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Advanced Cogeneration Research Study

Survey of Cogeneration Potential

Marie L. Slonski

May 1983

Prepared for
Southern California Edison Company
Through an Agreement with
National Aeronautics and Space Administration
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ABSTRACT

Fifty-five facilities that consumed substantial amounts of electricity, natural gas, or fuel oil were surveyed by telephone in 1983. The primary objective of the survey was to estimate the potential electricity that could be generated in the SCE service territory using cogeneration technology.

An estimated 3667 MW_e could potentially be generated using cogenerated technology. Of this total, current technology could provide 2569 MW_e and advanced technology could provide 1098 MW_e. Approximately 1611 MW_t was considered not feasible to produce electricity with either current or advanced cogeneration technology.

ACKNOWLEDGMENTS

The author would like to acknowledge the support and contribution of the following individuals: Dr. Ned Levine, who designed the survey, developed the questionnaire, and performed the statistical analysis; Dr. Gajanana Birur, who guided the technical content of the questionnaire, developed the methodology for estimating the cogeneration potential, performed the cogeneration potential analysis, and provided answers to many technical questions; Rebecca Wheeler, who coordinated the entire interviewing process and contributed to every aspect of the survey from questionnaire development to data entry; and Valerie Gray, Sue Jones, Elisabeth Dutzi, Leonard Reiter, and Reed Wilcox, who comprised the staff of interviewers.

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SECTION I

INTRODUCTION

A. BACKGROUND

The Southern California Edison Company (SCE) is pursuing a research program in advanced cogeneration systems. To provide information for program planning, SCE sponsored research in this area at the Jet Propulsion Laboratory (JPL). One element of this research was determining the potential, from heat sources currently not cogenerating, available to generate electricity using cogeneration technology in the SCE service territory. SCE's intent is to capture as much as possible of the cogeneration potential (MW_e) available with conventional cogeneraton technology and to make significant inroads into the potential that can be captured using advanced cogeneration technology.

Cogeneration is the simultaneous generation of electricity and useful thermal energy that leads to greater fuel utilization efficiency than would result from the independent generation of equivalent units of each. In this study, cogeneration potential is viewed as a technology bound limit. Current cogeneration potential is the electricity that could be generated using conventional, off-the-shelf equipment; advanced cogeneration potential is the additional electricity that could be generated if better technology, available in 5 to 15 years, were used instead. Finally, because any heat source could be utilized to generate electricity, the thermal energy from heat sources below $300^{\circ}F$ is thermal potential that is not feasible.

The approach used to estimate the cogeneration potential was to conduct a telephone survey using probability sampling methods. The methodology comprised establishing a sampling frame that represents the population of heat producers within the SCE service territory and drawing a sample. A questionnaire was developed and administered to the sample.

B. PURPOSE AND SCOPE

The purpose of this report is to present the results of the survey conducted and to describe the approach used to obtain them. Eighty-one facilities were selected initially from which information was obtained about heat processes, energy sources feeding those processes, and some aspects of energy management.[1] None of the information obtained for individual facilities is included in this document; only aggregate results for the entire sample are reported.

In addition to technical factors such as temperature and efficiency, there are economic and institutional factors that affect the adoption of cogeneration by industry. These include ownership, buy-back rates, price of alternative fuels, pollution restrictions, etc. However, none of these factors have been addressed in this study.

C. OBJECTIVES OF SURVEY

The primary objective of the survey was to estimate the potential electricity that could be generated in the SCE service territory using cogeneration technology. The estimate was to be subdivided into three categories:

(1) that which may be generated using conventional technology;

(2) the additional amount that could be generated using advanced technology; and

(3) the thermal energy that did not have potential for cogeneration.

A secondary objective was to identify those factors that would indicate a likelihood of cogeneration potential in each category to provide a focus to the direction of cogeneration efforts. In particular, it was intended to identify factors that would indicate where the most cogeneration potential could be gained and where cogeneration efforts might prove most successful.

D. SUMMARY OF RESULTS

There is sizable potential electricity in the SCE service territory that could be generated using cogeneration technology. Specifically, the total cogeneration potential was estimated to be 3667 MW_e.[2] The manufacturing sector had the greatest potential for current technology while the mining sector had the greatest potential for advanced technology. These two sectors combined had the most significant potential with both current and advanced technology.

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[1] The sample size was subsequently reduced to 70 due to a number of factors as discussed in Section II.B.

[2] The 95% confidence interval for this estimate is 2745 MW_e to 4589 MW_e.

Processes with waste streams, particularly liquid waste streams, and processes with boilers, as one would expect, had the most potential for current technology; both processes would also gain more potential from advanced technology than other types of processes.

Consumption of natural gas was positively correlated with cogeneration potential for both current and advanced technology. Because fuel oil is not widely used in Southern California, its use was not evident in the survey results. However, it would be expected that, in regions where fuel oil is widely used, it would be as good an indicator of cogeneration potential as natural gas. More interesting, however, was the result that electricity consumption may show a positive correlation with advanced cogeneration potential. The basis for this result was not fully understood, although it seems to be associated with direct fired processes. It was not a direct artifact of the site specific estimates of cogeneration potential because electricity consumption was not included in the methodology. This may be a significant result, but further analysis is required to establish the basis for it.

Finally, because very few facilities had adopted cogeneration systems to date, effects of organizational differences on adoption rates could not be adequately assessed. Large facilities had the greatest potential and would be the likely place to start encouraging the adoption of cogeneration. Another likely target is the manufacturing sector, which had the greatest potential. More than half the manufacturing facilities had not yet considered cogeneration.

SECTION II

METHODOLOGY

A. SAMPLING FRAME

The population comprised all facilities in the SCE service territory that have high rates of thermal energy production; that is, facilities generating sizeable amounts of heat through ovens, boilers, furnaces or other means. Criteria were developed for quantifying the terms "high rates" and "sizeable" that were used to construct the sampling frame. Because it was prohibitive to construct a complete list of all facilities in the population, the sampling frame was used to simulate the population; it contained facilities, or sampling units, that represented the population. In practice, facilities were included in the sampling frame on the basis of whether or not they used electricity, natural gas, or fuel oil that matched or exceeded the established criteria. The best data available to construct the sampling frame consisted of a list of SCE electric customers and a list of facilities that have been issued boiler permits by the South Coast Air Quality Management District (AQMD).

The criteria developed for including facilities in the sampling frame and for subdividing it into two segments, large facilities and medium facilities, are presented in Table 2-1. The sampling frame was segmented into large and medium facilities to ensure that the very large users would be sampled. Small facilities were not included because the sum of the potential from this group was considered negligible. The first criterion was to quantify, as a lower bound, what was meant by "high rates of thermal energy production", and the second was to establish a boundary between large and medium facilities. Because the SCE list and the AQMD lists were different in their basic units, comparable values were established for each list.

The principal factor used for dividing the SCE list between large and medium facilities was the percentage of the total demand. The large facilities account for about 15% of the total MW_e demand for facilities in the sampling frame. A comparable value based on Btu/h was then established for the AQMD list. Similarly, the lower bound of 1 MW_e demand was set by SCE and a comparable value based on Btu/h was established for the AQMD list.

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Table 2-1. Criteria for Dividing Sampling Frame

Source List	Medium Facilities		Large Facilities	
SCE Electric Customer List	Electric Demand		Electric Demand	
	$1\ MW_e - 25\ MW_e$		$25\ MW_e$ and above	
AQMD Boiler Permit List (any combination)	No. Boilers	Size Range (10^6Btu/h)	No. Boilers	Size Range (10^6Btu/h)
	1	5,000-15,000	1	200,000 & above
	3	1,500- 5,000	1 - 2	100,000-200,000
	10	650- 1,500	3	50,000-100,000
			8	15,000- 50,000

Once each list had been divided into large and medium facilities they were compared to eliminate duplication. The facilities included in the AQMD list that were not located in the SCE service territory were also eliminated; this included facilities in the City of Los Angeles and regions serviced by other utilities. The initial sampling frame included a total of 31 large facilities, 11 from the SCE list and 20 from the AQMD list, and 1093 medium facilities, 740 from the SCE list and 353 from the AQMD list. Finally, adjustments were made for listing errors (duplication, incorrect addresses, etc.), and the final sampling frame included 25 large facilities and 984 medium facilities, which were used as multipliers for the population estimators.

The principal form of bias in the sampling frame arose because cogeneration requires heat processes, not electric processes, and the primary list of facilities was based on electric consumption. An unbiased sampling frame would include all electric users, natural gas users, and fuel oil users. Other biases in the sampling frame arose because the AQMD list was used to represent natural gas and fuel oil users, but there were some problems associated with the list. In particular, the list was a few years old and not complete; this resulted in the exclusion of facilities in the northern areas of the territory that had low electricity consumption but high thermal usage.

Additionally, the list did not cover the entire SCE service territory. The SCE service territory with an overlay of the area covered by the AQMD list is shown in Figure 2-1.

B. SAMPLE

Two sampling fractions were used to avoid the bias that would result if very large users were not sampled. All large facilities were sampled and approximately 4.6% of all medium facilities were included. The result was a final sample of 25 large facilities and 45 medium facilities.[3] Seventeen interviews were obtained from the large segment and 38 interviews were obtained from the medium segment. The breakdown of the sample is presented in Table 2-2.

Table 2-2. Breakdown of Sample

	Large Facilities	Medium Facilities
Facilities selected	31	50
Facilities contacted	28	48
Facilities eliminated	6	5
Facilities in sample	25	45
Interviews completed	17	38*
Refusals	8	7

*One facility was dropped from the analysis.

One of the medium facilities for which data were obtained was dropped from the sample because it appeared to have characteristics that were inconsistent with the criteria used to distinguish between large and medium facilities. The facility in question had about 12 MW_e electricity demand and had no boilers,

[3] From the initial sampling frame, 31 large facilities (100% of the facilities) and 50 medium facilities (4.6% of the facilities) were drawn. Of the 31 large facilities, two were double counted because they had been listed under two different names, one had moved out of the state of California, one could not be located, and two were mistakenly selected. Of the 50 medium facilities, two had gone out of business, two had been mistakenly selected, and one was dropped at SCE's request.

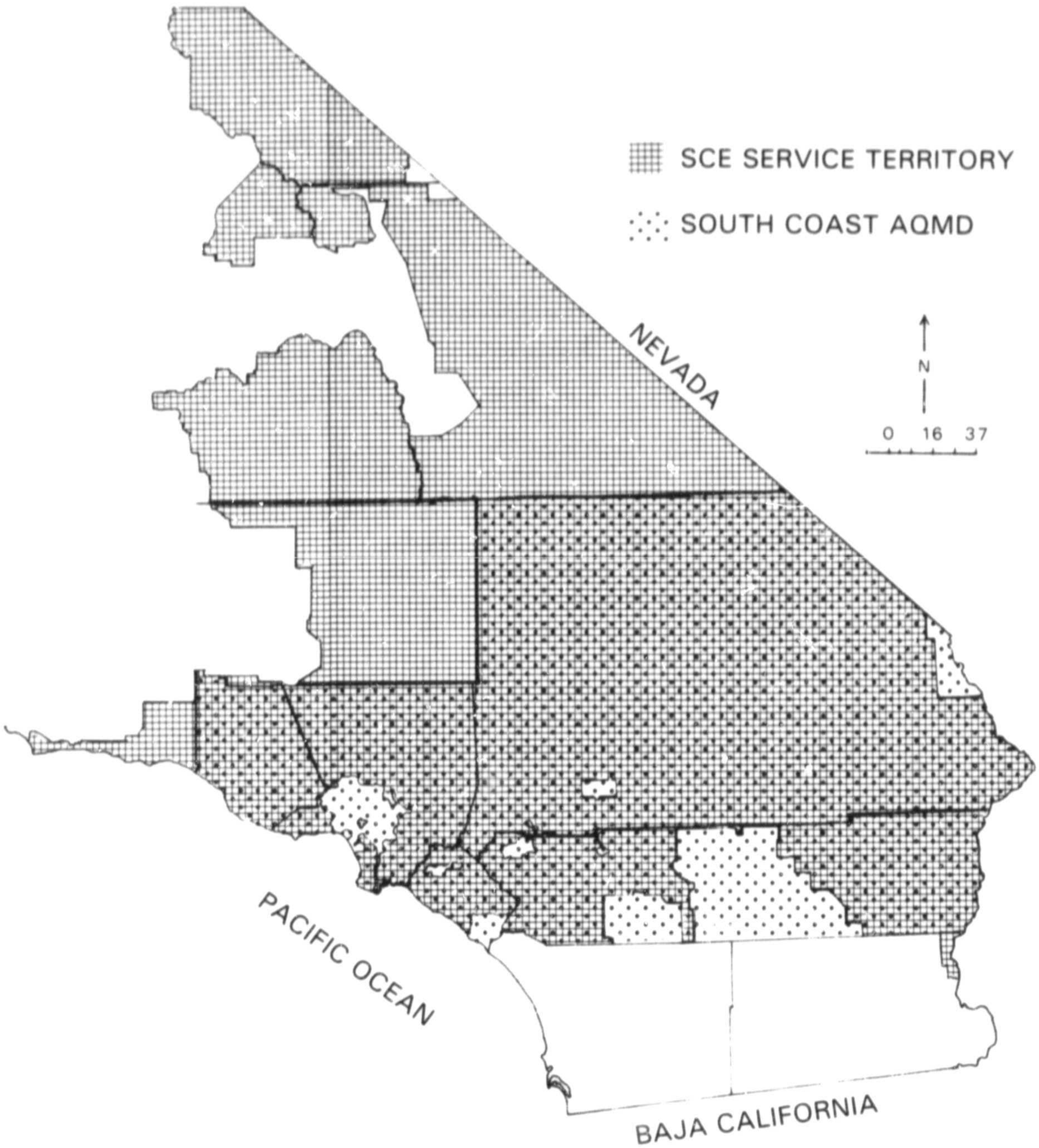

Figure 2-1. Southern California Area Covered in the Sampling Frame

but rather it had large engines that produced large quantities of waste heat. Thus, by the stated criteria it was classified as a medium facility, but estimated cogeneration potential was more typical of large facilities. Including this facility in the sample would have caused very much larger confidence intervals for cogeneration potential. Excluding the facility resulted in possibly underestimating total cogeneration potential in the SCE service territory.

C. QUESTIONNAIRE

The questionnaire was developed through an iterative process over a 2-month period. The content was formulated and reviewed by the cogeneration research team at JPL and by SCE personnel. A pre-test was conducted with four facilities using a preliminary form of the questionnaire to determine operational difficulties. Pre-test interviewers were instructed to write detailed notes on the content and format of the questionnaire, noting difficulties encountered. The data obtained were analyzed to ensure that an estimate of the potential could be made. An extensive debriefing involving both the interviewers and the analyst was held and, on the basis of their reports, the questionnaire was further revised to the final version, which is included in Appendix A.

The final questionnaire is divided into four main sections. First is a Call Record Sheet (p. 1) to record the history of the telephone calls. Second is the introduction and screening question (p. 2) used to locate the plant engineer or highest ranking technical person responsible for energy consumption in the organization. Third, there is an Informed Consent Statement (p. 3) that was read to the selected respondent stating the rights of the respondent and the organization, as well as indicating the conditions under which the data would be collected. This is done to establish an ethical basis for the interview. Fourth, is the body of the questionnaire (pp. 3-24), used to conduct the survey; the body is subdivided into five parts:

1) Overview: Q1-Q6
2) Industrial heating processes: Q7-Q14
3) General energy consumption: Q15-Q18
4) Energy conservation and management: Q19-Q24
5) Technology development and wrap-up: Q25-Q27.

Specific content of the questions within each section is discussed in Section III, Results.

D. DATA COLLECTION AND ANALYSIS

The interviews were conducted over an eight-week period during February and March 1983. The interviewers were all JPL personnel. Upon completion, each questionnaire was analyzed to estimate the cogeneration potential in the three categories and then coded and processed. Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) computer program (Reference 1).

1. Cogeneration Potential Analysis Methodology

Technical characteristics for distinguishing between current technology and advanced technology were determined and are presented in Tables 2-3, 2-4, and 2-5. Information used in developing these three tables was extracted from References 2 through 8. Each questionnaire was then evaluated independently to estimate the cogeneration potential at the facility surveyed. The first step consisted of evaluating the responses to questions 7 through 16 and determining or estimating the capacities (Btu_t/h), flow rates (lb/h), pressure (psi), and temperature (^oF) of the following:

(1) steam boiler;

(2) thermal processes that use steam;

(3) directly fired thermal processes;

(4) waste streams from thermal processes.

Next, for thermal processes using steam, the steam boiler was replaced with a gas turbine topping cycle and a waste heat boiler. For directly fired thermal processes, a gas turbine was placed upstream of the thermal process. A further assumption for direct fired processes was that current technology can supply exhaust temperatures only up to 1000^oF and advanced technology will supply exhaust temperatures up to 1400^oF; processes that require temperatures above 1400^oF were not considered feasible for either current or advanced technology. Then, using the parameters listed in Table 2-3, Steam Boiler Parameters, and Table 2-4, Gas Turbine Topping Cycle Parameters, the path of Btu_t through the system was traced and the cogeneration potential was estimated. In Figure 2-2, a hypothetical example illustrates the approach used. Part A shows a hypothetical representation of a steam process as may

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Table 2-3. Steam Boiler Parameters

Source	Source Temperature °F	Efficiency %
Fuel	Not Applicable	75-82
Waste Stream	650	60
Waste Stream	1000	70

Table 2-4. Gas Turbine Topping Cycle Parameters

Size Range MW_e	Current Technology		Advanced Technology	
	Efficiency %	Exhaust Temp °F	Efficiency %	Exhaust Temp °F
0.5	20	900	35	1200
4.0	27	1000	37	1500
20.0	37	1400	40	1500

Table 2-5. Bottoming Cycle Parameters

Size MW_e	Source Temperature	Working Fluid	Efficiency %
0.5 and up	400 to 1000	Steam	14-36
0.5 - 1	300 to 350	Organic Fluid	9 (Current) 15 (Advanced)
2 and up	300 to 350	Organic Fluid	12 (Current) 16 (Advanced)

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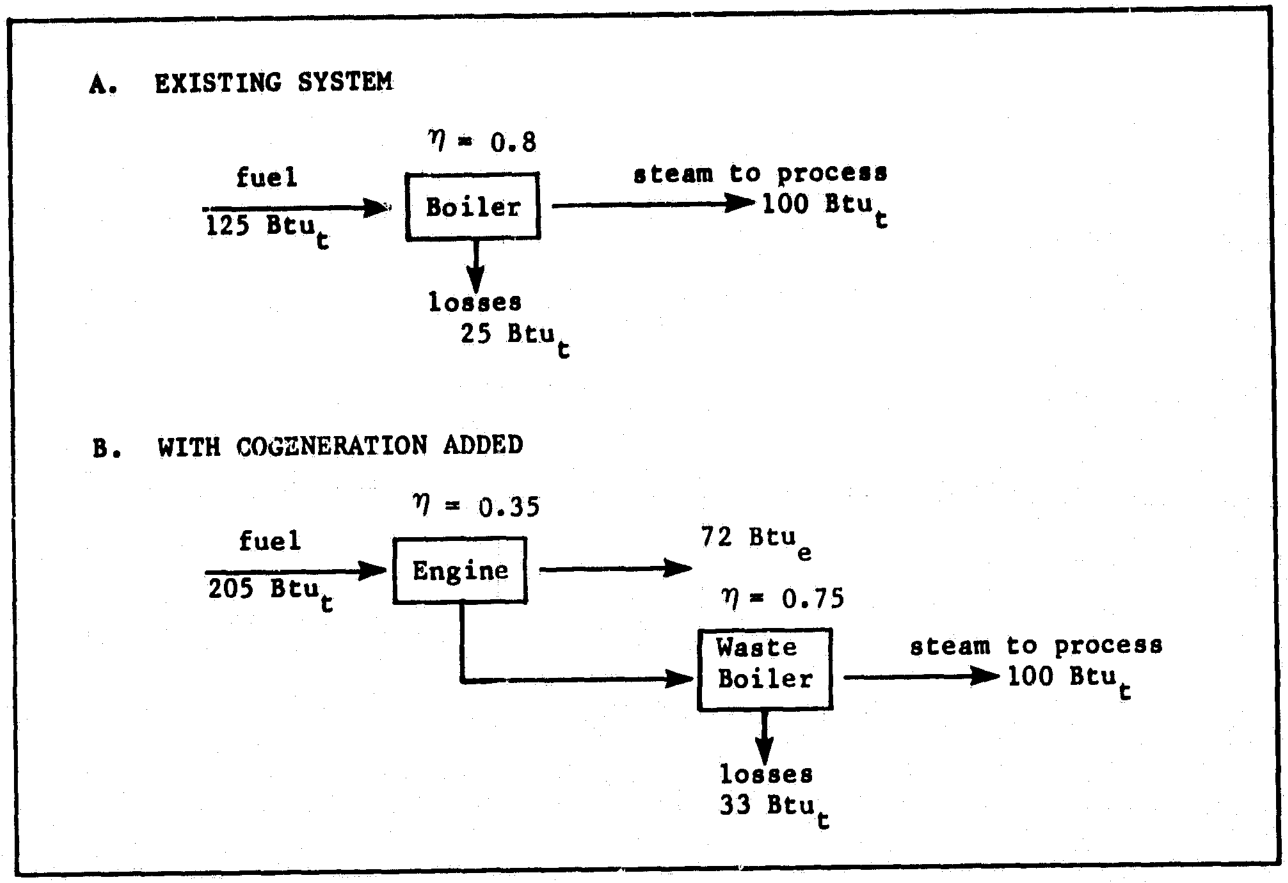
Figure 2-2. Hypothetical Example of Analysis Approach



exist in a facility, and Part B represents that same process with the addition of cogeneration. The approach was specifically tailored to match the processes and requirements for each facility.

The cogeneration potential from liquid and gas waste streams and stack gases was evaluated based on the use of bottoming cycle engines. Additionally, it was assumed that liquid waste streams below 300°F and gas waste streams, including stack gas, below 340°F had no cogeneration potential. The estimate was then made using the parameters from Table 2-5, Bottoming Cycle Parameters, in a manner similar to that described above.

The current and advanced cogeneration potentials were calculated in MW_e and the non-potential estimate was calculated in MW_t; these are power ratings that can be converted to Btu_t/h or Btu_e/h by multiplying by 3.413×10^6. To determine the cogeneration potential in either MWh_e or Btu_e, the power rating must be multiplied by the total annual hours of operation in the plant. That is,

$$\text{cogeneration potential in } MWh_e\text{/year} = \text{cogeneration potential in } MW_e \times \text{hours of operation/year}$$

$$\text{cogeneration potential in } Btu_e\text{/year} = \text{cogeneration potential in } MW_e \times \text{hours of operation/year} \times 3.413 \times 10^6$$

The estimates of cogeneration potential are subject to two different types of errors, reporting errors and calculation errors. Reporting errors occur because of inaccurate or incorrect answers, missing or insufficient data, and inconsistencies among data. An attempt was made to resolve discrepancies and fill in missing data by making follow-up telephone calls or using reasonable engineering judgment when possible. Calculation errors are due primarily to biases in the methodology that may favor one type of cogeneration system over another, as well as the characteristics assumed for each type of system.

2. Statistical Analysis Methodology

The statistical analysis was conducted in three stages. First, the cogeneration potential in each of the three categories was estimated for all facilities in the SCE service territory. The estimates for the large sample were obtained by multiplying the average potential for all facilities for which there were data (17) by the total number of large facilities (25). It was assumed that the eight facilities for which there were no data had the same attributes, in general, as the average of the 17 facilities for which there were data. Because the sample is the entire population, the results are deterministic and there is no confidence interval associated with the estimates. The estimates for the sample of medium facilities were obtained by multiplying the average potential by the total number of facilities in the population (984). Confidence intervals for the estimates were then calculated. The equations for these calculations are included in Appendix B.

Second, characteristics associated with energy consumption and with the production process were examined through correlation analyses to determine the major factors associated with cogeneration potential. This step provides the basis for understanding how potential is related to the type of operation and the amount of energy consumed to operate the plant.

Finally, a variety of factors associated with the facilities were examined through correlation analyses to identify variables that correlate with size and conservation policy to gain further understanding of cogeneration potential and some underlying factors.

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SECTION III

RESULTS

A. COGENERATION POTENTIAL

Current cogeneration potential (MW_e) is the electricity that could be generated in the industrial-commercial sector using conventional, off-the-shelf equipment. Advanced cogeneration potential (MW_e) is the additional electricity that would be generated if advanced technology, currently unavailable, were used in place of the current technology. The potential (MW_t) that is not feasible is from heat sources below 300°F. The cogeneration potential was calculated separately for both large and medium facilities. Based on the number of facilities in each segment, the total cogeneration potential for the SCE service territory is estimated to be 3667 MW_e. The uncertainty associated with this estimate can be expressed by a confidence interval. The 95% confidence interval for the estimate is 2745 MW_e to 4589 MW_e, which contains the true value with probability 0.95. The potential that was considered not feasible is 1611 MW_t, with a 95% confidence interval of 1209 MW_t to 2013 MW_t. A further breakdown of these estimates by size of facility and for current and advanced technology is presented in Table 3-1.

Table 3-1. Cogeneration Potential (MW_e)

Category	All Facilities	Large Facilities	Medium Facilities
Current Technology	2569 ± 666	1069	1500 ± 666
Advanced Technology	1098 ± 304	286	812 ± 304
TOTAL	3667 ± 922	1355	2312 ± 922
Not Feasible (MW_t)	(1611 ± 402)	706	905 ± 402

To gain further insight into the potential sources for cogeneration, the estimates were grouped by economic sector, by type of process, and by seasonal energy fluctuations.

The breakdown of the cogeneraton potential by economic sector is presented in Table 3-2. While the manufacturing sector has the highest average potential for current technology, the mining sector has the most potential for advanced technology.

Table 3-2. Cogeneration Potential by Economic Sector (Average MW_e)

Sector	With Current Technology	With Advanced Technology	Number of Facilities
Manufacturing	24.9	6.1	26
Mining	10.6	9.3	6
Transportation	5.0	2.5	5
Government	2.4	1.9	4
Other*	0.7	0.6	9

*Includes trade, finance, and services.

Average cogeneration potential by type of process, for facilities both with and without the process, is listed in Table 3-3. Most of the current potential comes from boilers and waste streams; with advanced technology, there is a gain of about 30% for each. With direct-fired processes, the average potential is relatively small for both current and advanced technology, but the gain with advanced technology is about 80%.

Table 3-3. Cogeneration Potential by Type of Process (Average MW_e)

Process	With Current Technology	With Advanced Technology	Number of Facilities
A. With Boilers	21.9	6.3	33
Without Boilers	1.7	1.9	18
B. With Waste Streams	22.3	6.5	29
Without Waste Streams	5.1	2.4	21
C. With Direct-Fired	4.6	3.8	33
Without Direct-Fired	33.5	6.4	18

Finally, the effect of seasonal energy peaking on cogeneration potential is indicated in Table 3-4. Estimated potential is related to actual peaks in energy demand for facilities. For facilities that have electricity peaks, peaking tends to occur in the summer and is coincident with the most potential for both current and advanced technologies in this group. For facilities that have seasonal peaks for natural gas, peak use tends to occur in the winter and is coincident with the most potential in this group. However, the potential gained from facilities with natural gas peaking is significantly higher than from facilities with electricity peaking.

Table 3-4. Cogeneration Potential by Seasonal Energy Fluctuations (Average MW_e)

Season		With Current Technology	With Advanced Technology	Number of Facilities
ELECTRICITY	Winter (Dec - Feb)	5.5	2.4	4
	Spring (Mar - May)	-	-	0
	Summer (Jun - Aug)	7.3	3.5	15
	Fall (Sep - Nov)	0.5	0.5	6
	No Seasonal Peaks	23.9	6.7	26
NAT. GAS	Winter (Dec - Feb)	26.3	4.6	20
	Spring (Mar - May)	-	-	0
	Summer (Jun - Aug)	11.3	4.2	5
	Fall (Sep - Nov)	3.4	0.9	3
	No Seasonal Peaks	9.5	7.2	17

B. MAJOR FACTORS THAT PREDICT COGENERATION POTENTIAL

Correlation analyses were performed to identify those factors that would be most likely to predict cogeneration potential. The correlation coefficients for a number of variables tested against the estimated potential are listed in Table 3-5.[5] From this analysis, the use of natural gas is a significant

[5] Correlation coefficients are indices of linear association, varying from -1.00 to + 1.00. The significance tests indicate the likelihood that a correlation could be due to chance and is based on a theoretical sampling distribution. Generally, if the likelihood that the particular correlation is due to chance is less than 5% ($p \leq .05$) or less than 1% ($p \leq .01$), the correlation is treated as a "real" effect. Otherwise, it is considered the same as a zero correlation.

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Table 3-5. Correlation (r) of Various Variables with Cogeneration Potential

Variable	With Current Technology	With Advanced Technology
Large Facility	0.29*	0.41**
1982 Nat. Gas Use	0.49***	0.61***
1982 Electricity Use	0.11	0.43**
Number of Employees	-0.01	0.03
Number of Days Operate Per Week	0.19	0.32*
Number of Shifts Per Day	0.14	0.19
% Energy Cost/Product Cost	-0.01	0.03
Seasonal Energy Fluctuation	0.09	-0.06
Boilers	0.15	0.19
Direct-Fired Process	-0.21	-0.11
Waste Streams	0.13	0.18
Liquid Streams	0.27	0.32*
Gas Streams	0.20	0.23

*Significant at $p \leq .05$
** Significant at $p \leq .01$
*** Significant at $p \leq .001$

indicator of cogeneration potential for both current and advanced technologies, as one would naturally expect. Because fuel oil is not widely used in Southern California, its use was not evident in the analysis. Of special interest, however, is the significance of electricity use as an indicator of potential with advanced technology, where there is not a significant relationship for current technology. The basis for this result is not fully understood at this time. Correlation analyses were performed to establish the basis for the result, and it appears to be related to the presence of direct-fired processes. Facilities with direct-fired processes typically use electricity to fuel these processes and there appears to be a potential with advanced technology. Any further explanation of the relationship, generally, was not found.

Other factors that correlate well with cogeneration potential are the size of the facility and, for advanced cogeneration, the number of days per week in operation and the presence of liquid waste streams. The number of days per week can be explained because it is another indicator of the size of the facility, which is shown in Section III.C.

C. OTHER RELATED FACTORS

The annual energy use in 1982 by economic sector is listed in Table 3-6. The manufacturing and mining sectors are the biggest electricity users and the mining and transportation sectors are the biggest natural gas users. The use of natural gas and electricity has a different composition across industry sectors. The column headed "Sector E/G Ratio" is the ratio of electricity use to gas use (total electricity use divided by total natural gas use x 100), by sector, which demonstrates the nature of that difference. Notice, in particular, that the "Other" category, which includes primarily the service sector, uses a lot of electricity relative to gas, probably because it has more air conditioning and lighting requirements. The manufacturing sector also uses a lot of electricity and, as discussed previously in Section II.A., this sector also has the largest cogeneration potential with current technology.

Table 3-6. Annual Energy Use in 1982 by Economic Sector

Sector	Average Electricity Use (10^6 kWh)	Average Nat. Gas Use (10^9 Btu)	Sector E/G Ratio
Manufacturing	75.5	909.1	8.3
Mining	67.2	3673.7	1.8
Transportation	47.1	3662.7	1.3
Government	8.9	438.5	2.0
Other	17.6	59.7	29.5

The size of facilities was determined based on electricity demand or the size/number of boilers and is associated with some basic differences in operation which are highlighted in Table 3-7. Large facilities not only consume more electricity and natural gas, but also are more likely to have boilers, waste heat streams (especially liquid streams), and waste heat recovery systems. Because the facilities consume larger quantities of energy, they typically will generate higher temperatures and will have more excess heat available in their waste heat streams. At the same time, there are no significant differences in the use of ovens and other direct-firing processes, in gas streams, in combustible waste products, and the proportion of total

Table 3-7. Size Differences for Selected Variables

Variables	Large Facilities	Medium Facilities	Statistical Significance
1982 Electricity Use (10^6 kWh)	125.8	22.4	***
1982 Nat. Gas Use (10^9 Btu)	2292.1	575.6	*
Boilers (%)	94.1	50.0	**
Number of Boilers	4.8	0.9	***
Direct-Fired Process (%)	58.8	68.4	n.s.
Waste Heat Streams (%)	82.4	48.6	*
Liquid Stream (%)	58.8	13.2	***
Gas Stream (%)	52.9	34.2	n.s.
Combustible Waste Products (%)	35.3	31.6	n.s.
Waste Heat Recovery Systems (%)	76.5	42.4	*
Energy Cost/Product Cost (%)	23.1	14.6	n.s.
Number of Days Per Week	6.4	5.7	*
Number of Shifts Per Day	2.6	2.1	*

n.s. Not significant
* Significant at $p \leq .05$
** Significant at $p \leq .01$
*** Significant at $p \leq .001$

Table 3-8. Positive Cogeneration Potential Suggested by Previous Feasibility Study

Sector	% of Firms
Government	50.0
Transportation	40.0
Manufacturing	24.1
Mining	16.7
Other	10.0

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product cost consumed by energy (large facilities are higher on these variables, but not significantly so).

Facilities were asked whether they had conducted a feasibility study for cogeneration and if so, did it indicate any cogeneration potential. Table 3-8 lists the percentage of firms, by sector, for which previous cogeneration feasibility studies had indicated cogeneration potential. These results are contrary to the results presented in Table 3-2. To better understand the underlying factors for those facilities that conducted feasibility studies, a correlation analysis was performed. Table 3-9 lists the correlation coefficients for a number of variables tested against positive results for cogeneration from feasibility studies.

Table 3-9. Correlation of Previous Feasibility Study Results

Variable	Correlation (r)
Large Facilities	0.15
1982 Natural Gas Use	0.03
1982 Electricity Use	0.31*
Number of Employees	0.29*
Number of Days Operate Per Week	0.35**
Number of Shifts Per Day	0.25
Energy Cost/Product Cost	0.11
Seasonal Energy Fluctuations	-0.22
Boilers	0.27*
Direct-Fired Processes	0.01
Waste Streams	0.15
Liquid Streams	0.39**
Gas Streams	0.18

* Significant at $p \leq .05$

** Significant at $p \leq .01$

Because of the significant relationship between electricity use and suggested potential (0.31) and the insignificant relationship between gas use and suggested potential (0.03), it is possible that previous feasibility studies that showed positive cogeneration potential may not be reliable and industry may be operating and making decisions without good information.

Finally, the effects of size differences related to whether a facility had taken steps to adopt conservation measures or had considered cogeneration

Table 3-10. Size Differences for Conservation Measures and Cogeneration Considered

Variable	Large Facilities %	Medium Facilities %	Statistical Significance (P)
Study Suggests Cogen Feasibility	35.3	21.1	n.s.
Conservation Measures			
Lighting	88.2	84.2	n.s.
Heating	82.3	62.5	n.s.
Air Conditioning	75.0	64.7	n.s.
Insulation	68.8	85.3	n.s.
Vehicle Fleet Management	56.3	51.5	n.s.
Conservation During Production	87.5	90.3	n.s.
Other Measures	50.0	31.7	n.s.
Energy Audit Taken	94.1	68.4	*
Formal Energy Policy	94.1	57.7	**
Priority of Conservation During Production (5-Point Scale)	4.5	3.7	**
Energy Office	93.8	81.6	n.s.
Perceived Obstacles to Effective Energy Management	37.5	51.4	n.s.

* Significant at $p \leq .05$
** Significant at $p \leq .01$
n.s. Not significant

were evaluated. Table 3-10 indicates these differences. There are a few variables for which there are significant differences between large and medium facilities. Large facilities are more likely to have conducted an energy audit and are more likely to have a formal energy policy; they also place a higher priority on conservation during the production process. In terms of specific conservation measures taken, large facilities are slightly more likely (but not significantly so) to have enacted measures in lighting, heating, and air conditioning. On the other hand, medium facilities are slightly more likely to have installed insulation than large facilities. When the number of types of conservation measures are totalled (data not presented), large facilities have installed, on average, more types of conservation measures than medium facilities.

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Energy policy variables do not have a direct relationship with cogeneration potential. However, large facilities have been slightly more willing to adopt conservation measures, suggesting they might be more willing to adopt cogeneration. Up to now, very few of the facilities sampled had adopted cogeneration (one facility had cogeneration equipment and two more were in the process of installing cogeneration).

Table 3-11 indicates the percent of facilities that have considered installing cogeneration, broken down by economic sectors. The manufacturing sector has been the slowest, in general, to consider cogeneration; less than half have done so. However, as was shown earlier, the potential for cogeneration technology is greatest in the manufacturing sector, especially with current technology. It appears that the manufacturing sector is the most likely target for cogeneration.

Table 3-11. Facilities That Have Considered Installing a Cogeneration System by Economic Sector

Sector	% of Firms
Other	70
Mining	67
Transportation	60
Government	50
Manufacturing	45

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APPENDIX A

QUESTIONNAIRE AND FINAL FREQUENCIES

ID#:

___ (1-3)

FINAL FREQUENCIES

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FIRM I.D.#: ____________

CARD#: 1 (4)

S.C.E. COGENERATION SURVEY

FIRM NAME: ______________________ CITY/STATE: ____________

CONTACT PERSON: ______________________

TELEPHONE #: ________ / ______________
AREA CODE

TIME BEGINNING: ______ AM PM   TIME ENDING: ________ AM PM   TOTAL # OF MINUTES: *$\bar{X}$ = 33.019 MED = 30.15*

#MINUTES: ___ (5-6)

OF MINUTES INTERRUPTION: ____________

RECORD OF CONTACT ATTEMPTS

DATE	DAY OF WK	TIME	RESULT	INTERVIEWER I.D.#.	COMMENTS
1.		AM PM			
2.		AM PM			
3.		AM PM			
4.		AM PM			

#CALLS: ___ (7)

IF CONTACT CANNOT BE REACHED ON THIRD ATTEMPT, USE A PROXY CONTACT - A PERSON WHO IS KNOWLEDGEABLE ABOUT ENERGY USE IN FIRM.

RESULT

R NOT AVAILABLE ....SPECIFY ABOVE...01
CALL BACK ARRANGED..SPECIFY ABOVE...02
R REFUSED..........SPECIFY ABOVE...03
TERMINATED.........SPECIFY ABOVE...04
INCAPABLE..........SPECIFY ABOVE...05
COMPLETED WITH R....................06
COMPLETED WITH PROXY................07
INCOMPLETE..........................08
OTHER..............SPECIFY ABOVE...09

	DATE	INITIAL
LOGGED OUT		
LOGGED IN		
EDITING COMPLETE		

	DATE	INITIAL
CODING COMPLETE		
KEYPUNCHED		
KEYPUNCHED VERIFIED		

1

ASK TO CONTACT PERSON

(Good morning/afternoon/evening). I'm ____________________ from the Jet Propulsion Laboratory in Pasadena, California. We are conducting a survey for the Southern California Edison Company of organizations that use sizeable amounts of process heat. The purpose of the survey is to estimate the potential amount of electricity which could be generated with industrial process heat as a by-product. This will help SCE in planning electricity demand over the next few years.

Your firm has been systematically selected from all heat-producing firms in the Southern California area.

B1. I need to talk to the plant engineer or highest-ranking technical person responsible for energy consumption in your organization. Who would that be?

IF MORE THAN ONE PERSON MENTIONED, ASK: Which one of these persons would know the most about all heat processes and the amount of fuel going into these processes?

NAME: ______________________________

TITLE: ______________________________

TELEPHONE: ________/____________________
AREA CODE

I.D.#: ______________________ CONFIDENTIAL

I would like to read an informed consent statement to you.

We would like to obtain information about your organization's heat processes, the energy sources that feed into these processes, and some aspects of energy management in your organization. The informaton we obtain from this survey will be used in preparing an estimate of the amount of electricity that could be produced using both current and advanced cogeneration technology. Southern California Edison Company is seeking this information as part of their planning of electricity supply and demand over the next few years and as part of their strategy to promote cogeneration development.

The interview will take approximately 50 minutes. All information will be protected by the Jet Propulsion Laboratory and Southern California Edison Company.

1. No information about individual firms will be released to the public or industry. Only group results for the entire sample will be released.

2. None of the information you provide will be shown to any person at the Jet Propulsion Laboratory outside the survey team or at Southern California Edison Company other than key individuals that are involved in cogeneration studies.

3. If your responses to the questionnaire suggest a positive cogeneration potential, your organization may be contacted by a representative from Southern California Edison Company to further explore this potential.

Your participation in this survey is entirely voluntary and you may refuse to answer any question or terminate the interview at any time. However, your cooperation is very important because Southern California Edison is compiling a comprehensive set of information on heat processes to plan accurately for future electricity supply and demand and to accelerate the adoption of cogeneration equipment. The information you provide will help in assessing the potential for cogeneration technology.

INTERVIEWER ACKNOWLEDGES READING INFORMED CONSENT STATEMENT.

______________________________ ______________

INTERVIEWER SIGNATURE DATE

(1)

I.D.#: ______________________ CONFIDENTIAL

TIME BEGINNING: ______________________ AM / PM

First, I'd like to ask you some questions about your firm.

1. What kind of organization are you? What do you make or do? RECORD VERBATIM.

Q1 -SIC ___ ___ ___ ___ (8-11)

2. What are your major energy-intensive products (processes), that is products (processes) which consume a large amount of energy? LIST IN ORDER OF MENTION UP TO FIVE MENTIONS.

PRODUCT#1: ______________________

PRODUCT#2: ______________________

PRODUCT#3: ______________________

PRODUCT#4: ______________________

PRODUCT#5: ______________________

Q2

1: ___ ___ ___ (12-14)

2: ___ ___ ___ (15-17)

3: ___ ___ ___ (18-20)

4: ___ ___ ___ (21-23)

5: ___ ___ ___ (24-26)

3. On average, what percentage of your total product costs (operating costs) are energy costs? (the cost of all energy sources - gas, electricity, fuel oils)

IF UNSURE, ASK: Approximately what percentage of the total product cost does energy account for? A rough estimate is all we need.

PERCENTAGE OF TOTAL PRODUCT COST ACCOUNTED FOR BY ENERGY: $\bar{X}$ = 17.711 MED = 12.5 %

Q3

27 28

①

4. In your firm at this location, how many employees are there? RECORD NUMBER. Q4

IF UNSURE, ASK: Approximately how many employees are there? A rough estimate is all that we need.

NUMBER OF EMPLOYEES IN FIRM AT THIS LOCATION: $\bar{X}$ = 987.418 MED = 240

29 30 31 32

A. Compared to the output of other manufacturing firms (organizations similar to yours), would you describe your firm as: Q4A

Very Large,..............12..............5

Large,..............20..............4

Medium,..............16..............3

Small, or..............6..............2 33

Very Small?..............1..............1

TOTAL 55

5. On average, how many days a week do you operate? (produce/service). RECORD NUMBER OF DAYS. Q5

AVERAGE NUMBER OF DAYS PER WEEK FIRM OPERATES: $\bar{X}$ = 5.927 MED = 5.6

34

6. Typically, how many shifts do you run each day? RECORD NUMBER. Q6

TYPICAL NUMBER OF SHIFTS PER DAY: $\bar{X}$ = 2.291 MED = 2.469

35

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(1)

Now I'd like to ask you some questions about any industrial heating processes that your organization operates.

7. Does your organization use steam from a boiler for industrial or commercial processes? Q7

YES.....35......ASK A.................1

NO.....20......SKIP TO Q8, p. 8..........2 36

A. How many boilers does your organization normally operate? RECORD NUMBER. Q7A

NUMBER OF BOILERS NORMALLY OPERATING: $\bar{X} = 3.294$ MED = 2.045 37 38

B. What is the major fuel source used for the boilers? Is it: CIRCLE APPROPRIATE CODE. Q7B

Natural Gas,..............24..........1

Electricity,..............1...........2

Fuel Oil,..............2..........3 39

SPECIFY TYPE: ________________

Coal, or..............................4

Something Else?..............8..........5

SPECIFY: ________________

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(1)

Q7 (continued)

C. On average, how much (...) is used each month to heat the boilers? INSERT NAME OF FUEL SOURCE FOR (...). RECORD AMOUNT. BE SURE TO SPECIFY UNITS

Q7C ($x10^9$)

AVERAGE QUANTITY OF FUEL USED PER MONTH: $\bar{X}$ = 129.79×10⁹ MED = 16.017×10⁹ ~~KTHERMS KWH KGALS TONS~~ Btu OTHER → ______: SPECIFY

40 41 42 43

D. On average, how much steam does/do your boiler(s) produce? (a typical amount of steam for an average use). RECORD AVERAGE CAPACITY.

Q7D ($x10^3$)

AVERAGE AMOUNT OF STEAM: $\bar{X}$ = 65.177 MED = 25.5 LBS/HOUR

44 45 46

E. What is the typical temperature (Fahrenheit) at the boiler exits? RECORD TEMPERATURE.

Q7E

TYPICAL TEMPERATURE AT BOILER EXITS: $\bar{X}$ = 426.9 MED = 362.5 °F

47 48 49 50

F. What is the typical pressure inside the boiler (pounds per square inch)? RECORD PRESSURE.

Q7F

TYPICAL PRESSURE INSIDE BOILER: $\bar{X}$ = 198.636 MED = 140 PSI

51 52 53

G. What the typical temperature (Fahrenheit) at the boiler stack?

Q7G

TYPICAL TEMPERATURE AT BOILER STACK: $\bar{X}$ = 429.464 MED = 400.833 °F

54 55 56 57

END CARD 1

START CARD :

ID#:

1 2 3

CARD#:

2
4

Q7 (continued)

H. What are the major processes which require steam?
LIST PROCESSES UP TO FIVE MENTIONS. RECORED IN COLUMN A.

I. FOR EACH PROCESS MENTIONED, ASK: What is the temperature required for (...)? INSERT NAME OF PROCESS FOR (...). RECORD IN COLUMN B.

II. FOR EACH PROCESS MENTIONED, ASK: What is the pressure required for (...)? INSERT NAME OF PROCESS FOR (...)? RECORD IN COLUMN C.

III. FOR EACH PROCESS MENTIONED, ASK: On average, how many pounds of steam are required for each hour of (...)? INSERT NAME OF PROCESS FOR (...). RECORD IN COLUMN D.

A PROCESS	B TEMPERATURE(F°)	C PRESSURE	D POUNDS OF STEAM PER HOUR
1.			
2.			
3.			
4.			
5.			

8. Does your firm use direct-fuel heating processes, such as ovens, furnaces, kilns or dryers?

YES..........36.....ASK A............1 5

NO..........19.......SKIP TO Q9........2

A. What are the major direct-fuel heating processes? LIST PROCESSES UP TO FIVE MENTIONS. RECORD IN COLUMN A.

I. FOR EACH PROCESS MENTIONED, ASK: What is the temperature required for (...)? INSERT NAME OF PROCESS FOR (...). RECORD IN COLUMN B.

II. FOR EACH PROCESS MENTIONED, ASK: What is the major fuel source for (...)? Is it natural gas, electricity, fuel oil, or something else? INSERT NAME OF PROCESS FOR (...). RECORD IN COLUMN C.

III. FOR EACH PROCESS MENTIONED, ASK: On average, how much (natural gas/electricity/fuel oil/other) is used each month for (...)? USE MAJOR FUEL SOURCE. INSERT NAME OF PROCESS FOR (...). RECORD IN COLUMN D.

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(2)

Q8 (continued)

A PROCESS	B TEMPERATURE	C MAJOR FUEL SOURCE	D MONTHLY QUANTITY OF FUEL SOURCE
1.		NAT.GAS.......28..1 ELECTRICITY....3....2 FUEL OIL..........3 TYPE: ______ OTHER:.........4...7 TYPE: ______	
2.		NAT.GAS......16...1 ELECTRICITY...2...2 FUEL OIL..........3 TYPE: ______ OTHER:........2..7 TYPE: ______	
3.		NAT.GAS........6...1 ELECTRICITY....2..2 FUEL OIL..........3 TYPE: ______ OTHER:...........2..7 TYPE: ______	
4.		NAT.GAS.......1....1 ELECTRICITY....1....2 FUEL OIL..........3 TYPE: ______ OTHER:...........2..7 TYPE: ______	
5.		NAT.GAS.......1....1 ELECTRICITY........2 FUEL OIL..........3 TYPE: ______ OTHER:..........1...7 TYPE: ______	

Q8

PROCESS

1: __ __ 6 7
2: __ __ 8 9
3: __ __ 10 11
4: __ __ 12 13
5: __ __ 14 15

FUEL

1: __ 16
2: __ 17
3: __ 18
4: __ 19
5: __ 20

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(2)

9. Do you have any processes which are heated by another source other than boilers or direct-fuel firings, for example solar, biomass or waste products? Q9

YES........4.....ASK A..................1
NO........51.....SKIP TO Q10............2 ‾21

A. What type of heat source is it? Could you describe it briefly and the type of process for which it is used? RECORD VERBATIM Q9A

SOLAR POND 1
METHANE 1
EXOTHERMIC REACTOR 1

‾22 ‾23

B. What is the total capacity or amount of heat produced by this heat source (in Btu per hour)? RECORD AMOUNT. BE SURE TO SPECIFY UNITS IF NOT IN BTU/HOUR. Q9B ($x10^6$)

CAPACITY OF HEAT FROM ALTERNATIVE HEAT SOURCE: ONLY 1 RESPONSE OUT OF 55 2240 BTU/HOUR

‾24 ‾25 ‾26 ‾2

C. What is the typical temperature (Fahrenheit) of the heat stream produced by this heat source? RECORD TEMPERATURE. Q9C

TYPICAL TEMPERATURE OF ALTERNATIVE HEAT SOURCE: ONLY 2 RESPONSES OUT OF 55 95 & 180 °F

‾28 ‾29 ‾30 ‾3

10. Are there any waste heat streams in your industrial or commercial processes? (effluent streams) Q10

YES......32....ASK A..................1
NO......22....SKIP TO Q11............2 ‾32

Q10 (continued)

Q10A

A. Are there any liquid waste streams?

YES......15......ASK I.................1

NO......19......SKIP TO B.............2

33

I. How many liquid waste streams are there? RECORD NUMBER.

NUMBER OF LIQUID WASTE STREAMS: $\bar{x}$ = 10.462 MED = 1.312

II. FOR EACH STREAM, ASK: What does the stream consist of? LIST SUBSTANCE UP TO FIVE MENTIONS, RECORD IN COLUMN A.

III. FOR EACH STREAM, ASK: From what process does the stream come from? RECORD IN COLUMN B.

IV. FOR EACH STREAM, ASK: What is the temperature of the stream? RECORD IN COLUMN C.

V. FOR EACH STREAM, ASK: What is the flow rate of the stream? (capacity in gallons per minute). RECORD IN COLUMN D.

A SUBSTANCE	B PROCESS	C TEMPERATURE(°F)	D FLOW RATE GALS/MINUTE	LIQUID
LIQUID#1: WATER (17)				1: 34 35
LIQUID#2:				2: 36 37
LIQUID#3:				3: 38 39
LIQUID#4:				4: 40 41
LIQUID#5:				5: 42 43

Q10 (continued)

Q10B

B. Are there any gas waste streams, other than boiler stacks?

YES.......22....ASK I..................1

NO........12....SKIP TO C..............2

44

I. How many gas streams are there? RECORD NUMBER.

NUMBER OF GAS WASTE STREAMS: $\bar{x}$ = 4.05 MED = 2.5

II. FOR EACH STREAM, ASK: What is the gas in the stream? LIST GAS UP TO FIVE MENTIONS. RECORD IN COLUMN A.

III. FOR EACH STREAM, ASK: From what process does the stream come from? RECORD IN COLUMN B.

IV. FOR EACH STREAM, ASK: What is the temperature of the stream? RECORD IN COLUMN C.

V. FOR EACH STREAM, ASK: What is the flow rate of the stream? (capacity in cubic feet per hour). BE SURE TO SPECIFY UNITS IF OTHER THAN CU.FT/HR. RECORD IN COLUMN D.

A SUBSTANCE	B PROCESS	C TEMPERATURE(°F)	D FLOW RATE CU.FT/HR.	GAS/ SUBSTANCE
GAS#1: COMBUSTION PRODUCTS (11)				1: 45 46
GAS#2: AIR (5)				2: 47 48
GAS#3: NAT GAS (4)				3: 49 50
GAS#4: STEAM (3)				4: 51 52
GAS#5:				5: 53 54

2

Q10 (continued)

C. How clean are the waste streams (either liquid or gas)? Would you say:

			Q10C
Very Clean,	6	4	55
Clean,	17	3	
Dirty, or,	5	2	
Very Dirty?	1	1	

D. Could the waste streams be used in heat exchangers to extract heat?

			Q10D
YES	22	1	56
NO	7	2	

11. Do you have any waste products that are combustible? (waste products you currently are not using and could be burned)

				Q11
YES	18	ASK A	1	57
NO	37	SKIP TO Q12	2	

A. What waste products do you have that are combustible? RECORD IN ORDER OF MENTION UP TO THREE MENTIONS. RECORD IN COLUMN A.

B. What is the average amount monthly of (...) that you accumulate? INSERT NAME OF WASTE PRODUCT FOR (...). RECORD IN COLUMN B. BE SURE TO SPECIFY UNITS.

	A: WASTE PRODUCTS	B: AVERAGE MONTHLY AMOUNT	UNITS
WASTE #1:	PAPER TRASH 13		
WASTE #2:	WOOD 2		
WASTE #3:			

Q11A

WASTE

1: 58 59

2: 60 61

3: 62 63

END CARD 2

START CARD

ID#: ___ ___ ___ (1 2 3)

CARD#: 3 (4)

12. Do you currently have any waste heat recovery systems? — Q12 (5)

YES.......27....ASK A..................1

NO.......23.....SKIP TO Q13............2

A. What type of waste heat recovery system do you have? RECORD VERBATIM. — Q12A (6 7)

HEAT EXCHANGER 21
CONVECTION SECTIONS 3
CONDENSATE RECOVERY 2

B. From which processes does the waste heat come from? RECORD VERBATIM. — Q12B 1: (8 9 1) 2: (11 12 1)

BOILERS 12
CHILLERS 2

C. What do you use the waste heat for? RECORD VERBATIM. — Q12C 1: (14 15) 2: (16 17)

PREHEAT BOILER WATER 14

13. Do you currently have any on-site electricity generation (for current or back-up use)? — Q13 (18)

YES.......18....ASK A..................1

NO........37....SKIP TO E..............2

A. Do you generate electricity with a separate generator or with a co-generation system (using heat to generate electricity)? — Q13A (19)

SEPARATE
GENERATOR.....15.SKIP TO E.............1

CO-GENERATION
SYSTEM.........1..ASK B.................2

BOTH..........2.ASK B..................3

B. Is your co-generation system a topping cycle or a bottoming cycle? — Q13B (20)

TOPPING CYCLE..................1........1

BOTTOMING CYCLE.........................2

Q13 (continued)

C. What is the rated kilowatt (kW_e) capacity of the system? (power) | Q13C | 21 22 23 24

RATED KILOWATT CAPACITY OF CG SYSTEM ONLY 2 RESPONSES 14 & 3500 kW_e

D. Does your firm sell any excess electricity to local utilities? | Q13D | 25

YES....../.........ASK a..................1

NO....../.........SKIP TO Q14............2

a. On average, how many kilowatt-hours of electricity are sold monthly to local utilities? RECORD AMOUNT. BE SURE TO SPECIFCY UNITS IF OTHER THAN KWH. | Q13Da

AVERAGE MONTHLY ELECTRICITY SOLD TO UTILITIES: ONLY 1 RESPONSE 5000 KWH | 26 27 28 29

SKIP TO Q 14

E. Has your firm ever conducted a feasibility study for co-generation? | Q13E | 30

YES.......26....ASK a..................1

NO.......28.....SKIP TO F..............2

a. Did the feasibility study indicate that there was sufficient potential for co-generation or did the study show that there was not sufficient potential for co-generation? | Q13Ea | 31

SUFFICIENT POTENTIAL...............14..............1

NOT SUFFICIENT POTENTIAL...............11..............2

Q13 (continued)

F. Has your organization ever considered installing co-generation equipment? — Q13F

YES.......................30..........1 — 32

NO........................23..........2

Now I'd like to ask you some questions about your general energy consumption in your firm at this location. — Q14 ($\times 10^6$)

14. Let's start with electricity consumption. What was your annual kilowatt-hour consumption in 1982? RECORD AMOUNT. — 33 34 35

IF UNSURE, ASK: Approximately what was the annual electricity consumption in kilowatt-hours? A rough approximation is all we need.

ANNUAL
KWH
CONSUMPTION $\bar{X} = 54.738$
FOR 1982: MED = 11.05 kWh $\times 10^6$

A. In 1982, what was your peak power load during the entire year (kW_e) (15 minute load) RECORD AMOUNT. BE SURE TO SPECIFY WHETHER KW_e or MW_e. — Q14A ($\times 10^3$)

36 37

PEAK
POWER LOAD $\bar{X}$ 16.497 kW_e
FOR 1982: MED 7.4 (MW_e)

B. Do you have seasonal (monthly) fluctuations in your power loads? — Q14B

YES......28....ASK a.................1 — 38

NO.......27....SKIP TO C.............2

a. In what month is your peak power load? RECORD MONTH. — Q14Ba

39 40

MONTH $\bar{X} = 8.107$
FOR PEAK
POWER LOAD: MED = 8.115

C. Do you have any daily (hourly) fluctuations in your firm's power load? (kilowatts) — Q14C, 41

YES.......29.......ASK a..................1

NO........25.......SKIP to Q15............2

a. During which hour of the day is your peak power load? RECORD HOUR. IF MORE THAN ONE, SPECIFY EACH. — Q14Ca, 1: 42 43, 2: 44 45

HOUR FOR PEAK POWER LOAD: $\bar{X}$ = 16.552 MED = 14.8 AM PM

15. Now, let's talk about gas consumption (natural gas). What was your annual gas consumption in 1982? RECORD AMOUNT. BE SURE TO SPECIFY UNITS. — Q15 (x10[9]), 46 47 48 4·

IF UNSURE, ASK: Approximately what was the annual gas consumption? A rough approximation is all we need.

ANNUAL NATURAL GAS CONSUMPTION IN 1982: $\bar{X}$ = 1103.803 MED = 211.0 BTU × 10[9] ~~THERMS~~ ~~CU. FT.~~

A. Do you have seasonal (monthly) fluctuations in your gas consumption? — Q15A, 50

YES.......28.......ASK a..................1

NO........19.......SKIP TO B..............2

a. In what month is your peak gas consumption? RECORD MONTH. — Q15Aa, 51 52

MONTH FOR PEAK GAS CONSUMPTION: $\bar{X}$ = 5.143 MED = 2.346

Q15 (continued)

B. Do you have any daily (hourly) fluctuations in your firm's gas consumption? — Q15B

53

YES.......24.....ASK a..................1

NO........22.....SKIP TO Q16............2

a. During which hour of the day is your peak gas consumption? — Q15Ba

HOUR FOR PEAK GAS CONSUMPTION: $\bar{X}$ = 11.261 MED - 11.0 AM PM

1: 54 55

2: 56 57

16. In your organization, has the balance between electricity, gas, (coal), and fuel oils (and other energy sources) remained relatively constant or has the balance changed? — Q16

58

BALANCED HAS REMAINED RELATIVELY CONSTANT....39..SKIP TO Q17........... 1

BALANCE HAS CHANGED..14.ASK A..................2

A. Is the relative price of the different energy sources the only factor affecting changes in the balance between the different energy sources or are there additional factors? — Q16A

59

PRICE ONLY FACTOR..........9..SKIP TO Q17............1

ADDITIONAL FACTORS........8...ASK B..................2

B. What additional factors are there, aside from price, that affects the balance between electricity, gas and fuel oils (and other energy sources)? RECORD VERBATIM. — Q16B

1: 60 61

2: 62 63

3: 64 65

17. Over the next few years, do you expect the prices of the different energy sources to change relative to each other? (for example, expect natural gas to become more expensive than electricity or vice versa). — Q17

66

YES.......35.....ASK A..................1

NO........12.....SKIP TO Q18............2

Q17 (continued)

Q17A

A. Which fuel source do you expect to become relatively more expensive than it is now? (relative to the price of other energy sources)

67 68

ELECTRICITY..........8..........01

NATURAL GAS..........23..........02

COAL..........03

FUEL OILS (OTHER THAN NATURAL GAS)......04

→ SPECIFY: ______________

OTHER..........5..........10

→ SPECIFY: BOTH GAS & ELEC

END CARD 3

START CARD

ID #: ___ ___ ___ (1 2 3)

CARD#: 4 (4)

Now I'd like to ask you some general questions about energy conservation and management in your firm.

18. Has your firm implemented conservation measures in: READ a-g. CIRCLE APPROPRIATE CODE.

		YES	NO	Q18
a.	Building lighting?	1 47	2 8	a: 5
b.	Space heating within buildings? (e.g., temperature control, thermostat adjustment, timeclocks)	1 34	2 15	b: 6
c.	Air conditioning of building?	1 34	2 16	c: 7
d.	Insulation of buildings, pipes, and equipment?	1 40	2 10	d: 8
e.	Vehicle fleet management programs? (gasoline and oil consumption for transportation vehicles)	1 26	2 23	e: 9
f.	Saving energy during the production process?	1 42	2 5	f: 10
g.	Any other sphere?	1 21	2 20	g: 11

SPECIFY: BUILDING DESIGN 3
COMPUTER CONTROL 3

g1: 12 13
g2: 14 15

A. IF ANY ITEM ANSWERED "YES", ASK: For all the conservation measures implemented, what is the expected time for a payback from these changes? (in years)

Q18A 16 17

TYPICAL TIME FOR PAYBACK FOR CONSERVATION MEASURES: $\bar{X}$=6.473 MED=2.033 YEARS

NO ITEM ANSWERED "YES"..................95

19. Has your firm ever conducted an energy conservation audit or conservation feasibility study?

Q19 18

YES.........42.......ASK A..................1

NO..........13.......SKIP TO Q20............2

A. What type of audit or feasibility study was it? RECORD VERBATIM.

Q19A 19 20

ELECTRIC AUDITS 8
SEVERAL TYPES 7
PROCESS AUDIT 5

4

Q19 (continued)

B. Who conducted the study? RECORD NAME OR TYPE OF ORGANIZATION. Q19B

21 22

PERSON OR ORGANIZATION WHO CONDUCTED CONSERVATION STUDY

IN-HOUSE	23
PRIV. CONSULT	10
SCE	7
SO CAL GAS	2

C. What proportion of the recommended changes have been implemented? Would you say: Q19C

23

All recommendations have been implemented,.......8.....4

Most recommendations have been implemented,.......22.....3

A Few of the recommendations have been implemented, or.......7.....2

None of the recommendations have been implemented?.......2.....1

20. Does your firm have a formal energy conservation program? (an explicit policy or program for energy conservation). Q20

24

YES.......38.......1

NO.......17.......2

21. Within the manufacturing section of your firm (within your organization), how high a priority is energy conservation? Would you say: Q21

25

A Very High priority,.......21.....5

a High priority,.......15.....4

a Moderate priority,.......15.....3

a Low priority, or,.......3.....2

a Very Low priority?.......1.....1

22. In your organization, is there a department, section or office responsible for energy management and planning? — Q22

YES.......46.....ASK A..................1 — 26

NO........8......SKIP TO Q23............2

A. What type of department, section or office is it? What is it called? RECORD VERBATIM. ENGINEERING 9 — Q22A

27 28

B. Approximately how many employees work within this department/ section/office on energy management and planning? RECORD NUMBER. — Q22B

29 30

NUMBER OF EMPLOYEES WORKING ON ENERGY MANAGEMENT: $\bar{X} = 8.619$ MED = 3.5

C. Approximately what proportion of their (his/her) working time is spent on energy-related issues? Would you say: — Q22C

Greater than 75%,...................9........5 — 31

Between 50% and 75%,..........6........4

Between 25% and 50%,..........3..........3

Between 10% and 25%, or.......14........2

Less than 10%?....................10.......1

D. With what part of the organizational line structure does this department/section/office belong? Is it part of production? Is it part of maintenance? Is it part of R&D? or what? CIRCLE APPROPRIATE CODE BUT OBTAIN SPECIFICS. — Q22D

CODE: 32

PRODUCTION.......................6.........1 — DETAIL: 33

SPECIFY: ____________

MAINTENANCE...................17.........2

SPECIFY: ____________

R&D..............................0.........3

SPECIFY: ____________

OTHER...........................17.........4

SPECIFY: ____________

Q22 (continued)

E. Does this department/section/office have direct access to top level management? (without having to go through intermediaries)

Q22E

YES.................41................1
NO..................4.................2

34

23. Are there any obstacles to effective energy management and planning within your firm?

Q23

YES......25.....ASK A..................1
NO.......28.....SKIP TO Q24............2

35

A. What are these obstacles? RECORD VERBATIM.

LIMITED FUNDS 11
PEOPLES' HABITS 6
PAYBACK PERIOD 4

Q23A

1: 36 37

2: 38 39

Finally, I'd like to ask you about technology development in general in your firm.

24. Does your firm conduct research and development (R&D) on any technology, whether it is energy-related or not?

Q24

YES........31....ASK A..................1
NO.........22....SKIP TO 25.............2

40

A. How high a priority is research and development within your firm? Would you say:

Q24A

A Very High priority,..............6......5
a High priority,..................16......4
a Moderate priority,...............5......3
a Low priority, or.................3......2
a Very Low priority?...............1......1

41

Q24 (continued)

B. In your firm, what is the longest acceptable time period for a pay-off from a technology which you have developed? (in general) (approximately)(the longest time period before the sales on the product pays back the cost of the R&D). Q24B 42 43

LONGEST
ACCEPTABLE
TIME PERIOD $\bar{X}=3.92$
FOR TECHNOLOGY
PAY-OFF: MED=3.0 YEARS

25. If I have any more questions, is it alright to telephone you back? Q25 44

YES..........51..........1

NO..........2..........2

On behalf of the Jet Propulsion Laboratory and the Southern California Edison Company, I would like to thank you for providing us with some very valuable information. Again, I would like to reassure you that all information will be protected.

TIME ENDING:________ AM/PM

POTENTIAL	$\bar{X}$	MED	
CURRENT	14.801	.902	MW_e
ADV. TECH	4.705	.803	MW_e
NOT FEASIBLE	10.376	.85	MW_t

CURRENT TECH: - 45 46 47 48 ($x10^9$)
ADVANCED TECH: - 49 50 51 52
NON-POTENTIAL: - 53 54 55 56

APPENDIX B
EQUATIONS

EQUATIONS

C_L = total cogeneration potential for large facilities

C_m = total cogeneration potential for medium facilities

C = total cogeneration potential for large and medium facilities = $C_L + C_m$

X_L = cogeneration potential for a large facility

X_m = cogeneration potential for a medium facility

X_{mp} = cogeneration potential for a medium facility having nonzero potential

N_L = total number of large facilities

n_L = number of large facilities in data base

N_m = total number of medium facilities

n_{mp} = number of medium facilities in sample having nonzero cogeneration potential

n_{mo} = number of medium facilities in sample having zero cogeneration potential

For large facilities

(1) $$C_L = \left[\frac{1}{n_L} \sum_{i=1}^{n_L} X_{Li}\right] N_L$$

For medium facilities, cogeneration potential is assumed to have the following structural characterization:

(2) $$\Pr(X_m = 0) = p$$
$$\Pr(X_m > 0) = q = 1 - p$$

The population mean and variance of X_{mp} are defined by

(3) $$E(X_{mp}) \equiv \mu_{mp}$$
$$V(X_{mp}) \equiv \sigma^2_{mp}$$

The sample mean and variance of X_{mp} are given by

(4) $$\bar{X}_{mp} = \frac{1}{n_{mp}} \sum_{i=1}^{n_{mp}} X_{mpi}$$ which is an unbiased estimater of μ_{mp}

$$s^2_{mp} = \frac{1}{n_{mp}-1} \sum_{i=1}^{n_{mp}} \left(X_{mpi} - \bar{X}_{mp}\right)^2$$ which is an unbiased estimater of σ^2_{mp}.

A 95% confidence interval for μ_{mp} is defined by

$$(5) \qquad Pr\left\{-t_{.025}(n_{mp} - 1) < \frac{\bar{X}_{mp} - \mu_{mp}}{s_{mp}/\sqrt{n_{mp}}} < t_{.025}(n_{mp} - 1)\right\} = .95$$

or, equivalently,

$$(6) \qquad Pr\left\{\bar{X}_{mp} - \frac{s_{mp}}{\sqrt{n_{mp}}} t_{.025}(n_{mp} - 1) < \mu_{mp} < \bar{X}_{mp} + \frac{s_{mp}}{\sqrt{n_{mp}}} t_{.025}(n_{mp} - 1)\right\} = .95$$

The expected value of C_m is given by

$$(7) \qquad E\,(C_m) = (p \cdot 0 + q \cdot \mu_{mp})\, N_m = q\, \mu_{mp}\, N_m$$

which follows from (2) and (3).

(6) and (7) can then be combined to derive

$$(8) \qquad Pr\left\{qN_m\left[\bar{X}_{mp} - \frac{s_{mp}}{\sqrt{n_{mp}}} t_{.025}(n_{mp} - 1)\right] < E(C_m) < qN_m\left[\bar{X}_{mp} + \frac{s_{mp}}{\sqrt{n_{mp}}} t_{.025}(n_{mp} - 1)\right]\right\} = .95$$

which defines a 95% confidence interval for $E(C_m)$. However, q is an unknown parameter in this representation.

We know that

$$(9) \qquad \hat{q} = \frac{n_{mp}}{n_{mp} + n_{mpo}} \text{ is an unbiased estimater of q.}$$

Therefore, we can combine (8) and (9) to find

$$(10) \qquad Pr\left\{\hat{q}N_m\left[\bar{X}_{mp} - \frac{s_{mp}}{\sqrt{n_{mp}}} t_{.025}(n_{mp} - 1)\right] < E(C_m) < \hat{q}N_m\left[\bar{X}_{mp} + \frac{s_{mp}}{\sqrt{n_{mp}}} + t_{.025}(n_{mp} - 1)\right]\right\} \simeq .95$$

which defines an approximate 95% confidence interval for $E(C_m)$.

From the definition of C we find

ORIGINAL PAGE IS
OF POOR QUALITY

$$E(C) = C_L + E(C_m) \tag{11}$$

Then we can combine (10) and (11) to derive

$$\Pr\left\{C_L + \hat{q}N_m\left[\bar{X}_{mp} - \frac{s_{mp}}{\sqrt{n_{mp}}}\, t_{.025}(n_{mp}-1)\right] < E(C) < C_L + \hat{q}N_m\left[\bar{X}_{mp} + \frac{s_{mp}}{\sqrt{n_{mp}}}\, t_{.025}(n_{mp} - 1)\right]\right\} \simeq .95 \tag{12}$$

This defines an approximate 95% confidence interval for E(C).