^q	= coefficient of generalizability
m	= variables
λ_i	= associated eigenvalue

Two charactersitics of alpha factor analysis need to be underscored. Alpha factors with eigenvalues greater than one enable common factors existing in the universe of content to be retained in the alpha factor solution. Second, the number of alpha factors which result from alpha analysis will equal the number of dimensions with eigenvalues greater than one, which result from a principal components analysis.

Factor loadings are rotated to reduce the complexity of the factor description of the variables. Rotation techniques used in this study are both othogonal, e.g. I do not assume any correlation between factors. The two rotation techniques used are quartimax and varimax. Quartimax minimizes the sum of the products of all possible pairs of factor loads for a variable. Varimax maximizes the variance of the squared factor loadings in each column.

4.2 DESCRIPTION OF RESPONDENTS

The research instrument for this study was organized into three distinct segments. First a short segment of identification and screening information allows for easy classification of respondents. Second, policy questions using a five point agree-disagree scale sought to develop information on company strategic, long range planning, and physical plant operational policy. Finally, the third segment of the study dealt with operational efficiency and energy use in the existing physical plant. Descriptive information on respondents is provided from frequency distributions, two way and three way cross tabulations. Frequency distribution tables and selected cross tabulation tables are included in Appendix B.

4.2.1 Identification Questions

Respondents include 87 (74.4 percent) private or private non profit organizations and 30 (25.6 percent) public sector facilities. SIC classifications include one (1) from the agriculture group, one (1) from contract construction, forty three (43) from manufacturing, seven (7) from transportation, five (5) from wholesale and retail trade, twelve (12) from banking, thirty (30) from services, and sixteen (16) from government. Eighteen (18) organizations function as educational institutions, eleven (11) in medicine, five (5) in housing, twenty one (21) in commerce, forty six (46) in manufacturing, and fifteen (15) in government. For the majority of organizations the area served by the electric account (which this study uses as the basis for defining the population of this study) included a complex of buildings. Fifty three (53) facilities constituted a complex of several buildings, twelve (12) additional facilities contain one building and at least one other building, while twenty nine (29) constituted one building and outside lighting. Twenty (20) facilities were single buildings while only two (2) accounts represented part of one large building. In the case of one of these last two accounts, a third account number for an additional part of the same building has been combined to form a single facility.

4.2.2 Strategic Questions

Table 4.7 below summarizes the distribution and percentage of responses for the strategic questions in this study. A few points need to be emphasized. As expected, there is strong agreement on policy supporting energy independence from "foreign energy" sources "imported oil" and favoring energy efficiency. However, independence only rarely extends to eliminating the electric utility company from an organization's energy supply picture. Only 3 respondents, or 2.7 percent of responses strongly agreed and 14 respondents, or 12 percent, moderately agreed with independence from the electric utility.

Joint projects with either other organizations or with the electric utility elicited no very strong feelings. Most respondents were neutral on these three questions with slightly more respondents (34 or 29.3 percent) favoring joint ventures with the utility than with other organizations. Further, nearly 42 percent of respondents disagreed with the statement that under no circumstances would a joint venture with a utility be conducted.

Financial and economic limits are stronger limitations on the use of cogeneration than expected. Between 27 and 29 percent of respondents disagreed that these variables limit use of cogeneration at the present. However, 35 percent agreed that economic conditions or financial constraints did limit cogeneration options for them at the present time, even if the technology was cost effective.

Table 4.7

STRATEGIC QUESTIONS RESPONSE DISTRIBUTION

Variable number and name	STRONGLY AGREE FREQ.(%)	MODERATELY AGREE FREQ.(%)	NEUTRAL FREQ.(%)	MODERATELY DISAGREE FREQ.(%)	STRONGLY DISAGREE FREQ.(%)
VAR010 - Our organization policy supports federal government policy favoring energy independence from foriegn energy sources.	63(56.8)	23(20.7)	25(22.5)	--	--
VAR011 - Organization policy strongly favors energy independence from our utility - our organization will actively seek to supply our own electrical energy needs.	3(2.7)	14(12.0)	43(36.8)	17(14.5)	34(29.1)
VAR012 - Our organization actively engages in energy conservation work at this facility, seeking to achieve the most efficient use of energy resources.	86(76.1)	24(21.2)	2(1.8)	1(0.9)	--
VAR013 - Our organization actively engages in energy conservation work at this facility to reduce oil and natural gas consumption and therefor US oil imports.	74(65.7)	24(22.2)	12(11.1)	1(0.9)	--
VAR014 - Official policy favors having this organiza - tion enter into jointly funded energy projects.	16(14.4)	10(9.0)	62(55.9)	11(9.9)	12(10.8)
VAR015 - Assuming we were to cogenerate, we would consider a jointly funded project at this facility ONLY if our electric utility is willing to be the joint partner.	9(8.2)	23(20.9)	46(41.8)	19(17.3)	13(11.8)
VAR016 - Under NO circumstances would this organiza - tion engage in a jointly funded project with an electric utility.	6(5.5)	8(7.3)	49(45.0)	27(24.8)	19(17.4)
VAR017 - An official policy of energy conservation would make no sense at this facility because we have many more important uses for our money.	1(0.9)	4(3.9)	9(8.3)	24(22.0)	71(65.1)
VAR018 - Availability of financing effectively prohi bits cogeneration for us.	8(7.4)	30(27.8)	38(35.2)	17(15.7)	15(13.9)
VAR019 - Assuming we wanted to invest in cogeneration We wouldn't do it until the economy improves.	6(5.6)	31(28.7)	42(38.9)	18(16.7)	11(10.2)
VAR036 - We are generally happy with the service our electric utility provides us and would not be inclined to risk our good relations by generating electricity on our own.	12(10.9)	15(13.6)	39(35.5)	27(24.5)	17(15.5)
VAR037 - We believe cogeneration is a viable cost saving investment for us at this facility.	8(7.3)	21(19.1)	50(45.5)	22(20.0)	9(8.2)
VAR038 - Even if oil fired cogeneration were cost effective here, we would still not invest since it would mean we would consume more scarce oil.	4(3.7)	14(12.8)	42(38.5)	35(29.9)	14(12.0)

Twenty nine respondents indicate cogeneration is a viable technology for their facility. When asked if cogeneration would be ignored, even though cost effective, to avoid increased use of imported oil, 42 percent of respondents essentially disagreed. Neither the possibility of an organization being regulated as a utility (25 percent disagree) nor the risk of poor relations with a utility (40 percent disagree) would strongly affect the decision to use cogeneration, assuming it was cost effective at a facility.

4.2.3 Long Range Planning

The three elements of long range planning or capital budgeting included in this study include finance, timing of investment, and uncertainty of regulation.

Finance issues were covered by two questions involving a five point scale, variables 18 and 26. Financial limits were cited as a limit to cogeneration by nearly 35 percent of respondents while most respondents (71 percent) indicated they faced annual capital budget limits. The interesting financing questions discuss the planning horizon for capital budgeting items, the calculation method used for evaluating a potential cogeneration system, discount rates and discount rate premiums used. The planning horizon provided by most respondents (47 percent) was five years. Only four respondents indicated a planning horizon longer than five years where one indicated eight years and three respondents would use ten years.

Consistent with this planning horizon is the type of calculation method used to evaluate a cogeneration project. Respondents indicated they would use payback and ROI (Return on Investment) by a wide margin as both the primary method (67.1 percent) and secondary method (61.1 percent) of calculation. Only in the third method used would managers rely upon judgement (24 percent) or use an annual capital charge method (17 percent) more often than payback or ROI (each 13.7 percent). These results are somewhat at odds with financial theorists who would argue in favor of discounted cash flow methods. I also tested whether there may be a confounding effect in the question interpretation by respondents. Primary calculation could be interpreted as either a "first cut" or as the most important method. If interpreted as first cut, use of simple payback to "ball park" an estimate of cost effectiveness is reasonable, if followed by use of discounted cash flow methods for more indepth analysis. However, response sequences listed in Table 4.8 indicate the above mentioned sequence is not common.

Table 4.8
CALCULATION SEQUENCE
PAYBACK FOLLOWED BY DISCOUNTED CASH FLOW
(n) Indicated Number of Times Sequence Occurred

First Method	Second Method	Third Method
Payback	Net Present Value (NPV) (1)	Internal Rate of Return
	Return on Investment (ROI) (5)	NPV
	NPV (1)	Accounting Rate of Return
	NPV (1)	ROI
	NPV (1)	Management Judgement

Finally, the discount rate which would be used in calculations of discounted cash flows is an indicator of the perceived cost of capital for a firm based upon the risk of the asset. Previously, in this study the Capital Asset Pricing Model was used to develop a rough estimate of the cost of capital for an electric generation investment. The calculated estimate of the discount rate is 17.4 percent. The majority of discount rates cited by respondents were at or below that estimate (69.5 percent). The lowest estimates come from local and state government and private non profit organizations while consistantly higher estimates come from private organizations.

Adding interest premium estimates to the discount rates yields only a slight change in the percentage of respondents at or below the CAPM estimated discount rate. Of 39 private respondents, 58.9 percent were at or below the estimated discount rate. Similarly, 6 of 11 private non profit organizations, 3 of 4 local government, 4 of 6 state government, and the one federal government were all at or below the CAPM estimated discount rate.

Timing of investment is the second element of long range planning around which questions are designed. Three variables are included, economic conditions, planning horizon and year to retirement. Only economic conditions (VAR019) requires a scale answer. It is included in Table 4.7 with the strategic questions. It can easily be seen nearly 35 percent of respondents agree that even if cogeneration were cost effective, they would not invest until the economy improves. The combination of planning horizon and years to retirement is an important

Table 4.9
LONG RANGE PLANNING

Variable number and name	STRONGLY AGREE FREQ.(%)	MODERATELY AGREE FREQ.(%)	NEUTRAL FREQ.(%)	MODERATELY DISAGREE FREQ.(%)	STRONGLY DISAGREE FREQ.(%)
VAR030 - Air quality regulations create severe planning problems for us because we feel they change too much over time.	7(6.4)	20(17.1)	50(42.7)	25(21.4)	8(6.8)
VAR032 - Changes in air quality regulation will cause heavy and unexpected expenses if we cogenerate.	9(8.2)	24(21.8)	50(45.5)	23(20.9)	4(3.6)
VAR033 - If we do decide to produce electricity, it will be for our own use with none left over to sell to the electric utility.	10(9.2)	24(22.0)	48(44.0)	21(19.3)	6(5.5)
VAR034 - We won't cogenerate because we cant get a fair price for our electricity sold to the utility.	1(0.9)	6(5.5)	63(57.8)	24(22.0)	15(12.8)
VAR035 - Our organization is concerned about regulation. If we sell any electricity outside the organization it may make us a regulated utility.	5(4.5)	18(16.4)	59(53.6)	22(20.0)	6(5.5)
VAR039 - Backup charges for electric energy purchased from the utility prevents cogeneration.	5(4.6)	8(7.4)	66(61.1)	19(17.6)	10(9.3)
VAR041 - PURPA provides that each State Public Utility Commission set rates for electric utilities purchase of electricity from cogeneration or small power producers. The law also states that qualifying cogenerators and small power producers will not be regulated. In your opinion, will knowledge about PURPA change your organization's policy towards cogeneration.	--	11(10.3)	42(39.3)	43(40.2)	11(10.3)

one because of the "planning window" phenomenon mentioned earlier. If the planning horizon and years to retirement of physical plant converge with a desire to cogenerate, then consideration of cogeneration investment can coincide with a company's energy investment decision and according to Bulpitt (1982), this coincidence makes cogeneration more likely to occur. From Table 4.10 below, it is easy to see only 18 of 96 organizations responding to these two questions meet the criteria of 5 years or greater planning horizon coinciding with a need to replace the heating plant within the next five to ten year period of time.

TABLE 4.10
COMPARISON OF PLANNING HORIZON
AND
YEARS TO RETIREMENT

Planning Horizon Years	Less Than 5	5-10	11-15	16-20	21-25	26-30	Over 30
1	1	0	1	2	1	0	1
2	1	5	6	1	3	2	2
3	0	2	2	5	2	0	4
4	0	0	0	0	0	1	0
5	2	7	7	10	7	1	17
10	0	1	1	0	0	0	1
Total	4	15	17	18	13	4	25

Finally, long range planning contains uncertainty due to regulation, environmental or utility, pricing of potential electricity output, and upcoming changes in Federal regulations due to PURPA. All of these questions use five point agree - disagree scale answers. Variable 41 uses different terminology to describe the scale response, ranging from definately will make a difference in company policy toward cogeneration to definately would not make a difference.

In all cases respondents are predominantly neutral (53.6 percent) on issues of potential regulation as a utility. Slightly stronger agreement exists that air quality regulations could cause unexpected expense (30 percent agree) and any electricity production would be for internal use (31.2 percent).

PURPA, designed as legislation to give firms bargaining power if they choose to cogenerate, is an unknown factor at the present. Forty-nine percent of respondents were not familiar with PURPA and an additional 31 percent were only somewhat familiar with PURPA. When given a brief description of PURPA and asked if this legislation would change the organization's policy toward cogeneration, no one thought it definately will change company policy. Only 10.3 percent of respondents felt it probably will change policy while 40 percent felt it probably will not have an effect. Of the 11 respondents who believe PURPA probably will make a difference, only 3 agree to any extent that cogeneration is viable at their facility. Those respondents unsure about the effects of PURPA include 14 of 29 organizations who agree that cogeneration can be viable at their facility. Either they knew nothing about PURPA (6) or were only somewhat familiar (7), and only one indicated strong familiarity.

4.2.3 Operational Planning

Two aspects of operational planning are included in this study. First, a small number of questions look at operating policy constraints. Second, a much larger group of questions looks at a rough cut indication of present operating conditions.

The five point scale questions indicate most organizations presently don't have personnel who are able to operate a cogeneration plant (54.9 percent). Conversely, make up water supply (21 percent agree it limits technology) and electricity sale price (6 percent agree it limits technology) do not appear to be a major limitation.

The operating characteristics of the respondents are of interest in determination of cogeneration potential. These questions are divided into three types. The first type defines the plant, the second type defines how the plant is used and the third type defines energy conservation activities accomplished. Among the last type of question, installation of a sophisticated electric load management system is an important indication that cogeneration will not be inaccurately valued for electric peak shaving (reduction of KW demand charges). Similarly, the most likely set of physical plant conditions which favor cogeneration is a steam system having condensate return and with air conditioning provided in part by an existing absorbtion chiller. Use of the physical plant should show very stable thermal energy use over the course of a work week, preferably with a three shift, seven day a week schedule uniform need for thermal and electric energy. The physical plant used by many respondents is conducive to the addition of cogeneration technology. Forty five percent (45 percent) of respondents (53) have steam systems while an additional 19 percent (22) have purchase steam from a commercial vendor. Of the 29 respondents who agreed to some extent that cogeneration was viable at their facility, twenty four (24) have steam systems at the facility or purchase steam. Of the remaining respondents who indicate cogeneration is viable, one is a forced hot air system (rooftop units with air ducts) and three are electric. (Note: these are all verified responses: they are not keypunch errors.) Clearly, the electric systems are a long shot for cogeneration. Responses showed, as expected, there has been a shift of boiler fuel from No. 6 oil to natural gas as supplies of interruptable gas became more available in the last few years.

Operational charcteristics included present levels of cogeneration, if any, hours of operation, and amount of steam and hot water use. Only 16 respondents used steam above 150 psig and the level of use ranged from 2 percent to 97 percent of heating energy requirements. Low pressure steam use (15-150 psig) occurred in 36 percent of the cases. Twenty-five percent of respondents used pressurized hot water to some degree ranging from 5 to 90 percent of heating energy.

Energy conservation activites of primary interest were load control devices installed to control peak demand. Only 27 percent of respondents installed load shedding while 56 percent had installed nighttime setback procedures. Thirty six respondents (31 percent) have a load management system installed.

Table 4.11
DEMAND CONTROL STATUS
FOR
RESPONDENTS WHO BELIEVE COGENERATION IS VIABLE

Cogeneration Viable	Load Shedding		Load Management	
	Complete	Incomplete	Complete	Incomplete
Strongly Agree	2	6	2	6
Moderately Agree	7	14	7	14

Table 4.11 clearly shows load shedding or load management to have been reported by respondents as completed in only 9 of a potential 29 organizations where cogeneration is considered viable. While very preliminary, this table does indicate that the assessment of cogeneration's viability may be based on an intuitive assumption of reduction in (KW) demand which could be unnecessarily large.

Finally, evidence clearly exists that coal conversion will enhance the cost effectiveness of cogeneration of steam and electricity far more than any other single factor in the New England states. Yet, 96 of 117 organizations said consideration of use of coal is not likely, 2 considered and rejected coal use and only 5 indicated it would be considered or would be used. Consideration of coal derived fuel is only slightly more likely. Nineteen respondents indicated they would consider coal derived fuels but 60 (56.6 percent) had not and were not likely to consider such fuels.

4.3 Underlying relations in the responses

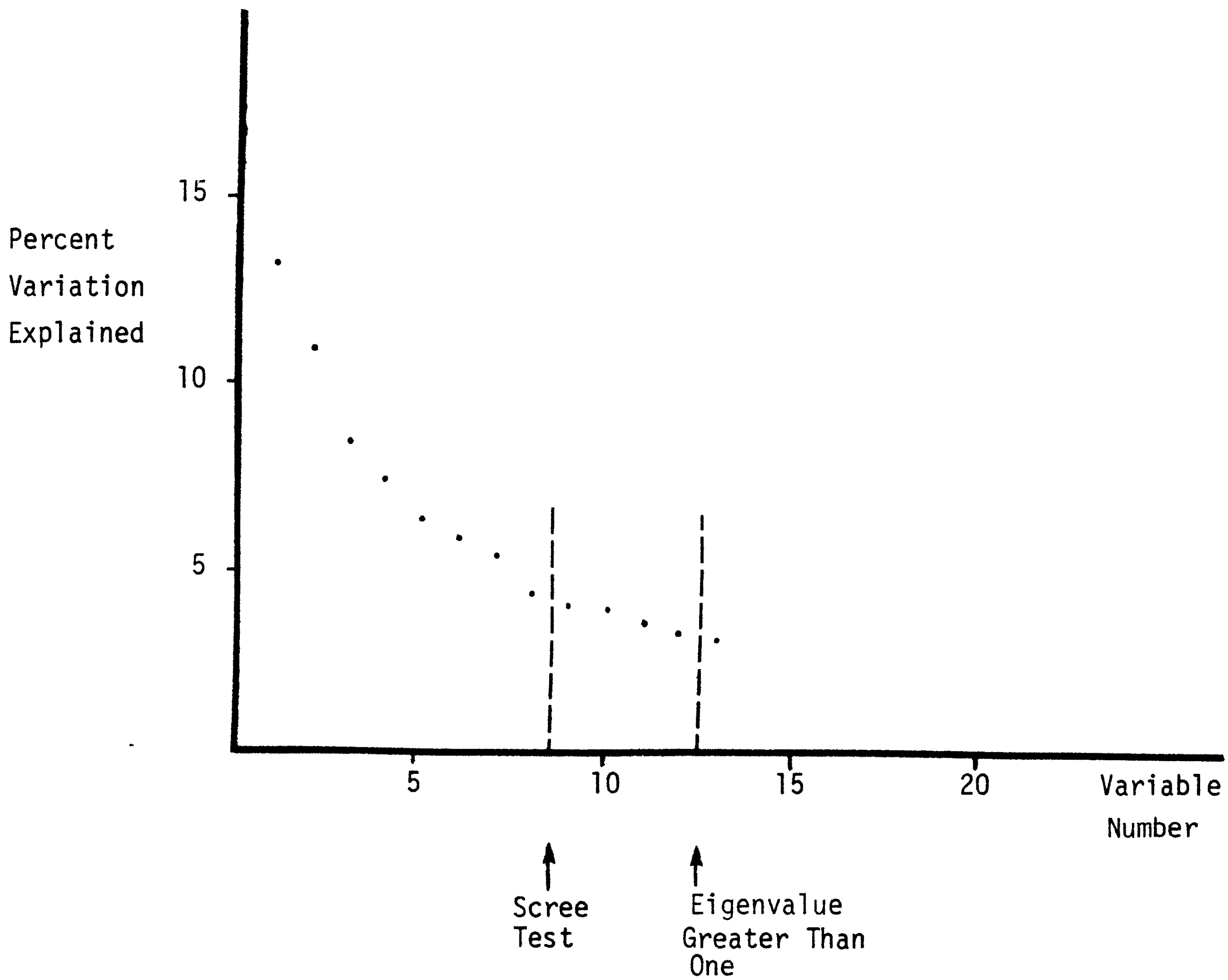
From its inception this study sought to test empirically the underlying relationships between various segments of the decision process to engage in cogeneration of steam and electricity. The method chosen to define these underlying relationships is factor analysis. Two factor analysis methods were used to test two different approaches to analysis of the information. Principle components factor analysis develops inferred factors from the data set. In the specific method used, the software automatically inserts an estimate of communality in the matrix diagonal and iterates until the "best" communality estimate is found. Alpha factoring assumes the variables are part of a larger but unknown universe of all variables which could explain the phenomenon of cogeneration. The factors defined by this method have maximum generalizability, we can infer information about the universe of variables from the sample which this study analyses. We use alpha factoring as the primary solution method because I seek to identify the maximum generalizability of variables to answer the question of cogeneration decision process under the assumption that the variables used are a random sample of items from "the universe" of variables.

In both types of factor analysis this study uses rotation techniques to achieve a more complete solution and to test if the behavior of the data is robust. The two rotation techniques are varimax and quartimax. Both techniques are orthogonal, no assumption of correlation among factors is made. Quartimax seeks to simplify the number of rows of a factor matrix by rotating the matrix so that a variable loads highly on one factor but not on another. Conversely, varimax seeks to simplify the columns of a factor matrix.

Two methods are commonly used to select the number of factors from a factor analysis solution; eigenvalue test and a scree test. The eigenvalue test uses the criteria that all factors should be selected which have a calculated eigenvalue of 1.0 or greater. The scree test, shown in Figure 4.2 below, consists of plotting additional variation explained by a factor and cutting off the number of factors at the point where the slope changes sharply. By the eigenvalue test, the number of factors should be 12, while by the scree test the number of factors should be 8. We chose to report 12 factors since the factor loadings on variables did not change very much when forced down to a limit of 8 factors (See Appendix D).

The principle components factor method, using the same data set as alpha factoring, determined almost exactly the same results. With the exception of "Utility Price Constraints" which is not a factor inferred from principle components, the results are very similar (see Figures D-1 to D-4 in Appendix D).

Figure 4.2
Scree Test Results



The "importance" of the factors is, in a very special and limited sense, that they successively explain smaller and smaller amounts of total variance common or shared by all variables in the data set. Consequently, the first factor derived may be considered the most important on explaining variation and therefore one can infer it is the most important of the factors.

Each of the derived factors is discussed below:

Factor 1 - COST UNCERTAINTY DUE TO REGULATION

With the exception of variable 17 (more important uses for money than energy conservation) the remaining variables describe the volatility and expense of regulation.

Factor 2 - SELF SUFFICIENCY

These variables pertain to the degree of energy self sufficiency a utility customer seeks. Cogeneration requires a high degree of energy self sufficiency. These variables indicate the stronger the agreement with independence from the utility the more viable cogeneration appears to the respondents and the more likely it is respondents will not change their attitude due to PURPA.

Factor 3 - PRESENT COGENERATOR

Two variables isolate the level of present cogeneration from the remaining factors. The strength of the factor loadings for these two variables indicates that they are not at all correlated with the other factors.

Factor 4 - CONSERVATION OBJECTIVES

Corporate policy and its relation to cogeneration is factor 4. Respondents express a strong support for energy efficiency. While the coefficient for variable 13 is negative, the interpretation of this coefficient supports strong energy conservation objectives as a factor in the decision to adopt cogeneration technology. The question is worded to determine if respondents would not adopt oil fired cogeneration, even if it were cost effective, since adopting cogeneration under these circumstances would increase use of imported oil.

Factor 5 - FINANCIAL FLEXIBILITY

All three variables loading on this factor refer to some limitation upon available finances, either imposed by the financial markets or by company policy.

Factor 6 - JOINT VENTURES POLICY

Respondents are not generally open to jointly funded projects but are open to having the utility involved as a joint partner if they were to cogenerate.

Factor 7 - UTILITY PRICE CONSTRAINTS

Both make-up water supplies and electricity pricing for purchase of electricity from an organization by a utility do not have a part in determining a decision to cogenerate. These questions were both negatively worded in the survey and , consequently, have positive factor loadings.

Factor 8 - HUMAN RELATIONS

Both variables load highly and positively on the factor, indicating neither personnel limits nor good utility relations are going to limit adoption of cogeneration technology if the technology is cost effective.

Factor 9 - COST OF CAPITAL

Variable 24, the discount rate, loads highly and negatively on factor 11. This loading pattern indicates that as discount rates get higher the relationship with cogeneration is higher. This anomoly comes from responses by private sector firms which both use discounted cash flow methods and higher discount rates compared to public sector respondents.

Factor 10 - TIMING

Variable 19 indicates the economic cycle does have an effect on the decision to choose cogeneration.

Factor 11 - INVESTMENTS POLICY

Cogeneration, a cost saving investment, requires that an organization has a policy which allows cost saving investment as well as revenue production. Positive loading on variable 31 indicates that investment policy may be a factor in use of cogeneration.

Factor 12 - PLANNING FACTORS

Variables 21 and 28 are both elements of the calculation of economic viability for a cogeneration system. While the calculation method is important, inclusion of make up water supplies is unimportant as a limiting factor.

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 Summary

Cogeneration is the joint production of thermal energy and electricity. Most commonly in the United States, cogeneration occurs at a single facility of an organization and supplies energy only within the given facility. Since 1975, public and private sector sponsored evaluations of cogeneration in the U.S. have forecast increased levels for cogeneration of thermal energy and electricity. Most often, these reports base forecasts of increased use on cogeneration on the thermodynamic efficiency to be gained from relatively low incremental heat rates for electric production compared to electric utility generation of electric energy. In spite of forecasts of increased cogeneration capacity and energy, the reality of cogeneration is declining production of cogenerated steam over the last fifteen (15) years and electricity over the last ten (10) years. While cogeneration forecasts projected increases and cogeneration actually declined, the literature explained the differences by anecdotal references to a number of non economic issues. The issues commonly cited are included in the table below.

Table 5.1

ATTRIBUTES OF COGENERATION DECISIONS FROM LITERATURE

Regulation - Utility	Regulation - Environmental
Utility Attitude	Line of Business
Uncertainty	Financial Limits
Market Imperfections in Price	Timing
Power Pool Relations	

This study sought to identify existing and potential users of cogeneration within a utility service territory in the Northeast U.S. To accomplish this objective, a population of potential cogenerators was selected by identifying all electric utility accounts which used 750 KW or more of electricity in any one month of 1981. The population was surveyed using a mailed survey instrument and telephone follow up of incomplete responses. A total of 400 electric accounts surveyed resulted in 129 usable responses (32.2 percent). By aggregating those responses with multiple account numbers for a physical location into one response, the total number of cases analyzed was reduced to 117 (29.25 percent). While the response rate was low, time constraints did not allow for rigorous follow up procedures needed to boost response rates. Fortunately, tests for response bias by KW demand, organization type, and title of person to whom the survey was sent were all statistically not significant.

This study sought to answer three questions:

1) Are non economic variables important in the decision to use cogeneration technology?

2) If non economic variables are important in the decision to use cogeneration technology, which variables are most important?

3) What can be inferred about the prospect of cogeneration technology penetration in this utility market area from the results of this study?

To answer question 1, non-economic variables are clearly important in the decision process. These non-economic "factors" inferred from the analysis generally correspond to strategic and long range planning aspects of the capital budget process discussed in the literature. Strategic factors for an organization include:

Self Sufficiency
Present Cogenerator
Conservation Objectives
Joint Ventures Policy

Long range planning or capital budgeting factors for an organization include:

Cost Uncertainty Due to Reglations
Utility Price Constraints
Human Relations
Timing
Planning Factors
Cost of Capital

In seeking to identify which variables are most important in the decision process, factor analysis provides the opportunity to infer a rank ordering of factors from those which explain most variance to those which explain least variance. As a crude approximation, the factor order is a measure of the "importance" of each factor in the special and limited sense that they successively explain smaller and smaller amounts of total variance common to all variables in the set. However, the reader is cautioned that data for this study comprised a small group of respondents and the variables analyzed are ordinal in scale. Further, the factor analysis solution provides no measure of importance in terms of the effect each factor has on the decision to adopt or not adopt cogeneration.

Finally, question three asks if there is some inference I can draw from analysis of the data about the prospects for use of cogeneration technology within the utility territory. Clearly, the answer is yes.

We used five criteria to screen respondents for potential to cogenerate. These screening criteria include:

1) <u>Physical Plant</u>

Variables 42 to 48 - Hours of Operation.

Operation of the physical plant should approach 7 days a week, 24 hours a day to be most economic. The threshold value for hours of operation in a year, taken as the lowest figure for hours of operation of an existing cogenerator in the service territory is 102 hours per week.

Variables 51 and 52 - Heating Plant Type and Primary Heating Fuel Type.

Coal use (or willingness to convert to coal) constitutes the most cost effective fuel for steam turbine cogeneration systems. An acceptable alternative to coal is No. 6 oil, No. 5 oil, or natural gas (interruptable contract). Less likely to be cost effective because of added capital or operating expense is No. 4 oil or purchase steam. No. 2 oil fired systems will probably not be cost effective.

2) Policy

Variable 37 - Cogeneration is a viable investment.

The organization must perceive cogeneration to be workable at the facility.

3) Existing Cogeneration

Variable 48 - Present cogenerators are assumed to continue cogenerating and therefore will be excluded from further consideration.

4) Air Quality won't be significant problem

Location of respondent is checked to determine if attainment of air quality regulations may cause inordinate expense. For example, downtown Boston is a likely area for added air quality control expense to meet summertime emission control requirements.

5) Planning Horizon

Variables 20 and 54 - Planning Horizon and Years to Retirement of the Primary Heating Plant

For purposes of this estimation process, I am using a 5 year planning horizon and replacement of physical plant within 20 years to provide a potential cogeneration investment schedule.

What results from this screening process and the assumptions about relative energy prices, air quality regulations, and corporate investment planning horizons is a rough estimate of cogeneration capacity additions over the coming 20 years.

STEP 1: Is the physical plant suitable for an easy addition of cogeneration technology?

Starting with physical plant suitability, the criteria allow sorting of respondents into appropriate groups. Some 46 percent of respondents have suitable physical plants (steam boilers of one kind or another) and an additional 19 percent have purchased steam systems, a total of 75 facilities.

STEP 2: Does the facility manager consider cogeneration to be viable?

Of the 75 respondents with appropriate physical plant characteristics, only 40 indicated they thought cogeneration was viable or were neutral on the question(29 agree, 11 neutral). Of these 40, 11 had insufficient hours of operation per week to meet threshhold requirements. Of the 29 remaining, 1 used an incompatible fuel type for heating, leaving only 28 facilities.

STEP 3: Does cogeneration presently occur at the facility?

Of the 28 facilities remaining, 6 are presently cogenerating steam and electricity.

STEP 4: Do air quality control laws potentially restrict use of "dirtier" fuels?

Of the 22 remaining presently non cogenerating potentially suitable facilities, 11 are in downtown Boston, and likely to incur significant difficulty meeting stringent air quality control standards which apply to that area. All 11 use purchased steam for heating, thus necessitating the purchase of both boiler and steam turbine units if they are to cogenerate. Follow up telephone calls indicate the primary reason for considering cogeneration is the high cost of purchased steam. Eight of the 11 respondents discussed here are neutral on the use of cogeneration and are therefore not selected as potential cogenerators. Three of the 11 moderately agreed cogeneration was viable at their facility. In light of both regulatory uncertainty due to the location and the investment cost for both boiler and turbine, we elect to exclude these 3 respondents also.

STEP 5: What is the maximum KW cogeneration capacity needed to serve all electrical demand for these potential cogenerators which remain? Further, what will the potential for cogeneration technology selection imply in terms of timing of capacity additions?

Finally, consideration of planning horizon and years to retirement allow completion of a table of projected maximum cogeneration potential given the assumptions listed above and assuming facilities provide only sufficient capacity to meet 1981 peak demand.

Responses to this survey are scaled up by a factor of 3 to approximate total population potential for cogeneration. We have entered only summary information to maintain confidentiality. Estimating energy generated at a 60 percent capacity factor provides a rough estimate of energy (KWH) given KW capacity estimates. The equation for electrical energy (KWH) is:

$$\begin{aligned} KWH &= \text{Capacity Factor} \times \text{KW Capacity} \times \text{Hours Per Year} \\ &= .6 \times 20666 \times 8760 \\ &= 108620496 \end{aligned}$$

Table 5.2
MAXIMUM POTENTIAL
ADDITIONAL KW FROM COGENERATION RETROFIT
1982 - 2002

Year	KW	MWH
0 - 5	20666	108620
5 - 10	-	-
10 - 15	-	-
15 - 20	85666	450261
TOTAL	106332	558881

5.2 Conclusions

There are a number of interesting results which become clear in evaluation of survey responses. Most of the organizations presumed to be of sufficient size to consider cogeneration technology do not have staff who believe it to be viable at that facility. While the majority of organizations can agree that independence from "foreign energy" or "imported oil" is supported by the organization, only some 15 percent of respondents agree to any extent that they would consider supplying their own electrical energy.

This study sought to identify and measure the factors underlying a decision to use cogeneration technology. To accomplish this objective, this study uses factor analysis of a selected set of attitudinal variables from the survey. The results of the factor analysis are interesting because different factor methods arrive at essentially the same results. While various factors may change position, the twelve factors are robust.

Table 5.3
INFERRED FACTORS

Factor
1 - Cost Uncertainty Due to Regulation
2 - Self Sufficiency
3 - Present Cogenerator
4 - Conservation Objectives
5 - Financial Flexibility
6 - Joint Ventures Policy
7 - Utility Price Constraints
8 - Human Relations
9 - Cost of Capital
10 - Timing
11 - Investment Policy
12 - Planning Factors

It is essential the reader understand that factor analysis is being applied in this study to ordinal data. The implication of a five point scale answer is that the scale encompasses all possible responses and that these responses are exactly equidistant. While these results are consistant with the anecdotal references given in the literature, the strong relationship of the last four factors to planning issues leads me to believe there may be a higher order factor which encompasses these variables.

3.0 Recommendations for Further Study

This research began the process of applying new product marketing techniques to an industrial marketing issue, cogeneration of steam and electricity. From the factor analysis results it is clear the technique provides useful insights. However, much work remains to be accomplished to further pursue these objectives. We recommend:

1) Use of discriminant analysis or multinomial logit to develop a predictive function for the probability of cogeneration at a facility. Work has begun on an extension of this study to pursue research on such a function. Either discriminant analysis or multinomial logit would answer the question of which variables are most important in the decision to use cogeneration technology.

2) Engage in survey research to determine the degree of internal consistency between management and physical plant operator in terms of their perception about the viability of cogeneration. This research requires a separate approach to each participant in the decision process. Implicitely, there may be additional participants within an organization, such as corporate level finance people, whose attitude should be surveyed.

3) Use the predictive function along with market penetration models to forecast potentially more realistic penetration rates for cogeneration than provided by thermodynamically based forecasts.

4) Extend the analysis of cogeneration technology from the three traditional systems usd in this study to include the impact of new technology such as solar thermal/solar photovoltaic equipment. Some conversations with respondents indicated a market may exist for a clean, on-site, electric generation technology which did not require constant monitoring by engineering staff. While such solar thermal/solar photovoltaic systems are not now cost effective in most grid connected applications, future systems may be economically viable by the 1990's.

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APPENDIX A

COVER LETTER

and

QUESTIONNAIRE

Energy Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

April 1, 1982

U.S. Government
General Services Administration
5 Post Office Square
Boston, MA 02109

Dear Sir ;

I am writing to you to ask for your assistance in a major research project at the Massachusetts Institute of Technology Energy Laboratory. The Utility Systems Program is responsible for research into the economic effects of new energy technologies. My colleagues and I have identified a problem which we cannot solve without your help.

For the past five years, researchers at a number of private and governmental institutions have studied the economics of cogeneration in the United States. Cogeneration is the sequential production of thermal energy and electricity. All of the previous work on cogeneration investment decisions has been based on theoretical economics. The present study focuses on actual management criteria used to evaluate cogeneration investment decisions. Your assistance in responding to the attached questions will offer a realistic basis on which both electric utilities and governmental agencies can project future demand for cogeneration. This information is particularly important to electric utilities as they consider additional generation capacity and possible new opportunities for joint project development with large commercial, industrial or government electricity customers.

Our research is funded by a group of electric utility companies operating in the Northeast United States. Aside from funding, the utility firms have provided for us a population of electric energy users from which we have drawn our sample. We expect to complete research on this topic in mid-May and to have a report ready in early July. To help us with this project PLEASE RETURN THE ENCLOSED QUESTIONNAIRE BY APRIL 16, 1982. Robert Radcliffe and I will be happy to answer any questions you may have regarding the research project or the questionnaire. We can be reached at 617-253-4013.

All responses will be held in the strictest confidence by Utility Systems Program research staff assigned to this project. I would, of course, be very happy to make available a copy of the final report for you if you would like to receive one.

Sincerely yours,

Dr. Richard D. Tabors
Manager, Utility Systems Program

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ENERGY LABORATORY

UTILITY SYSTEMS PROGRAM

MANAGEMENT DECISIONS FOR COGENERATION : A SURVEY ANALYSIS

DR. RICHARD D. TABORS

ROBERT R. RADCLIFFE

RESEARCH METHOD

To select our sample we have identified a population of public and privately owned facilities in the Northeast which have monthly electricity demand greater than 750 KW. In our study, we wish to survey facilities owned or held in long term lease by the occupant to determine attitudes and criteria used in making cogeneration decisions.

This questionnaire is divided into three (3) sections.

1)The first part of this study asks for information which will help us to better understand your organization's activities.
2)The second part of the study explores your organization's official position about cogeneration systems.
3)The third part of this study develops information about your physical plant and energy use characteristics.

ORGANIZATION INFORMATION

The label to the right contains your facility name and address as we have them in our files.

All responses should be made specific to this particular facility.

Electric Usage Account Number:______________________________

DIRECTIONS

ENTER THE NUMBER FOR EACH RESPONSE IN THE SPACE TO THE RIGHT OF EACH QUESTION.

1. Describe the type of organization in which you work? . . . (11-12)

1)Private
2)Private nonprofit
3)Local government agency
4)State government agency
5)Federal government agency

2. There is a list of S.I.C.(Standard Industrial Classification) numbers on page 11 of this questionnaire. Please find your S.I.C. number on that list and enter it here. . . . (13-14)

3. Which term best describes this organization's function? . . . (15-16)

1)Education
2)Medicine
3)Housing
4)Commerce
5)Manufacturing
6)Government

4. Which term best describes the use of this facility? . . . (17-18)

1)Office space	7)Classroom/teaching lab
2)Retail/commercial space	8)Dormitory
3)Manufacturing space	9)Residential/Rental housing
4)Storage/warehouse	10)Residential/Condominium - Coop
5)Power plant	11)Recreational
6)Medical lab/hospital	12)Other________________

5. Which term best describes the area in this building and/or other buildings which receive electricity under this account number? . . . (19-20)

1)Part of one building
2)One entire building
3)This building and some outside lighting
4)This building and at least one other building
5)A complex of several buildings

6. Enter the approximate area, in square feet, which receives electricity under this account number? . . . . (21-27)

7. Enter the number which describes your facility ownership position? . . (28)

1)We own the facility outright (fee simple ownership)
2)We own the facility as a joint venture (joint ownership)
3)We hold a long term lease (three year or more)
4)We rent space on an annual or short term renewal basis

If you rent this particular facility's space which you occupy on an annual or short term renewal basis, please enter the name of the leasing/ rental agent so that we may contact them directly.

Name:____
Address:______________________________ State__________
Telephone:(   )________________

If you rent the space which you occupy in this facility, you need not fill out the rest of this questionnaire. Simply return the survey to us in the enclosed envelope and accept our thanks for your help with this research.

If you own or hold a long term lease (three years or more) to the space you occupy in this facility, please continue to fill out the remainder of the questionnaire.

PLANNING FOR ENERGY PROJECTS

In planning for energy conservation or energy supply at this facility, a number of issues have an impact on how you decide to invest in a capital budget item. We need to begin to understand the planning process for energy related projects in your organization. Each question in the next set asks you if you agree or disagree with the statement given. There is no right or wrong answer to these questions.

PLEASE CIRCLE YOUR CHOICE ACCORDING TO THE FOLLOWING CODE.

SA	MA	N	MD	SD
Strongly Agree	Moderately Agree	Neutral	Moderately Disagree	Strongly Disagree

8. Our organization policy supports federal government policy favoring energy independance from foriegn energy sources.	SA	MA	N	MD	SD
9. Organization policy strongly favors energy independence from our utility - our organization will actively seek to supply our own electrical energy needs.	SA	MA	N	MD	SD
10. Our organization actively engages in energy conservation work at this facility, seeking to achieve the most efficient use of energy resources.	SA	MA	N	MD	SD
11. Our organization actively engages in energy conservation work at this facility to reduce oil and natural gas consumption and therefor US oil imports.	SA	MA	N	MD	SD
12. Official policy favors having this organization enter into jointly funded energy projects.	SA	MA	N	MD	SD
13. Assuming we <u>were</u> to cogenerate, we would consider a <u>jointly</u> funded project at this facility <u>ONLY</u> if our electric utility is willing to be the <u>joint</u> partner.	SA	MA	N	MD	SD
14.Under NO circumstances would this organization engage in a jointly funded project with an electric utility.	SA	MA	N	MD	SD
15. An official policy of energy conservation would make no sense at this facility because we have many more important uses for our money.	SA	MA	N	MD	SD
16. Availability of financing effectively prohibits cogeneration for us.	SA	MA	N	MD	SD
17. Assuming we wanted to invest in cogeneration We wouldn't do it until the economy improves.	SA	MA	N	MD	SD

18. Enter the number of years you use, on average, for a capital budget item planning horizon? E.G. "We try to look 3 years into the future for planning purposes." . . . Years (41-42)

19. Organizations may use a number of different methods to evaluate the cost effectiveness of a cogeneration project. Assuming your organization were interested in buying and installing a cogeneration system, which one (or combination) of the following evaluation methods would you use? Please enter them in order of importance (no more than three).

. . . (43-44)
. . . (45-46)
. . . (47-48)

1)Internal rate of return
2)Net present value
3)Payback (simple)
4)Accounting rate of return
5)Return on investment
6)Annual capital charge
7)Experience and judgement of managers
8)Profitability index
9)Other (specify) ______________________

20. What discount rate (rate of interest) would your organization apply to evaluate the worth of a cogeneration project? . . . (49-50)

1) 4-7 %
2) 7.1-10 %
3) 10.1-13 %
4) 13.1-16 %
5) 16.1-19 %
6) 19.1-22 %
7) 22.1-25 %
8) 25.1-28 %
9) 28.1-31 %
10) 31.1- 34 %
11) 34.1- 37 %
12)Over 37 %

21. Organizations sometimes apply an interest premium (i.e. above the regular interest rate) when they evaluate energy projects. Enter the number which best corresponds to the interest rate premium your organization would apply in the case of a cogeneration project? . . . (51-52)

1) -4% to -2%
2) -1.9% to -0.1%
3) 0% to 1.9%
4) 2% to 3.9%
5) 4% to 5.9%
6) 6% to 7.9%
7) 8% to 9.9%
8) 10% to 11.9%
9) 12% and over

PLEASE CIRCLE YOUR CHOICE ACCORDING TO THE FOLLOWING CODE.

SA	MA	N	MD	SD
Strongly Agree	Moderately Agree	Neutral	Moderately Disagree	Strongly Disagree

22. We have explicit limits on capital improvement budgets each year.	SA	MA	N	MD	SD
23. We do not have personnel who can operate the cogeneration equipment.	SA	MA	N	MD	SD
24. Make up water supplies limit our use of cogeneration technologies.	SA	MA	N	MD	SD
25. Air quality control regulations are the only reason we do not cogenerate at the present time.	SA	MA	N	MD	SD

26. Air quality regulations create severe planning problems for us because we feel they change too much over time.	SA	MA	N	MD	SD
27. Our organization is ONLY interested in investments which produce added revenues.	SA	MA	N	MD	SD
28. Changes in air quality regulation will cause heavy and unexpected expenses if we cogenerate.	SA	MA	N	MD	SD
29. If we do decide to produce electricity, it will be for our own use with none left over to sell to the electric utility.	SA	MA	N	MD	SD
30. We won't cogenerate because we can't get a fair price for our electricity sold to the utility.	SA	MA	N	MD	SD
31. Our organization is concerned about regulation. If we sell any electricity outside the organization it may make us a regulated utility.	SA	MA	N	MD	SD
32. We are generally happy with the service our electric utility provides for us, and would not be inclined to risk our good relations by generating electricity on our own.	SA	MA	N	MD	SD
33. We believe cogeneration is a viable cost saving investment for us at this facility.	SA	MA	N	MD	SD
34. Even if oil-fired cogeneration were cost effective here, we would still not invest since it would mean we would consume more scarce oil.	SA	MA	N	MD	SD
35. Backup charges for electric energy purchased from the utility prevents cogeneration.	SA	MA	N	MD	SD

36. Recently the U.S. Congress passed a law which favors use of cogeneration and small power production facilities. Are you familiar with the Public Utility Regulatory Policy Act (PURPA)? . . . (68-69)

1) Yes   2) No   3) Somewhat

37. PURPA provides that each State Public Utility Commission set rates for electric utilities purchase of electricity from cogeneration or small power producers. The law also states that qualifying cogenerators and small power producers will not be regulated. In your opinion, will knowledge about PURPA change your organization's policy towards cogeneration? . . . (70-71)

1) Definately will
2) Probably will but it is too soon to tell
3) Unsure
4) Probably will not have any effect
5) Definately will make no difference to us

ENERGY USE CHARACTERISTICS

We need to be able to evaluate, in a very rough manner, whether this facility could become a cogenerator. To accomplish this evaluation, we need some information about how you use this facility, what energy conservation work you have done in the past, and your energy consumption for calender year 1981.

38. In the matrix below, enter an "H" in the cell for the times when the facility is fully used during a typical workweek, a "P" for the times it is partially used, and an "N" for the times it is not in use.

For example, a school may be fully used from 8 AM to 12 Noon on Monday - Friday:(An "H" would be entered in those five cells), partially used from 12 noon to 4 PM (A "P" would be entered in these five cells), and not used from 4 PM until 8 AM or on weekends.

	MON	TUES	WED	THUR	FRI	SAT	SUN	FOR MIT USE
8 AM-12 Noon								. . .
12 Noon-4 PM								. . .
4 PM- 8 PM								. . .
8 PM- 12 Mid								. . .
12 Mid- 4 AM								. . .
4 AM- 8 AM								. . .
								(11-22)

39. Do you presently cogenerate electricity at this facility? . . . (23-24)

1) Yes 2) No

40. What proportion of your total electric energy consumption (kwh) at this facility do you cogenerate ? . . . (25-26)

1) 0% to 10%
2) 11% to 20%
3) 21% to 30%
4) 31% to 40%
5) 41% to 50%
6) 51% to 60%
7) 61% to 70%
8) 71% to 80%
9) 81% to 90%
10) 91% to 100%

41. What proportion of your peak electricity demand (kw) at this facility do you cogenerate ? . . . (27-28)

1) 0% to 10%
2) 11% to 20%
3) 21% to 30%
4) 31% to 40%
5) 41% to 50%
6) 51% to 60%
7) 61% to 70%
8) 71% to 80%
9) 81% to 90%
10) 91% to 100%

42. From the list below which term best describes the heating plant in this facility? . . . (29-30)

1)Not heated
2)Steam boiler-constructed
3)Steam boiler-package
4)Steam from a central power plant which you own (with condensate return)
5)Steam from a central power plant which you own (no condensate return)
6)Hot water boiler
7)Forced air furnace
8)Heat pump
9)Purchased steam (utility)
10)Purchased hot water
11)Other ____________

For the next two questions use the list of fuel types below for code numbers.

1)Kerosene
2)Home heat/diesel
3)Number four oil
4)Number five oil
5)Number six oil
6)Propane
7)Electricity
8)Natural Gas
9)Steam
10)Anthracite coal
11)Bituminous coal
12)Wood

43. Enter the primary type of energy you use for heating? . . . (31-32)

44. If you have converted your primary heating plant from one fuel type to a different fuel type since 1972, enter the code number for the PREVIOUS primary heating fuel type you used? . . . (33-34)

45. Enter the approximate number of years to retirement of your primary heating plant? . . . (35-36)

1)Less than 5 years
2) 6 - 10 years
3) 11 - 15 years
4) 16 - 20 years
5) 21 - 25 years
6) 26 - 30 years
7) over 30 years

46. Describe the dominant type of air conditioning equipment at this facility? . . . (37-38)

1)Not cooled
2)Mechanical ventilation
3)Direct expansion system
4)Centrifugal
5)Heat pump
6)Absorption chiller
7)Window units
8)Purchased chilled water
9)Other ____________

47. If you use steam or pressurized water in this facility what is the approximate share of annual steam use that must be served by:

	Percent
1)High pressure steam (150 PSIG or more)	. . .
2)Low pressure steam (15 - 150 PSIG)	. . .
3)Hot water	. . .
	(39-44)

48. Please check off from the following list any energy conservation activities you have completed in this facility in the past five years?

Building envelope
- Added insulation ____
- Reduced window area ____
- Added double glazing ____
- Added solar tint ____

Heating
- Replaced/repaired boiler ____
- Replaced burner ____
- Install auto draft damper ____

Lighting
- Replace fixtures ____
- Reduce light levels ____

Cooling and ventilation
- Reduced air volumes ____
- Insulate pipe/duct ____

Controls
- Install load shedding device ____
- Nightime setback ____
- Load management system ____

Domestic hot water
- Solar hot water ____
- Temperature reduced ____
- Waste heat recovery ____

(46-62)

49. As a rough estimate, how much have you reduced heating fuel and electricity consumption at this facility since 1972?

1)0-5 %	4)15.1-20 %	Heating fuel	. . (66)
2)5.1-10 %	5)20.1-25 %	Electricity (Where seperate from heat)	. . (67)
3)10.1-15 %	6)Greater than 25 %		

50. Did you consider converting this facility's heating plant to coal? . . (68)

1) Yes, we plan to do so soon.
2) Yes, but serious planning has not started.
3) No, but we may in the future.
4) No, and it is unlikely we would for this facility.

51. If a coal derived fuel were available for use in your existing boiler, (such as solvent refined coal or coal/oil mixture) would you use it? . . (69)

1) Yes, we plan to do so soon.
2) Yes, but serious planning has not started.
3) No, but we may in the future.
4) No, and it is unlikely we would for this facility.

ENERGY USE TABLE
INSTRUCTIONS

52. We need to have information on electricity, oil, and other fuels which you consume at this facility. This information will be sufficient for us to screen facilities for their cogeneration potential.

1) Using the FUEL CODE from the list at the top of the next page, enter the type of energy in Line 1, marked by the large letters "FUEL" in the left column.

2) Enter the units in which the energy is measured in Line 2 "UNITS". Use the UNIT CODE which corresponds to the fuel type from the list at the top of the next page.

3) Enter the amount of each fuel, IN PERCENT, which you use for industrial process energy in Line 3 "PROCESS". If you don't have any industrial process energy use, please enter a zero (0).

4) Enter the monthly fuel use for each month in line 5 to 16 (JAN TO DEC). Please round off the data to whole numbers.

5) Enter annual energy use in Line 17 "TOTALS".

	FUEL CONSUMPTION CALENDER YR 1981-MONTHLY FIGURES FOR ALL FUELS								
				ELECTRICITY		OIL	OTHER	OTHER	OTHER
		YR	MON	ENERGY	DEMAND	ENERGY	ENERGY	ENERGY	ENERGY
FUEL	1			ELEC					
UNITS	2			KWH	KW				
PROCESS	3								
	4								
	5	81	Jan						
	6	81	Feb						
	7	81	Mar						
	8	81	Apr						
	9	81	May						
	10	81	Jun						
	11	81	Jul						
	12	81	Aug						
	13	81	Sep						
	14	81	Oct						
	15	81	Nov						
	16	81	Dec						
TOTALS	17	81							

(FOR MIT USE ONLY)

(11-15) (16) (17-24) (25-30) (31-36) (37-42) (43-48)

(49-52) (53-58) (59-64) (65-68) (69-72) (73-75)

FUEL CODE TABLE

FUEL TYPE	FUEL CODE	UNITS	UNIT CODE
Kerosene	N01	Gallons	GAL
Home Heat/Diesel	N02	Gallons	GAL
Number 4 Oil	N04	Gallons	GAL
		Barrels	BBL
Number 5 Oil	N05	Gallons	GAL
		Barrels	BBL
Number 6 Oil	N06	Gallons	GAL
		Barrels	BBL
Propane	LPG	Gallons	GAL
		Pounds	LBS
Electric Energy	ELEC	Kilowatt hours	KWH

FUEL TYPE	FUEL CODE	UNITS	UNIT CODE
Natural Gas	NG	Hundred Cu Ft	CCF
		Thousand Cu Ft	MCF
		Therm	THRM
Steam	STM	Thousand Pounds	KLB
		Million BTU	MBTU
Anthracite Coal	AC	Short Tons	STON
		Long Tons	LTON
Bituminous Coal	BC	Short Tons	STON
		Long Tons	LTON
Wood	WD	Tons (Air Dry)	TAD
		Cords	CORD

UNITED STATES GOVERNMENT
STANDARD INDUSTRIAL CLASSIFICATION CODE

AGRICULTURE, FORESTRY, FISHERIES
01. Agricultural production
07. Agricultural services/hunting
08. Forestry
09. Fisheries

MINING
10. Metal mining
11. Anthracite mining
12. Bituminous coal/lignite mining
13. Crude oil/natural gas
14. Mining/quarrying nonmetallics

CONTRACT CONSTRUCTION
15. Building construction-general contractors
16. Construction-other
17. Construction-special trade contractors

MANUFACTURING
19. Ordnance/accessories
20. Food/kindred products
21. Tobacco manufacturers
22. Textile mill products
23. Apparel/finished fabrics
24. Lumber/wood products
25. Furniture/fixtures
26. Paper/allied products
27. Printing/publishing
28. Chemical/allied products
29. Oil refining/related industries
30. Rubber/miscellaneous plastics
31. Leather/products
32. Stone,clay,glass/concrete product
33. Primary metal industries
34. Fabricated metal products
35. Machinery, nonelectrical
36. Electrical machinery
37. Transportation
38. Professional,scientific,control instruments
39. Miscellaneous manufacturing

TRANSPORTATION,COMMUNICATION SERVICES
40. Railroad transportation
41. Local & suburban tansportation
42. Motor freight/warehousing
44. Water transportation
45. Air transportation
46. Pipe line transportation
47. Transportation services
48. Communication
49. Electric,gas/sanitary services

WHOLESALE & RETAIL TRADE
50. Wholesale trade
52. Building/hardware/farm equipment
53. Retail trade-general
54. Food stores
55. Auto dealers/service stations
56. Apparel/accessory stores
57. Furniture/furnishings/stores
58. Eating/drinking places
59. Miscellaneous retail stores

FINANCE, INSURANCE & REAL ESTATE
60. Banking
61. Credit agencies not banks
62. Security/commodity brokers and services
63. Insurance carriers
64. Insurance agents,brokers
65. Real estate
66. Combinations of real estate, insurance,loans,law offices
67. Holding/investment companies

SERVICES
70. Hotels/rooming houses,camps/etc.
72. Personal services
73. Miscellaneous business services
75. Auto repair,auto services/garages
76. Miscellaneous repair services
78. Motion pictures
79. Amusement/recreational services
80. Medical/health services
81. Legal services
82. Educational services
84. Museums/art galleries/gardens
86. Nonprofit membership organizations
88. Private households
89. Miscellaneous services*

GOVERNMENT
91. Federal government
92. State government
93. Local government
94. International government

NONCLASSIFIABLE
99. Nonclassifiable establishments

*Note: Miscellaneous services includes public accounting, auditing and bookkeeping services.

PLEASE RETURN THIS SURVEY IN THE ENCLOSED ENVELOPE TO:

Massachusetts Institute of Technology
Energy Laboratory
Utility Systems Program
Building E40-433
1 Amherst Street
Cambridge, Massachusetts 02139
c/o Dr. Richard D. Tabors

Thank you.