1997 FUEL SUBSTITUTION PROGRAM

FIRST YEAR LOAD IMPACT EVALUATION

FINAL REPORT

Study ID No. 1016

Prepared for

San Diego Gas & Electric
San Diego, California

Prepared by

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1 INTRODUCTION

1.1 INTRODUCTION

San Diego Gas & Electric (SDG&E) commissioned XENERGY Inc. to evaluate the first year load impacts of measures installed under its *1997 Fuel Substitution (FuelSub) Program*. These measures were installed to provide resource value by improving the energy efficiency of the facilities that participated in the *FuelSub Program*.

The overall objectives of SDG&E's *1997 Fuel Substitution Program First Year Load Impact Evaluation* were to:

- evaluate the gross and net load impacts of the measures installed at these facilities; and
- verify the physical installation of the measures identified in the program tracking system.

These objectives were accomplished using the following methodology:

- verifying the physical installation of the measures identified in the program tracking system (electronic and hard copy);
- gathering data through direct measurement, observation, and interviews with site personnel; and
- performing engineering analysis of energy impacts based on the data.

1.2 REPORT ORGANIZATION

The remainder of this report is organized as follows:

Section 2	Summary Load Impact Estimates
Section 3	Analysis of Load Impacts for Process Measures
Section 4	Analysis of Load Impacts for HVAC Measures
Appendix A	Table 6: Process Measures: Protocols for Reporting of Results of Impact Measurement Studies Used to Support an Earnings Claim
Appendix B	Table 6: HVAC Measures: Protocols for Reporting of Results of Impact Measurement Studies Used to Support an Earnings Claim
Appendix C	Table 7: Documentation Protocols for Data Quality and Processing

2 ANALYSIS AND RESULTS

2.1 INTRODUCTION

This section provides the analysis and results of the first year load impact evaluation for fuel substitution measures installed under SDG&E's *1997 Fuel Substitution Program*.

2.2 SUMMARY OF PROCESS MEASURES

Table 2-1 shows a summary of the ex post load impact evaluation for process measures.

Table 2-1
Ex Post Load Impacts
Process Measures
1997 Fuel Substitution Program Summary

	kWh Savings	kW Reduced	Therm Savings
EA Gross Impacts	2,043,510	507.56	-89,881
EA Net Impacts	1,702,099	413.18	-75,000
EP Gross Impacts	1,899,778	449.65	-57,000
EP Program NTGR	0.68	0.70	0.68
EP Net Impacts	1,286,324	313.96	-38,543
Gross RR	93.0%	88.6%	63.4%
Net Realization Rate	75.6%	76.0%	51.4%
No. Measures-Program	15		
No. Measures - Surveyed	5		
No. Projects-Program	6		
No. Projects-Surveyed	3		

2.3 SUMMARY OF HVAC MEASURES

Table 2-2 shows a summary of the ex post load impact evaluation for HVAC measures.

Table 2-2
Ex Post Load Impacts
HVAC Measures
1997 Fuel Substitution Incentive Program Summary

	kWh Savings	kW Reduced	Therm Savings
Ex Ante Gross Impacts	811,422	555.97	-32,514
Ex Ante Net Impacts	439,493	283.73	-17,611
Ex Post Gross Impacts	1,812,631	90.8	-72,763
Ex Post Program NTGR	0.42	0.42	0.42
Ex Post Net Impacts	721,135	11.76	-28,948
Gross Realization Rate	223.4%	16.3%	223.8%
Net Realization Rate	173.2%	13.44%	173.5%
No. Measures	21		
No. Projects	1		

3 PROCESS MEASURES

3.1 INTRODUCTION

This section provides the analysis and results of the first year load impact evaluation for fuel substitution measures installed under SDG&E's *1997 Fuel Substitution* (FS) *Program*. Section 3.2 provides a summary of this ex post load impact evaluation. Sections 3.3 through 3.5 are project-specific analyses conducted in this evaluation. Section 3.6 describes the estimation of program load impacts.

3.2 SUMMARY OF RESULTS

The projects installed under the program in 1997 are shown in Table 3-1. This table shows that the six projects were projected to save over 2 million kWh and reduce demand by approximately 500 kW, while consuming almost 90,000 therms of natural gas annually. On-site surveys and project-specific ex post load impact studies were conducted for three projects, comprising almost three-quarters of the ex ante load impacts for electricity and natural gas use.

Table 3-1
Process Measures
1997 Fuel Substitution Program Summary

				Ex Ante Gross Load Impacts		
Survey	**Project No.**	**Measure Description**	**Measure Quantity**	**kWh Savings**	**kW Reduced**	**Therm Savings**
yes	45329	Natural Gas Catalytic Thermoforming Heater	1	632,003	150.80	-26,963
yes	46972	Gas Fired Resistance Heaters for Standby Engines	3	499,320	60.00	-20,049
yes	49834	Natural Gas Fired Wastewater Concentrator	1	366,562	41.96	-18,029
no	46563	Gas Ovens/Paint, Cure, Putty	3	193,639	48.80	-9,438
no	46627	Steam Heater Exchanger	1	62,021	12.00	-3,024
no	47599	Natural Gas Steam Boilers	3	131,209	24.00	-5,601
no	47599	Natural Gas Steam Boilers	3	158,756	170.00	-6,777
Total			**15**	**2,043,510**	**507.56**	**-89,881**

Table 3-2 shows a summary of the ex post load impact evaluation.

Table 3-2
Ex Post Load Impacts
Process Measures
1997 Fuel Substitution Program Summary

	kWh Savings	kW Reduced	Therm Savings
Ex Ante Gross Impacts	2,043,510	507.56	-89,881
Ex Ante Net Impacts	1,702,099	413.18	-75,000
Ex Post Gross Impacts	1,899,778	449.65	-57,000
Ex Post Program NTGR	0.68	0.70	0.68
Ex Post Net Impacts	1,286,324	313.96	-38,543
Gross Realization Rate	93.0%	88.6%	63.4%
Net Realization Rate	75.6%	76.0%	51.4%
No. Measures-Program	15		
No. Measures - Surveyed	5		
No. Projects-Program	6		
No. Projects-Surveyed	3		

3.3 PROJECT NO. 45329 - NATURAL GAS CATALYTIC THERMOFORMING HEATER

3.3.1 Summary of Findings

The savings for this site were based on the installation of a natural gas catalytic heater to replace an electric quartz heater for thermoforming of plastic sheets. Table 3-3 shows a summary of the ex post evaluation. The results of the ex post evaluation was different than those of the ex ante estimate due to differences in the ex post operation and basecase from the ex ante assumptions. The result for therm impacts needs to be examined closely. The definition of the therm impact is therm saved. In this case, because of the fuel switching we see a decrease in gas consumed. This saves energy. However, when the realization rate is calculated the results in 42.2%. While this realization rate seems low, its inverse, 236.9%, may be a more appropriate value. This value indicates that the ex post therm impact estimate reduces gas consumption when compared with the ex ante estimate.

Table 3-3
Summary of Ex Post Load Impacts
Project No. 45329

	kWh	kW	Therms
Ex Ante	632,003	150.80	(26,963)
Ex Post	606,252	150.81	(11,380)
Realization Rate	95.9%	100.0%	42.2%

3.3.2 Facility Description

This site manufactures portable hot tub spas. There are two electric quartz resistance-type heating lines and two natural gas catalytic heating lines used to thermoform plastic sheets into spa tub basins. Flat ABS plastic sheets are suspended between heat sources to soften them for molding. Through carefully controlled heating, the sheets are softened until they deform a predetermined amount. Softened sheets are pressed into molds to form finished tub basins. Molded tubs are then trimmed and staged for the assembly line.

3.3.3 Overview of Facility Schedule

This facility operates 20 hours per day, four days per week, except during eight holiday periods when the plant is shut down. The plant runs at capacity during the summer months, utilizing four thermoforming heaters. During the balance of the year production levels are reduced.

The current shift schedule is two ten-hour shifts per day, four days per week for production workers, and one ten-hour shift per day, four days per week for assembly line and office workers. Currently the plant is operating four molding heaters.

In calendar year 1998, the first complete year of savings for this measure at this site, the ex post hours of operation are shown in Table 3-4.

Table 3-4
1998 Plant Operation Schedule
Project No. 45329

Day of the Week	Start Time	End Time	Total Hours/Day
Monday	Shut Down	Shut Down	-
Tuesday	6:00 AM	2:00 AM	20
Wednesday	6:00 AM	2:00 AM	20
Thursday	6:00 AM	2:00 AM	20
Friday	6:00 AM	2:00 AM	20
Saturday	Shut Down	Shut Down	-
Sunday	Shut Down	Shut Down	-
Holidays/Year			-
Total Work Days/Year			209
Shutdown Hours/Year			4,580
Total Annual Hours			4,180

3.3.4 Measure Description

A new 9-foot square, *natural gas catalytic heating unit* along with piping, valves and controls was installed to replace an *existing electric quartz resistance-type main oven* for thermoforming ABS plastic sheets. The new thermoforming heater consists of two 9-foot square, parallel, horizontal heating panels which catalytically oxidize natural gas to produce infrared radiation. This radiation is absorbed by flat plastic panes suspended between the heating panels which softens the plastic so that it can be formed into desired shapes. In this process, natural gas enters the back of the heating panels and is dispersed through preheated catalyst pads. At the same time, oxygen passes into the catalyst pads from the front of the heaters. Oxidation occurs where the gas and oxygen meet, promoted by catalytic action. This reaction releases the Btu content of the gas in the form of radiant energy that is more closely matched to the absorption characteristics of the plastic than the quartz spectra of the electric quartz oven. Oxidation takes place at a temperature that is below the flame ignition temperature of the gas. As the plastic absorbs the infrared energy it softens and becomes ready for molding.

The controls are set to admit natural gas in 3-second bursts to the catalytic elements, alternated with 12-second interruptions of flow. Use of this heating technology has several advantages over the previously employed electric resistance type thermoforming heaters including:

- Less energy use
- Shorter heating cycles

- More even heating, leading to improved product quality
- Less maintenance
- Improved plant safety with elimination of exposed high temperature elements.

Pre-Retrofit Conditions

- One 9-foot square electric quartz resistance-type main thermoforming oven.
- Timed on/off controls regulated the rate of heat input to the resistance heating elements.
- Production facility operates 20 hours per day, four days per week, except during eight holiday periods when the plant is shut down.
- Production workers work two ten-hour shifts per day, four days per week, while assembly line and office workers work one ten-hour shift per day, four days per week.
- The plant runs at capacity during the summer months, utilizing four molding heaters, and production levels are reduced during the balance of the year.

Post-Retrofit Conditions

- One new 9-foot square natural gas catalytic thermoforming heater.
- Main electric quartz oven demolished.
- Timed solenoid valves control the flow of gas to the heating panels in bursts of 3 seconds on, 12 seconds off until desired softness is achieved (about 1 minute total).
- Production facility operates 20 hours per day four days per week, except during eight holiday periods when the plant is shut down.
- Production workers work two 10-hour shifts per day, four days per week, while assembly line and office workers work one 10-hour shift per day, four days per week.
- The plant runs at capacity during the summer months, utilizing four molding heaters, and production levels are reduced during the balance of the year.

3.3.5 Ex Ante Load Impact Estimates

The *ex ante* load impact estimates were based on replacing electric powered thermoforming heating equipment with a catalytic natural gas fueled unit. Spot measurements were made to verify the basecase operating parameters of the system. The results of this monitoring revealed that gas fueled thermoforming heaters could provide the necessary heat for thermoforming the flat plastic sheets with lower overall energy consumption than the existing electric heating system.

Based on monitoring data, it was determined that 260 kW was being used in the pre-retrofit thermoforming heater. A gas fueled heater could provide the same heat input more efficiently. Table 3-5 summarizes key ex ante operating parameters of the pre-retrofit heater, and the load impact estimates. Total *ex ante* gross load impacts were 632,003 kWh saved per year, 150.8 kW reduced, and 26,963 therms consumed per year.

Table 3-5
Ex Ante Operating Parameters of the Pre- and Post-Retrofit Heaters
Project No. 45329

	Electric Resistance Oven	Natural Gas Catalytic Oven
Volts	480	
Amps	313	
Power Factor	1	
Phases	3	
Total Demand, kW	260	
Utilization Factor	58%	
Average Running Demand, kW	150.8	
Annual Hours of Operation	4,191	
Annual kWh	632,003	
Gas Consumption, Therms/yr		26,963

Ex Ante Analysis Approach

The *ex ante* load impact estimates were based on monitoring of the pre-retrofit equipment. Spot measurements were made to verify the current operating parameters of the system. The results of this monitoring revealed that the on/off controls had the power on 58% of the time in the main oven. It was assumed that the heat input provided by the post-retrofit equipment would be the same as that provided by the pre-retrofit equipment. Gas consumption estimates were based on the total Btu consumption of the pre-retrofit oven.

Ex Ante Basecase Definition

For the ex ante basecase (pre-retrofit), the electric quartz resistance heater provides heat for thermoforming flat ABS plastic sheets. When on, power consumption of the heater was measured to be 260 kW, while the utilization factor for the oven was measured to be 58%. The thermoforming oven is in operation continuously during all production shifts during the year.

Ex Ante Postcase Definition

For the ex ante postcase (post-retrofit), the gas catalytic heater provides heat for thermoforming flat ABS plastic sheets. Btu input from the post retrofit heater is assumed to be equivalent to the Btu input from the pre-retrofit heater. Therefore, cycle times and utilization factors are assumed to be the same for both the pre- and post-retrofit cases. The efficiency of the post-retrofit heater was assumed to be 80% of the basecase equipment.

Ex Ante Operating Schedule

This facility operates 20.5 hours per day four days per week, except during four holiday periods when the plant is shut down. The plant runs at capacity during the summer months, utilizing four molding heaters. During the balance of the year production levels are reduced.

The ex ante shift schedule was two 10-hour shifts per day, four days per week for production workers, and one 10-hour shift per day, four days per week for assembly line and office workers. Currently, the plant is operating four molding heaters.

The ex ante hours of operation are shown in Table 3-6.

Table 3-6
Ex Ante Plant Operation Schedule
Project No. 45329

Day of the Week	Start Time	End Time	Total Hours/Day
Monday	Shut Down	Shut Down	-
Tuesday	6:00 A.M.	2:00 A.M.	20.5
Wednesday	6:00 A.M.	2:00 A.M.	20.5
Thursday	6:00 A.M.	2:00 A.M.	20.5
Friday	6:00 A.M.	2:00 A.M.	20.5
Saturday	Shut Down	Shut Down	-
Sunday	Shut Down	Shut Down	-
Total Hours/Week			82
Holiday Hours/Year			-
Shutdown Hours/Year			4,484
Total Annual Hours			4,276

The plant runs at capacity during the summer months, utilizing four molding heaters, and production levels are reduced during the balance of the year.

Ex Ante Algorithms

Based on the measured pre-retrofit power consumption of an electric heater, energy use for the resistance heater was calculated to be:

$$\text{kWh / yr}_{\text{Basecase}} = (260\text{ kW}) \times (0.58) \times (4{,}191\text{ hrs / yr})$$

$$= 632{,}003\text{ kWh / yr}$$

Post-retrofit gas consumption was calculated based on the conversion of kW to therms divided by the efficiency of the heater times the annual hours of operation:

$$\text{Therms consumer per year}_{\text{postcase}} = \left(\frac{260\ \text{kW} \times 3413\ \text{Btu / kW}}{0.8}\right) \times \left(\frac{1\ \text{therm}}{100{,}000\ \text{Btu}}\right) \times (0.58) \times (4{,}191\ \text{hrs / yr})$$

$$= 26{,}963\ \text{therms / yr}$$

Ex Ante Key Assumptions

- Assumed that pre- and post-retrofit Btu requirements from thermoforming heaters are identical.
- Gas fired thermoforming heater thermal efficiency is 80% of the quartz equipment.
- Assumed that pre- and post-retrofit production schedules would be the same.

Ex Ante Data Sources

- Thermoforming heater nameplate data and manufacturer's equipment data sheets.
- Spot measurements of equipment.
- Customer interviews.

3.3.6 Ex Post Load Impact Estimates

Ex ante electrical power monitoring data was used along with ex post system operating values obtained at the ex post site visit and the manufacturer's nameplate to calculate the gross impacts of the ex post equipment using a similar methodology to the ex ante calculations. Annual impacts were found by summing the hourly impacts across an 8,760 hour year.

Ex Post Basecase Definition

For the ex post basecase (pre-retrofit), the electric quartz resistance heaters provides heat for thermoforming flat ABS plastic sheets. When on, power consumption of the main heater was measured to be 260 kW with a utilization factor of 58%. The thermoforming oven is in operation continuously during all production shifts during the year.

Ex Post Postcase Definition

For the ex post postcase (post-retrofit), the gas catalytic heater provides heat for thermoforming flat ABS plastic sheets. The efficiency of the post-retrofit heater is higher than that of the pre-retrofit equipment because more of the radiation produced by the catalytic process is absorbed by the plastic than was produced by the electric quartz equipment. Plastics have a main absorption range of 6 to 10 microns with a sharp spike at 3.7 microns. Quartz resistance elements that glow red, emit short wave infrared with peak emission in the range of 1 to 3 microns which is outside the range for effective absorption in plastic. The catalytic heating process also produces radiation in the invisible infrared range of 4.5 to 9 microns. Thus, more of the radiation produced by the catalytic process is absorbed by the plastic than was produced by the electric quartz equipment.

Tests by the manufacturer have measured this effect to be a 45% reduction in equivalent heat input per pound of plastic.

Production Level Changes

Installation of the energy efficiency measure did not affect the production level of the plant directly. However, when plant production increased for other reasons, the higher throughput capacity of the post-retrofit equipment helped the customer accommodate higher production levels without installing additional thermoforming capacity. The overall ex post heating requirements are the same as the ex ante levels.

Data Collected Ex Post

Basecase power consumption data obtained by spot measurement for the ex ante analysis on the pre-retrofit equipment is used. Post-retrofit operating and nameplate data was noted during the ex post site visit conducted in November 1998. Relative heater efficiencies was obtained from manufacturer's literature.

Ex Post Algorithms

Ex post algorithms are the same as those used in the ex ante analysis. The results of the algorithms are summarized in Table 3-7.

Table 3-7
Ex Post Impact Summary
Project No. 45329

	Electric Quartz Main Oven	Natural Gas Catalytic Oven
Volts	480	
Amps	313	
Power Factor	1	
Phases	3	
Total Demand, kW	260	
Utilization Factor	58%	
Average Running Demand, kW	150.81	
Annual Hours of Operation	4,020	
Annual kWh	606,252	
Annual Therms		11,380

Annualization of Results

The average basecase and postcase gross impacts were extended to the 8,760-hour annual period using the schedule discussed above in the ex post Operating Schedule section. According to customer staff, this facility operates a nearly identical schedule year-round. The only variation occurs due to the seasonality of the business.

Annual ex post impacts were found to be 606,252 kWh, 150.81 kW, and 11,380 therms of gas consumed per year.

Ex Post Load Impacts By Time-Of-Use Period

Ex post load impacts by time of use period were found assuming the average kW impact occurred during all the hours of each costing period. A summary of ex post load impacts by time of use period calculated as described in the Ex Post Algorithm Section is presented in Table 3-8.

Table 3-8
Ex Post Load Impacts By Time of Use Period
Project No. 45329

Time-of-Use Period	kWh Adjustment Factor	kWh Savings	Average kW Reduced	kW Reduced Coincident with System Peak Period	Annual Gross Therm Savings
Summer On-peak	0.1463	88,676	150.81	150.81	
Summer Semi-peak	0.1881	114,012	150.81		
Summer Off-peak	0.0836	50,672	150.81		
Winter On-peak	0.0873	52,934	150.81	150.81	
Winter Semi-peak	0.3784	229,380	150.81		
Winter Off-peak	0.1164	70,579	150.81		
Total	**1.0000**	**606,252**			**(11,380)**

Gross Therm Impact

Gross therms consumed per year were calculated by converting the total kW reduction to therms divided by the efficiency of the heater times the annual hours of operation:

$$\text{Therms consumed per yr}_{\text{postcase}} = (150.81 \text{ kW}) \times (3{,}413 \text{ Btu/kW}) \times (0.55) \times \left(\frac{1 \text{ therm}}{100{,}000 \text{ Btu}}\right) \times (4{,}120 \text{ hrs/yr})$$

$$= 11{,}380 \text{ therms/yr}$$

This is lower than the 26,963 therms/year claimed in the ex ante load impacts due to the actual ex post performance of the equipment versus the assumed ex ante performance. The ex ante analysis assumed that the efficiency of the postcase equipment was lower than the basecase equipment, when it was actually higher, as determined in the ex post evaluation.

3.4 PROJECT NO. 46972 - GAS FIRED RESISTANCE HEATERS FOR STANDBY GENERATOR ENGINES

3.4.1 Summary of Findings

The savings for this site were based on the installation of three gas fired water heaters to replace the output of three electric water heaters. The hot water from these heaters is used to elevate and maintain the temperature of standby generators at this facility. The results of the ex post evaluation for kWh impacts, shown in Table 3-9, are slightly lower than the ex ante estimates due to discrepancies in the annual hours of operation between the ex ante and ex post evaluations. The ex post kW impact is 40 kW because pre-retrofit electrical equipment remains connected and in ready/standby mode and one of the pre-retrofit units has operated in most months due to flame out problems with the gas fired units. The ex ante kW impact was 60 kW as the ex ante analysis assumed removal of the pre-retrofit electrical equipment. The ex post therm impact is higher than ex ante estimations due to a lower ex post heater efficiency than assumed in the ex ante analysis.

Table 3-9
Summary of Ex Post Load Impacts
Project No. 46972

	kWh	kW	Therms
Ex Ante	499,320	60.00	(20,049)
Ex Post	496,200	40.00	(21,169)
Realization Rate	99.4%	67%	105.6%

3.4.2 Facility Description

This facility is a computer data center. Critical company and public service functions are carried out by the computers on site, and they must have 100% availability. In order to ensure the availability of this must run facility, all of the support systems have built in redundancies and backup equipment to ensure the facility can ride through equipment breakdowns and natural disasters. A power interruption of any kind, no matter how short, would cause intolerable interruptions in computer system operation. While the facility UPS system provides ride through capability for short duration outages of up to 15 minutes, three backup power generators powered by dual fuel 4,500 hp engines are in standby service. Site requirements are that two engine/generator sets must start up and come up to speed within 50 seconds of the start of an outage, and then synchronize and pick up and carry the entire facility electrical load and stabilize within 100 seconds. The third engine remains as a backup for the other two, and autostarts if one of the other engines trips off or cannot stabilize within 100 seconds. In the event of a loss of utility gas pressure during a power outage, enough diesel fuel is stored onsite to operate these engines at full power for 45 days.

3.4.3 Overview of Facility Schedule

This must run facility operates 24 hours per day every day of every year and never shuts down. Backup generators are run monthly for two hours each eleven months of the year, and for eight hours each one month of each year.

3.4.4 Measure Description

In order to ensure the quick and reliable start up of the 4,500-hp engines driving the 3,000 kW generators, jacket water and engine oil are continuously circulated at operating temperatures. Jacket water is heated by three new gas fired water heaters to 170°F and circulated through the engines by pre-retrofit pumps. Frame oil is heated by the hot water in a small shell and tube heat exchanger and is circulated by its own pumps. The pre-retrofit electric water heaters remain in stand by service as back up to the new gas fired water heaters. Use of an electric heater is controlled by a thermostat which energizes an electric heater in the event of a failure of a gas fired unit. Since the installation of the gas fired heaters, the electric heaters have operated during periods of high winds which have extinguished the flames in the gas fired heaters. According to facilities staff, flameouts have occurred on numerous occasions associated with high winds including summer/fall Santa Ana conditions.

Pre-Retrofit Conditions

- Three 3,000 kW engine driven power generators in hot stand by condition.
- Circulating engine jacket water and frame oil heated by electric water heaters. Jacket water leaves the heaters at 170°F and returns to the heaters from the engines at 150°F.
- Electric heating is continuous except during engine test runs when heaters shut down.

Post-Retrofit Conditions

- Three 3,000 kW engine-driven power generators in hot stand by condition.
- Circulating engine jacket water and frame oil heated by gas fired water heaters. Jacket water leaves the heaters at 170°F and returns to the heaters from the engines at 150°F.
- Gas fired heating is continuous except during engine test runs when heaters shut down.
- Electric water heaters remain connected as backup units in case of failure of gas fired units.

3.4.5 Ex Ante Load Impact Estimates

The *ex ante* load impact estimates were based on replacing electric powered water heating equipment with natural gas fired units. A site-specific study of the facility's backup power generation system was conducted by a consultant provided by SDG&E's IEEI Program. The study comprised a detailed audit, including an inventory of backup power generation system equipment, current operating procedures, measurements of existing operating performance, evaluation of the plant requirements, and recommendations that would reduce system operating costs, including energy savings. Spot measurements were made to verify the current operating parameters of the system. The results of this monitoring revealed that gas fired water heaters could provide the necessary hot water to the stand by generator engines with lower overall power consumption than the existing electric heating system.

Based on monitoring data, it was determined that 20 kW was being used in the pre-retrofit water heaters. Gas fired heaters could provide the same heat input more efficiently. Table 3-10 shows a summary of the load impact estimates and savings calculations, respectively. This table shows total *ex ante* gross load impacts of 499,320 kWh/year saved and consumed 20,049 therms/year of natural gas.

Table 3-10
Ex Ante Gross Impact Summary
Project No. 46972

			Resistance Heater		Gas Fired Heater		
Engine #	**Heat Input kW**	**Annual Capacity Factor**	**Heating Efficiency**	**Annual Energy Use kWh**	**Heating Efficiency**	**Gas Use Btu/hr**	**Annual Gas Use Therms/yr**
1	20	95%	100%	166,440	85%	80,306	6,683
2	20	95%	100%	166,440	85%	80,306	6,683
3	20	95%	100%	166,440	85%	80,306	6,683
Total	**60**			**499,320**		**240,918**	**20,049**

Table 3-11 summarizes key ex ante operating parameters of the pre- and post-retrofit heaters.

Table 3-11
Ex Ante Operating Parameters of the Pre- and Post-Retrofit Heaters
Project No. 46972

Coolant	Distilled Water
Heat Capacity	1.0 Btu/lb-°F
Heat Input, kW	20 kW
Run Time	95%
Gas Heater Efficiency	85%
Conversion Factor	3,412.2 Btu/hr/kW
Heat Input, Btu/hr	74,000 Btu/hr
Conversion Factor	8.34 lb/gal
Circulation Rate, gpm	40 gpm
Circulation Rate, lb/hr	20,000 lb/hr
Minimum Temperature	130 °F
Minimum Temperature Rise	3.7 °F

All of the post-retrofit gas fired heaters are of the same type, Model 133A, 2-pass, water tube hydronic heating boilers manufactured by the Raypak Company. Rated heat input is 136,000 Btu/hr for 45 gpm. Heater firing is regulated by a thermostatically controlled valve to maintain 150°F jacket water to the engines.

Ex Ante Basecase Definition

For the ex ante basecase (pre-retrofit), the three 4,500-hp engines for the 3,000 kW backup power generators are maintained in hot standby condition by circulating heated jacket water and frame oil through the engines. Heat input is from three 20 kW electric water heaters that provide heat whenever the engines are not running. Standby readiness is required 24 hours per day, every day of the year, and monitoring data indicates that the electric heaters are on 95% of the time throughout the year.

Ex Ante Postcase Definition

For the ex ante postcase (post-retrofit), the three 4,500-hp engines for the 3,000 kW backup power generators are maintained in hot standby condition by circulating heated jacket water and frame oil through the engines. Heat input is from three 136,000 Btu/hr gas fired water heaters that provide heat whenever the engines are not running. Standby readiness is required 24 hours per day, every day of the year, and monitoring data indicates that the gas fired heaters are on 100% of the time throughout the year.

Ex Ante Operating Schedule

This must-run facility runs 24 hours per day every day of every year and never shuts down. Backup generators are run monthly for two hours each eleven months of the year, and for 8 hours each one month of each year.

Ex Ante Algorithms

Based on the measured 20 kW pre-retrofit power consumption of an electric heater, energy use for one resistance heater was calculated to be:

$$\text{kWh / yr}_{\text{Basecase}} = 20\ \text{kW} \times 0.95 \times 8{,}760\ \text{hrs / yr}$$

$$= 166{,}440\ \text{kWh / yr / heater}$$

and then total kWh/year for the three basecase heaters is 499,320 kWh/year.

Gas fired heater gas consumption was calculated based on the conversion of kW to therms divided by the efficiency of the water heater times the annual hours of operation:

$$\text{Therms consumed per year per heater}_{\text{postcase}} = \frac{20\ \text{kW} \times 3{,}413\ \text{Btu / kW}}{0.85} \times \frac{1\ \text{therm}}{100{,}000\ \text{Btu}} \times 0.95 \times 8{,}760\ \text{hrs / yr}$$

$$= 6{,}683\ \text{therms / yr / heater}$$

The total therms consumed per year for the three postcase heaters is 20,049 therms/year.

Ex Ante Key Assumptions

- Post-retrofit heating requirements are the same as pre-retrofit requirements.
- Gas fired water heater thermal efficiency is 85%.
- Efficiency of electric water heater is 100%
- Post-retrofit engine testing schedule is the same as the pre-retrofit testing schedule.

3.4.6 Ex Post Load Impact Estimates

Ex ante electrical power monitoring data was used along with ex post system operating values obtained at the site visit and the manufacturer's nameplate to calculate the gross impacts of the ex post equipment using a similar methodology to the ex ante calculations.

Ex Post Basecase

For the ex post basecase (pre-retrofit), the three 4,500-hp engines for the 3,000 kW backup power generators are maintained in hot standby condition by circulating heated jacket water and frame oil through the engines. Heat input is from three 20 kW electric water heaters that provide heat whenever the engines are not running. Standby readiness is required 24 hours per day, every day of the year, and it is assumed that the electric heaters are on 95% of the time throughout the year.

Ex Post Postcase

For the ex post postcase (post-retrofit), the three 4,500-hp engines for the 3,000 kW backup power generators are maintained in hot standby condition by circulating heated jacket water and frame oil through the engines. Heat input is from three 136,000 Btu/hr gas fired water heaters that provide heat whenever the engines are not running. Nameplate efficiency of the water heaters is 80%. Standby readiness is required 24 hours per day, every day of the year, and it is assumed that the gas fired heaters are operating 100% of the time throughout the year.

Ex Post Production Level Changes

Installation of the energy efficiency measure did not affect the production level of the plant. The overall ex post standby requirements are the same as the ex ante levels.

Data Collected Ex Post

Basecase power consumption data collected over two days for the ex ante analysis on the pre-retrofit equipment is used. Post-retrofit operating and nameplate data was noted during the site visit in December 1998. Heater efficiency was obtained through a phone call to the manufacturer.

Ex Post Operating Schedule

This must-run facility runs 24 hours per day every day of every year and never shuts down. According to customer staff, this facility operates a nearly identical schedule year-round. The only variation occurs during engine testing. The engine testing is done to test the ability of the engines and the controls to operate as required in an unplanned outage. The schedule consists of a one hour parallel run of each engine on the first Tuesday, Wednesday, and Thursday of each month (except October) followed by a one hour run under load of all three engines together on the last Sunday of each month (except October). The second run each month is initiated by tripping incoming utility power to simulate an unplanned outage. On the third Sunday in October, all three engines are run simultaneously for eight hours following a trip of incoming power. Therefore, there are three hours part peak and three hours off peak each month when basecase power is off, except in October when basecase power is off for eight off peak hours. Ex post equipment is assumed to run 95% of the time throughout the year, and backup generators are run monthly for two hours each eleven months of the year, and for 8 hours each one month of each year. Ex post hours of operation are therefore:

$$\text{Annual Hours of Operation}_{\text{ex post}} = (8{,}760 \text{ hrs/yr}) \times 0.95 - (2 \text{ hrs/mo} \times 11 \text{ mos.}) - (8\text{hrs/mo} \times 1 \text{ mo})$$

$$= 8{,}292 \text{ hrs/yr}$$

Ex Post Algorithms

Ex post algorithms are the same as those used in the ex ante analysis.

Annual ex post impacts were found to be 496,200 kWh, 0 kW, and 21,169 therms of gas/year.

Ex Post Load Impacts By Time-Of-Use Period

The allocation of kWh savings to the time-of-use (TOU) periods was based on the operating hours in each TOU period times the difference between the average basecase kW and the average postcase kW. The results are shown in Table 3-12.

Table 3-12
Ex Post kW and kWh Impacts by Time-of-Use Period
Project No. 46972

Time-of-Use Period	kWh Adjustment Factor	kWh Savings	Average kW Reduced	kW Reduced Coincident with System Peak Period	Annual Gross Therm Savings
Summer On-peak	0.0860	42,693	60.00	40.00	
Summer Semi-peak	0.1088	53,991	60.00		
Summer Off-peak	0.2245	111,420	60.00		
Winter On-peak	0.0507	25,137	60.00	40.00	
Winter Semi-peak	0.2173	107,847	60.00		
Winter Off-peak	0.3126	155,112	60.00		
Total	**1.0000**	**496,200**			**(21,169)**

For all costing periods, the average basecase kW impact is 60 kW. However, because of post-retrofit flame out problems due to wind, one of the pre-retrofit electric heaters has operated for short periods in most of the months since start up of the ex post equipment. Therefore, since the basecase equipment remains connected and could go into service at any time, the postcase kW coincident with the system peak is 40 kW, which is the 60 kW reduced by the impact of one electric heater running during the system peak, 20 kW.

Gross Therm Impact

Gross therm savings are calculated by converting the total kW reduction to therms divided by the efficiency of the water heaters times the annual hours of operation:

$$\text{Therms consumed per year}_{\text{postcase}} = \frac{60\text{ kW} \times 3{,}413\text{ Btu / kW}}{0.80} \times \frac{1\text{ therm}}{100{,}000\text{ Btu}} \times 8{,}270\text{ hrs / yr}$$

$$= 21{,}169\text{ therms / yr}$$

3.4.7 Load Impact Summary

The ex post load impact estimates are summarized in Table 3-13 and are compared to the ex ante estimates.

Differences between the ex ante and ex post kWh and gross therm impacts occur because the ex ante analysis did not include the testing schedule of the engines during which the heaters are not operating. Ex post therm impacts are also higher due to the use of a lower ex post heater efficiency than assumed in the ex ante analysis.

Table 3-13
Summary of Ex Post Load Impacts
Project No. 46972

	kWh	kW	Therms
Ex Ante	499,320	60.00	(20,049)
Ex Post	496,200	40.00	(21,169)
Realization Rate	99.4%	67%	105.6%

3.5 PROJECT NO. 49834 - NATURAL GAS FIRED WASTEWATER CONCENTRATOR

3.5.1 Summary of Findings

The savings for this site were based on the installation of a natural gas fired wastewater concentrator to replace an electric resistance heater for waste water concentration. The results of the ex post evaluation, shown in Table 3-14, were different than those of the ex ante estimate due to differences in the ex post operation and basecase from the ex ante assumptions, and calculation errors in the ex ante analysis.

Table 3-14
Summary of Ex Post Load Impacts
Project No. 49834

	kWh	kW	Therms
Ex Ante	366,562	41.96	(18,029)
Ex Post	290,078	33.11	(8,698)
Realization Rate	79.1%	78.9%	48.2%

3.5.2 Facility Description

This site is a metal forming operation, manufacturing metal stampings and forgings for jet engines. There are many typical machine shop processes taking place utilizing presses, lathes, milling machines, welders, rolling mills, drill presses, etc. Wastewater from various streams, including lathe coolants, hydraulic oils, and soap residue, is created as a byproduct of the metal forming process and is collected for treatment and disposal.

3.5.3 Overview of Facility Schedule

This facility operates 24 hours per day, six days per week, except during eight holiday periods when the plant is shut down. The plant runs at capacity and production levels are fairly high throughout the year.

The current shift schedule is three eight-hour shifts per day, six days per week for production workers, and one eight-hour shift per day, five days per week for office workers. The plant is normally shut down on Sundays except for critical “must work” jobs. However, wastewater is processed from storage continuously 24 hours per day, every day of the year, to reduce liquid waste volume and disposal costs. Therefore, ex post annual hours of operation are 8,760 hours per year.

3.5.4 Measure Description

A new 255-gallon natural gas fired wastewater heating unit along with piping, valves and controls was installed to replace an existing electric resistance-type wastewater concentration tank. Wastewater streams are collected from the metal forming shops in a storage tank and pumped into the concentrator. Floating free oil is skimmed from the top of the surface of the wastewater in the concentrator and collected for recycling. The wastewater is heated to 210°F to drive off water. Concentrated sludge is collected in the bottom of the concentrator and then dumped into a pit for disposal.

The pre-retrofit unit was made on site from materials on hand and utilized three electric resistance bar-type elements on the underside of an insulated aluminum tank to heat the waste water. The post-retrofit concentrator is a commercially available unit utilizing a fire tube immersed in the wastewater for heating the liquid. The pre-retrofit unit was capable of processing 200 gallons per day of wastewater and was operated seven days per week, 24 hours per day. The new unit processes 400 gallons per day and is operated seven days per week, 24 hours per day.

Use of the post-retrofit heating technology has several advantages over the previously employed resistance type evaporator.

- Less liquid waste disposal volumes
- Less energy used/lb processed
- Higher processing capacity
- More efficient skimming of tramp oils for recycling
- Less maintenance
- Improved APCD compliance

Pre-Retrofit Conditions

- One 200-gallon “homemade” electric resistance-type wastewater evaporator processing wastewater from metal forming operation.
- Thermostatic controls regulated the rate of heat input to the resistance heating elements.
- On/off level control regulates the flow of wastewater into the concentrator for processing.
- One ¼-hp, induced draft fan draws off water vapor and non-condensable vapors to rooftop exhaust.
- One ¼-hp pump draws off skimmed tramp oil to barrels for recycling.
- Production facility operates 24 hours per day six days per week, except during eight holiday periods when the plant is shut down.

- Production workers work three eight-hour shifts per day, six days per week, while office workers work one eight-hour shift per day, five days per week.
- The plant runs at capacity, and production levels are fairly steady throughout the year.
- Wastewater not processed by the pre-retrofit equipment was disposed of as untreated by the customer at additional cost.

Post-Retrofit Conditions

- One new 255-gallon commercially available, gas fired wastewater concentrating tank processing wastewater from the metal forming operation.
- Pre-retrofit 200-gallon “homemade” electric resistance-type wastewater evaporator unused, but in place as a maintenance spare for the post-retrofit unit.
- Thermostatic controls regulate the rate of heat input to the resistance heating elements.
- On/off level control regulates the flow of wastewater into the concentrator for processing.
- ¼-hp, induced draft fan draws off water vapor and non-condensable vapors to rooftop exhaust.
- ¼-hp, pump draws off skimmed tramp oil to barrels for recycling.
- Production facility operates 24 hours per day 6 days per week, except during 8 holiday periods when the plant is shut down.
- Production workers work three eight-hour shifts per day, six days per week, while office workers work one eight-hour shift per day, five days per week.
- The plant runs at capacity, and production levels are fairly steady throughout the year.

3.5.5 Ex Ante Load Impact Estimates

The *ex ante* load impact estimates were based on replacing electric powered wastewater heating equipment with a natural gas fueled unit. Spot measurements were made to verify the current operating parameters of the system. The results of this monitoring revealed that a gas fueled wastewater concentrator could provide the necessary heat for water evaporation with lower overall power consumption than the existing electric heating system.

Based on the manufacturer’s equipment data sheet, it was determined that the post-retrofit equipment would consume 18,030 gas therms while evaporating 151,320 gallons per year. It was assumed that the same heat input would have been required of the pre-retrofit “homemade” equipment, and that the thermal efficiency of the pre-retrofit concentrating tank was only 10%.

Table 3-15 summarizes key ex ante operating parameters of the pre-retrofit heater, and the load impact estimates. Total *ex ante* gross load impacts were predicted to be 367,603 kWh per year 41.96 kW, and 18,030 therms per year.

Table 3-15
Ex Ante Operating Parameters of the Pre- and Post-Retrofit Heaters
Project No. 49834

	Pre-Retrofit	Post Retrofit
Annual Capacity	151,320	151,320 gallons
lb/gal H_2O	8.3	8.3 lb/gal
Annual lbs Evaporated	1,254,627	1,254,627 lbs
Btu's Required/lb H_2O	1,000	1,000 Btu/lb
Annual MBtu's Required	1,254,627	1,254,627 MBtu
Annual MBtu's Consumed	12,546,274	1,802,900 MBtu
Concentrator Thermal Efficiency	10.0%	69.6%
Conversion Factor	3,413	Btu/kWh
Annual kWh Required	366,562	kWh
Annual kWh Consumed	366,562	kWh
Annual Operating Hours	8,760	Hours
Hourly kWh Consumption	41.96	kW

The *ex ante* load impact estimates were based on the manufacturer's data sheet for the post-retrofit equipment. Pre-retrofit heat requirements were assumed to be the same for the same volume of wastewater corrected by the efficiencies of the pre- and post-retrofit equipment. Thus, an equivalent kWh for the pre-retrofit equipment was derived based on the assumed gas consumption of the post-retrofit equipment for a similar volume of wastewater. It was assumed that both the pre- and post-retrofit equipment operated 8,760 hours per year and processed the same amount of wastewater.

Ex Ante Basecase Definition

For the ex ante basecase (pre-retrofit), a "homemade" electric resistance wastewater heater provided heat for evaporating 151,320 gallons of wastewater per year to reduce site waste volume to a concentrated solid sludge. The wastewater was heated in an insulated aluminum tank by three electric resistance bar heaters which were fastened to the underside of the tank. The thermal efficiency of this equipment was assumed to be 10%.

Floating oil was skimmed from the surface of the wastewater and collected for recycling. Sludge was removed by hand and barreled for disposal. Water vapor and non-condensables were exhausted to a roof top vent through a small induced draft fan. The wastewater concentrator was in operation continuously during all production shifts during the year.

Wastewater not processed by the pre-retrofit equipment was disposed of as untreated by the customer at additional cost.

Ex Ante Postcase Definition

For the ex ante postcase (post-retrofit), a commercially available gas fired wastewater heater provided heat for evaporating 151,320 gallons of wastewater per year to reduce site waste volume to a concentrated solid sludge. The wastewater was heated in an insulated aluminum tank utilizing a fire tube immersed in the wastewater.

Floating oil was skimmed from the surface of the wastewater and collected for recycling. Sludge was removed by hand and barreled for disposal. Water vapor and non-condensables were exhausted to a roof top vent through a small induced draft fan. The wastewater concentrator was in operation continuously during all production shifts during the year.

Ex Ante Operating Schedule

This facility operated 24 hours per day, six days per week, except during eight holiday periods when the plant was shut down. The plant ran at capacity and production levels were fairly high throughout the year.

Wastewater processing operated continuously 24 hours per day, each day of the year. Ex ante annual hours of operation of the wastewater concentrator were therefore 8,760 hours per year.

Key Ex Ante Assumptions

- Assumed efficiency of basecase equipment was 10%.
- Assumed basecase processing rate equal to postcase processing rate.
- Assumed 1,000 Btu/lb were required to evaporate water.

Ex Ante Algorithms

Based on the post-retrofit manufacturer's data sheet, the annual therms of gas required were found as follows:

From the Manufacturer's data sheet, the annual cost to process 151,320 gallons of waste water at \$0.47/therm = \$8,774.00. Therefore the annual natural gas consumption is:

$$\begin{aligned}\text{Annual Therms} &= \$8{,}474 / \text{yr} / (\$0.47 / \text{therm}) \\ &= 18{,}030 \text{ therms} / \text{yr}\end{aligned}$$

The annual pounds of wastewater evaporated were:

$$\begin{aligned}\text{Annual Pounds Evaporated} &= 151{,}320 \text{ gallons} / \text{yr} \times 8.3 \text{ lb} / \text{gallon} \\ &= 1.255 \text{ MMlb} / \text{yr}\end{aligned}$$

It was assumed that 1,000 Btu/lb were required to evaporate water. The efficiency of the post-retrofit equipment was:

$$\text{Efficiency}_{\text{post-retrofit}} = \frac{\text{Annual Btu Required}}{\text{Annual Btu Consumed}}$$

$$= \frac{1.255\text{MMlb / yr} \times 1{,}000 \text{ Btu / lb}}{18{,}030 \text{ therms / yr} \times 100{,}000 \text{ Btu / therm}}$$

$$= 69.6\%$$

The electric heat required to evaporate the same amount of wastewater at the 10% efficiency of the pre-retrofit equipment was:

$$\text{kWh / yr}_{\text{Basecase}} = \frac{1.255 \text{ MMlb / yr} \times 1{,}000 \text{ Btu / lb}}{3{,}413 \text{ Btu / kWh} \times 0.10}$$

$$= 366{,}562 \text{ kWh / yr}$$

This result is wrong by a factor of ten due to a computational error, and understates the ex ante savings by 90%. The correct result for this calculation is 3,676,025 kWh. Using the ex ante basecase kWh/yr savings, the kW impact was calculated by dividing the annual kWh by the annual hours of operation:

$$\text{kW}_{\text{basecase}} = \frac{366{,}562 \text{ kWh}}{8{,}760 \text{ hrs / yr}}$$

$$= 41.96 \text{ kW}$$

This result is also understated by 90% because of the computational error made in calculating basecase kWh/year. Using the correctly calculated result for kWh/yr, would result in a $\text{kW}_{\text{basecase}}$ of 419.76 kW.

Ex Ante Data Sources

- Postcase wastewater concentrator heater nameplate data and manufacturer's equipment data sheets.
- Customer interviews.

3.5.6 Ex Post Load Impact Estimates

Customer electrical power monitoring data of the pre-retrofit equipment was used along with ex post system operating values obtained during the ex post site visit and from the manufacturer's nameplate to calculate the gross impacts of the ex post equipment using a similar methodology to the ex ante calculations. Annual impacts were found by summing the average hourly impacts across an 8,760 hour year.

Ex Post Basecase Definition

For the ex ante basecase (pre-retrofit), a "homemade" electric resistance wastewater heater provided heat for evaporating an average of 200 gallons per day (73,000 gallons/year) of wastewater to reduce site waste volume to a concentrated solid sludge. The wastewater was heated in an insulated aluminum tank by three electric resistance bar heaters which were fastened to the underside of the tank bottom.

Floating oil was skimmed from the surface of the wastewater and collected for recycling. Sludge was removed by hand and barreled for disposal. Water vapor and non-condensables were exhausted to a roof top vent through a small induced draft fan. The wastewater concentrator was in operation continuously during all hours of the year.

Wastewater not processed by the pre-retrofit equipment was disposed of as untreated by the customer at additional cost.

Ex Post Postcase Definition

For the ex post postcase (post-retrofit), a commercially available gas fired wastewater heater provides heat for evaporating 73,000 gallons of wastewater per year (200 gallons per day) to reduce site waste volume to a concentrated solid sludge. The wastewater is heated in an insulated aluminum tank utilizing a fire tube immersed in the wastewater.

Floating oil is skimmed from the surface of the wastewater and collected for recycling. Sludge is removed by hand and barreled for disposal. Water vapor and non-condensables are exhausted to a roof top vent through a small induced draft fan. The wastewater concentrator is in operation continuously during all hours of the year.

Ex Post Production Level Changes

Installation of the energy efficiency measure did not affect the production level of the plant. However, it did allow processing of all of the customer's wastewater (approximately twice as much wastewater than the pre-retrofit equipment). The additional wastewater processed by the post-retrofit equipment had been previously disposed of untreated by the customer.

Ex Post Collected Data

Basecase power consumption data obtained by spot measurement by the customer on the pre-retrofit equipment is used. Post-retrofit operating and nameplate data was recorded during the ex post site visit in November 1998.

Ex Post Algorithms

Spot measurements made by the customer prior to the shutdown of the pre-retrofit equipment were used to determine the heat input and the efficiency of the pre-retrofit equipment through the following equations:

$$kJ/sec = \frac{(Amps)^2 \times \Omega}{(1{,}000\ J/kJ)}$$

$$Btu/hr = (0.0009478\ Btu/kJ) \times (kJ/sec) \times (3{,}600\ sec/hr)$$

$$Btu/yr = (Btu/hr) \times (8{,}760\ hr/yr)$$

The results of these equations is summarized in Table 3-16.

Table 3-16
Ex Post Basecase Power Consumption Data and Heat Input Requirement
Project No. 49834

Heating Bar	Volts	Amps	Resistance (Ω)	kJ/sec	Btu/hr	Btu/yr
A	208.7	51.5	5.1	13.5	46.153	404,304
B	208.7	41.5	5.2	9.0	30.558	267,684
C	208.7	46.6	4.9	10.6	36.307	318,047
Total Heat Required				**33.1**	**113.0**	**990,035**

The annual ex post gallons processed was 73,000 gallons/year and the annual pounds of wastewater evaporated was:

$$\text{Annual Pounds Evaporated}_{\text{ex post}} = 73{,}000\ \text{gallons/yr} \times 8.3\ \text{lb/gallon}$$
$$= 605{,}900\ \text{lb/yr}$$

From published data on the properties of saturated steam and water[1], 1,123.11 Btu/lb are necessary to evaporate 60°F water at 14.7 psia. Therefore, the amount of heat required to evaporate this water is:

$$\text{Annual MBtu's Required}_{\text{ex post}} = (605{,}900\ \text{lb/yr}) \times (1{,}123.11\ \text{Btu/lb})$$

$$= 680{,}492\ \text{MBtu/yr}$$

The efficiency of the pre-retrofit equipment is:

[1] *Flow of Fluids Through Valves, Fittings, and Pipe*, Twenty Fifth Printing; Crane Technical Paper No. 410, page A-12 Properties of Saturated Steam and Saturated Water.

$$\text{Efficiency}_{\text{pre-retrofit}} = \frac{\text{Annual Btu Required}}{\text{Annual Btu Consumed}}$$

$$= \frac{680.492 \ \text{Mlb / yr}}{990{,}035 \ \text{MBtu / yr}}$$

$$= 68.7\%$$

The electric heat required to evaporate the ex post basecase wastewater at the 68.7% efficiency of the pre-retrofit equipment is:

$$\text{kWh / yr}_{\text{basecase}} = \frac{605{,}900 \ \text{lb / yr} \times 1{,}123.11 \ \text{Btu / lb}}{3{,}413 \ \text{Btu / kWh} \times .687}$$

$$= 290{,}078 \ \text{kWh / yr}$$

Ex post kW impact is calculated by dividing the annual kWh by the annual hours of operation:

$$\text{kW Impact}_{\text{ex post}} = \frac{290{,}078 \ \text{kWh}}{8{,}760 \ \text{hrs / yr}}$$

$$= 33.11 \ \text{kW}$$

From the ex ante analysis, 1,803 MMBtu/yr is required to concentrate 151,320 gallons of wastewater in the post-retrofit concentrator, or an average of 11.92 MBtu/gal of wastewater processed. For the ex post equipment:

$$\text{MBtu's consumed per yr}_{\text{postcase}} = (11.92 \ \text{MBtu / yr / gallon}) \times (73{,}000 \ \text{gallons})$$

$$= 869{,}806 \ \text{MBtu / yr}$$

The efficiency of the post-retrofit equipment is then:

$$\text{Efficiency}_{\text{post-retrofit}} = \frac{\text{Annual Btu Required}}{\text{Annual Btu Consumed}}$$

$$= \frac{680.492 \ \text{Mlb / yr}}{869{,}806 \ \text{MBtu / yr}}$$

$$= 78.2\%$$

Ex post impacts are summarized in Table 3-17.

Table 3-17
Ex Post Impact Summary
Project No. 49834

	Basecase	Postcase	Units
Annual Capacity	73,000	73,000	gallons
lb/gal H2O	8.3	8.3	lb/gal
Annual lbs Evaporated	605,900	605,900	lbs
Btu's Required/lb H2O	1,123.11	1,123.11	Btu/lb
Annual MBtu's Consumed	680,492	680,492	MBtu
Annual MBtu's Required	990,035	869,806	MBtu
Concentrator Thermal Efficiency	68.7%	78.2%	
Conversion Factor	3,413		Btu/kWh
Annual kWh Required	199,382		kWh
Annual kWh Consumed	290,078		kWh
Annual Operating Hours	8,760		Hours
Hourly kWh Consumption	33.11		kW

Annualization of Results

The average basecase and postcase gross impacts were extended to the 8,760-hour annual period using the schedule discussed above in the ex post Operating Schedule section. According to customer staff, this facility operates a nearly identical schedule year-round. Wastewater is processed continuously every hour of the year.

Annual ex post impacts were found to be:

kWh Savings = 290,078 kWh;
kW Reduced = 33.11 kW; and
Therms Savings = -869,806 therms of gas/year.

Ex Post Load Impacts By Time-Of-Use Period

Ex post load impacts by time of use period were found assuming the average kW impact occurred during all the hours of each costing period. A summary of ex post load impacts by time of use period calculated as described in the Ex Post Algorithm Section is presented in Table 3-18.

Table 3-18
Ex Post Load Impacts By Time of Use Period
Project 49834

Time-of-Use Period	kWh Adjustment Factor	kWh Savings	Average kW Reduced	kW Reduced Coincident with System Peak Period	Annual Gross Therm Impact
Summer On-peak	0.0855	24,802.30	33.11	33.11	
Summer Semi-peak	0.1099	31,888.68	33.11		
Summer Off-peak	0.2237	64,903.23	33.11		
Winter On-peak	0.0503	14,603.23	33.11	33.11	
Winter Semi-peak	0.2182	63,280.64	33.11		
Winter Off-peak	0.3123	90,599.60	33.11		
Total	**1.0000**	**290,078**			**(869,806)**

3.5.7 Summary of Ex Post Load Impacts

Table 3-19 shows a summary of the ex post load impacts and a comparison with the ex ante impacts.

Table 3-19
Summary of Ex Post Load Impacts
Project No. 49834

	kWh	kW	Therms
Ex Ante	366,562	41.96	(18,029)
Ex Post	290,078	33.11	(8,698)
Realization Rate	79.1%	78.9%	48.2%

Differences between the ex ante and ex post kWh and gross therm impacts occur because:

- The ex ante analysis basecase did not take into account the higher processing capacity of the post-retrofit equipment; 200 gallons per day for the pre-retrofit equipment, and 400 gallons per day for the post-retrofit equipment. The basecase wastewater concentrator could not process all of the wastewater produced by the plant. The wastewater that was not processed was disposed of by the customer untreated.
- There was a difference in the efficiency of the basecase electric heaters where the ex ante analysis assumed a thermal efficiency of 10% versus the ex post analysis calculated

efficiency of 68.7%. Moreover, the ex ante analysis calculation errors also understated predicted impacts. Ex post therm impacts were lower when the equipment is evaluated at the pre-retrofit processing levels. Less gas is consumed since the amount of wastewater processed is less.

3.6 PROGRAM EX POST LOAD IMPACTS

3.6.1 Gross Load Impacts

The ex post gross load impacts for the surveyed sites is shown in Table 3-20. These realization rates were applied to the ex ante program load impacts to estimate the ex post program impacts.

Table 3-20
Ex Post Gross Load Impacts for Surveyed Sites
Process Measures
1997 Fuel Substitution Program

			Ex Ante Gross			Ex Post Gross		
Project No.	**Measure Description**	**Meas. Qty**	**kWh Savings**	**kW Reduced**	**Therm Savings**	**kWh Savings**	**kW Reduced**	**Therm Savings**
45329	Natural Gas Catalytic Thermoforming Heater	1	632,003	150.80	-26,963	606,252	150.81	-11,380
46972	Gas Fired Resistance Heaters for Standby Engines	3	499,320	60.00	-20,049	496,200	40.00	-21,169
49834	Natural Gas Fired Wastewater Concentrator	1	366,562	41.96	-18,029	290,078	33.11	-8,698
Total		**15**	**1,497,885**	**252.76**	**-65,041**	**1,392,530**	**223.92**	**-41,247**
Gross Realization Rates						**93.0%**	**88.6%**	**63.4%**

The gross realization rates were applied to the ex ante load impacts for the non-survey projects in Table 3-21.

Table 3-21
2-25 Ex Post Gross Program Load Impacts
Process Measures
1997 Fuel Substitution Program

	kWh Savings	kW Reduced	Therm Savings
Ex Ante Gross Impacts	2,043,510	507.56	-89,881
Gross Realization Rate	93.0%	88.6%	63.4%
Ex Post Gross Impacts	1,899,778	449.65	-57,000

3.6.2 Net Load Impacts

The net-to-gross ratios were estimated using the M&E Protocols default net-to-gross ratios. The defaults are based on project paybacks: NTGR is 1.0 for projects with payback periods of two years or more; 0.75 if the payback period is more than six months and less than 2 years; and 0.4 if the payback period is six months or less. The ex post net-to-gross ratios are shown in Table 3-22.

Table 3-22
Ex Post Net-To-Gross Ratios
Process Measures
1997 Fuel Substitution Program

Project No.	Measure Description	Ex Ante NTGR	Payback Period (Years)	Ex Post NTGR
45329	Natural Gas Catalytic Thermoforming Heater	0.90	1.00	0.75
46972	Gas Fired Resistance Heaters for Standby Engines	0.75	0.71	0.75
49834	Natural Gas Fired Wastewater Concentrator	0.90	0.22	0.40

The program net-to-gross ratio was estimated by dividing the ex post net load impacts by the ex post gross load impacts for the survey projects. These results are shown in Table 3-23.

Table 3-23
Program Ex Post Net-To-Gross Ratio
Process Measures
1997 Fuel Substitution Program

		Ex Post Gross Impacts			Ex Post Net Impacts		
Project No.	**Measure Description**	**kWh Savings**	**kW Reduced**	**Therm Savings**	**kWh Savings**	**kW Reduced**	**Therm Savings**
45329	Natural Gas Catalytic Thermoforming Heater	606,252	150.81	-11,380	454,689	113.11	-8,535
46972	Gas Fired Resistance Heaters for Standby Engines	496,200	40.00	-21,169	372,150	30.00	-15,877
49834	Natural Gas Fired Wastewater Concentrator	290,078	33.11	-8,698	116,031	13.24	-3,479
		1,392,530	**223.92**	**-41,247**	**942,870**	**156.35**	**-27,891**
Ex Post Program Net-To-Gross Ratio					**0.68**	**0.70**	**0.68**

The ex post net load impacts are shown in Table 3-24.

Table 3-24
Program Ex Post Net Load Impacts
Process Measures
1997 Fuel Substitution Program

	kWh Savings	kW Reduced	Therm Savings
Ex Post NTGR	0.68	0.70	0.68
Ex Post Gross Load Impacts	1,899,778	449.65	-57,000
Ex Post Net Impacts	1,286,324	313.96	-38,543
Ex Ante Net Impacts	1,702,099	413.18	-75,000
Net Realization Rate	75.6%	76.0%	51.4%

4 HVAC MEASURES

4.1 INTRODUCTION

This section provides the analysis and results of the first year load impact evaluation for fuel substitution measures installed under SDG&E's *1997 Fuel Substitution Incentives* (FSI) *Program*.

4.2 SUMMARY OF RESULTS

There was one HVAC measure project installed under the Fuel Substitution Program in 1997. A total of 21 measures, gas humidifiers, were installed under this project. The ex ante load impacts are summarized in Table 4-1. This table shows that the ex ante load impacts for this project 811,422 kWh saved, 555.97 kW reduced, and consumed 32,514 therms in natural gas annually.

Table 4-1
Ex Ante Load Impacts
HVAC Measures
1997 Fuel Substitution Incentive Program Summary

Survey	Project No.	Measure Description	Measure Quantity	Ex Ante Gross kWh Savings	Ex Ante Gross kW Reduced	Ex Ante Gross Therm Savings
yes	46794	Gas Humidifier 50 #hr	1	2,208	17.25	-88
yes	46794	Gas Humidifier 20 #/hr	1	9,270	6.90	-371
yes	46794	Gas Humidifier 90 #/hr	1	16,216	31.07	-650
yes	46794	Gas Humidifier 50 #/hr	1	20,964	17.30	-840
yes	46794	Gas Humidifier 75 #/hr	1	54,674	26.32	-2,191
yes	46794	Gas Humidifier 100 #/hr	4	219,765	141.88	-8,806
yes	46794	Gas Humidifier 75 #/hr	12	488,325	315.25	-19,568
Total			**21**	**811,422**	**555.97**	**-32,514**

A project-specific ex post evaluation was conducted for this project. Table 4-2 shows a summary of the ex post load impact estimates for HVAC measures.

Table 4-2
Ex Post Load Impacts
HVAC Measures
1997 Fuel Substitution Incentive Program Summary

	kWh Savings	kW Reduced	Therm Savings
Ex Ante Gross Impacts	811,422	555.97	-32,514
Ex Ante Net Impacts	439,493	283.73	-17,611
Ex Post Gross Impacts	1,812,631	90.8	-72,763
Ex Post Program NTGR	0.42	0.42	0.42
Ex Post Net Impacts	721,135	11.76	-28,948
Gross Realization Rate	223.4%	16.3%	223.8%
Net Realization Rate	173.2%	13.44%	173.5%
No. Measures	21		
No. Projects	1		

4.3 PROJECT ID 46794 - GAS HUMIDIFIERS

4.3.1 Summary of Findings

The savings for this site were based on the installation of twenty one gas fired humidifiers to condition clean room air for process quality control. Savings were based on the use of steam from gas fired boilers to avoid use of electrical power to make steam. The results of the ex post evaluation for kWh impacts and therm impacts are higher than the ex ante estimates and the ex post kW impacts are lower due to differences in calculation methodology between the ex ante and ex post evaluations. Table 4-1 shows a summary of the ex post load impacts and compares them to the ex ante estimates.

Table 4-1
4-1 Summary of Ex Post Load Impacts
Project No. 46794

	kWh	kW	Therms
Ex Ante	811,424	556.05	(32,515)
Ex Post	1,812,631	90.8	(72,763)
Realization Rate	223.4%	16.3%	223.8%

4.3.2 Facility Description

Cathode Ray Tubes (CRT's) for computer video display terminals are manufactured at this site. In order to ensure product quality and reduce defective parts, critical manufacturing steps take place in a Class 10,000 clean room environment. By controlling the velocity, temperature, humidity and purity of air in the clean room area, phosphor deposition band width tolerances and drying rates are improved that result in increased product quality.

Clean room environmental controls include heating and cooling coils, dehumidifying coils, and humidifying spargers. Clean room air is circulated by 21 air handling units with an average of 25% of the air exhausted from the building and replaced with outside make up air. New make up air must be conditioned before introduction into the clean room. Precise temperature control is provided by hot and cold water coils in the air handling units. The clean room temperature set point is 74°F and the relative humidity setpoint is 47% ± 3%. Humidity levels are raised by spraying steam from a gas fired boiler into the circulating air stream in the air handling units through banks of sparging nozzles. Humidity levels can also be lowered when necessary by chilling the circulating air stream through banks of low temperature glycol coils and draining off the resulting condensate. Cold, de-humidified air is then reheated as necessary before introduction into the clean room.

4.3.3 Overview of Facility Schedule

This facility operates 24 hours per day every day of every year except during the annual two week screen line maintenance period in March of each year, and two holiday periods. During the holiday periods, air handling units maintain circulation, but temperature and humidity controls are turned off. Therefore, ex post hours of operation of the humidifiers are as follows:

$$\text{Ex Post Annual Hours of Operation} = (365 \text{ days/yr} - 14 \text{ Maintenance Days/yr} - 2 \text{ Holidays/yr}) \times 24 \text{ hrs/day}$$

$$= 8{,}376 \text{ hrs/yr}$$

4.3.4 Measure Description

In order to ensure specified temperature and humidity, in the manufacturing environment for CRT's, a portion of an existing manufacturing building was converted to clean room space. New air handling units were installed with twenty one new duct mounted humidifiers supplied with steam from one of three on site gas fired boilers. The boilers also provide hot water to the facility through a heat exchanger. Pre-retrofit practice at the site was the use of electric humidifiers which have a lower first cost than gas fired units.

Pre-Retrofit Conditions

- General purpose manufacturing building space conditioned by the building HVAC system.
- Ten electric humidifiers in service in other site buildings.

Post-Retrofit Conditions

- Portion of pre-retrofit manufacturing space gutted and converted to Class 10,000 clean room for the manufacture of video display terminal CRT's.
- Twenty one gas fired humidifiers installed in clean room air handling units to maintain desired levels of clean room relative humidity as controlled by the building energy management system (EMS).
- Three steam boilers generating 12.2 psig steam for humidification and steam tracing.
- Clean room HVAC system operates 24 hours per day, 365 days per year except during an annual two week long maintenance period in March of each year. EMS humidity and temperature controls are also off during two holidays each year.

4.3.5 Ex Ante Load Impact Estimates

Ex ante load impacts were estimated using *HCalc*, a proprietary computer modeling program for the sizing of humidifying equipment developed by the Stulz Humidifier Company. The capacity of each humidifying unit and the design supply and outside air volumes were entered into the model along with San Diego area bin temperature data. Using this information, the model predicts the required capacity and the full load operating hours for each electrical humidifying unit necessary to maintain specified clean room process conditions. Assuming the same duty for the gas humidifiers as the electrical units, the predicted full load hours from the model and the capacity of each unit were then used to determine savings from using gas to create the required steam versus using electricity. Based on the boiler manufacturer's data sheet, it was assumed that the efficiency of the steam boiler supplying steam to the humidifying units was 80%.

The HCalc software was developed for applications where comfort is the primary reason for the installation of the humidifier. Since outside air above 70°F is normally cooled to maintain comfort levels, humidification is unnecessary, and *HCalc* does not calculate humidification demands when outside air dry bulb temperature exceeds 70°F. However, the customer's process needs often require humidification of the outside air when it is above 70°F. This introduced a large discrepancy between ex ante and ex post evaluation results.

The ex ante model was constructed by sorting hourly temperature data for the San Diego area into bins for every 10°F increment. It was assumed that all of the hours in each bin were at the same temperature, and that the average relative humidity for the hours in each bin was 60%. A calculation was performed to find the amount of water vapor that must be added to the outside air from the bins at the process design temperature to achieve the design humidity set point. The process design temperatures, humidity set points, and the outside air volumes were all manipulated to get the model to calculate a water rate and an annual full load hour rate that did not exceed the rating of the humidifier installed. This manipulation skewed the results.

Table 4-2 shows a summary of the equipment installed, the ex ante modeling assumptions, and the operating output and schedule predicted by the *HCalc* model by the ex ante methodology.

Table 4-2
4-2 Ex Ante Equipment and Operating Summary
Project No. 46794

	Ex Ante System Design Data							HCalc Predictions	
Unit #	Supply Air Rate CFM	Steam Rate lb/hr	Outside Air Percentage	Design Temperature °F	Relative Humidity Setpoint %	Ambient Relative Humidity %	Hours of Operation	Required Capacity lb/hr	Full Load Humidifier hr/yr
301	10,000	75	35%	72	45%	60%	8,760	75.21	2,077
302	20,000	75	20%	73	40%	60%	8,760	75.06	1,549
303	20,000	75	20%	73	40%	60%	8,760	75.06	1,549
304	21,000	90	14%	71	40%	60%	8,760	49.42	1,212
305	25,000	90	30%	72	25%	60%	8,760	49.29	128
306	4,320	20	26%	72	40%	60%	8,760	19.96	1,327
307	25,000	90	30%	74	30%	60%	8,760	88.76	522
321	27,000	100	20%	73	40%	60%	8,760	101.34	1,549
322	27,000	100	20%	73	40%	60%	8,760	101.34	1,549
323	20,000	75	20%	73	40%	60%	8,760	75.06	1,549
324	20,000	75	20%	73	40%	60%	8,760	75.06	1,549
325	20,000	75	20%	73	40%	60%	8,760	75.06	1,549
326	20,000	75	20%	73	40%	60%	8,760	75.06	1,549
327	27,000	75	20%	73	40%	60%	8,760	75.06	1,549
328	27,000	100	20%	73	40%	60%	8,760	101.34	1,549
329	27,000	100	20%	73	40%	60%	8,760	101.34	1,549
330	20,000	75	20%	73	40%	60%	8,760	75.06	1,549
331	20,000	75	20%	73	40%	60%	8,760	75.06	1,549
332	20,000	75	20%	73	40%	60%	8,760	75.06	1,549
333	20,000	75	20%	73	40%	60%	8,760	75.06	1,549
334	20,000	75	20%	73	40%	60%	8,760	75.06	1,549

Ex Ante Basecase

The ex ante basecase (pre-retrofit) assumes 21 electric humidifiers conditioning clean room air as necessary to maintain specified process conditions. Based on the measured relative humidity in the clean room space, the building EMS operates electric humidifying units to generate steam into the air handling unit ducts to create desired conditions. Dry bulb temperatures from a typical meteorological year (TMY) for San Diego, California are sorted into 10°F bins which are assumed to be at 60% relative humidity as basecase ambient conditions. Clean room HVAC system operating to satisfy process requirements assumed to occur 8,760 hours per year.

Ex Ante Postcase

The ex ante postcase (post-retrofit) assumes 21 gas fired humidifiers conditioning clean room air as necessary to maintain specified process conditions. Based on the measured relative humidity in the clean room space, the building EMS operates humidifying units to admit steam from gas fired boilers into air handling unit ducts when necessary to create desired conditions. Dry bulb temperatures from a typical meteorological year (TMY) for San Diego, California are sorted into 10°F bins that are assumed to be at 60% relative humidity as basecase ambient conditions. Clean room HVAC system operating to satisfy process requirements assumed to occur 8,760 hours per year.

Ex Ante Algorithms

Values for ex ante impacts shown in Table 4-3 were calculated based on the heat input required to generate a pound of 12.5 psig steam from 70°F water. From tables of published steam data, it takes 1,122 Btu/lb. to generate one pound of steam from 70°F water, and the electrical energy required to generate 1 lb. of steam is:

$$\mathrm{kW / lb}_{\text{pre-retrofit}} = \frac{(\text{Heat Required to Make Steam, Btu / lb})}{(\text{Electric Boiler Efficiency, \%}) \times (\text{3,413 Btu / kW})}$$

$$= \frac{\text{1,122 Btu / lb}}{0.95 \times \text{3,413 Btu / kW}}$$

$$= 0.35 \text{ kW / lb}$$

Electrical impacts were then determined by the general equations:

$$\mathrm{kW}_{\text{basecase}} = (\text{Energy Required to Make Steam, kW / lb}) \times (\text{Required Capacity, lbs / hr})$$

$$\mathrm{kWh}_{\text{basecase}} = \mathrm{kW} \times (\text{Full Load Humifier hrs / yr})$$

Natural gas consumption was calculated as follows:

$$\text{Therms consumed / yr} = \frac{(\text{Heat Required to Make Steam, Btu / lb}) \times (\text{Required Capacity, lbs / hr})}{(\text{Boiler Efficiency, \%}) \times (\text{100,000 Btu / therm})}$$

$$\times (\text{Full Load Humidifier hrs / yr})$$

Table 4-3 shows a summary of ex ante energy impacts calculated for each humidifying unit based on the *HCalc* results. Total impacts were a reduction of 556.06 kW and 811,424 kWh/yr, and an increase of 32,515 therms of natural gas burned per year.

Table 4-3
4-3 Ex Ante Impact Summary
Project No. 46794

	HCalc Predictions		Ex Ante Electric Impacts			Ex Ante Gas Impacts			
Unit #	**Required Capacity lb/hr**	**Full Load Humidifier hr/yr**	**Energy Required to Make Steam kW/lb**	**kW**	**kWh**	**Heat Required to Make Steam Btu/lb**	**Boiler Efficiency %**	**Btu/hr**	**Therms/yr**
301	75.21	2,077	0.35	26.32	54,674	1,122	0.80	105,482	2,191
302	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
303	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
304	49.42	1,212	0.35	17.30	20,964	1,122	0.80	69,312	840
305	49.29	128	0.35	17.25	2,208	1,122	0.80	69,129	88
306	19.96	1,327	0.35	6.99	9,270	1,122	0.80	27,994	371
307	88.76	522	0.35	31.07	16,216	1,122	0.80	124,486	650
321	101.34	1,549	0.35	35.47	54,941	1,122	0.80	142,129	2,202
322	101.34	1,549	0.35	35.47	54,941	1,122	0.80	142,129	2,202
323	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
324	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
325	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
326	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
327	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
328	101.34	1,549	0.35	35.47	54,941	1,122	0.80	142,129	2,202
329	101.34	1,549	0.35	35.47	54,941	1,122	0.80	142,129	2,202
330	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
331	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
332	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
333	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
334	75.06	1,549	0.35	26.27	40,694	1,122	0.80	105,272	1,631
Total				**556.05**	**811,424**				**32,515**

Key Ex Ante Assumptions

- TMY data for San Diego for pre- and post retrofit equipment.
- steam boiler efficiency of 80%.
- HVAC design air supply and outside air volumes.
- pre- and post-retrofit clean room HVAC needs are identical.
- 8,760 hours per year facility operation.
- no humidification required for outside air temperatures above 70°F.
- 60% average humidity for each hour of the 8,760 hour year below 70°F.

4.3.6 Ex Post Load Impact Estimates

Customer EMS data was collected and analyzed to verify operation of the 21 clean room gas fired humidifiers and the efficiency of the steam boilers. TMY dry bulb, wet bulb, and humidity ratio weather data for Escondido, California, was used to calculate the required humidification for each hour of the year to satisfy the customer's process needs. Weather data for Escondido was selected since it is in the same climate zone and is about five miles due north of the facility, and thus provides weather conditions that are more representative for the plant location than those from the San Diego International Airport. Electrical power required to generate the required humidity was then calculated for each hour of the year. Based on the efficiency of the steam boilers, the gas required to generate the same amount of steam as was generated by the electric humidifiers was then calculated.

Ex Post Basecase

The ex post basecase (pre-retrofit) assumes 21 electric humidifiers conditioning clean room air as necessary to maintain specified process conditions of 74°F and 47% RH ± 3%. Based on the measured relative humidity in the clean room space, the building EMS operates electric humidifying units to generate steam into the air handling unit ducts to create desired process conditions. Weather data from a typical meteorological year (TMY) for Escondido, California was used to calculate impacts for each hour of the 8,760 hour year. Clean room process requirements were assumed to occur 8,376 hours per year.

Ex Post Postcase

The ex post basecase (post-retrofit) assumes 21 gas fired humidifiers conditioning clean room air as necessary to maintain specified process conditions of 74°F and 47% RH ± 3%. Based on the measured relative humidity in the clean room space, the building EMS operates gas humidifying units to generate steam into the air handling unit ducts to create desired conditions. Weather data from a typical meteorological year (TMY) for Escondido, California is then used to calculate impacts for each hour of the 8,760 hour year. Clean room process requirements were assumed to occur 8,376 hours per year.

Production Level Changes

Installation of the energy efficiency measures did not affect the production level of the plant. The overall ex post production levels are the same as the ex ante levels.

Data Collected Ex Post

The hours of operation of each of the humidifiers was measured by the building EMS system along with outside air data and steam boiler operating data. The following data were collected on-site:

- Valve position of steam admission valves.
- Steam boiler steam output and gas consumption.
- Outside dry bulb and wet bulb temperatures.

Data was collected on one hour intervals over a three day period in January, 1999.

Ex Post Algorithms

During the monitoring period, *Screening Line B*, one of the two screen manufacturing lines in the clean room manufacturing area was not operating, and many of the humidifiers supplying that area of the production clean room were not operating. However, since the two screen manufacturing lines are identical, the demand on the idle humidification units, once they are running again, is expected to be the same as the demand recorded during the monitoring period for the humidification units supplying *Screening Line A*. The data showed that not all of the humidifiers operate at the same time, and that some of the humidifiers do not operate at all.

Boiler Efficiency

Boiler data for the month of January 1999 could not be used to calculate the actual efficiency of the boilers as the customer's gas totalizer meter for the steam boilers was non-functional and natural gas use could not be determined. Therefore, the ex ante efficiency of 80% was used. This is lower than the value that would be obtained by using the boiler nameplate data, but was considered to be a more realistic value than could be obtained otherwise. Monitoring data did show that the average production from the boilers was 12.15 psig saturated steam.

Humidifier Loads

Humidifier load was found by determining the amount of humidification required to condition outside air to the required process set points of 74°F and 47% relative humidity. From the ASHRAE psychrometric chart, at the set points, the air entering the clean room must have a humidity ratio of 0.0084 lb H_2O/lb of dry air. When the humidity ratio (HR) of outside air, or the air leaving the make up air cooling coils is less than this, the humidifiers must add sufficient water vapor to raise the HR to the desired set point HR. When the HR of the outside air exceeds the HR set point, the entering air stream must be refrigerated to condense the excess moisture. This cooled air is then reheated to the set point temperature and enters the clean room.

Using weather data for a typical meteorological year (TMY) for Escondido, CA, the *amount of water vapor needed to condition the outside air* to the HR set point when the temperature of the outside air is less than the clean room setpoint is calculated by multiplying the difference of the HR's between the set point and the outside air by the outside air make up rate times the density of the outside air:

Amount of Water Vapor Needed to Condition Outside Air

$$\text{lb } H_2O/\text{hr}_{\text{outside air}} = \left(HR_{\text{setpoint}} - HR_{\text{outside air}}\right) \times \left(\text{OA Circ Rate}\right) \times \left(\text{OA Density}\right) \times \left(60 \text{ min/hr}\right)$$

When the temperature of the outside air is higher than the clean room setpoint temperature, the outside air is cooled to 50°F and then reheated as necessary to maintain the clean room setpoint temperature of 74°F. When the outside air is cooled to 50°F, the HR of the cooled air can be no higher than the saturation value of 0.0076, which is lower than the HR of 0.0084 required in the clean room. Therefore, sufficient water must be added to the air leaving the cooling coil to raise the HR to 0.0084. This is calculated by multiplying the difference of the HR's between the set point and the air leaving the cooling coil by the outside air make up rate times the density of the air leaving the cooling coil:

$$\text{Amount of Water Vapor Needed to Condition Cooled Air}$$
$$\text{lb } H_2O/\text{hr}_{\text{cooled air}} = \left(HR_{\text{setpoint}} - HR_{\text{cooled air}}\right) \times (\text{OA Circ Rate}) \times (\text{Cooled Air Density}) \times (60 \text{ min/hr})$$

From customer EMS data, the average outside air make up rate was found to be 25% of the total clean room air handler circulation rate. From the data in Table 4-2, the sum of the air handler circulation rates was 440,320 cfm. Therefore, the *average outside air make up rate was 110,080 cfm*.

Assuming an *average make up water temperature* of 70°F, the following published enthalpy data[1] for the boiler feedwater and the steam were utilized:

Make up Water Temperature	70 °F
Make up Water Enthalpy	38.05 Btu/lb.
Steam Pressure	12.15 psig
Steam Enthalpy	1,162.03 Btu/lb

The *heat required to make 12.15 psig saturated steam* is the change in enthalpy between 70°F water and the steam, or 1,123.98 Btu/lb., and the ex post *electrical energy required to generate 1 lb. of steam* is:

$$\text{kW/lb of steam}_{\text{ex post}} = \frac{(\text{Heat Required to Make Steam, Btu/lb})}{(\text{Electric Boiler Efficiency, \%}) \times (3{,}413 \text{ Btu/kW})}$$

$$= \frac{1{,}123.98 \text{ Btu/lb}}{0.95 \times 3{,}413 \text{ Btu/kW}}$$

$$= 0.35 \text{ kW/lb}$$

The ex post electrical impact for each hour was determined by the general equations:

$$\text{kW}_{\text{ex post}} = \left(\text{kW/lb}_{\text{ex post}}\right) \times \left(\text{lb/hr } H_2O_{\text{ex post}}\right)$$

[1] *Flow of Fluids Through Valves, Fittings, and Pipe*; Crane Technical Paper No. 410, Twenty Fifth Printing-1991, Properties of Saturated Steam and Saturated Water, page A-12.

Gross kWh Impacts

Gross kWh impacts for costing period *c* were then determined by summing the hourly ex post kW impacts across all the hours in the costing period:

$$\text{kWh impact}_c = \sum_{i \in c} (\text{kW}_i)$$

where *i* was incremented hourly.

Table 4-4 shows an excerpt of the entire worksheet used to estimate the ex post load impacts. Two days of the year are shown. The entire worksheet had 8,760 rows.

Table 4-4
4-4 Ex Post Load Impact Calculations
Project No. 46794

Mon	Day	Hr	WBT	DBT	Hum. Ratio	Density lb/ft^3	Design Hum. Ratio	H2O Added TO OA	@50° lb/ft^3	Added To CA	OA Circ. Rate, cfm	H_20 lb/hr	kW/lb	kW/Hr	Btu/lb	Boiler Eff.	Btu/Hr
1	1	1	39	57	0.00138	0.077	0.0084	0.00702	0.077	0.00000	110,080	3572.48	0.35	1250.37	1123.98	80%	-5019242.8
1	1	2	40	57	0.00147	0.077	0.0084	0.00693	0.077	0.00000	110,080	3522.51	0.35	1232.88	1123.98	80%	-4949043.6
1	1	3	40	56	0.00157	0.077	0.0084	0.00683	0.077	0.00000	110,080	3472.80	0.35	1215.48	1123.98	80%	-4879202.6
1	1	4	38	53	0.00157	0.078	0.0084	0.00683	0.077	0.00000	110,080	3518.74	0.35	1231.56	1123.98	80%	-4943739.4
1	1	5	36	50	0.00137	0.078	0.0084	0.00703	0.077	0.00000	110,080	3620.65	0.35	1267.23	1123.98	80%	-5086916.7
1	1	6	36	50	0.00137	0.078	0.0084	0.00703	0.077	0.00000	110,080	3620.65	0.35	1267.23	1123.98	80%	-5086916.7
1	1	7	35	49	0.00137	0.078	0.0084	0.00703	0.077	0.00000	110,080	3620.94	0.35	1267.33	1123.98	80%	-5087330.3
1	1	8	38	53	0.00147	0.078	0.0084	0.00693	0.077	0.00000	110,080	3569.28	0.35	1249.25	1123.98	80%	-5014754.5
1	1	9	40	57	0.00157	0.077	0.0084	0.00683	0.077	0.00000	110,080	3472.55	0.35	1215.39	1123.98	80%	-4878844.4
1	1	10	42	61	0.00157	0.076	0.0084	0.00683	0.077	0.00000	110,080	3426.53	0.35	1199.28	1123.98	80%	-4814184.7
1	1	11	44	64	0.00167	0.076	0.0084	0.00673	0.077	0.00000	110,080	3376.50	0.35	1181.77	1123.98	80%	-4743894.7
1	1	12	45	66	0.00167	0.076	0.0084	0.00673	0.077	0.00000	110,080	3376.09	0.35	1181.63	1123.98	80%	-4743327.0
1	1	13	46	68	0.00158	0.075	0.0084	0.00682	0.077	0.00000	110,080	3380.10	0.35	1183.04	1123.98	80%	-4748961.0
1	1	14	46	68	0.00168	0.075	0.0084	0.00673	0.077	0.00000	110,080	3331.30	0.35	1165.95	1123.98	80%	-4680387.6
1	1	15	46	68	0.00168	0.075	0.0084	0.00673	0.077	0.00000	110,080	3331.30	0.35	1165.95	1123.98	80%	-4680387.6
1	1	16	46	68	0.00158	0.075	0.0084	0.00682	0.077	0.00000	110,080	3380.10	0.35	1183.04	1123.98	80%	-4748961.0
1	1	17	44	65	0.00158	0.076	0.0084	0.00682	0.077	0.00000	110,080	3425.72	0.35	1199.00	1123.98	80%	-4813046.3
1	1	18	42	61	0.00167	0.076	0.0084	0.00673	0.077	0.00000	110,080	3377.15	0.35	1182.00	1123.98	80%	-4744816.0
1	1	19	40	57	0.00157	0.077	0.0084	0.00683	0.077	0.00000	110,080	3472.55	0.35	1215.39	1123.98	80%	-4878844.4
1	1	20	40	56	0.00167	0.077	0.0084	0.00673	0.077	0.00000	110,080	3422.86	0.35	1198.00	1123.98	80%	-4809025.8
1	1	21	40	56	0.00177	0.077	0.0084	0.00663	0.077	0.00000	110,080	3372.91	0.35	1180.52	1123.98	80%	-4738848.9
1	1	22	40	54	0.00177	0.077	0.0084	0.00663	0.077	0.00000	110,080	3373.51	0.35	1180.73	1123.98	80%	-4739699.6
1	1	23	39	54	0.00186	0.077	0.0084	0.00654	0.077	0.00000	110,080	3323.60	0.35	1163.26	1123.98	80%	-4669570.0
1	1	24	39	53	0.00196	0.078	0.0084	0.00644	0.077	0.00000	110,080	3316.56	0.35	1160.79	1123.98	80%	-4659679.3
1	2	1	39	52	0.00186	0.078	0.0084	0.00654	0.077	0.00000	110,080	3367.46	0.35	1178.61	1123.98	80%	-4731193.3
1	2	2	37	50	0.00196	0.078	0.0084	0.00644	0.077	0.00000	110,080	3317.72	0.35	1161.20	1123.98	80%	-4661318.1
≈					≈			≈			≈			≈			≈
12	30	24	41	55	0.00245	0.077	0.0084	0.00595	0.077	0.00000	110,080	3023.68	0.35	1058.29	1123.98	80%	-4248191.2
12	31	1	40	54	0.00216	0.077	0.0084	0.00624	0.077	0.00000	110,080	3173.85	0.35	1110.85	1123.98	80%	-4459181.3
12	31	2	40	54	0.00236	0.077	0.0084	0.00604	0.077	0.00000	110,080	3074.02	0.35	1075.91	1123.98	80%	-4318922.2
12	31	3	40	53	0.00235	0.078	0.0084	0.00605	0.077	0.00000	110,080	3114.38	0.35	1090.03	1123.98	80%	-4375619.1
12	31	4	39	52	0.00235	0.078	0.0084	0.00605	0.077	0.00000	110,080	3114.82	0.35	1090.19	1123.98	80%	-4376249.4
12	31	5	38	49	0.00245	0.078	0.0084	0.00595	0.077	0.00000	110,080	3065.81	0.35	1073.03	1123.98	80%	-4307391.1
12	31	6	37	47	0.00254	0.078	0.0084	0.00586	0.077	0.00000	110,080	3016.51	0.35	1055.78	1123.98	80%	-4238121.9
12	31	7	35	44	0.00254	0.079	0.0084	0.00586	0.077	0.00000	110,080	3057.15	0.35	1070.00	1123.98	80%	-4295221.8
12	31	8	39	49	0.00274	0.078	0.0084	0.00566	0.077	0.00000	110,080	2914.42	0.35	1020.05	1123.98	80%	-4094680.5
12	31	9	42	54	0.00294	0.077	0.0084	0.00546	0.077	0.00000	110,080	2774.53	0.35	971.09	1123.98	80%	-3898144.9
12	31	10	45	60	0.00305	0.077	0.0084	0.00535	0.077	0.00000	110,080	2721.69	0.35	952.59	1123.98	80%	-3823913.4
12	31	11	46	62	0.00325	0.076	0.0084	0.00515	0.077	0.00000	110,080	2586.74	0.35	905.36	1123.98	80%	-3634302.2
12	31	12	48	64	0.00354	0.076	0.0084	0.00486	0.077	0.00000	110,080	2437.67	0.35	853.18	1123.98	80%	-3424860.6
12	31	13	49	66	0.00374	0.075	0.0084	0.00466	0.077	0.00000	110,080	2307.18	0.35	807.51	1123.98	80%	-3241525.6
12	31	14	50	65	0.00433	0.076	0.0084	0.00407	0.077	0.00000	110,080	2041.84	0.35	714.64	1123.98	80%	-2868731.8
12	31	15	51	65	0.00482	0.076	0.0084	0.00358	0.077	0.00000	110,080	1794.72	0.35	628.15	1123.98	80%	-2521532.8
12	31	16	53	64	0.00610	0.076	0.0084	0.00230	0.077	0.00000	110,080	1152.95	0.35	403.53	1123.98	80%	-1619866.5
12	31	17	51	61	0.00570	0.076	0.0084	0.00270	0.077	0.00000	110,080	1352.84	0.35	473.49	1123.98	80%	-1900701.2
12	31	18	50	58	0.00590	0.077	0.0084	0.00250	0.077	0.00000	110,080	1273.18	0.35	445.61	1123.98	80%	-1788782.8
12	31	19	48	54	0.00579	0.077	0.0084	0.00261	0.077	0.00000	110,080	1326.99	0.35	464.45	1123.98	80%	-1864387.7
12	31	20	46	52	0.00530	0.078	0.0084	0.00310	0.077	0.00000	110,080	1599.02	0.35	559.66	1123.98	80%	-2246586.0
12	31	21	45	51	0.00500	0.078	0.0084	0.00340	0.077	0.00000	110,080	1751.59	0.35	613.06	1123.98	80%	-2460944.3
12	31	22	45	50	0.00519	0.078	0.0084	0.00321	0.077	0.00000	110,080	1651.65	0.35	578.08	1123.98	80%	-2320525.7
12	31	23	46	52	0.00530	0.078	0.0084	0.00310	0.077	0.00000	110,080	1599.02	0.35	559.66	1123.98	80%	-2246586.0
12	31	24	48	54	0.00579	0.077	0.0084	0.00261	0.077	0.00000	110,080	1326.99	0.35	464.45	1123.98	80%	-1864387.7
					0.00049								**kWh/yr**	**1,812,631**		**Therms/yr**	(72,763)

Annual Gross kWh Impact

The kWh impacts were summed across the six SDG&E costing periods (*c*) to determine the total annual gross kWh impact:

$$\text{Annual kWh impact} = \sum_{c=1}^{6} \text{kWh impact}_c$$

Average Gross kW Impacts

Average gross kW impacts were developed for each costing period by dividing the total kWh impacts for the costing period by the total number of hours in the costing period:

$$\overline{\text{kW impact}_c} = \frac{\text{kWh impact}_c}{\sum_{i \in c} \text{hours}_c}$$

where *i* was incremented hourly.

Annual Gross Natural Gas Impact

Due to the nature of the measure, substituting electricity use for natural gas use, the load impact on natural gas was an increase in consumption. The natural gas consumed due to the installation of the humidifiers was calculated as follows for each hour:

$$\text{Therms consumed / hr} = \frac{(\text{Heat Required to Make Steam, Btu / lb}) \times (\text{Required Capacity, lbs / hr})}{(\text{Boiler Efficiency, \%}) \times (100{,}000 \text{ Btu / therm})}$$

The total gas use for the year was found by summing the hourly gas impacts:

$$\text{Therms consumed / yr} = \sum (\text{Therms}_i \text{ / hr})$$

where i was incremented hourly.

These results are shown in Table 4-4.

Annualization of Results

The average basecase and postcase kW were extended to the 8,760-hour annual period using the schedule discussed above in the ex post Operating Schedule section. According to customer staff, this facility operates a nearly identical schedule year-round.

Ex Post Load Impacts By Time-Of-Use Period

A summary of ex post load impacts by time of use period calculated as described in the Ex Post Algorithm Section is presented in Table 4-5.

Table 4-5
4-5 Ex Post kW and kWh Impacts by Time-of-Use Period
Project No. 46794

Costing Period	Avg. kW Savings	kWh Savings	kWh Adjustment Factor	Annual kWh Savings	Therm Savings
Summer On Peak	90.82	68,021	0.0375	1,812,631	(2,731)
Summer Part Peak	57.13	55,014	0.0304	1,812,631	(2,208)
Summer Off Peak	62.62	122,734	0.0677	1,812,631	(4,927)
Winter On Peak	233.64	103,037	0.0568	1,812,631	(4,136)
Winter Part Peak	267.67	511,521	0.2822	1,812,631	(20,534)
Winter Off Peak	348.06	952,304	0.5254	1,812,631	(38,228)
Total		**1,812,631**	**1.0000**		**(72,763)**

Average summer kW savings are lower than average winter savings because outside air TMY humidity ratios are often higher than the process humidity setpoint during the summer period, which causes the humidifiers to shut off.

4.3.7 Net Load Impacts

The net-to-gross ratios were estimated using the M&E Protocols default net-to-gross ratios. The defaults are based on project paybacks: NTGR is 1.0 for projects with payback periods of two years or more; 0.75 if the payback period is more than six months and less than two years; and 0.4 if the payback period is six months or less. The ex post net-to-gross ratios for each surveyed measure are shown in Table 4-6. The weighted average of the measure NTGR’s, weighted by ex ante kWh savings was taken to estimate the NTGR for the program.

Table 4-6
Ex Post Net-To-Gross Ratios
HVAC Measures
1997 Fuel Substitution Program

Project No.	Measure Description	Measure Quantity	Ex Ante Gross kWh Savings	Payback Period (Years)	Ex Post NTGR per Measure	Ex Post NTGR (Weighted Avg of Measure NTGR)
46794	Gas Humidifier 50 #hr	1	2,208	4.80	1.00	
46794	Gas Humidifier 20 #/hr	1	9,270	0.45	0.40	
46794	Gas Humidifier 90 #/hr	1	16,216	1.10	0.75	
46794	Gas Humidifier 50 #/hr	1	20,964	0.46	0.40	
46794	Gas Humidifier 75 #/hr	1	54,674	0.25	0.40	
46794	Gas Humidifier 100 #/hr	4	219,765	0.35	0.40	
46794	Gas Humidifier 75 #/hr	12	488,325	0.41	0.40	
Weighted Average NTGR						**0.42**

The ex post net load impacts are shown in Table 4-7.

Table 4-7
Program Ex Post Net Load Impacts
HVAC Measures
1997 Fuel Substitution Program

	kWh Savings	kW Reduced	Therm Savings
Ex Post Program NTGR	0.42	0.42	0.42
Ex Post Gross Impacts	1,710,201	27.90	-68,651
Ex Post Net Impacts	721,135	11.76	-28,948
Ex Ante Net Impacts	439,493	283.73	-17,611
Net Realization Rate	164.1%	4.1%	164.4%

A

TABLE 6 - PROCESS MEASURES

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY97 SECOND EARNINGS CLAIM FOR FUEL SUBSTITUTION INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, February 1999, STUDY ID NO. 1016

Designated Unit of Measurement: Load Impacts per Project
End Use: Process

					5. A. 90% Confidence Level				5. B. 80% Confidence Level			
					Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
1. Average Participant Group and Average Comparison Group		**Part Group**		**Comp Group**	**Part Group**	**Part Group**	**Comp Group**	**Comp Group**	**Part Group**	**Part Group**	**Comp Group**	**Comp Group**
A. Pre-install usage:	Pre-install kW	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Pre-install kWh	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kW	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kWh	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kW/ designated unit of measurement	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kWh/ designated unit of measurement	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B. Impact year usage:	Impact Yr kW	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kWh	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kW/designated unit	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kWh/designated unit	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2. Average Net and Gross End Use Load Impacts		**Avg Gross**		**Avg Net**	**Avg Gross**	**Avg Gross**	**Avg Net**	**Avg Net**	**Avg Gross**	**Avg Gross**	**Avg Net**	**Avg Net**
	A. i. Load Impacts - kW	74.94		52.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. ii. Load Impacts - kWh	316,630		214,387	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. iii. Load Impacts - therm	-9,500		-6,424	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. i. Load Impacts/designated unit - kW	74.9417		52.3267	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. ii. Load Impacts/designated unit - kWh	316,629.7		214,387.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. iii. Load Impacts/designated unit - therm	-9,500		-6,424	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. i. a. % change in usage - Part Grp - kW	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. i. b. % change in usage - Part Grp - kWh	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. ii. a. % change in usage - Comp Grp - kW	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. ii. b. % change in usage - Comp Grp - kWh	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D. Realization Rate:	D.A. i. Load Impacts - kW, realization rate	0.8860		0.7600	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. ii. Load Impacts - kWh, realization rate	0.9300		0.7560	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. iii. Load Impacts - therm, realization rate	0.6340		0.5140	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.B. i. Load Impacts/designated unit - kW, real rate	0.8859		0.6186	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.B. ii. Load Impacts/designated unit - kWh, real rate	0.9297		0.7557	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.B. iii. Load Impacts/designated unit - therm, real rate	0.6342		0.5139	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3. Net-to-Gross Ratios		**Ratio**			**Ratio**	**Ratio**			**Ratio**	**Ratio**		
	A. i. Average Load Impacts - kW	0.70			N/A	N/A			N/A	N/A		
	A. ii. Average Load Impacts - kWh	0.68			N/A	N/A			N/A	N/A		
	A. iii. Average Load Impacts - therm	0.68			N/A	N/A			N/A	N/A		
	B. i. Avg Load Impacts/designated unit of measurement - kW	0.70			N/A	N/A			N/A	N/A		
	B. ii. Avg Load Impacts/designated unit of measurement - kWh	0.68			N/A	N/A			N/A	N/A		
	B. iii. Avg Net Load Impacts/designated unit of measurement - therm	0.68			N/A	N/A			N/A	N/A		
	C. i. Avg Load Impacts based on % chg in usage in Impact year relative to Base usage in Impact year - kW	N/A			N/A	N/A			N/A	N/A		
	C. ii. Avg Load Impacts based on % chg in usage in Impact year relative to Base usage in Impact year - kWh	N/A			N/A	N/A			N/A	N/A		
	C. iii. Avg Load Impacts based on % chg in usage in Impact year relative to Base usage in Impact year - therm	N/A			N/A	N/A			N/A	N/A		
4. Designated Unit Intermediate Data		**Part Group**		**Comp Group**	**Part Group**	**Part Group**	**Comp Group**	**Comp Group**	**Part Group**	**Part Group**	**Comp Group**	**Comp Group**
	A. Pre-install average value	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. Post-install average value	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6. Measure Count Data		**Number**										
	A. Number of measures installed by participants in Part Group	5										
	B. Number of measures installed by all program participants in the 12 months of the program year	15										
	C. Number of measures installed by Comp Group	N/A										
7. Market Segment Data		**SIC**	**Percent**									
	Distribution by 3 digit SIC	549	0.125									
		394	0.125									
		372	0.125									
		384	0.250									
		481	0.125									
		806	0.125									
		399	0.125									

B

TABLE 6 - HVAC MEASURES

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY97 SECOND EARNINGS CLAIM FOR FUEL SUBSTITUTION INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, February 1999, STUDY ID NO. 1016

Designated Unit of Measurement: Load Impacts per Project
End Use: HVAC

					5. A. 90% Confidence Level				5. B. 80% Confidence Level			
					Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
1. Average Participant Group and Average Comparison Group		**Part Group**		**Comp Group**	**Part Group**	**Part Group**	**Comp Group**	**Comp Group**	**Part Group**	**Part Group**	**Comp Group**	**Comp Group**
A. Pre-install usage:	Pre-install kW	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Pre-install kWh	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kW	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kWh	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kW/ designated unit of measurement	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kWh/ designated unit of measurement	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B. Impact year usage:	Impact Yr kW	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kWh	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kW/designated unit	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kWh/designated unit	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2. Average Net and Gross End Use Load Impacts		**Avg Gross**		**Avg Net**	**Avg Gross**	**Avg Gross**	**Avg Net**	**Avg Net**	**Avg Gross**	**Avg Gross**	**Avg Net**	**Avg Net**
	A. i. Load Impacts - kW	90.80		11.76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. ii. Load Impacts - kWh	1,812,631		721,135	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. iii. Load Impacts - therm	-72,763		-28,948	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. i. Load Impacts/designated unit - kW	90.8000		11.7600	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. ii. Load Impacts/designated unit - kWh	1,812,631.0		721,135.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. iii. Load Impacts/designated unit - therm	-72,763		-28,948	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. i. a. % change in usage - Part Grp - kW	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. i. b. % change in usage - Part Grp - kWh	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. ii. a. % change in usage - Comp Grp - kW	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. ii. b. % change in usage - Comp Grp - kWh	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D. Realization Rate:	D.A. i. Load Impacts - kW, realization rate	0.1630		0.1344	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. ii. Load Impacts - kWh, realization rate	2.2340		1.7320	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. iii. Load Impacts - therm, realization rate	2.2380		1.7350	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.B. i. Load Impacts/designated unit - kW, real rate	0.1633		0.0414	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.B. ii. Load Impacts/designated unit - kWh, real rate	2.2339		1.6408	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.B. iii. Load Impacts/designated unit - therm, real rate	2.2379		1.6437	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3. Net-to-Gross Ratios		**Ratio**			**Ratio**	**Ratio**			**Ratio**	**Ratio**		
	A. i. Average Load Impacts - kW	0.42			N/A	N/A			N/A	N/A		
	A. ii. Average Load Impacts - kWh	0.42			N/A	N/A			N/A	N/A		
	A. iii. Average Load Impacts - therm	0.42			N/A	N/A			N/A	N/A		
	B. i. Avg Load Impacts/designated unit of measurement - kW	0.42			N/A	N/A			N/A	N/A		
	B. ii. Avg Load Impacts/designated unit of measurement - kWh	0.42			N/A	N/A			N/A	N/A		
	B. iii. Avg Net Load Impacts/designated unit of measurement - therm	0.42			N/A	N/A			N/A	N/A		
	C. i. Avg Load Impacts based on % chg in usage in Impact year relative to Base usage in Impact year - kW	N/A			N/A	N/A			N/A	N/A		
	C. ii. Avg Load Impacts based on % chg in usage in Impact year relative to Base usage in Impact year - kWh	N/A			N/A	N/A			N/A	N/A		
	C. iii. Avg Load Impacts based on % chg in usage in Impact year relative to Base usage in Impact year - therm	N/A			N/A	N/A			N/A	N/A		
4. Designated Unit Intermediate Data		**Part Group**		**Comp Group**	**Part Group**	**Part Group**	**Comp Group**	**Comp Group**	**Part Group**	**Part Group**	**Comp Group**	**Comp Group**
	A. Pre-install average value	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. Post-install average value	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6. Measure Count Data		**Number**										
	A. Number of measures installed by participants in Part Group	21										
	B. Number of measures installed by all program participants in the 12 months of the program year	21										
	C. Number of measures installed by Comp Group	N/A										
7. Market Segment Data		**SIC**	**Percent**									
	Distribution by 3 digit SIC	365	1.000									

M&E PROTOCOLS TABLE 7
DATA QUALITY AND PROCESSING DOCUMENTATION
For 1997 Fuel Substitution Incentives Program
First Year Load Impact Evaluation
February 1999
Study ID No. 1016

A. OVERVIEW INFORMATION

1. **Study Title and Study ID:** 1997 Fuel Substitution Incentives Program: First Year Load Impact Evaluation, February 1997, Study ID No. 1016.

2. **Program, Program Year(s), and Program Description (design):** 1997 Fuel Substitution Incentives Program for the 1997 program year. The Program is designed to help nonresidential customers control energy costs by providing incentives for the installation of energy efficient equipment of alternate fuels at their facilities.

3. **End Uses and/or Measures Covered:** All end uses combined disaggregated by process and HVAC.

4. **Methods and models used:** Site-specific simplified engineering models with verified inputs.

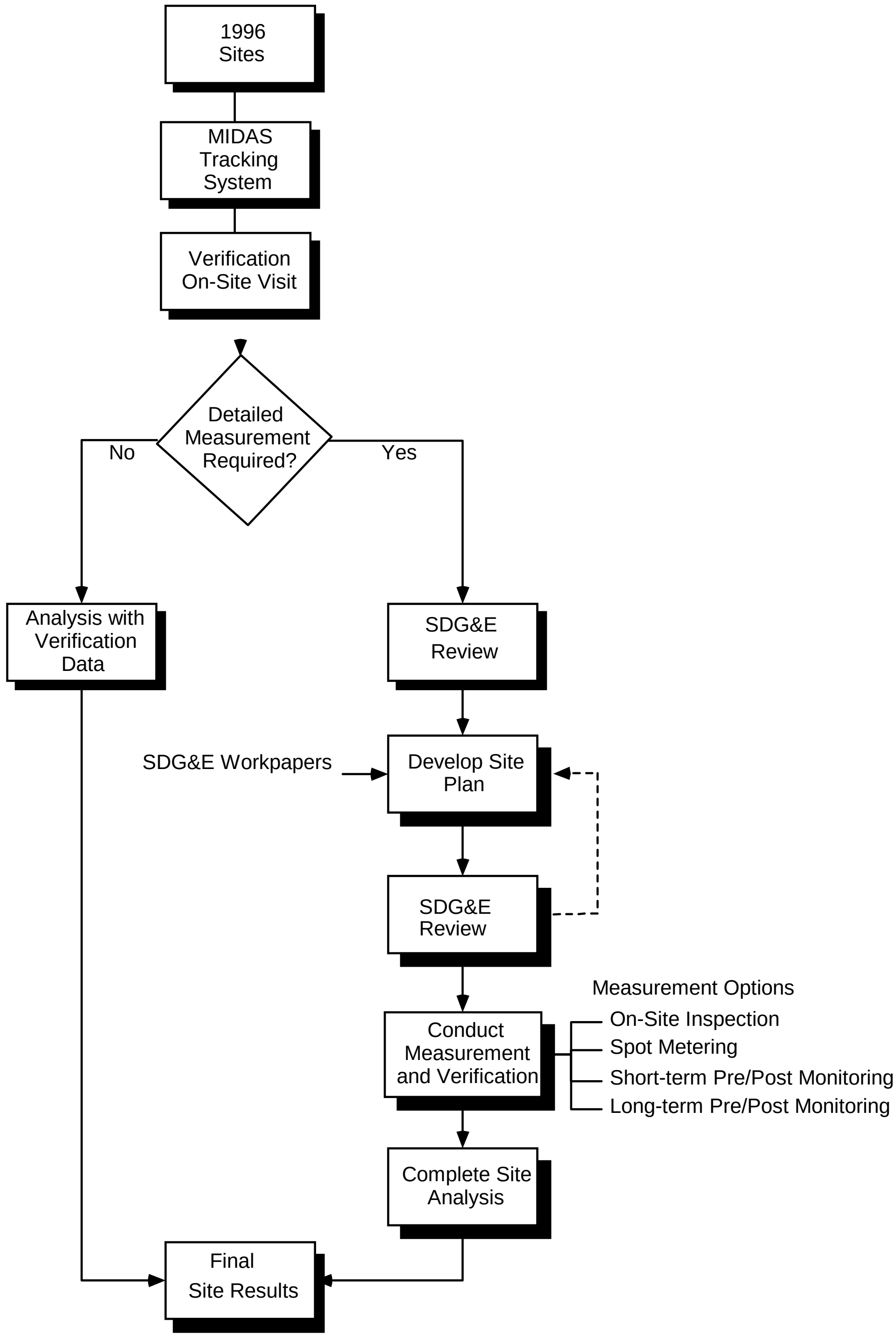
5. **Participant and comparison group definition:** For the load impact analysis, the participants in the 1997 Fuel Substitution Incentives Program are defined as having at least one of the aforementioned measures installed.

6. **Analysis sample size:**

Electric Participant Sample for 1997 Fuel Substitution Incentives Program			Gas Participant Sample for 1997 Fuel Substitution Incentives Program		
Measure Type	**No. of Projects**	**No. of Measures**	**Measure Type**	**No. of Projects**	**No. of Measures**
Process	3	5	**Process**	3	5
HVAC	1	21	**HVAC**	1	21
Total	4	31	**Total**	4	31

B. DATABASE MANAGEMENT

1. Flow Charts:



2. Data sources: the data came from the following sources:

- Customer name, address, installed measures, and participation date from the program tracking database.
- Electric and gas consumption history, where applicable, from the Customer Master File.
- *Ex ante* engineering assumptions and analyses from program project files.
- *Ex post* on-site survey data, including spot measurements, monitoring and verification of measure installation.

3. Data Attrition:

a. Participant Sample - Load Impact Analysis

No attrition.

b. Nonparticipant Sample - Load Impact Analysis

Not applicable.

4. Data Quality Checks

Not applicable for this evaluation.

5. All data collected for this analysis were utilized.

C. SAMPLING

1. Sampling procedures and protocols: Process: Projects were randomly drawn until at least 70% of the total load impacts were included in the evaluation. HVAC: not applicable, a census of the one project was conducted.

2. Survey information: On-site inspections were conducted that included a review of operations logs, interviews of on-site staff, and measurements of the measures in operation.

3. Statistical Descriptions: Not applicable.

D. DATA SCREENING AND ANALYSIS

1. **Outliers:** Not applicable.

   Missing data points: Not applicable.

   Weather adjustments were implicit in the engineering models used in the evaluation.

2. **"Background" variables:** Not applicable.

3. **Screening procedures:** Not applicable.

4. **Regression statistics:** Not applicable.

5. **Specification:**

   a. Not applicable.

   b. Not applicable.

   c. Not applicable.

   d. Not applicable.

   e. Not applicable.

6. **Error in measuring variables:** On-site observation of measure installation and on-site measurements were taken to mitigate possible errors from project files.

7. **Autocorrelation:** Not applicable.

8. **Heteroskedasticity:** Not applicable.

9. **Collinearity:** Not applicable.

10. **Influential data points:** Not applicable.

11. **Missing Data:** Not applicable.

12. **Precision:** Not applicable. Standard errors and other statistically based measures of precision are not applicable to the site-specific engineering analyses employed in this analysis.

E. DATA INTERPRETATION AND APPLICATION

1. Calculation of net impacts: Not applicable.

2. **Processes, choices made and rationale for E.1:** Not applicable.