1996 INDUSTRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION

FINAL REPORT

Study ID No. 995

Prepared for

San Diego Gas & Electric
San Diego, California

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1 INTRODUCTION

1.1 INTRODUCTION

This is an evaluation of the 1996 Program Year (PY96) first year load impacts for SDG&E's industrial customers, who are a subset of the nonresidential customers that participated in SDG&E's 1995 Commercial/ Industrial/Agricultural (C/I/A) Energy Efficiency Incentives (EEI) Programs. The C/I/A EEI Programs help customers reduce energy costs and increase energy efficiency at their facilities. There are three major end uses covered by this report: (1) lighting, (2) motors, and (3) industrial process.

The industrial process, interior lighting and motors end use evaluations completed by XENERGY entail on-site verifications of the *ex ante* engineering assumptions.

The IEEI Program study results shown in the designated unit of measurement for each end use are as shown in Table 1-1.

Table 1-1
Study Results for the PY96 IEEI Program
First Year Load Impact Evaluation

End Use	Industrial Participants	Energy Savings[1] (kWh)	Realization Rate	Demand Savings[1] (kW)	Realization Rate	Net-to-Gross Ratio
Indoor Lighting	253	0.22	360%	0.40	671%	84%
Motors	97	719.7	76%	0.0863	68%	54%
Process	21	353,649	88%	55.93	50%	95%

1 Lighting DUOM: load impacts per square foot per 1000 hours of operation
Process DUOM: load impacts per project
Motors DUOM: load impacts per hp

1.2 REPORT ORGANIZATION

The report is organized into several sections.

Section 2: Study Overview: This section presents the program description and a discussion of the evaluation approach used in this study.

Section 3: Indoor Lighting Evaluation: This section discusses the evaluation approach and results obtained for the first year load impact study for lighting.

Section 4: Industrial Process Study: This section contains the first year load impact study for industrial processes.

Section 5: Industrial Motors Study: This section contains the first year load impact study for industrial processes.

Appendices: This section contains all the appendices referenced throughout the report, and the Revised Table E-3 for the PY96 Industrial EEI Program, and the M&E Protocols Reporting Requirements Tables 6 and 7 for the various end uses.

2 STUDY OVERVIEW

2.1 INTRODUCTION

This section presents the program description, a discussion of the participant database and data collection.

2.2 PROGRAM DESCRIPTION

San Diego Gas & Electric offers the C/I/A EEI Programs to help customers reduce energy costs and increase energy efficiency at their facilities. The C/I/A EEI Programs, supported through audit programs, energy services representatives, and account executives, provide cost-effective DSM energy savings when existing customers have retrofit opportunities. SDG&E has three main market delivery mechanisms for providing incentives for retrofit or replace-on-burnout applications: (1) Commercial/Industrial (C/I) Incentives Program, (2) Power to Save Program, and (3) Commercial Rebates Programs. Through this marketing strategy, SDG&E is provided the flexibility needed to encourage the adoption of energy efficient measures that would not otherwise be installed by customers due to economic market barriers.

C/I Incentives. This program typically targets large customers where SDG&E's account executives are involved in assisting customers with major retrofit applications. This program offers incentives to customers for the installation of standard mechanical and complex custom energy efficient measures. Energy efficient measures that have been identified as cost-effective when applied to specific building types are categorized as standard measures. Incentives are also available for measures on a customized basis, providing the project meets the program cost-effectiveness tests. Energy savings are determined and reviewed by SDG&E's engineering staff. Additionally, for further verification, an outside consulting engineering firm performs semi-annual reviews of the completed job files.

Power to Save. This marketing strategy offers incentives to customers for the installation of energy efficient lighting and mechanical technologies. This full service strategy focuses on standard and custom lighting applications, as well as less complex standard and custom mechanical applications for all sizes of commercial and industrial customers, but tends to accommodate medium/small commercial/industrial customers.

Customer participation begins with an energy audit and recommendations for energy efficient equipment based on audit results. Customers are encouraged to participate in this program by installing cost-effective energy efficient measures and receiving incentives for those measures.

Commercial Rebates. These rebates are delivered through retailers/wholesalers who give the commercial/industrial/agricultural customer an instant incentive at the point of purchase. This program offers rebates to these customers for the following measures: (1) high efficiency refrigerators, (2) compact fluorescent lamps, (3) other energy efficient lighting technologies, (4) energy efficient motors, and (5) HVAC measures.

2.3 EVALUATION METHODOLOGY

The approach used to conduct the *Evaluation* utilized end-use **engineering models** with verified input assumptions. Measurements of equipment performance and monitoring of equipment operations were performed to refine the inputs into the engineering models developed for each measure. The methodology used for this study is consistent with Table C-5 of *the M&E Protocols*. The approach used for estimating *ex post* load impacts for industrial process measures is described in Section 2.3.1, while the approach used for estimating the *ex post* load impacts for motor measures is described in Section 2.3.2. The load impact estimation approach for interior lighting measures is discussed in Section 3.

2.3.1 Ex Post *Load Impact Estimation Approach For Industrial Process Measures*

This section describes the approach and tasks used to conduct the site-specific impact studies for the 1996 IEEI Program.

Task 1: Gather Available Site Data

Site data were gathered and compiled from available sources. Typically, these sources included hard copies of customer applications, SDG&E work papers, design reports, invoices, billing information and pre-retrofit and post- retrofit field surveys. A site profile was developed from which an evaluation plan was designed.

Task 2: Develop Site Evaluation Plan

The initial evaluation plan for each site was developed by XENERGY and submitted to SDG&E for review. An example of the *general* work flow is displayed as Figure 2-1. Process sites totaling a minimum of 70 percent of the load impacts were targeted for on-site visits.

Evaluation Approach and Methodologies

The measurement approach must take into account the various types of technologies, processes, and operations schedules found in the industrial sector.

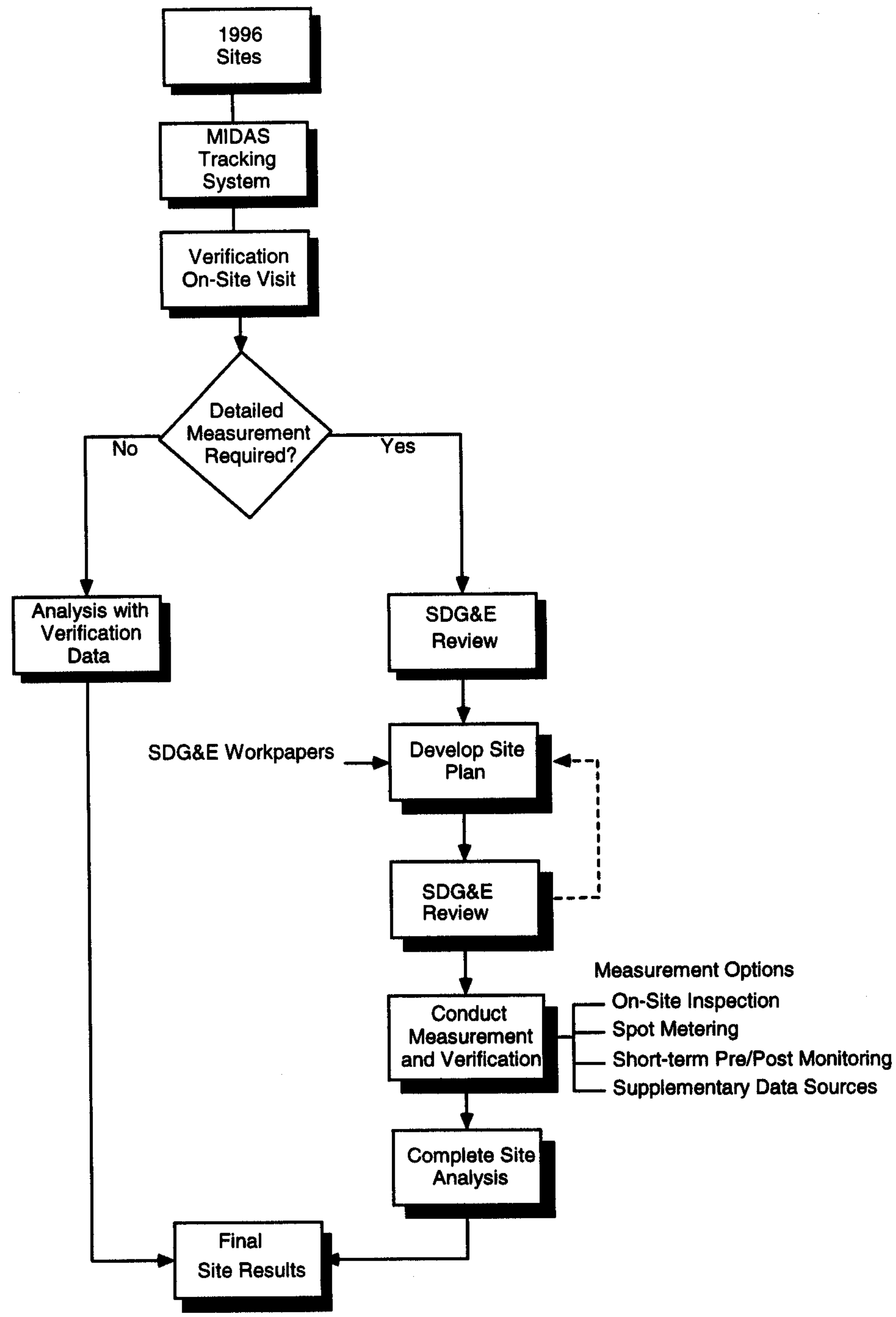
To meet the impact measurement needs of this project, appropriate combinations of the following tools were used:

- engineering models and analysis;
- equipment data collection tools and methods;
- on-site surveys; and

- short-term metering and spot measurements.

On-site surveys were conducted to verify the installation of the measures, and to verify or improve the engineering assumptions that were used to estimate *ex ante* load impacts. Previously collected data were used to help reduce the scope of the on-site data collection effort where feasible. Project documentation provided by SDG&E was the primary source for engineering calculations of *ex ante* energy impact estimates in most cases.

Figure 2-1
General Study Work Flow



Task 3: Conduct Site-Specific Analysis of IEEI Program Projects

Site-specific analyses were completed for all participants of *SDG&E's 1996 Industrial Energy Efficiency Incentives Program* that installed measures classified as industrial process.

Sub-Task 3a: Develop Project-Specific Evaluation Plan

Individual evaluation plans were developed for each IEEI Program participant and summarized in spreadsheet form.

Sub-Task 3b: Determine Gross Site-Specific Impacts

The next subtask was to estimate the gross impacts for each site.

2.3.11.Data Collection

On-site data collection activities were conducted from September 1997 through December 1997 for those sites evaluated through the on-site approach. Measure installations were verified, measurements were taken to support load impact estimation, and other on-site data were collected via interview with site personnel and inspection of operating records.

For those sites not evaluated on site, data from the project files were reviewed and augmented as appropriate with data from credible secondary sources.

Gross impacts were calculated on an individual project basis.

2.3.12.Load Impacts For Process Measures

The gross load impacts of industrial process measures were estimated *ex post* using engineering based models. Detailed analysis based on on-site measurements and observations was carried out. The power of major electrical measures was monitored for at least one week to verify operating schedule and loading patterns. When monitoring was not feasible or not appropriate, the systems were observed in operation and operating staff interviewed and logs reviewed to verify schedule and other key engineering assumptions used in the *ex ante* analysis.

For those sites not visited on-site, a review of the *ex ante* load impact estimates was conducted and *ex post* load impacts estimated using file data augmented by telephone or alternate algorithms.

In general, the engineering approach used to estimate the *ex ante* impacts was the basis for the *ex post* analysis. Where possible and appropriate, impacts were calculated by a second method. In several cases where savings were a significant proportion of total use at the site, a billing analysis, or "unit energy consumption" method was used.

Task 4: Estimate Total Gross Impacts

Gross impacts were estimated for the PY96 industrial energy efficiency measures. This includes total gross kW, kWh and therm impacts, as appropriate. Realization rates were calculated for each type of measure as defined in Table 6 of the *M&E Protocols*, where it is defined as "the load impacts estimated by the Evaluation, divided by the load impacts filed in a utility's first year earnings claim."

Integrate Site-Specific Gross Impacts

After the individual impacts from each project were estimated, the results were aggregated to estimate total program gross impacts.

Task 5: Determine Total Net Impacts

Net impacts were addressed through an assessment of the net-to-gross ratio. An interview was conducted with each site contact as part of the on-site post-installation field visit. Assessment of net-to-gross was done through self-reported responses to questions about the factors that affected the customer's decision to implement the measure recommendation, as well as supporting documentation found in project files.

A net-to-gross ratio was estimated for each measure installed based on information gathered during the site visit and from the project files. The decision rules for estimating the net-to-gross are shown in Table 2-1. Among the underlying principles on which these rules were based is a basic consumer behavior model comprised of four steps:

1. awareness of a problem or need;
2. information gathering for solutions;
3. evaluation and (more information gathering if necessary); and
4. the purchase.

Through the IEEI Program, SDG&E has several opportunities to intervene and facilitate this consumer process. SDG&E can proactively identify energy efficiency opportunities and quantify their potential impacts and costs. The customer can be made aware of energy efficiency measures and provided information on associated costs and benefits. Incentives may be provided to reduce the cost barriers to implementation. The customer will go through an evaluation phase, where additional information may be gathered, perhaps a different equipment configuration. Finally, a decision will be made whether to implement the measure or not.

Figure 2-2 shows a decision tree that reflects the rules described in Table 2-1 for assigning the net-to-gross ratio on a site-specific basis.

Table 2-1
Decision Rules For Estimating Net-To-Gross Ratio

Level of SDG&E Involvement	Description	Net-To-Gross Ratio
High: Clear evidence that: (1) SDG&E performed or commissioned a site-specific engineering study in advance of the conceptual development of the project was found; or (2) the unincentivized paybacks were outside the firm's payback investment threshold and the incentive allowed the firm to invest in the measure.	The IEEI Program was primarily responsible for the development of the energy efficiency concept and/or ultimate development of the measure through a combination of technical and financial assistance.	1.00
Medium: SDG&E prepared analysis that provided cost-justification through engineering analysis and the incentives in advance of the installation of the measure. The originator of the project concept was not clear. SDG&E did however, provide clear assistance in the evaluation and implementation phases of the process.	The IEEI Program was instrumental in providing information to the customer. The project concept, however, may have been originated by a non-program source, e.g., a vendor. In these cases, project cost barriers may have been reduced through incentives offered through the program.	**If incentive influenced the decision:** If payback w/o incentive >2.0 years: 1.00 If payback w/o incentive is 0.5-2.0 years: 0.75 If payback w/o incentive <0.5 years: 0.40 **If incentive did not influence the decision:** If payback w/o incentive >0.5 years: 0.50 If payback w/o incentive <0.5 years: 0.40
Low: Little evidence of technical support and/or engineering analysis that affected the final decision making, e.g., the origination of the measure concept.	The IEEI Program appeared to have little involvement and little influence on the decision to implement. Unincentivized paybacks were not sufficiently long enough to affect the purchase decision.	**If incentive influenced the decision:** 0.40 **If incentive did not influence the decision:** 0.00

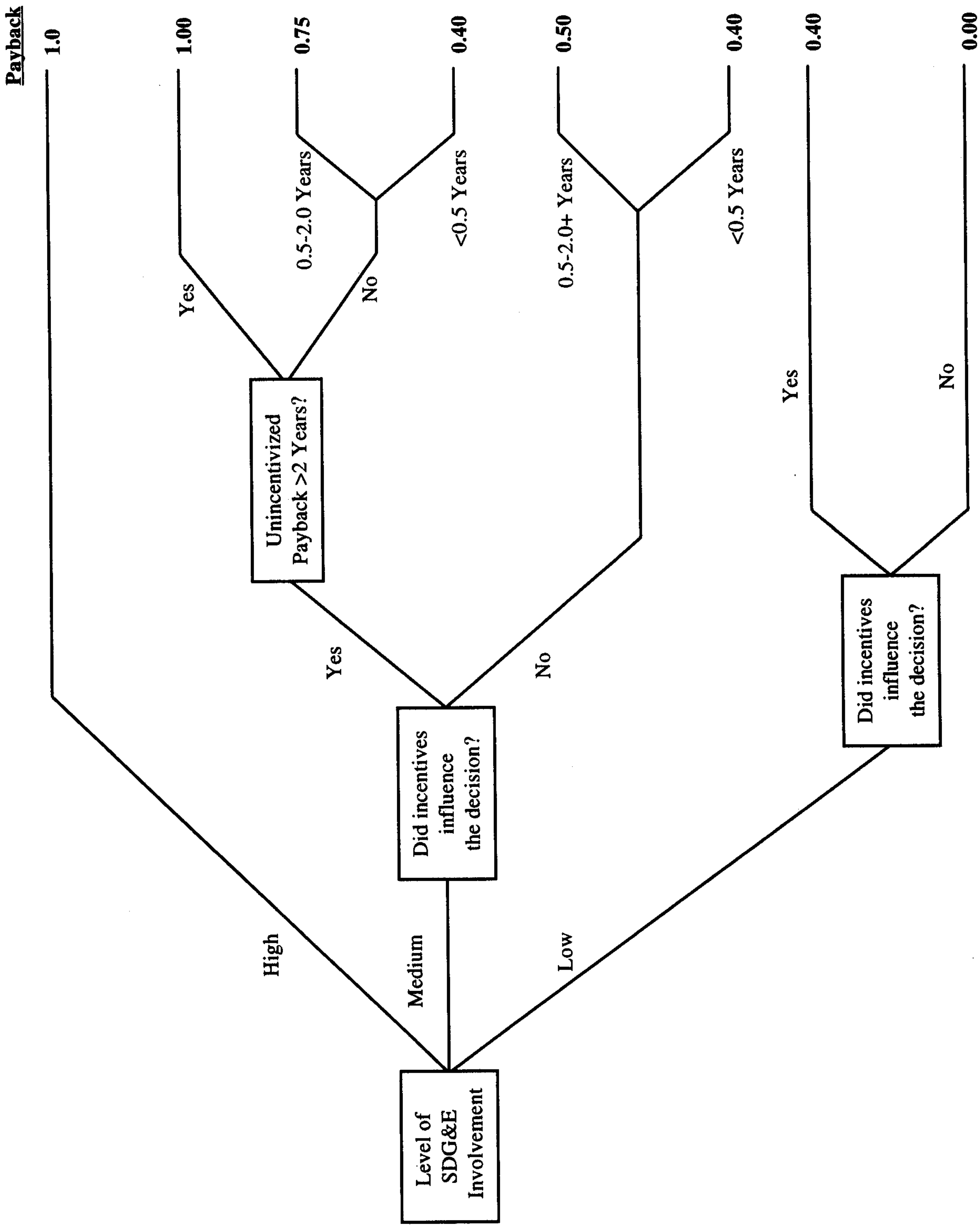
Process Measures. By evaluating information gathered from customer personnel and the project files the net-to-gross ratios were assigned for each site. The site specific net-to-gross ratios were combined with the gross savings estimate per site to estimate the net impacts on site-specific basis. The net impacts were then aggregated to the program level.

The net-to-gross ratio for the program was estimated by dividing the *ex post* net load impacts by the *ex post* gross load impacts. Thus, the program net-to-gross is weighted by the individual measure load impacts.

Lighting Measures. For lighting measures a net-to-gross ratio was estimated for each participant. A weighted average of the net-to-gross ratios was taken, using *ex ante* gross kWh savings as the basis for the weight. The weighted average net-to-gross was applied to the program gross impacts to estimate the net impacts of the program for lighting measures.

Motor Measures. Large motor measures were evaluated using the above methodology. Small motor measures were evaluated based on: (1) whether the motor was installed due to a replace on burnout (ROB) scenario (net-to-gross assigned 0.0); or (2) a true retrofit of an operational motor (net-to-gross assigned 1.0).

Figure 2-2
Net-To-Gross Decision Tree



2.3.2 Ex Post *Load Impact Estimation Approach For Industrial Motor Measures*

This section provides an overview of the *ex ante* and *ex post* methodologies and general equations for estimating the load impacts of the industrial motor measures.
During 1996 two technologies were included as motor measures. These were:

- adjustable speed drives, (ASDs); and
- high efficiency (HE) motors.

Adjustable speed drives accounted for 89.5% and 86.8% of the total kWh and kW impacts, respectively, for the 1996 industrial motors program. Separate methodologies were used both *ex ante and ex post* for estimating impacts of measures using the two technologies.

Sampling

The sample was drawn from program participants in accordance with Table C-5 of the *M&E Protocols*. Overall, measures representing 91.2 percent of the total *ex ante* kWh impacts and 92.5 percent of the total *ex ante* kW impacts for the motor end use element were evaluated with a site specific approach.

Ex Ante Load Impact Estimation Methodology

This section describes the method used to estimate *ex ante* load impacts for industrial motors measures installed during PY96.

HE Motors

Each of the motor measures was installed as part of SDG&E's Energy Efficient Motor Rebate Program. Under this program, the nonresidential market in San Diego was targeted. Open Drip-Proof (ODP) and Totally Enclosed Fan-Cooled (TEFC) motors from 1 to 200 HP were included in the program. These motors were single-speed energy efficient motors. A method documented by EPRI[1] was used to estimate *ex ante* impacts for single-speed motors. Equations 2-1 and 2-2 were used to estimate *ex ante* load impacts, using standard assumptions regarding the operations of the motors. Among these assumptions were 4,000 hours of operation annually and rated load factor for base and energy efficient motors of 0.75.

1 Electric Power Research Institute, Engineering Methods for Estimating the Impacts of Demand-Side Management Programs, Volume 2: Fundamental Equations for Residential and Commercial End Uses, pp. 3-84 to 3-85.

$$\text{(Eq. 2-1)} \quad \Delta kWh = (units)(0.746)\left[\frac{(hp_{base})(RLF_{base})}{\eta_{base}} - \frac{(hp_{ee})(RLF_{ee})}{\eta_{ee}}\right](FLH),$$

where:

ΔkWh = gross annual energy savings,

$units$ = number of motors installed under the program,

η_{base} = efficiency of base motor,

η_{ee} = efficiency of high-efficiency motor,

hp_{base} = horsepower of base motor (hp),

hp_{ee} = horsepower of high-efficiency motor (hp),

RLF_{base} = rated load factor for the base motor,

RLF_{ee} = rated load factor for the high-efficiency motor,

FLH = full-load hours, and

0.746 = conversion factor (kW / hp).

Ex ante demand impacts were estimated using Equation 2-2.

$$\text{(Eq. 2-2)} \quad \Delta \text{kW} = (\text{units})(0.746)\left[\frac{(\text{hp}_{\text{base}})(\text{RLF}_{\text{base}})}{\text{h}_{\text{base}}} - \frac{(\text{hp}_{\text{ee}})(\text{RLF}_{\text{ee}})}{\text{h}_{\text{ee}}}\right](\text{DF})(\text{CF}),$$

where:

ΔkW = gross coincident demand savings,

units = number of motors installed under the program,

h_{base} = efficiency of base motor,

h_{ee} = efficiency of high-efficiency motor,

hp_{base} = horsepower of base motor (hp),

hp_{ee} = horsepower of high-efficiency motor (hp),

RLF_{base} = rated load factor for the base motor,

RLF_{ee} = rated load factor for the high-efficiency motor,

FLH = full-load hours,

DF = demand diversity factor,

CF = coincidence factor, and

0.746 = conversion factor (kW / hp).

Adjustable Speed Drive Measures

Adjustable speed drive measures installed at six measures were included in the 1996 Industrial EEI Program as motor measures. Three measures were included in this evaluation. The *ex ante* impacts for this sites were estimated using the drive vendor's proprietary software. The key elements of the ASD estimates method were:

- a typical annual loading profile for the motor was projected from customer estimates of operating schedule and flow requirements;
- the load profile was subjected to a proprietary comparison model provided by the drive vendor. The difference between the motor power to serve the output load profile over

time using the base case flow control strategy (usually a valve or damper) versus the power and energy requirements for a motor using an ASD to achieve the same output is calculated at each 10 percent loading point (i.e. 10%, 20%, 30%, ..., 100%).

- the kW impact is the difference in kW at the 100% loading; and
- the energy savings is the difference in power at each loading multiplied by the estimated number of hours each year that the loading condition occurs.

Ex Post Gross Load Impact Estimation Methodology

Engineering analysis with verified data on operating characteristics was the basis for *ex post* load impact estimates for motor measures. Different approaches were used for the HE motors and the ASDs.

HE Motors

Verification of the operating conditions of the motors was performed through on-site inspections and/or telephone interviews. Interviews with site personnel were conducted to confirm motor operating hours and to estimate the loading pattern.

The *ex post* estimation methodology used Equations 2-3 and 2-4 to estimate the load impacts of each of the motor measures.

$$\text{(Eq. 2-3)} \qquad \Delta kWh = (units)(0.746)\left[\frac{(hp_{base})(RLF_{base})}{h_{base}} - \frac{(hp_{ee})(RLF_{ee})}{h_{ee}}\right](H),$$

where:

ΔkWh = gross annual energy savings,
units = number of identical motors installed under the program,
h_{base} = efficiency of base motor at operating load factor (Motormaster),
h_{ee} = efficiency of high-efficiency motor at operating load factor (Motormaster),
hp_{base} = horsepower of base motor (hp),
hp_{ee} = horsepower of high-efficiency motor (hp),
RLF_{base} = observed operating load factor for the base motor (0.75 default),
RLF_{ee} = observed operating load factor for the high-efficiency motor (0.75 default),
H = annual operating hours (customer estimate), and
0.746 = conversion factor (kW / hp).

Ex post demand impacts were estimated using Equations 2-4 and 2-5. For most industrial systems the operation was consistent during the on-peak period. Where loads or cycle duration varied, the variation was reported to be random.

(Eq. 2-4)

$$\Delta kWh_{on\text{-}peak} = \left(\Delta kWh_{annual}\right) \times \left(\frac{\text{Equipment Operating Hours}_{on\text{-}peak}}{\text{Equipment Operating Hours}_{annual}}\right),$$

where,

$\Delta kWh_{on\text{-}peak}$ = kWh savings during on-peak period,

ΔkWh_{annual} = annual kWh savings,

$\text{Equipment Operating Hours}_{on\text{-}peak}$ = total hours equipment operated during on-peak period,

$\text{Equipment Operating Hours}_{annual}$ = total hours equipment operated per year.

(Eq. 2-5)

$$\Delta kW_{on\text{-}peak} = \frac{\Delta kWh_{on\text{-}peak}}{\text{Hours}_{on\text{-}peak}},$$

where,

$\Delta kWh_{on\text{-}peak}$ = kWh savings during on-peak period,

$\text{Hours}_{on\text{-}peak}$ = Total hours during on-peak period.

2.3.21. Estimating Base Case For HE Motor Measures

For those sites where the new motor was a *retrofit of a working motor*, the description of the old motor from the Energy Efficient Motor Program Customer Enrollment Form ("Enrollment Form") was used to define the base case. However, (1) for those motors where the new motor was *replacing a burned out unit*, (2) for those sites where a *new facility or application* was indicated on the "Enrollment Form," or (3) for those measures where the old motor information was not provided on the "Enrollment Form," a base case motor representing an "average" motor that would typically be purchased over the counter was developed using the following procedures.

Baseline (standard) motor efficiency data was obtained from the MotorMaster+ database (Washington State Energy Office, 1996). This database contains cost and efficiency data on more than 10,000 NEMA Design B motors. Baseline motor data was chosen by searching the database for motors with efficiencies less than the NEMA 12-6B standard and selecting the motor with the median efficiency at 100 percent load. Efficiency and Power Factor curve data were available for load conditions from 25 percent to 100 percent in quartile increments.

2.3.22. Load Impact Estimation of HE Motor Measures

The gross load impacts for the motor were estimated by taking the difference of energy use for the baseline and energy efficient motors.

Realization rates were calculated for the Program as defined in Table 6 of the *M&E Protocols*, where it is defined as "the load impacts estimated by the Evaluation, divided by the load impacts filed in a utility's first year earnings claim."

The realization rate was applied to the *ex ante* total kWh saved and kW reduced to estimate the Program gross load impacts.

Adjustable Speed Drive Measures

Adjustable speed drive measures installed at six project sites for three customers were included in the 1996 Industrial Motors Program savings claim. Measures installed under three ID No. comprised 93.7 and 96.3 percent of the *ex ante* kWh and kW savings. These measures were selected for detailed on-site analysis.

The *ex post* impacts were estimated using a general methodology which is similar to the proprietary method used for the *ex ante* estimates, however, the analysis is reversed to reflect the fact that post-retrofit project measurements and observations are taken. The key elements of the *ex post* load impact estimation approach were:

- power input to the fan motor was measured at each site for at least one week. This is the post project load profile;
- using interviews, the one week profile was adjusted, if necessary, to reflect a full year typical operation;
- post-retrofit output motor loading profile was estimated using the appropriate affinity (power to flow) relationships, and efficiency of the drive motor system;
- the same flow profile, the corresponding motor input power using the base case control strategy was derived from EPRI tables or from affinity laws;
- the difference between the pre- and post-retrofit fan energy for the post-retrofit flow profile was the *ex post* kWh impact; and
- kW impacts were evaluated as follows: The profile during the peak period was isolated to define the kWh savings during the on-peak period. The total kilowatt-hour savings were divided by the annual hours of the on peak time-of-use period.

Net-To-Gross Analysis

The net-to-gross ratio was estimated for motors based on customer reported responses during the survey. The responses were categorized into two categories: (1) always buy energy efficient motors; and (2) the program/rebate made a difference. A net-to-gross ratio was assigned to each surveyed motor. A net-to-gross ratio of zero was assigned to the first category and a net-to-gross of 1.0 was assigned to the latter, as shown in Table 2-2.

Table 2-2
Net-To-Gross Categories
Industrial Motor Measures

Category	Net-To-Gross Ratio
Always buy energy efficient motors	0.00
Program/rebate made a difference	1.00
No response	N/A

The assigned net-to-gross ratios were applied to the gross *ex post* energy and demand impacts to estimate the net impacts for the motors studied. The Program net-to-gross ratio for industrial motors was estimated by dividing total net impacts by total gross impacts for the studied motors. The Program net load impacts were estimated by applying the Program net-to-gross to the total Program *ex post* gross load impacts.

3 INDUSTRIAL LIGHTING MEASURES

During PY96 indoor lighting measures were installed as part of San Diego Gas & Electric's *Industrial Energy Efficiency Incentives Program (Industrial EEI Program)*. This section describes the methodology used and presents the results of the first year *ex post* load impact evaluation of these lighting measures. Table 3-1 shows an *ex ante* summary of the program. It shows that 52,605 individual measures were installed saving an estimated 4,546,408 kWh per year at the sites of 253 facilities defined as participants. A participant is defined as a premise served by an electric meter. The ID No. is a unique variable that was used to identify specific participants.

Table 3-1
Summary of *Ex Ante* Load Impacts
PY96 Industrial EEI Program
Lighting Measures

	Program Participants	Survey Participants	Percent of Program Participants
No. Participants	253	57	23%
No. Measures Installed	52,605	48,795	93%
Gross *Ex Ante* kWh Savings	4,546,408	3,839,211	84%
Gross *Ex Ante* kW Reduced	1,606.49	1,479.45	92%
Net *Ex Ante* kWh Savings	3,803,355	3,111,552	82%
Net *Ex Ante* kW Reduced	1,377.26	1255.35	91%
Max. kWh Savings per Part.	589,109	589,109	
Min. kWh Savings per Part.	281	1,123	

Table 3-2 shows a summary of *ex ante* load impacts by measure category. Clearly, T8 Lamps and electronic ballasts, were the major contributor to the *ex ante* load impacts for the program.

Table 3-2
Summary of *Ex Ante* Load Impacts By Measure Category
PY96 Industrial EEI Program
Lighting Measures

Measure Category	No. Measures	*Ex Ante* kWh Savings	*Ex Ante* kW Reduced
T8-EB	47,499	3,103,010	1,266.67
CFL	2,090	358,708	101.3
CONTROL	55	182,734	31
HPS	45	71,507	14.61
Total	52,605	4,546,408	1,606.49

3.1 *Ex Post* Evaluation Approach

To evaluate the lighting measures on-site verification visits were conducted at a sample of participants. During these visits:

- the installation of the measures was verified and quantified;
- lighting schedules were verified through interviews and/or by installing light loggers for a period of time to estimate hours of operation; and
- spot measurements of a sample of fixtures were taken to estimate *ex post* connected watts.

The data collected were used to adjust the *ex ante* gross kWh impact estimates using a series of adjustment factors for:

- measure installation
- hours of operation
- post-retrofit connected watts

Net savings were estimated at the participant level. An interview was conducted during the site visit to determine the extent the program influenced the decision to install the energy efficient lighting. A net-to-gross ratio was estimated for each on-site evaluation participant. The net-to-gross ratio was applied to the participant-specific gross impacts for those visited on-site. These net impacts were used to determine the net-to-gross ratio for the program. This approach provides a result that was weighted by the energy savings.

3.2 Sampling

The sample design was a Dalenius-Hodges stratification with the Neyman Allocation. The stratification was based on the *ex ante* kWh saved. Table 3-3 shows the boundaries for the three strata design.

Table 3-3
Dalenius Hodges Strata Boundaries
PY96 Industrial EEI Program
Lighting Measures

		kWh Savings Strata Boundaries	
Stratum	**N**	**Minimum**	**Maximum**
1	184	281	3,700
2	49	3,701	15,600
3	20	15,601	589,110
Total	253	281	589,110

Table 3-4 shows the results of the Neyman Allocation. Clearly, the emphasis of the design is towards the participants with the larger load impacts.

Table 3-4
Neyman Allocation
PY96 Industrial EEI Program
Lighting Measures

Strata	Boundaries	Program Participants (N)	Sample (n)	Total *Ex Ante* kWh Savings
1	0 to 3,700	141	3	250,358
2	3,701 to 15,600	65	4	517,449
3	Over 15,600	47	47	3,778,601
Total		253	54	4,546,408

3.3 Estimation of Adjustment Factors

Several adjustment factors were estimated for hours of operation, measure installation and post-retrofit connected watts, as described previously. These factors were developed to adjust the gross *ex ante* load impacts to reflect the conditions observed during the *ex post* on-site verification survey. This section describes the estimation of these adjustment factors.

3.3.1 Hours of Operation

The *ex post* hours of operation for the lighting fixtures was estimated using light loggers that record the number of hours the light fixtures are on. Two types of light loggers were used: run-time loggers that gather data on an aggregate basis and time-of-use (TOU) loggers that collect data that allow the estimation of the number of hours a fixture is turned-on on a time differentiated basis. The TOU logger data are downloaded from the logger via a serial port of a

PC, and are accessible through proprietary software called SmartWare Ver. 3.2 from Pacific Science & Technology, Inc.

The *ex post* hours of operation was estimated for 20 of the largest participants through the installation of light loggers at each facility. Loggers were installed in locations that were considered to be typical of the operations represented by the lighting retrofit project. The percent of time the lights are on was calculated for each logger and then annualized. The average annualized hours of operation were calculated for each participant. Average hours of operation for each participant was calculated for both *ex ante* and *ex post.*

For the remaining participants operating schedules were obtained from site personnel through interviews. The schedules were annualized.

Realization rates were calculated for each participant by dividing the *ex post* hours by *ex ante* hours. The adjustment factor for hours of operation was estimated by taking the weighted average of the participant-specific realization rates, using the gross *ex ante* energy savings as the weight. The results are shown in Table 3-5.

Table 3-5
Adjustment Factor for Hours of Operation
PY96 Industrial EEI Program
Lighting Measures

Adjustment factor for all on-site participants	1.2804
Adj. Factor for Monitored Sites	1.3414

The results indicate an increase in operating hours from the *ex ante* estimates. This would be consistent with the general increase in industrial activity in the San Diego area. Site contacts indicated that shifts were added, resulting in higher hours of operation.

Table B-1 shows a complete listing of the hours of operation for sites visited on-site.

3.3.2 Measure Installation

Measure installations were verified and quantified. A realization rate was calculated for each measure. A weighted average of these realization rates was taken to estimate the adjustment factor for measure installations.

As shown in Table 3-6 the adjustment factor was 0.967, indicating that, just over three percent of the measures installed were no longer in place.

Table 3-6
Adjustment Factor for Measure Installation
PY96 Industrial EEI Program
Lighting Measures

Adjustment Factor for Measure Installation Weighted by *Ex Ante* kWh Savings per Measure	0.967

Table E-2 in Appendix E shows a detailed table of the verified measure counts.

3.3.3 Adjustment Factor for Post-Retrofit Connected Watts

As part of the industrial protocols for M&V the measurement of end use connected loads is required in estimating pre- and post-retrofit load impacts. A series of spot measurements was taken on a sample of fixtures to estimate the adjustment factor for connected watts for the fixtures installed under the program. These measurements were compared to *ex ante* assumptions of the connected watts of post-retrofit fixtures and an adjustment factor for connected watts was estimated.

Volts and amps were measured. The power factor was assumed to be 1.0. Watts per fixture were calculated by multiplying volts time amps and dividing by the number of fixtures measured.

A raw adjustment factor was calculated by dividing the *ex ante* watts by the *ex post* watts for each measurement. Thus, if *ex post* watts is greater than *ex ante*, then the *ex post* load impacts will be less than the *ex ante*. Conversely, if *ex post* watts are less than *ex ante*, then the *ex post* load impacts will be greater than the *ex ante*.

The raw adjustment factors for the individual fixtures were weighted by the *ex ante* kWh savings aggregating by category of the fixture.

Table 3-7 shows the results of the spot measurement of the fixtures measured. It also shows the adjustment factor for fixture wattage to be 0.9839. This value indicates that the *ex post* measurements were slightly higher than the *ex ante* assumptions for the post-retrofit fixture. These measurements were corroborated through measurements taken for the First Year Load Impact Evaluation for SDG&E's Commercial EEI Program for the Military Sector, PY96.

Table 3-7
Adjustment Factor for Connected Watts
PY96 Industrial EEI Program
Lighting Measures

			Ex Post Watts				*Ex Ante* Watts				
Measure Category	ID No.	Fixture	No. Fixtures Measured	Volts	Amps per Fixture	Watts per Fixture	Watts per Fixture	Realization Rate (Ex Ante / Ex Post)	Average per Measure Category	*Ex Ante* Gross kWh Savings	Weighted Realization Rates
HPS High Pressure Sodium	18196	1HP400	5	120.3	18.000	433.1	465.0	1.0737	1.0737	71,507.0	0.0242
T8-EB T8 Lamps with Electronic Ballasts	45108	2LF17EL	2	119.8	0.56	33.5	32.0	0.9540			
	7097	2LF32EL	12	119.4	5.90	58.7	58.0	0.9880			
	45108	2LF32EL	1	119.6	0.49	58.5	58.0	0.9917			
	41621	2LF32EL	4	120	1.960	58.8	58.0	0.9864			
	41621	2LF32EL	1	120.1	0.50	59.8	58.0	0.9697			
	20501	2LF32EL	1	119.5	0.489	58.4	58.0	0.9925			
	20501	2LF32EL	1	119.9	0.490	58.8	58.0	0.9872			
	20501	2LF32EL	1	120	0.489	58.7	58.0	0.9884			
	7097	2LF32ELR EF	1	120.1	0.49	58.8	58.0	0.9856			
	11878	2LF32ELR EF	6	120	2.928	58.6	58.0	0.9904			
	11878	2LF32ELR EF	4	120.3	1.996	60.0	58.0	0.9662	0.9818	3,103,010.0	0.9597
Adjustment Factor for Post-Retrofit Connected Watts											**0.9839**

Only one measurement was taken for the HPS measure, however, the measured wattage is consistent with measurements taken for the *First Year Load Impact Evaluation for SDG&E's Commercial EEI Program for the Military Sector, PY96*. In this study HPS fixtures were measured with a mean realization rate of 1.0713 with a standard deviation of 0.0074.

3.4 Net-To-Gross Ratio

The net-to-gross ratio was estimated using the approach discussed in Section 3.2.5. The program net-to-gross ratio was applied to the *ex post* gross program impacts to estimate the *ex post* net program load impacts.

The *ex post* net-to-gross ratio estimated is shown in Table 3-11.

Table 3-8
Net-to-Gross
PY96 Industrial EEI Program
Lighting Measures

Program Net-to-Gross	**0.8434**

3.5 Ex Post KWH Savings Estimation

The *ex ante* gross kWh impacts for the Industrial EEI Program was multiplied by the adjustment factors for hours of operation, measure installation and post-retrofit fixture wattage. The *ex post* gross kWh impact is shown in Table 3-9.

Table 3-9
***Ex Post* kWh Impacts**
PY96 Industrial EEI Program
Lighting Measures

Ex Ante kWh Savings	4,546,408
Adjustment Factor - Hours of Operation	1.280
Adjustment Factor - Measure Installation	0.967
Adjustment Factor - Fixture Wattage	0.984
Ex Post Gross kWh Savings	5,538,477
Net-to-Gross	0.84
Ex Post Net kWh Savings	4,652,320
Gross Realization Rate	1.218
Ex Ante Net kWh Savings	3,803,355
Net Realization Rate	1.223

3.6 Ex Post KW Reduction Estimation

The *ex post* kW impact estimate was based on the TOU loggers that were in the field. The question that needed to be addressed was whether the lights at a given building would have been turned on at the time of SDG&E system peak. SDG&E's system peaked on September 4, 1997 at 15:30. Since the loggers were installed on a short-term basis, the measurement of the actual peak coincidence was not possible. The approach used to determine whether a set of monitored lights would have been turned on was to examine the TOU logger data and determine whether the lights of the logger would be on during the time from 13:00 to 15:00 on a weekday. A series of five working days were assessed. The percentage of time the logger was on during the 13:00 to 15:00 period was recorded. If the percentage was 0.5 or higher then the lights were assigned an On-Off value of one and were the on state . Otherwise the logger was assigned an On-Off value of zero and were in the off state. This value indicates whether the light was likely on for each of the five days assessed. The five On-Off states for the 22 loggers were summed by logger.

The value of this sum was used to determine whether the lights were likely to be on for that logger during the system peak period. If the value was 2.5 or higher then the lights were assigned to the On state. Otherwise it was assigned to the Off state. The peak coincidence factor was taken as the fraction of loggers in the On state. The results show a peak coincidence factor of 0.864, as shown in Table 3-10.

Table E-4 in Appendix E shows a detailed view of the data used to estimate the coincidence factor.

Table 3-10
***Ex Post* Peak kW Coincidence Factor**
PY96 Industrial EEI Program
Lighting Measures

Status	Frequency	Percent
Off	3	0.136
On	19	0.864
Total	22	1.000
Peak Coincidence Factor		0.864

The Peak Coincidence Factor was applied to the total connected kW, that was calculated by dividing the total *ex ante* kW impacts by the *ex ante* coincidence factor. The results are shown in Table 3-11.

Table 3-11
***Ex Post* kW Impacts**
PY96 Industrial EEI Program
Lighting Measures

***Ex Ante* kW**	**1,606.49**
Ex Ante Coincidence Factor	0.76
Total *Ex Ante* Connected kW	2113.80
Adjustment Factor - Connected Watts	0.9839
Ex Post kW Coincidence Factor	0.864
***Ex Post* Gross kW**	**1796.17**
Net-to-Gross	0.84
Net kW Impacts	**1508.79**
Gross Realization Rate	**1.118**
***Ex Ante* Net kW**	**1,377.26**
Net Realization Rate	**1.095**

3.7 Ex Post Verified Lighted Building Square Footage

Lighted building square footage was verified during the site visit. The lighted square footage of the program participants was estimated by extrapolating the verified square footage of survey participants based on *ex ante* energy savings. This was done by dividing the *ex post* verified square footage by the share of *ex ante* gross kWh impacts of the total *ex ante* gross kWh impacts. This effectively scaled the square footage to the program level based on a known value. This approach was chosen as there were a number of missing values for square footage in the program tracking system extract that precluded the use of a realization rate. The results of the estimation are shown in Table 3-12.

Table 3-12
***Ex Post* kW Impacts**
PY96 Industrial EEI Program
Lighting Measures

Ex Post Verified Square Feet (Survey Participants)	3,753,848
Share of Ex Ante Gross kWh Impacts Surveyed	0.84
Ex Post Estimated Square Footage for Program Participants	4,468,867

4 PROCESS MEASURES

4.1 INTRODUCTION

This section provides the site specific analyses for the industrial process measures installed under San Diego Gas & Electric's *1996 Industrial Energy Efficiency Incentives (IEEI) Program.*

4.2 SUMMARY OF LOAD IMPACTS OF PROCESS MEASURES

Table 4-1 provides an overview of the program and *ex post* evaluation participants. The 32 projects identified as a single row in the table were installed at the sites of 21 participants. The *ex ante* load impacts for the program in 1996 were:

- 11,707,932 kWh
- 3,231 kW
- 2,176,732 therms

The current load impact evaluation included over 70 percent of the load impacts for kWh, kW and therms, with evaluation participants comprised 89 percent, 96 percent and 92 percent of the total load impacts for the program.

Table 4-2 shows the gross load impacts estimated *ex post* for the sample included in the evaluation. The results show that gross load impacts had realization rates of:

- kWh: 0.88
- kW: 0.50
- therms: 1.15

Table 4-3 shows the net load impacts estimated *ex post* for the sample included in the evaluation. The results show that net load impacts had realization rates of:

- kWh: 0.85
- kW: 0.48
- therms: 0.63

Table 4-4 shows the summary *ex post* load impacts for the 1996 IEEI Program process measures while Table 4-5 shows a summary of the fuel types of the measures and participants for the process measures installed under the program and the *ex post* evaluation.

Table 4-1
Overview of Program Participants and *Ex Post* Evaluation Participants
1996 Industrial Energy Efficiency Incentives Program
Process Measures

				Ex Ante Gross Load Impacts					
				Program Participants			*Ex Post* Evaluation Participants		
Participant No.	ID No.	On-Site Visit Conducted?	Measure Description	kWh Savings	kW Reduced	Therm Savings	kWh Savings	kW Reduced	Therm Savings
5	17477	Yes	Air Compressor Systems	2,871,399	955.5	0	2871399	955.5	0
11	40663	Yes	Compressed Air System	2,420,736	1,000.00	0	2420736	1,000.0	0
19	40516	Yes	Automated Die Cast Machine	1,043,113	142.7	0	1043113	142.7	0
12	40560	Yes	Compressed Air System with Controls, Valves & Storage	986,507	561.51	0	986507	561.5	0
16	43166	Yes	Optimized Compressed Air System	884,880	101	0	884880	101.0	0
8	41453	Yes	Optimized Air Cooled Compressed Air System	716,127	117.01	0	716127	117.0	0
19	40514	Yes	High Efficiency Air Compressors	675,792	124.29	0	675792	124.3	0
10	14200	Yes	Efficient Heat Exchanger, Pumps with ASDs	381,786	47.72	708,889	381,786	47.7	708,889
19	17751	Yes	Refrigerated Dryer	134,009	12.79	0	134009	12.8	0
19	45635	Yes	Efficient Die Cast Machine	127,532	5.95	0	127532	6.0	0
4	19318	Yes	High Efficiency Heat Treat Furnace	101,500	0	214,867	101,500	0.0	214,867
19	45635	Yes	Efficient Furnace with Ingot Loader	60,531	20	0	60531	20.0	n/a
10	20411	Yes	Improved Process Mixing	0	0	878,222	0	0.0	878,222
10	19400	Yes	Energy Efficient Heat Exchangers	0	0	191,366	0	0.0	191,366
2	40572	No	Compressor with Storage & Optimized System	341,188	55.03	0			
7	20561	No	Air Cooled Screw Compressor	227,147	0	0			
20	45381	No	VFDs on Injection Mold Machines 1x200T & 1x500T	207,480	25	0			
14	20420	No	Compressed Air Sys w/Additional Storage	170,476	19.5	0			
6	18311	No	ASD-50HP Pump for SD190 Type 2 Process Water	101,408	9.06	0			
1	14370	No	Solid State Variable Frequency Drives	86,788	19	0			
15	20497	No	ASD on Thermal Oxidizer	61,671	-0.6	0			
3	20849	No	New Receivers, Piping Changes & Add Regulators	47,695	14.5	0			
3	20849	No	Repair Disconnects on Compressed Air System	31,904	0	0			
6	20895	No	New Cycling Refrigerant Dryer	15,077	1.72	0			
3	20849	No	High Efficiency Blow Guns on Compressed Air System	14,677	0	0			
17	45287	No	Furnace with Insulation	0	0	61,748			
9	44515	No	Insulated Drum	0	0	41,740			
18	40676	No	New Heat Treating Furnace	0	0	35,149			
18	40678	No	Retrofit Existing Draw Furnace	0	0	20,314			
15	20487	No	Stack Economizer for New Steam Boiler	0	0	5,415			
13	44103	No	Boiler Heat Recovery Heat Exchanger	-232	-0.25	6,433			
21	40617	No	Boiler Exhaust Heat Exchanger	-1,259	-0.27	12,589			
				11,707,932	**3,231.16**	**2,176,732**	**10,403,912**	**3,088.5**	**1,993,344**
Percent of Program Participants Evaluated *Ex Post*							**89%**	**96%**	**92%**

Table 4-2
Summary of *Ex Post* Gross Load Impacts
1996 Industrial Energy Efficiency Incentives Program
Process Measures

			Ex Ante Gross Load Impacts			*Ex Post* Gross Load Impacts			Gross Realization Rates		
Partici-pant No.	ID No.	Measure Description	kWh Savings	kW Reduced	Therm Savings	kWh Savings	kW Reduced	Therm Savings	kWh Savings	kW Reduced	Therm Savings
10	14200	Efficient Heat Exchanger, Pumps with ASDs	381,786	47.7	708,889	326,691	37.3	708,889	0.86	0.78	1.00
5	17477	Air Compressor Systems	2,871,399	955.5	-	2,212,555	421.8	-	0.77	0.44	-
19	17751	Refrigerated Dryer	134,009	12.8	-	77,259	12.3	-	0.58	0.96	-
4	19318	High Efficiency Heat Treat Furnace	101,500	0.0	214,867	92,798	13.5	237,932	0.91	-	1.11
10	19400	Energy Efficient Heat Exchangers	-	-	191,366	-	-	191,423	-	-	1.00
10	20411	Improved Process Mixing	-	-	878,222	-	-	1,146,889	-	-	1.31
19	40514	High Efficiency Air Compressors	675,792	124.3	-	659,898	105.3	-	0.98	0.85	-
19	40516	Automated Die Cast Machine	1,043,113	142.7	-	361,381	53.6	-	0.35	0.38	-
12	40560	Compressed Air System with Controls & Storage	986,507	561.5	-	1,400,883	228.0	-	1.42	0.41	-
11	40663	Compressed Air System	2,420,736	1,000.0	-	2,154,298	423.6	-	0.89	0.42	-
8	41453	Optimized Air Cooled Compressed Air System	716,127	117.0	-	858,165	139.7	-	1.20	1.19	-
16	43166	Optimized Compressed Air System	884,880	101.0	-	847,740	96.8	-	0.96	0.96	-
19	45635	Efficient Die Cast Machine and Efficient Furnace with Ingot Loader	188,063	26.0	-	121,862	18.1	-	0.65	0.70	-
Total			**10,403,912**	**3,088.5**	**1,993,344**	**9,113,530**	**1,550.0**	**2,285,133**	**0.88**	**0.50**	**1.15**

Table 4-3
Summary of *Ex Post* Net Load Impacts
1996 Industrial Energy Efficiency Incentives Program
Process Measures

			Net *Ex Ante* Load Impacts				Net *Ex Post* Load Impacts				Net Realization Rates		
Partici-pant No.	ID No.	Measure Description	Net-to-gross	kWh Sav.	kW Reduced	Therm Sav.	Net-To-Gross	kWh Sav.	KW Red.	Therm Sav.	kWh Sav.	kW Red.	Therm Sav.
10	14200	Efficient Heat Exchanger, Pumps with ASDs	0.90	343,607	42.95	638,000	0.75	245,018	27.98	531,667	0.71	0.65	0.83
5	17477	Air Compressor Systems	1.00	2,871,399	955.50	-	1.00	2,212,555	421.80	-	0.77	0.44	-
19	17751	Refrigerated Dryer	0.90	120,608	11.51	-	1.00	77,259	12.30	-	0.64	1.07	-
4	19318	High Efficiency Heat Treat Furnace	0.90	91,350	0.00	193,380	0.00	0	0.00	0	0.00	-	0.00
10	19400	Energy Efficient Heat Exchangers	0.90	-	-	172,229	0.75	-	-	143,567	-	-	0.83
10	20411	Improved Process Mixing	0.90	-	-	790,400	0.40	-	-	458,756	-	-	0.58
19	40514	High Efficiency Air Compressors	1.00	675,792	124.29	-	1.00	659,898	105.30	-	0.98	0.85	-
19	40516	Automated Die Cast Machine	0.90	938,802	128.43	-	0.40	144,552	21.44	-	0.15	0.17	-
12	40560	Compressed Air System with Controls & Storage	1.00	986,507	561.51	-	1.00	1,400,883	228.00	-	1.42	0.41	-
11	40663	Compressed Air System	1.00	2,420,736	1,000.00	-	1.00	2,154,298	423.60	-	0.89	0.42	-
8	41453	Optimized Air Cooled Compressed Air System	1.00	716,127	117.01	-	1.00	858,165	139.70	-	1.20	1.19	-
16	43166	Optimized Compressed Air System	1.00	884,880	101.00	-	1.00	847,740	96.80	-	0.96	0.96	-
19	45635	Efficient Die Cast Machine and Efficient Furnace with Ingot Loader	0.90	169,257	23.36	-	0.40	48,745	7.24	-	0.29	0.31	-
Total				**10,219,065**	**3,065.55**	**1,794,010**		**8,649,113**	**1,484.16**	**1,133,990**	**0.85**	**0.48**	**0.63**
Average Net-to-Gross Ratio Average Net-to-Gross Ratio (Ex Post Net Impact/Ex Post Gross Impact)								**0.95**	**0.96**	**0.50**			

Table 4-4
***Ex Post* Load Impacts**
1996 Industrial Energy Efficiency Incentives Program
Process Measures

	kWh	kW	Therms
Ex Ante Impact	11,707,932	3,231	2,176,732
Gross Realization Rate	0.88	0.50	1.15
Gross Load Impact	**10,255,814**	**1,622**	**2,495,366**
Ex Post Net-to-Gross	0.95	0.96	0.50
Net Load Impact	**9,733,188**	**1,553**	**1,238,317**
Ex Ante Net Impact	11,448,619	3,203	1,959,059
Net Realization Rate	0.85	0.48	0.63

Table 4-5
1996 Industrial Energy Efficiency Incentives Program
Summary of Participants and Measures by Fuel Type
Process Measures

		Electric Only	Gas Only	Both	Total
No. Participants	Program	13	3	5	21
	Ex Post Evaluation	6	0	2	8
No. Measures	Program	111	11	9	131
	Ex Post Evaluation	17	7	5	29

4.3 ID No. 14200 - Efficient Heat Exchanger, Pumps with ASDs

This is an organic materials processing facility in San Diego. The facility produces food admixtures through a variety of thermal, mechanical and biological production processes. This project involves a process improvement which increased the size of heat exchangers in a key portion of the production process. Heat exchangers which were originally sized for lower production rates and lower fouling factors were increased with heat exchangers more properly sized for production and fouling.

The facility operates continuously, year-round. Thermal energy required for many processes is provided by steam generated by natural gas-fired boilers, rated at 90% overall efficiency. Electricity is also generated with steam from these boilers.

This project includes savings from four separate modifications to the production process stream. Two modifications result in natural gas savings and two result in electrical savings:

A. Replacement of heat exchangers that exchanged waste heat with incoming product. This resulted in improved heat transfer efficiency and reduced heat recovery downtime, and therefore less "new" steam from the boiler plant. The heat exchanger was the same as the heat exchangers removed from other process lines in Project ID # 19400.

B. Replacement of boiler feed pumps and installation of adjustable speed drives for boiler feed pumps.

C. Elimination of two 15 hp process transfer pumps from fluid transfer system by revising piping and valve operations.

D. Bypass of a supplemental process heater resulting from the process improvement in Project ID # 20411, and resulting lower make-up steam requirements.

4.3.1 Ex Ante Load Impact Estimates

This section describes the *ex ante* load impact estimates for each of the four modifications, A through D.

Modification A: Heat Exchanger Replacement

The *ex ante* load impact estimates were calculated using an engineering methodology based on operating assumptions provided by the customer. The savings are based on improved heat transfer efficiency and reduced downtime for cleaning heat exchangers which transfer heat from a waste liquid to an incoming material mixture that requires addition of heat. This is turn reduces the amount of "new" heat that must be added in the form of steam from a steam boiler. The result is a lower overall steam demand per unit of material heated. Savings in operating labor and improvements in overall plant output also result.

The modifications were carried out in one of three process lines at the plant. The equipment that was removed from this process line resulted in a reduction of a key process material. Additional savings for similar improvements in two other process lines are calculated and claimed under Project #19400.

The *ex ante* savings were based on reduced make-up steam requirements as a result of reduced downtime of a heat recovery heat exchanger, as shown in Equations 4-1 and 4-2.

$$\text{(Eq. 4-1)} \quad \text{Reduced make-up steam rqmt (A)}_{\text{Ex ante}} = (125\ \text{gpm}) \times (500\ \text{Btu/hr/gpmDeg-F}) \times (70^\circ\ \text{F}\ \Delta T) \times (1\ \text{Btu/lb Deg-F})$$

$$= 4.375\ \text{MMBtu//hr (as steam)}$$

XENERGY

$$\text{(Eq. 4-2)}\quad \text{Therms saved for Mod. A}_{\text{Ex ante}} = \frac{\left[\begin{array}{c}(\text{Reduced make-up steam rqmt (Mod. A)}_{\text{Ex ante}})\\ \text{x (Operating Hours)}\end{array}\right]}{\text{Boiler efficiency}}$$

$$= \frac{(4.375\ \text{MMBtu//hour})\ \text{x}\ (8{,}000\ \text{hours/year})}{0.90}$$

$$= 388{,}889\ \text{therms/year}$$

Modification B: Replace Boiler Feed Water Pumps and Install Adjustable Speed Drives

The *ex ante* load impact estimates for the replacement of boiler feed water pumps with new pumps and adjustable speed drives on the boiler feed pumps are shown in Equations 4-3 through 4-10. First, the reduced head and associated power reduction are calculated in Equations 4-3 and 4-4.

$$\text{(Eq. 4-3)}\quad \text{Estimated reduced head due to reduced overpumping} = 40\ \text{feet}$$

$$\text{(Eq. 4-4)}\quad \text{Power reduction due to reduced head} = \frac{(400\ \text{gpm})\ \text{x}\ (40\ \text{ft})\ \text{x}\ (8.33\ \text{lb/gallon})}{33{,}000\ \text{hp/lb-ft/min}}$$

$$= 4.03\ \text{hp}$$

From manufacturer's curves, it is estimated that efficiency improves from 0.51 to 0.57. These are used to estimate the power savings due to higher pump efficiency in Equation 4-5.

$$\text{(Eq. 4-5)}\quad \text{Savings due to higher pump efficiency} = 120\ \text{bhp x}\ (0.57 - 0.51)$$

$$= 7.2\ \text{hp}$$

Savings due to VFD at 50% capacity are estimated through Equations 4-6 through 4-10.

$$\text{(Eq. 4-6)}\quad hp_2 = hp_1\left(\frac{gpm_1}{gpm_2}\right)^3$$

$$= (20\ \text{hp})\left(\frac{200\ \text{gpm}}{400\ \text{gpm}}\right)^3$$

$$= (20\ \text{hp})\ \text{x}\ (0.125)$$

$$= 2.5\ \text{hp}$$

(Eq. 4-7) $\text{hp saved} = \text{hp}_1 - \text{hp}_2$

$$= (20\text{ hp}) - (2.5\text{ hp})$$

$$= 17.5\text{ hp}$$

(Eq. 4-8) $$\text{kW reduced ASD} = \frac{(\text{hp saved}) \times (0.746\text{ kW / hp})}{\text{Motor efficiency}} \times (\text{ASD Efficiency Factor})$$

$$= \frac{(17.5\text{ hp}) \times (0.746\text{ kW / hp})}{0.875} \times (0.844)$$

$$= 12.59\text{ kW}$$

(Eq. 4-9) $$\text{kW for Mod. B}_{\text{Ex ante}} = (\text{Power reduced due to reduced head}) + (\text{Savings due to higher efficiency}) + (\text{kW reduced ASD})$$

$$= \frac{(4.03\text{ hp}) \times (0.746\text{ kW / hp})}{0.92} + \frac{(7.2\text{ hp}) \times (0.746\text{ kW / hp})}{0.92} + 12.59\text{ kW}$$

$$= 21.7\text{ kW}$$

(Eq. 4-10) $$\text{kWh for Mod. B}_{\text{Ex ante}} = (\text{kW for Mod.2}_{\text{Ex ante}}) \times (\text{Operating hours})$$

$$= (21.7\text{ kW}) \times (8{,}000\text{ hours / year})$$

$$= 173{,}600\text{ kWh}$$

Modification C: Eliminate Transfer Pumps

Two 15 hp transfer pumps were eliminated by modifying piping, valves and pumping controls. The *ex ante* load impacts of these modifications are shown in Equations 4-11 and 4-12.

$$\text{(Eq. 4-11)} \quad \text{kW for Mod.C}_{\text{Ex ante}} = \frac{(\text{No. Motors})\text{x}(\text{hp / Motor})\text{x}(0.746 \text{ kW / hp})}{\text{Motor efficiency}}$$

$$= \frac{(2 \text{ Motors})\text{x}(15 \text{ bhp})\text{x}(0.746 \text{ kW / hp})}{0.86}$$

$$= 26.02 \text{ kW}$$

$$\text{(Eq. 4-12)} \quad \text{kWh for Mod.C}_{\text{Ex ante}} = \left(\text{kW for Mod.C}_{\text{Ex ante}}\right) \text{ x (Operating hours)}$$

$$= (26.02 \text{ kW}) \text{ x } (8{,}000 \text{ hours / year})$$

$$= 208{,}186 \text{ kWh / year}$$

Modification D: By-Pass Supplemental Process Heater

A steam heater which was used to provide supplemental heat to a process feed mixture was no longer required due to the process improvement described in Project ID # 20411. The mixture is processed at a rate of 600 gallons per minute. The mixture is now maintained at 80° F rather than 95° F required previously. The heat capacity of the mixture is 0.8 Btu/lb.Deg-F. Equation 4-13 shows the reduction in heat input required due to reducing the mixture temperature, and Equation 4-14 shows the energy savings as steam saved.

$$\text{(Eq. 4-13)} \quad \text{Reduced Heat Input} = 600 \text{ gpm x } (95^\circ \text{F} - 80^\circ \text{F}) \text{ x } (500 \text{ lb./hour / gpm}) \text{ x} (0.8 \text{ Btu / lb. Deg. F})$$

$$= 3.6 \text{ MMBtu / hour}$$

$$\text{(Eq. 4-14)} \quad \text{Annual Energy Savings for Mod. D (steam)} = \text{(Reduced heat input) x (Operating hours)}$$

$$= (3.6 \text{ MMBtu / hour}) \text{ x } (8{,}000 \text{ hours / year})$$

$$= 288{,}000 \text{ therms / year as steam}$$

At 90% efficiency, the annual input of natural gas saved is shown in Equation 4-15.

(Eq. 4 - 15) $$\text{Therm savings, Mod.D} = \frac{(\text{Annual Energy Savings for Mod.D (steam)})}{\text{Boiler efficiency}}$$

$$= \frac{(288{,}000 \text{ therms / year as steam})}{0.9 \text{ efficiency}}$$

$$= 320{,}000 \text{ therms / year}$$

Total Ex Ante Load Impact Estimate For Modifications A through D

Table 4-6 shows the total *ex ante* load impacts for all four of the modifications implemented under this project.

Table 4-6
Total *Ex Ante* Load Impacts
Project ID No. 14200

Modification	Description	Ex Ante Load Impacts kW Reduced	kWh Savings	Therm Savings
A	Heat exchanger replacement	0.00	0	388,889
B	Replacement of boiler feed pumps and installation of adjustable speed drives for boiler feed pumps.	21.7	173,600	0
C	Elimination of two 15 hp process transfer pumps from fluid transfer system by revising piping and valve operations.	26.02	208,186	0
D	Bypass of a supplemental heater	0.00	0	320,000
Total		47.72	381,786	708,889

4.3.2 Ex Post Load Impact Estimates

The evaluation analysis was carried out by the same method as the *ex ante* estimates using the observed values for key inputs such as raw material required. The site was visited on September 30, 1997. The improvements were observed in operation. Available manual operating logs were reviewed with operating staff.

Modification A: Heat Exchanger Replacement

The modification and operating conditions and the methodology used in the *ex ante* estimates were reviewed and discussed with the participant's site utility engineer. The *ex ante* methodology is a reasonable method of calculating the savings of the measure. Operating parameters and conditions have not changed since the *ex ante* estimates. Therefore, the *ex ante* load impact estimates are used for the *ex post* load impacts, as shown in Equation 4-16.

$$\text{(Eq. 4-16)} \quad \text{Therms saved for Mod. } A_{\text{Ex post}} = \frac{\left[\begin{array}{l}(\text{Reduced make-up steam rqmt (Mod. A)}_{\text{Ex ante}}) \\ \text{x (Operating Hours)}\end{array}\right]}{\text{Boiler efficiency}}$$

$$= \frac{(4.375 \text{ MMBtu//hour}) \times (8{,}000 \text{ hours/year})}{0.90}$$

$$= 388{,}889 \text{ therms/year}$$

Modification B: Replace Boiler Feed Water Pumps and Install Adjustable Speed Drives

Prior to the retrofit, five 50-hp pumps were installed. Three of the five pumps were operated continuously, year-round to provide feed water to process steam boilers. There was no way to throttle the pumps so operators partially shut a discharge valve to impose a larger pressure on the pump. The pump differential pressure was 250 psi versus about 200 psi required for the boiler feed rate and boiler pressure. Two of the 50 horsepower pumps were replaced with two 75 horsepower pumps controlled by adjustable speed drives. Three remaining pumps were retained, but they are maintained for standby service.

The 75 hp pump motor drives were operating at approximately 54 hertz at the time of the *ex post* evaluation visit. According to operating staff, the pump motors operate continuously in the range of 53 to 56 hertz. The operating hertz is used to estimate load factor. No records of pump speed or flow are maintained.

The *ex post* load impacts were calculated savings by two methods:

1. using the observed post-retrofit pump power at the observed speed, compared with the estimated pre-retrofit pump power and estimated load factor; and
2. the flow/pressure engineering methodology used in the *ex ante* load impacts estimates with some parameters adjusted for observed or reported operating conditions.

The calculations and results of the first method, using observed speed and loadings are shown in Equations 4-17 through 4-22 and Table 4-7. Equations 4-17 and 4-18 show the calculations for estimating the load factor for the pre- and post-retrofit systems.

$$\text{(Eq. 4-17)} \quad \text{Load Factor (observed)}_{\text{Post-retrofit}} = \left(\frac{\text{Observed ASD Hertz}}{\text{System Hertz}}\right)^3$$

$$= \left(\frac{53.75 \text{ Hz.}}{60 \text{ Hz.}}\right)^3$$

$$= 0.7189$$

$$\text{(Eq. 4-18)} \quad \text{Load Factor}_{\text{Pre-retrofit}} = \frac{(\text{\# machines operating}) \times (\text{motor load factor})}{\text{\# machines total}}$$

$$= \frac{(3) \times (0.85)}{5}$$

$$= 0.51$$

Operating horsepower for the pre- and post-retrofit configurations were calculated as shown in Equations 4-19 and 4-20.

$$\text{(Eq. 4-19)} \quad \text{Operating hp}_{\text{Pre-retrofit}} = (\text{Load factor}_{\text{Pre-retrofit}}) \times (\text{Total hp}_{\text{Pre-retrofit}})$$

$$= (0.51) \times (250 \text{ hp})$$

$$= 127.5 \text{ hp}$$

$$\text{(Eq. 4-20)} \quad \text{Operating hp}_{\text{Post-retrofit}} = (\text{Load Factor}_{\text{Post-retrofit}}) \times (\text{Total hp}_{\text{Post-retrofit}})$$

$$= (0.7189) \times (150 \text{ hp})$$

$$= 107.8 \text{ hp}$$

The operating horsepower were converted to kW, as shown in Equations 4-21 through 4-22, and multiplied by the hours of operation to estimate the annual hours of operation for the pre- and post-retrofit configurations.

$$\text{(Eq. 4-21)} \quad \text{kW}_{\text{Pre-retrofit}} = \frac{(\text{operating hp}_{\text{Pre-retrofit}}) \times (0.746 \text{ kW / hp})}{\text{Motor efficiency}}$$

$$= \frac{(127.5 \text{ hp}) \times (0.746 \text{ kW / hp})}{0.875}$$

$$= 108.7 \text{ kW}$$

$$\text{(Eq. 4-22)} \quad kW_{Post\text{-}retrofit} = \frac{(\text{operating hp}_{Post\text{-}retrofit}) \times (0.746\ kW/hp)}{\text{ASD efficiency}}$$

$$= \frac{(107.8\ hp) \times (0.746\ kW/hp)}{0.844}$$

$$= 95.3\ kW$$

Table 4-7
***Ex Post* Analysis of Boiler Feed Pump Replacement and ASD Using Observed ASD Speed**
Project ID No. 14200

	No. Motors or Drives	HP per Motor	Total HP	Est. Load Factor	Operating HP	Motor Efficiency	kW	Annual Hours	Annual kWh
Pre-Retrofit	5	50	250	0.51	127.5	0.875	108.7	8,760	952,237
Post-Retrofit	2	75	150	0.7189	107.8	0.844	95.3	8,760	834,975
Load Impacts							**13.4**		**117,262**

The equations used to calculate the *ex post* load impacts using the flow/pressure engineering methodology used in the *ex ante* load impacts estimates are shown in Equation 4-23 through 4-25. The inputs and the results of these calculations are shown Table 4-8.

$$\text{(Eq. 4-23)} \quad \text{Input horsepower} = \frac{(\text{Average flow, gpm}) \times (\text{Head, feet})}{(3{,}960) \times (\text{Pump efficiency}) \times (\text{Motor efficiency}) \times (\text{ASD efficiency})}$$

$$\text{(Eq. 4-24)} \quad kW = (\text{Input hp}) \times (0.746\ kW/hp)$$

$$\text{(Eq. 4-25)} \quad kWh = (kW) \times (\text{Hours of operation})$$

Table 4-8
***Ex Post* Load Impact Estimates Using Flow/Pressure Methodology**
Project ID No. 14200

	Avg. Flow	Head (ft)	Efficiency Ratings: Pump	Efficiency Ratings: Motor	Efficiency Ratings: Drive	BHP Input	kW	Annual Hours	Annual kWh
Pre-Retrofit	450	250	0.51	0.875	1	63.66	47.49	8760	416,028
Post-Retrofit	450	200	0.57	0.945	0.95	44.41	33.13	8760	290,242
Load Impacts							14.3591		125,786

The results of the two methods differed significantly. The average was used as the *ex post* load impact estimates for energy (121,524 kWh) and demand (13.9 kW).

Modification C: Eliminate Transfer Pumps

The *ex post* methodology is essentially the same as that used for the *ex ante* estimates. However, because documentation of pre-retrofit pump power was not provided, it is reasonable to assume a load factor of 0.90 for the pump in this application, as opposed to the load factor of 1.0 used in the *ex ante* estimation. The hours of operation were used in the *ex post* estimates was 8,760 annual hours of operation versus 8,000 hours used in the *ex ante* estimates, based on interviews with site staff. The load impact calculations are shown in Equations 4-26 and 4-27.

$$\text{(Eq. 4-26)} \quad kW_{\text{Pre-retrofit}} = \frac{(\text{hp}) \times (0.746\ \text{kW/hp}) \times (\text{part-load factor})}{\text{Motor Efficiency}}$$

$$= \frac{(2\ \text{motors} @\ 15\ \text{hp}) \times (0.746\ \text{kW/hp}) \times (0.90)}{0.86}$$

$$= 23.4\ \text{kW}$$

$$\text{(Eq. 4-27)} \quad kWh_{\text{Ex post}} = \left(kW_{\text{Ex post}}\right) \times (\text{Annual hours of operation})$$

$$= (23.4\ \text{kW}) \times (8{,}760\ \text{hours/year})$$

$$= 205{,}167\ \text{kWh/year}$$

Modification D: By-Pass Supplemental Process Heater

The modification and operating conditions and the methodology used for the *ex ante* estimates was reviewed and discussed with the facility engineer. The methodology used to estimate the *ex ante* savings was used to estimate the *ex post* load impacts. Key operating parameters and operating conditions have not changed since the *ex ante* estimate was prepared. Thus, the *ex post* load impact estimate is the same as the *ex ante* load estimate of 320,000 therms saved per year.

Total Ex Post Load Impact Estimate For Modifications A through D

Table 4-9 shows the *ex post* kWh and kW impacts by time-of-use period. The plant operates continuously at maximum production output except for unscheduled cleaning and repairs. Which can take place at any time. As a result the coincident demand reductions are equal to the average demand reductions.

Table 4-9
kW and kWh Impacts by Time-Of-Use Period
Project ID No. 14200

Time-of-Use Period	Total Hours	Site Operating Hours	kWh Adjustment Factor	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742	742	0.08470	27,672	37.3	37.3
Summer Mid-peak	954	954	0.10890	35,578	37.3	
Summer Off-peak	1,976	1,976	0.22557	73,692	37.3	
Winter On-peak	441	441	0.05034	16,446	37.3	37.3
Winter Mid-peak	1,911	1,911	0.21815	71,268	37.3	
Winter Off-peak	2,736	2,736	0.31233	102,035	37.3	
Total	8,760	8,760		326,691		

4.3.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-10 summarizes the *ex ante* and *ex post* load impact estimates.

Table 4-10
Demand and Energy Impact Summary
Project ID No. 14200

	Demand Peak kW	Energy kWh/Year	Nat. Gas Therms/Year
***Ex Ante* Load Impact**	47.7	381,786	708,889
***Ex Post* Load Impact**	37.3	326,691	708,889
Difference	10.4	55,095	-
Realization Rate	0.78	0.86	1.00

The *ex post* natural gas impact is equal to the *ex ante* estimates. The small differences in the electric impacts are due to differences in post-retrofit pump operating levels when compared to the *ex ante* estimates.

4.3.4 Persistence of the Measure

The projected 20 year projected life is reasonable for this equipment under the service conditions observed.

4.3.5 Net-To-Gross

SDG&E staff explained that the primary reason for the modifications was to increase production without adding major capital equipment. Apparently, SDG&E sponsored a process optimization consultant's study to investigate potential projects at the participant's site. It appears that there was an existing relationship between the consultant and the participant. Included in the list of projects were the measures installed under this project.

The participant's staff indicated that poor heat exchanger efficiency due to rapid fouling and loss of service during cleaning were the major area where production could be increased with improvements to relatively minor process equipment. According to the participant, the problem was apparent from the early period that the process was initiated.

Because the project had to compete with other process modifications and other plant improvements for capital, the project cost/benefit ratio is critical. The incentive of $150,000 reduced the participant's cost by 23 percent (based on *ex ante* costs). Participant's staff expressed that it is likely that the investments would have been made, but that the decision would have for a period of time.

The fact that SDG&E contributed to the technical analysis of the measures by sponsoring the in-depth study of the process that provided the basis for the recommendations adopted by the participant. It appears that the participant was, however, aware of the opportunity and probably helped direct the consultant to the problem. Thus, SDG&E offered a medium level of involvement. The financial incentives provided through the IEEI program provided the final impetus for the participant to adopt the measure. Thus, the net-to-gross value is 0.75.

4.4 ID No. 17477 - Air Compressor Systems

This is a heavy industrial metal working and fabrication facility located in San Diego.

There are two separate compressed air systems at this facility. Both systems were modified under this project. One compressor system serves a shop area, the second compressor system serves the main production area.

Prior to the retrofit, the shop system consisted of a 125 hp reciprocating compressor which, according to operating staff, operated continuously to maintain a pressure of approximately 90 psi for intermittent shop air requirements. Staff reported that the compressor operated at near full load continuously regardless of demand in the facility due to internal leaks and control problems.

The main air compressor system for the facility consisted of two Elliott centrifugal compressors rated at 2,750 cfm at 125 psig, and equipped with 4,160 volt, 700 hp synchronous motors, and an Ingersoll Rand XLE 2 stage reciprocating compressor rated at 1,548 cfm at 125 psig with a 330 hp motor.

In addition, the air dryer for this plant was an Ingersoll Rand water chiller type rated for 5,000 cfm at 100° F. Chilled water and condenser water was circulated by a total of 15 hp of pumps. This system reportedly also ran continuously at near full load regardless of air requirements.

End uses for the compressed air consisted of grinders, sand-blasting, chip blowing and leaks. Three diesel rental compressors were also maintained on standby for especially high compressed air demand during major sandblasting operations.

The compressor system modifications at this facility involved two separate modifications listed under one Project ID number. These are:

1. **Shop System:**
   - remove the 125 hp compressor from the machine shop area; and
   - install a new 40 hp, intermittently operating compressor.
2. **Main System:**
   - install one new 1,537 cfm / 125 psig Ingersoll Rand, Model SSR-EP350 compressor with a 350 hp motor;
   - install 10,000 gallon compressed air storage;
   - improve leaky drains;
   - install a "demand expander";
   - replace the chilled water cooler/dryer system with a direct-refrigeration, Zeks model 6000 HSD MA400 storage type air dryer system;
   - install a mist eliminator to allow main compressor air to be used for breathing air;
   - the Elliott and XLE compressors remained on line for backup and supplemental use as necessary; and
   - the pre-project chilled water cooling and air dryer system was abandoned.

The system improvements were identified by a study carried out by an air compressor system consultant with support of SDG&E staff.

Prior to the retrofit project, the shop compressor operated continuously at nearly full load. After the retrofit, the "new" compressor operated intermittently, only as compressed air was required. The compressor only operates about 30% of the time, typically during the first shift. The main compressor system operates continuously to maintain a storage pressure of about 110 psi and a system pressure of 95 psi. Air demands are highest during first shift and diminish during second shift and weekend operations.

4.4.1 Ex Ante Load Impact Estimation

The *ex ante* load impact estimates were calculated using an engineering-based methodology. The air flow and pressure requirements for each shift were estimated from short term air and power observations, measurements taken over several days and interviews with plant staff. The hours of occurrence of each shift's loading conditions during each time-of-use period was estimated. Measurements were reportedly taken during off hours to estimate system leaks. The compressor input power for each flow rate which occurred during each time-of-use period was estimated by multiplying the compressor rated power by the conversion factor 0.746 kW/hp and by a "loading factor" (also known as the part load power) for typical control strategies taken from a matrix provided by a compressor consultant hired through the *IEEI Program*. The power for each flow/pressure was then multiplied by the number of hours of occurrence of that condition to determine the annual kWh for the compressor plant. These calculations were provided in summary form by the consultant as a series of spreadsheet exhibits in the consultant's final report.

The anticipated post-retrofit air flow rate (after leak-abatement and system pressure reduction were implemented) was estimated by subtracting 50% of the measured system leakage from the observed 300 cfm leakage rate. A 50% leakage reduction, or 150 cfm was projected. The post-retrofit energy use was then calculated by estimating the compressor operating schedule and power for the new air flow rates in a similar fashion to the pre-retrofit power. The power input (kW) to the new compressors under each post-retrofit flow condition was calculated from the "new" compressors' anticipated flow and power/flow performance. Supporting data was not provided in the project file. The power was multiplied by the hours of operation at each flow condition during each time-of-use period and the periods summed to calculate the post-retrofit energy use (kWh).

The load impact methodology was similar for both compressor systems. The difference in the pre- and post-retrofit energy use (kWh) for each time of use period was reported as the savings. The savings by time-of-use period were summed to calculate the total kWh savings.

The *ex ante* load impacts are shown in Table 4-6. The total of the annual savings was 2,871,399 kWh.

The demand reduction was calculated as the difference between the maximum compressor kW for the on peak period prior to the retrofit and the maximum compressor kW after the retrofit. The *ex ante* demand impacts are also shown in Table 4-11.

Table 4-11
***Ex Ante* Savings Estimates**
Project ID No. 17477

MAIN SYSTEM

	Pre-Retrofit						Post-Retrofit						Ex Ante Load Impacts	
	Base kW	Hours/ TOU Period	Peak Compr kW	Hours/ TOU Period	kWh	Avg. kW	Base Compr kW	Hours/ TOU Period	Peak Compr kW	Hours/ TOU Period	kWh	Avg. kW	kWh Savings	kW Saved
Summer- on	566.1	641	1,117.1	94	467,878	637	201.2	735	201.2	-	147,882	201	319,996	435
Summer - semi	566.1	788	1,117.1	157	621,472	658	201.2	693	1,117.1	252	420,941	445	200,531	212
Summer - off	566.1	1,378	1,117.1	590	1,439,175	731	201.2	1,378	1,117.1	590	936,343	476	502,832	256
Winter - on	566.1	313	1,117.1	134	326,881	731	201.2	358	1,117.1	89	171,452	384	155,429	348
Winter - semi	566.1	1,714	1,117.1	223	1,219,409	630	201.2	1,669	1,117.1	268	635,186	328	584,223	302
Winter - off	566.1	1,910	1,117.1	818	1,995,039	731	201.2	1,910	1,117.1	818	1,298,080	476	696,959	255
Main System Total		6,744		2,016	6,069,852			6,743		2,017	3,609,882		2,459,970	

SHOP

	Pre-Retrofit						Post-Retrofit						Ex Ante Load Impacts	
	Base Compr kW	Hours/ TOU Period	Peak Compr kW	Hours/ TOU Period	kWh	Avg. kW	Base Compr kW	Hours/ TOU Period	Peak Compr kW	Hours/ TOU Period	kWh	Avg. kW	kWh Savings	kW Saved
Summer- on	68.9	735	68.9	-	50,642	68.9	29.3	735	29.3	-	21,536	29.3	29,106	39.6
Summer - semi	68.9	945	0	-	65,111	68.9	18.7	945	0	-	17,672	18.7	47,439	50.2
Summer - off	68.9	1,968	0	-	135,595	68.9	18.7	1,968	0	-	36,802	18.7	98,794	50.2
Winter - on	68.9	447	0	-	30,798	68.9	18.7	447	0	-	8,359	18.7	22,439	50.2
Winter - semi	68.9	1,937	0	-	133,459	68.9	29.3	1,937	0	-	56,754	29.3	76,705	39.6
Winter - off	68.9	2,728	0	-	187,959	68.9	18.7	2,728	0	-	51,014	18.7	136,946	50.2
Shop Total		8,760		-	603,564			8,760		-	192,135		411,429	-

RETROFIT PROJECT TOTAL

	Pre-Retrofit						Post-Retrofit						Ex Ante Load Impacts	
Time-of-Use Period	Base Compr kW	Hours/ TOU Period	Peak Compr kW	Hours/ TOU Period	kWh	Avg. kW	Base Compr kW	Hours/ TOU Period	Peak Compr kW	Hours/ TOU Period	kWh	Avg. kW	kWh Savings	kW Reduce
Summer On			1,186	735	518,519	705.5			230.5	735	169,418	230.5	349,102	**955.5**
Summer Semi				945	686,582	726.5				945	438,612	464.1	247,970	
Summer Off				1968	1,574,770	800.2				1968	973,144	494.5	601,626	
Winter On				447	357,679	800.2				447	179,810	402.3	177,869	
Winter Semi				1937	1,352,868	698.4				1937	691,940	357.2	660,928	
Winter Off				2728	2,182,998	800.2				2728	1,349,093	494.5	833,905	
Project Total				8,760	6,673,416					8,760	3,802,018		**2,871,399**	-

4.4.2 Ex Post Load Impact Estimation

The site was visited on October 2, 1997. The equipment operation was observed and the operating staff was interviewed regarding the pre- and post-retrofit air compressor plant operation. The *ex post* load impacts were calculated by a methodology similar to that used to estimate the *ex ante* load impacts. The *ex post* impacts were based upon operating hours and power determined from logs maintained by the customer, and post-retrofit operating practices determined by interviews with operating staff, as shown in Table 4-12. The difference between the pre- and post-retrofit kWh is reported as the *ex post* kWh savings. The *ex post* energy impacts are shown in Table 4-8.

Table 4-12
***Ex Post* Site Operating Characteristics**
Project ID No. 17477

SHOP COMPRESSOR SYSTEM (as of Oct. 2, 1997)				
	No. Hours since Jan. 1996	**No. Months since Jan. 1996**	**Hours per Month**	**Hours per Year**
Operating Hours	8,779	21	418.05	5,017
Loaded Hours	2,406	21	114.57	1,375
Unloaded Hours			303.48	3,642
MAIN COMPRESSOR SYSTEM (as of Oct. 2, 1997)				
	No. Hours since Aug. 1, 1996	**No. Days since Aug. 1, 1996**	**Hours per Day**	**Hours per Year**
Total Hours	7099	397	17.88	6,526
Hours Loaded	5250	397	13.22	4,825
Unloaded Hours			4.66	1,701

The total energy use for the pre- and post-retrofit configurations were estimated using Equation 4-28. The *ex post* kWh impacts are shown in Table 4-13.

$$\text{(Eq. 4-28)} \quad \sum_{\text{i=compressors for pre- or post-retrofit}} kWh_i = \frac{(\text{Motor hp}) \times (0.746\ \text{kW / hp}) \times (\text{Load Factor})_i}{(\text{Motor Eff.})_i}$$

Table 4-13
***Ex Post* Energy Savings Estimates**
Project ID No. 17477

MAIN SYSTEM										
	Pre-Retrofit					Post-Retrofit				Ex Post Impact
Equipment	Rated HP	Motor Eff.	Hours per Yr	Load Factor	kWh per Yr	Rated HP	Hours per Yr	Load Factor	kWh per Yr	kWh Savings
IR XLE	350	0.93	470	0.9	118,758	350	225	0.95	59,979	58,780
Elliott #1	700	0.94	5,850	0.9	2,896,602	700	2,775	0.9	1,387,364	1,509,238
Elliott #2	700	0.94	5,582	0.9	2,763,903	700	2,608	0.9	1,303,798	1,460,105
IR SSR - EP350	0		0	0	-	350	6,527	0.9	1,615,834	-1,615,834
IR Dryer + Pumps	40	0.9	8,760	1	290,443	-	-	-	-	290,443
Zeks Dryer	0		0	0	-	14	8,760	0.5	49,012	-49,012
Total - Main System	1,790				6,069,706	2,114			4,366,975	1,653,718
SHOP SYSTEM										
	Pre-Retrofit					Post-Retrofit				Ex Post Impact
Equipment	Rated HP	Motor Eff.	Hours per Yr	Load Factor	kWh per Yr	Rated HP	Hours per Yr	Load Factor	kWh per Yr	kWh Savings
Old Compressor: 125	125	0.93	8,760	0.69	603,430				-	603,430
New SSR EP40SE						40	1,375	1	44,593	-44,593
Total - Shop System					603,430				44,593	558,837
TOTAL RETROFIT PROJECT										
Total - Energy Savings										2,212,555

Table 4-14 shows the *ex post* load impacts by time-of-use period. The *ex post* demand impact is calculated from the time-of-use savings as follows: First the total savings for each time-of-use period are calculated by multiplying the total annual kWh savings by the ratio of loaded hours during each time-of-use period to the total annual loaded operating hours which occur during that time-of-use period. The average kW savings are calculated by dividing the kWh saved during the time of use period by the total annual hours of the TOU period.

Table 4-14
***Ex Post* kW and kWh Impacts by Time-Of-Use Period**
Project ID No. 17477

Time-of-Use Period	Total Period Hours	Estimated Load Factor	System Equivalent Full Load Hours	kWh Adjustment Factor	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742	0.50	371	0.14144	312,950	421.8	421.8
Summer Mid-peak	954	0.35	335	0.12770	282,549	296.2	
Summer Off-peak	1,976	0.20	395	0.15067	333,363	168.7	
Winter On-peak	441	0.28	122	0.04652	102,919	233.4	233.4
Winter Mid-peak	1,911	0.45	853	0.32505	719,194	376.3	
Winter Off-peak	2,736	0.20	547	0.20862	461,580	168.7	
Total	8,760		2,623		2,212,555		

4.4.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-15 summarizes the *ex ante* and *ex post* load impact estimates. Realization rates for kWh and peak kW are 0.77 and 0.44, respectively.

Table 4-15
Demand and Energy Impact Summary
Project ID No. 17477

	Demand Peak kW	kWh/Year	Therms/Year
***Ex Ante* Load Impact**	955.5	2,871,389	0
***Ex Post* Gross Impact**	421.8	2,212,555	0
Difference	533.7	658,834	0
Realization Rate	0.44	0.77	N/A

The primary reasons for the discrepancies are:

- A control system that was intended to control the operation of all compressors was installed and is operational, but had not been placed into service as of October 2, 1997.
- A program of deferring sand-blasting operations to off-peak periods during summer months has not been fully implemented.
- It appears that peak kW for the pre- and post-retrofit periods (and hence kW reductions) were based upon estimated and projected customer peak hour loads rather than averages impacts spread over time-of-use periods.
- The shop compressor system and air cooling/dryer systems are operating as projected.

4.4.4 Persistence of the Measure

The project file shows a life of 20 years for the two compressed air projects. This is a reasonable and possibly conservative estimate of life for compressors and other system hardware providing manufacturer's recommended maintenance is carried out regularly.

Some of the projected savings include reduction of system leaks. Savings projections also assume a control strategy and operating pattern which uses energy during the off-peak periods. These savings will only be retained with a continuing and on-going program of prevention and operational monitoring.

4.4.5 Net-To-Gross

Participant staff was interviewed to determine the extent the IEEI Program influenced the energy efficiency improvements at this site. The air compressors were identified as a significant end use by a screening survey carried out by SDG&E's staff. SDG&E sponsored a consultant's study to identify and quantify the impacts of specific system improvements. Most of the recommended improvements were carried out by the customer. Staff interviewed commented that it is likely that none of this would have happened without the study, as well as the encouragement and financial support from SDG&E.

Since SDG&E conducted the initial screening survey and sponsored an in-depth study that provided the basis for the recommendations adopted by the participant, SDG&E's level of involvement was high. Thus, the net-to-gross value is 1.00.

4.5 ID No. 17751 - Refrigerated Dryer

This is a mechanical products manufacturing and assembly facility in San Ysidro, CA. The plant typically operates three shifts per day, five days per week. Staff reports frequent single or double shifts on Saturdays and periodic Sunday operations as production requires.

SDG&E sponsored an in-depth consultant's study to identify energy saving opportunities and to quantify the potential load impacts of these opportunities. Compressed air is used extensively to operate process machinery at this plant. This project involved replacement of a 20 hp mechanical refrigeration-type air dryer with a refrigeration-type thermal storage air dryer: Zeks Model 1200 HSEA4WO. This work was carried out in concert with project ID No. 40514 in which the air compressors were replaced and other compressed air system improvements were carried out.

4.5.1 Ex Ante Load Impact Estimation

The *ex ante* estimates assumed that the pre-retrofit air refrigeration unit operated at full load constantly at all times, regardless of compressed air flow. The pre-retrofit demand and energy were estimated as shown in Equation 4-29 and 4-30.

$$\text{(Eq. 4-29)} \quad kW_{Pre\text{-}retrofit} = \frac{(20\ hp) \times (0.746\ kW/hp)}{0.875\ efficiency}$$

$$= 17.05\ kW$$

$$\text{(Eq. 4-30)} \quad kWh_{Pre\text{-}retrofit} = (17.05\ kW) \times (8{,}568\ hours/year)$$

$$= 146{,}097\ kWh$$

Because the load is assumed constant, the maximum kW is the same as the average kW and the kWh are in proportion to the number of hours which occur during each time-of-use period.

The post-retrofit demand during each time-of-use period was calculated by multiplying the post-retrofit dryer horsepower (indicated in the project file as 5 hp) by the 0.746 kW/hp conversion factor and dividing by the motor efficiency (0.875), as shown in Equation 4-31. The result is multiplied by the a "cycle factor" which is the ratio of the expected average flow rate during the time-of-use period (550 cfm) to the full flow capacity of the Zeks dryer: 1,000 scfm. The calculation for each time-of use period is shown in the project file.

$$\text{(Eq. 4-31)} \quad kW_{\text{Post-retrofit}} = \frac{(5\text{ hp}) \times (0.746\text{ kW/hp})}{0.875\text{ efficiency}}$$

$$= 4.26\text{ kW}$$

This value is the total maximum kW of the compressor, not the average operating kW.

The annual kWh for the on-peak TOU period was calculated as shown in Equation 4-32.

$$\text{(Eq. 4-32)} \quad kWh_{\text{Post-retrofit}} = (kW_{\text{Post-retrofit}}) \times \left(\frac{550\text{ average CFM}}{1{,}000\text{ rated CFM}}\right)$$

$$\times (2{,}040\text{ on-peak hours/year})$$

$$= 4{,}783\text{ kWh/year}$$

The post-retrofit kWh were calculated in a similar fashion for each of the other time-of-use periods. The TOU periods were summed. The total annual consumption of the post-retrofit equipment was 12,088 kWh.

The *ex ante* load impacts are shown in Equations 4-33 and 4-34.

$$\text{(Eq. 4-33)} \quad kW_{\text{Ex ante}} = kW_{\text{Pre-retrofit}} - kW_{\text{Post-retrofit}}$$

$$= 17.05\text{ kW} - 4.26\text{ kW}$$

$$= 12.79\text{ kW}$$

$$\text{(Eq. 4-34)} \quad kWh_{\text{Ex ante}} = kWh_{\text{Pre-retrofit}} - kWh_{\text{Post-retrofit}}$$

$$= 146{,}097 - 12{,}088\text{ kWh}$$

$$= 134{,}009\text{ kWh}$$

4.5.2 Ex Post Load Impact Estimation

The evaluation *ex post* load impacts were calculated by the same method as the *ex ante* estimates, however, the values were modified to reflect the actual air-flow rates observed in the post-retrofit operating conditions, and the power of the actual equipment which was installed.

The actual average operating air flow rate was 1,024 cfm and annual operating hours are estimated as 6,264 per year (refer to Attachment 1 of report for project ID #40514 [the air compressor replacement portion of this project] for corroborating data). The actual equipment installed was the ZEKS model 1200 HS series with a 6 horsepower motor.

The savings are calculated using the same procedures as the estimates as shown in Equations 4-35 through 4-39.

$$\text{(Eq. 4-35)} \quad \text{Ex Post kW}_{\text{Pre-retrofit}} = \frac{(20\text{ hp}) \times (0.746\text{ kW / hp})}{0.90\text{ efficiency}}$$

$$= 16.58\text{ kW}$$

$$\text{(Eq. 4-36)} \quad \text{Ex Post kWh}_{\text{Pre-retrofit}} = \left(\text{Ex Post kW}_{\text{Pre-retrofit}}\right) \times \left(\text{Hours / year}\right)$$

$$= (16.58\text{ kW}) \times (6{,}264\text{ hours / year})$$

$$= 103{,}843\text{ kWh / year}$$

$$\text{(Eq. 4-37)} \quad \text{Ex Post kW}_{\text{Post-retrofit}} = \frac{(6\text{ hp}) \times (0.746\text{ kW / hp})}{0.90\text{ efficiency}}$$

$$= 4.97\text{ kW}$$

$$\text{(Eq. 4-38)} \quad \text{Ex Post kWh}_{\text{Post-retrofit}} = \left(\text{Ex Post kW}_{\text{Post-retrofit}}\right) \times \left(\text{Cycle Factor}\right) \times \left(\text{Hours / year}\right)$$

$$= (4.97\text{ kW}) \times \left(\frac{1{,}024\text{ average CFM}}{1{,}200\text{ rated CFM}}\right) \times (6{,}264\text{ hours / year})$$

$$= 26{,}584\text{ kWh / year}$$

(Eq. 4 - 39) $\text{Ex Post kWh Savings} = (\text{Ex Post kWh}_{\text{Pre-retrofit}}) - (\text{Ex Post kWh}_{\text{Pre-retrofit}})$

$= 103{,}843 \text{ kWh} - 26{,}854 \text{ kwh}$

$= 77{,}259 \text{ kWh}$

Table 4-16 shows the *ex post* load impacts by time-of-use period.

Table 4-16
***Ex Post* kW and kWh Impacts by Time-of-Use Period**
Project ID No. 17751

Time-of-Use Period	Total Hours	Weekend Off Hours	Operating Hours	kWh Adjustment Factor	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742	0	742	0.11845	9,152	12.3	12.3
Summer Mid-peak	954	0	954	0.15230	11,766	12.3	
Summer Off-peak	1,976	1,040	936	0.14943	11,544	5.8	
Winter On-peak	441	0	441	0.07040	5,439	12.3	12.3
Winter Mid-peak	1,911	0	1,911	0.30508	23,570	12.3	
Winter Off-peak	2,736	1,456	1,280	0.20434	15,787	5.8	
Total	8,760		6,264		77,259		

4.5.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-17 summarizes the *ex ante* and *ex post* load impact estimates.

Table 4-17
***Ex Post* Demand and Energy Impact Summary**
Project ID No. 17751

	Demand Peak kW	Energy kWh/Year	Nat. Gas Therms/Year
Ex Ante Load Impact	4.3	134,009	-
Ex Post Load Impact	12.3	77,259	-
Difference	-8.1	56,750	-
Realization Rate	2.90	0.58	N/A

A comparison of the *ex ante* and *ex post* estimates shows a realization rate of 2.90 for demand reduction and 0.58 for annual energy savings. The primary reasons for the differences are:

- the post-retrofit refrigeration unit is 6 hp rather than 5 hp, and it is operating at more than 80% capacity (1,024 cfm) rather than at 55% (550cfm) average capacity as assumed in the savings estimates.

- The evaluation used 6,264 operating hours per year rather than 8,760 hours to account for 4-6 shift weekend shutdowns which staff reported and which were observed by monitoring the compressors.
- It appears there was a math error in the *ex ante* kW savings calculation

4.5.4 Persistence of the Measure

The 15 year life assigned to the air dryer is reasonable, however if this machine continues to operate nearly continuously at near full load conditions, a life expectancy of 10 to 12 years might be more realistic.

4.5.5 Net-To-Gross

Staff indicated that although they were aware of the age and inefficiency of their compressed air plant, the impact was not quantified until the consulting study, funded by SDG&E, was carried out. Once the impact of the system improvements was identified, it was clearly a wise business decision to replace the dryer, as well as the compressor. The new dryer was essentially a part of the compressor replacement project.

Since SDG&E sponsored the in-depth study that provided the basis for participant's decision to proceed with the compressed air system retrofits, SDG&E's level of involvement was high. Thus, the net-to-gross value is 1.00.

4.6 ID No. 19318 - High Efficiency Heat Treat Furnace

This facility is a large manufacturing complex with a number of high-energy-use processes. The fabricated metal products are for aircraft and other industries. The energy efficiency project implemented at the facility involved a single heat treat furnace that occupies a small portion of this large manufacturing complex. In the heat treat process, non-ferrous metal parts are placed in a wire container "basket." They are then conveyed by a hoist into the heat treat furnace where they are heated to approximately 1,250° F. The furnace is equipped with six radiant-tube heaters that provide indirect heating circulated by a 50 hp fan. After fifteen minutes of heating with all six burners, the temperature is reduced over a fifteen minute period to approximately 1,000° F, and the parts are "soaked" at that temperature for one hour. The number of burners during the soaking period are reduced from six to two. When the soaking period is complete, the parts are cooled by rapid quenching in a water mixture. The next batch is conveyed into the furnace and the process is repeated.

According to plant records, the process operates continuously three shifts per day, seven days per week, year round. Loads, or runs, during each eight hour shift range from four to seven, with the average for the first and second shifts about 4.5 runs and the average third shift about 2.4 runs. Weekday peak period shifts average 5.33 furnace runs per shift. Weekend shift furnace runs are generally lower, depending upon orders for parts. Sometimes Saturday, and, less frequently on Sunday, the furnace is shut down completely.

The retrofit project consisted of the installation of a new, high efficiency furnace with energy saving improvements over the typical "standard" heat treat furnace. The energy savings aspects of the furnace were:

- The installed system employs a light wire-mesh basket and hoist suspension system versus the standard hydraulic ram or elevator that is heavier, resulting in less material (metal plus ram or elevator) to heat;
- Low NO_x burners with ceramic recuperators to recover waste exhaust heat (efficiency of 0.68) versus standard burners without recuperator (efficiency of 0.53); and
- Improved 2-speed 50 hp furnace circulation fan motor and controls to operate the fan at low speed and reduce electrical energy requirements during the soaking period versus a standard single speed 50 hp fan.

4.6.1 Ex Ante Load Impact Estimation

The *ex ante* load impact estimates were based on an engineering methodology. The calculations generally were based on the *rated* product capacity, heat input, and component weights of the high efficiency and a comparative "standard" heat treat furnace.

Ex Ante Natural Gas Impacts

The heat requirements for the furnace was estimated by multiplying the total furnace heat requirement (3,300,000 Btu/hour) by the number of burners (6) to determine the burner input. From the data in the project files it appears that the furnace *input* stream, i.e., the burner *output*, is 550,000 Btu/hour.

From this value, burner heat was calculated by multiplying the assumed burner input rate by the number of burners in operation at each part of the furnace load profile, and the length of time each portion of the profile was maintained. A factor was also allowed for the turndown ratio.

Key *ex ante* assumptions are shown in Table 4-18.

Table 4-18
***Ex Ante* Assumptions**
Project ID No. 19318

	Pre-Retrofit	Post-Retrofit
Daily product throughput (lb.)	15,000	15,000
Product Capacity (lb.)	1,000	1,385
Furnace Efficiency	0.53	0.68
Weight of Rack (+ elevator) (lb.)	4,000	1,615
Duration of heat-up (hour)	.25	.25
Duration of ramp down to soak (hour)	.25	.25
Duration of soak (hour)	1.00	1.00
Total heat treat cycle (hour)	1.5	1.5
Circulation fan motor power (hp) during 1 hour soak	50 hp	12.5 hp (low-speed operation)
Burner Turndown Ratio	1:10	1:20

The *ex ante* estimates of natural gas fuel use for the post-retrofit case are shown in Equations 4-40 through 4-43.

$$\text{(Eq. 4-40)}\quad \text{No. of loads per day}_{\text{Post-retrofit}} = \frac{(15{,}000\ \text{lbs/day})}{1{,}385\ \text{lbs/load}}$$

$$= 10.83\ \text{loads/day}$$

$$\text{(Eq. 4-41)}\quad \text{Btu input per load}_{\text{Post-retrofit}} = \begin{bmatrix} \text{Btu}_{\text{Heat up}} + \text{Btu}_{\text{Ramp down to soak}} + \text{Btu}_{\text{Soak}} \\ + \text{Btu}_{\text{Burner turndown ratio}} \end{bmatrix}$$

$$= \begin{bmatrix} (6\ \text{burners x } 550{,}000\ \text{Btuh/burner x } 0.25\ \text{hour}) + \\ (4\ \text{burners x } 550{,}000\ \text{Btuh/burner x } 0.25\ \text{hour}) + \\ (2\ \text{burners x } 550{,}000\ \text{Btuh/burner x } 1.00\ \text{hour}) + \\ \left(4\ \text{burners x } \frac{1}{20}\ \text{x } 550{,}000\ \text{Btuh/burner}\right) \end{bmatrix}$$

$$= 25.85\ \text{therms/load}$$

$$\text{(Eq. 4-42)}\quad \text{Energy use per day}_{\text{Post-retrofit}} = (25.85\ \text{therms/load}) \times (10.83\ \text{loads/day})$$

$$= 280\ \text{therms/day}$$

$$\text{(Eq. 4-43)}\quad \text{Fuel use per day}_{\text{Post-retrofit}} = \frac{280 \text{ therms / day}}{0.68 \text{ furnace efficiency}}$$

$$= 411.76 \text{ therms natural gas / day}$$

A scaling factor for weight differences between weights of the pre- and post-retrofit loads of 1.667 was developed as shown in Equation 4-44. This factor was used to adjust the input heat requirements based on the differences in weight of materials heated.

$$\text{(Eq. 4-44)}\quad \begin{bmatrix}\text{Scaling Factor for Weight Differences} \\ \text{Between Pre- and Post-Retrofit}\end{bmatrix} = \frac{\begin{bmatrix}\text{(Weight of elevator)} \\ +\text{(Weight of rack)} \\ +\text{(Weight of product)}\end{bmatrix}_{\text{Pre-Retrofit}}}{\begin{bmatrix}\text{(Weight of frame)} \\ +\text{(Weight of product)}\end{bmatrix}_{\text{Post-Retrofit}}}$$

$$= \frac{(2{,}000) + (2{,}000) + (1{,}000)}{(1{,}685) + (1{,}385)}$$

$$= \frac{5{,}000 \text{ lb.}}{3{,}000 \text{ lb.}}$$

$$= 1.667$$

The *ex ante* estimates of daily natural gas fuel use for the pre-retrofit case are shown in Equations 4-45 through 4-48.

$$\text{(Eq. 4-45)}\quad \text{Btu input per cycle}_{\text{Pre-retrofit}} = \left[\text{Btu}_{\text{Heat up}} + \text{Btu}_{\text{Ramp down to soak}} + \text{Btu}_{\text{Soak}} + \text{Btu}_{\text{Burner turndown ratio}}\right]$$

$$\text{x} \begin{bmatrix}\text{Scaling Factor for Weight Differences} \\ \text{Between Pre- and Post-Retrofit}\end{bmatrix}$$

$$= \begin{bmatrix}(6 \text{ burners x } 550{,}000 \text{ Btuh / burner x } 0.25 \text{ hour}) + \\ (4 \text{ burners x } 550{,}000 \text{ Btuh / burner x } 0.25 \text{ hour}) + \\ (2 \text{ burners x } 550{,}000 \text{ Btuh / burner x } 1.00 \text{ hour}) + \\ \left(4 \text{ burners x } \frac{1}{10} \text{ x } 550{,}000 \text{ Btuh / burner}\right)\end{bmatrix} \text{x } 1.667$$

$$= 44.92 \text{ therms / load}$$

$$\text{(Eq. 4-46)} \quad \text{No. of loads per day}_{\text{Pre-retrofit}} = \frac{(15{,}000 \text{ lbs / day})}{1{,}000 \text{ lbs / load}}$$

$$= 15 \text{ loads / day}$$

$$\text{(Eq. 4-47)} \quad \text{Energy use per day}_{\text{Pre-retrofit}} = (44.92 \text{ therms / load}) \times (15 \text{ loads / day})$$

$$= 673.80 \text{ therms / day}$$

$$\text{(Eq. 4-48)} \quad \text{Fuel use per day}_{\text{Pre-retrofit}} = \frac{673.80 \text{ therms / day}}{0.53 \text{ furnace efficiency}}$$

$$= 1{,}271.2 \text{ therms natural gas / day}$$

The *ex ante* annual natural gas savings are shown in Equation 4-49.

$$\text{(Eq. 4-49)} \quad \text{Annual natural gas savings}_{\text{Ex Ante}} = (\text{Fuel Use}_{\text{Base Case}} - \text{Fuel Use}_{\text{Retrofit}}) \times (5 \text{ days / week}) \times (50 \text{ weeks / year})$$

$$= (1{,}271.2 \text{ therms / day} - 411.76 \text{ therms / day}) \times (5 \text{ days / week}) \times (50 \text{ weeks})$$

$$= 214{,}867 \text{ therms / year}$$

Ex Ante Electricity Impacts

The *ex ante* electricity savings were calculated using Equations 4-50 through 4-56. Equation 4-50 shows the fan kW for the soak period for the post-retrofit configuration.

$$\text{(Eq. 4-50)} \quad \text{Fan kW for Soak Period}_{\text{Post-Retrofit}} = \frac{(12.5 \text{ hp}) \times (0.746 \text{ kW / hp}) \times (0.8 \text{ load factor})}{0.904 \text{ Eff}}$$

$$= 8.25 \text{ kW}$$

The soak period is one hour, therefore the Fan $\text{kWh}_{\text{Post-Retrofit}}$ is equal to 8.25 kWh as shown in Equation 4-51.

$$\text{(Eq. 4-51)} \quad \text{Fan kWh}_{\text{Post-Retrofit}} = \left(\text{Fan kW}_{\text{Post-Retrofit}}\right) \times \left(\text{Hours per Load}\right)$$

$$= (8.25 \text{ kW}) \times (1 \text{ Hour per Load})$$

$$= 8.25 \text{ kWh / Load}$$

The post-retrofit daily fan kWh is shown in Equation 4-52.

$$\text{(Eq. 4-52)} \quad \text{Fan kWh}_{\text{Post-Retrofit}} = \left(\text{Fan kWh}_{\text{Post-Retrofit}}\right) \times \left(\text{\# Loads / day}\right)$$

$$= (8.25 \text{ kWh / Load}) \times (10.83 \text{ Load / day})$$

$$= 89.3 \text{ kWh / day}$$

The pre-retrofit fan kW for the soak period is shown in Equation 4-53.

$$\text{(Eq. 4-53)} \quad \text{Fan kW for Soak Period}_{\text{Pre-Retrofit}} = \frac{(50 \text{ hp}) \times (0.746 \text{ kW / hp}) \times (0.8 \text{ Load factor})}{0.904 \text{ Eff.}}$$

$$= 33.0 \text{ kW}$$

The soak period is one hour, therefore the Fan $\text{kWh}_{\text{Pre-Retrofit}}$ is equal to 33.0 kWh, as shown in Equation 4-54.

$$\text{(Eq. 4-54)} \quad \text{Fan kWh}_{\text{Pre-Retrofit}} = \left(\text{Fan kW}_{\text{Pret-Retrofit}}\right) \times \left(\text{Hours per load}\right)$$

$$= (33.0 \text{ kW}) \times (1 \text{ Hour per load})$$

$$= 33.0 \text{ kWh / load}$$

Equation 4-55 shows the daily kWh for the pre-retrofit configuration.

$$\text{(Eq. 4-55)} \quad \text{Fan kWh}_{\text{Pre-Retrofit}} = \text{Fan kWh}_{\text{Pre-Retrofit}} \times \text{\# Loads / day}$$

$$= 33 \text{ kWh} \times 15 \text{ Loads / day}$$

$$= 495 \text{ kWh / day}$$

The annual *ex ante* energy savings are shown in Equation 4-56.

(Eq. 4 - 56) $\text{Annual kWh Savings}_{Ex\ Ante} = (\text{Fan kWh}_{Pre\text{-}Retrofit} - \text{Fan kWh}_{Post\text{-}Retrofit}) \times (5\ \text{days / week}) \times (50\ \text{weeks / year})$

$= (495\ \text{kWh / day} - 89\ \text{kWh / day}) \times (5\ \text{days / week}) \times (50\ \text{weeks / year})$

$= 101{,}500\ \text{kWh / year}$

No *ex ante* kW demand reduction was claimed.

4.6.2 Ex Post Load Impact Estimation

An engineering approach similar to that used for the *ex ante* load impact estimates was used to estimate the *ex post* load impacts. The site was visited on October 2, 1997. The equipment operation was observed and the operating staff was interviewed regarding the oven loading and load frequency. Logs of oven operating cycles for each shift were obtained for four months of operation during 1997. Actual furnace loadings (in pounds) were obtained verbally from the furnace operator.

Ex Post Natural Gas Impacts

The *ex post* gas savings were calculated using a series of engineering calculations similar to those used for the *ex ante* estimates. The results are shown in the Tables 4-19 to 4-25.

Table 4-19
Process Heat Requirement
Total Heat Required (Btu/Load)
Project ID No. 19318

Process	No. Burners	Output (Btu/Hour)	Duration (Hour)	Total Btu
Heat up	6	3,300,000	0.25	825,000
Ramp down	4	2,200,000	0.25	550,000
Soak	2	1,100,000	1	1,100,000
Total Heat Required (Btu/load)				2,475,000

Table 4-20
Ratio of (Weight To Be Heated for Pre-Retrofit Oven) to (Weight To Be Heated for Post-Retrofit Oven)
Project ID No. 19318

	Oven Equipment (Elevator, rack, etc.) (pounds)	Product per Load (pounds)	Total
Pre-retrofit oven	4,000	700	4,700
Post-retrofit oven	1,615	700	2,315
Ratio			2.03

Table 4-21
Calculation of Natural Gas Requirement for Pre-Retrofit Oven
Project ID No. 19318

Burner Efficiency	0.53	
Product Weight per Load	700	lb.
Input Energy per Load	9,480,826	Btu
Input Energy Required per Pound	13,544	Btu/lb.

Table 4-22
Calculation of Natural Gas Requirement for Post-Retrofit Oven
Project ID No. 19318

Burner Efficiency	0.68	
Product Weight per Load	700	lb.
Input Energy per Load	3,639,706	Btu
Input Energy Required per Pound	5,200	Btu/lb.

Table 4-23
Savings (Natural Gas) per Pound
Project ID No. 19318

	Natural Gas (Btu/lb.)
Pre-Retrofit Oven	13,544
Post-Retrofit Oven	5,200
Savings in Input Energy (natural gas)	8,344

Table 4-24
Pounds of Product per Year

(Based on Plant Data)
Project ID No. 19318

Actual Runs per Day Over 4 Month Period	11.16 runs/day
Conversion to Annual	365 days/year
Annual Runs:	4,073 runs/year
Average Actual Pounds per Run (Rohr)	700 lb.
Total Annual Product Heat Treated	2,851,380 lb./year

Table 4-25
Calculation of Natural Gas Savings
Project ID No. 19318

Total Annual Product Heat Treated	2,851,380 lb./year
Savings in Input Energy (natural gas)	8,344 Btu/lb.
Annual heat savings: (lb. x Btu/lb.)	23,793,220,478 Btu/year
Annual therm savings: (Btu/100,000)	237,932 therms

Ex Post Electricity Impacts

The electric load impacts are derived from the installation of a two-speed fan motor that allows the motor to run at part-load for one hour of a 1.5 hour cycle. Table 4-26 shows the basic operating characteristics for the fan.

Table 4-26
***Ex Post* Operating Characteristics**
Project ID No. 19318

	Description	Operating Characteristics	No. Loads/Day
Pre-Retrofit Motor	Single-speed 50 hp	Runs at full-load for entire 1.5 hour cycle.	11.2
Post-Retrofit Motor	Two-speed High speed @ 50 hp Low speed @ 12.5 hp	Runs at low speed for one hour and high speed for 0.5 hours of the 1.5 hour cycle.	11.2

Table 4-27 shows the key inputs and the energy savings for the fan modifications.

Table 4-27
***Ex Post* kWh Savings**
Project ID No. 19318

	Fan Speed	Loads per Day	Days per Year	Hours per Load	Motor kW	Annual kWh
Pre-Retrofit	High speed only	11.2	365	1.5	33	202,356
Post-Retrofit	High speed	11.2	365	0.5	33	67,452
	Low speed	11.2	365	1.0	10.3	42,106
	Total Post-Retrofit					109,558
Energy Savings						92,798

Table 4-28 summarizes the *ex post* load impacts by time-of-use period.

Table 4-28
***Ex Post* kW and kWh Impacts by Time-Of-Use Period**
Project ID No. 19318

Time-of-Use Period	Total Hours	Proportion of Full Production Rate	Equivalent Load Hours	kWh Adjustment Factor	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742	1.00	742	0.10782	10,006	13.5	13.5
Summer Mid-peak	954	1.00	954	0.13863	12,865	13.5	
Summer Off-peak	1,976	0.60	1,186	0.17229	15,988	8.1	
Winter On-peak	444	1.00	444	0.06452	5,987	13.5	13.5
Winter Mid-peak	1,924	1.00	1,924	0.27959	25,945	13.5	
Winter Off-peak	2,720	0.60	1,632	0.23715	22,007	8.1	
Total	8,760		6,882		92,798		

4.6.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-29 summarizes the *ex ante* and *ex post* load impact estimates. Comparison of the *ex ante* and *ex post* peak demand values shows a realization rate of 0.91 for kWh and 1.11 for natural gas savings. There is no realization rate for kW since there was no *ex ante* demand impacts. The primary reason for this difference is the difference in the calculation methodology used.

Table 4-29
Demand and Energy Impact Summary
Project ID No. 19318

	Demand Peak kW	Energy kWh/Year	Natural Gas Therms/Year
***Ex Ante* Load Impacts**	0	101,500	214,867
***Ex Post* Load Impacts**	13.5	92,798	237,932
Difference	-13.5	8,702	-23,065
Realization Rate		0.91	1.11

The *ex post* estimates differed from the *ex ante* estimates for several reasons:

- The *ex post* estimates did not agree with the ex ante estimates of natural gas savings. The *ex post* approach did not utilize the adjustment of the pre-retrofit energy use by multiplication of the base case cycle energy by the factor 1.667. This factor represents the ratio of the weight of the support, elevator and product in the pre-retrofit and post-retrofit cases. This weight ratio is already factored into the time and furnace input and operating time values that were used.
- The *ex ante* estimates did not estimate a demand savings. A small but real kW savings can be expected to result when diversity is considered.

4.6.4 Persistence of the Measure

The 20 year measure life is reasonable. The equipment can be expected to last for that period with normal maintenance and periodic replacement of operating components.

4.6.5 Net-To-Gross

The participant's contact stated that the primary reason for replacing the existing furnace was that the old unit suffered frequent breakdowns which resulted in costly production delays and outsourcing of heat treating. When the new furnace was considered, three alternative furnaces were investigated. The furnace that was purchased had the highest cost but also had the highest efficiency and the lowest energy costs of the three alternatives. The contact stated that the additional cost of the higher efficiency unit was more than justified by the energy savings and operating convenience. He stated explicitly that the higher efficiency furnace would likely have been purchased at approximately the same time regardless of the SDG&E incentive.

SDG&E's level of involvement was low, since there was little evidence that the IEEI Program had significant influence on the decision to implement the project. The net-to-gross value for this project is 0.00.

4.7 ID No. 19400 - Energy Efficient Heat Exchangers

This is a organic materials processing facility in San Diego. The facility produces food admixtures through a variety of thermal, mechanical and biological production processes. This project involves a process improvement which increased the size of heat exchangers in a key part of the production process. Heat exchangers that were originally sized for lower production rates and lower fouling factors were increased with heat exchangers more properly sized for production and fouling.

The facility operates continuously, year-round. Thermal energy required for many processes is provided by steam generated in natural gas-fired boilers, rated at 90% overall efficiency. Electricity is also generated with steam from these boilers.

4.7.1 Ex Ante Load Impact Estimate

The *ex ante* load impact estimates were calculated using an engineering methodology based on assumptions provided by the customer. The savings are based on:

- improved average heat transfer efficiency during each operating cycle; and
- reduced downtime for cleaning a heat exchanger which transfers heat from an waste liquid to an incoming material mixture which requires addition of heat. This is turn reduces the amount of "new" heat which must be added in the form of steam from a utility steam boiler.

The result is a lower overall steam demand per unit of material heated. Substantial savings in operating labor and inconvenience and improvements in overall plant output also result.

The improvements were carried out in two of three process streams at the plant. The equipment that was removed from these process streams resulted in a reduction of a key process material. Additional savings for a third process line for similar improvements are calculated and claimed under Project No. 14200.

The *ex ante* savings were calculated for one process line. The savings for a second similar but larger process line were calculated by ratio of the capacity of the lines. Savings were based upon two improvements:

- a reduction of make-up steam requirements as a result of reduced downtime of a heat recovery heat exchanger; and
- an increase in the effective exiting temperature from the heat recovery boiler from an average 200° F to an average 250° F

Other operating assumptions include:

- pre-retrofit heat exchanger cleaning downtime: 90 days per year

- estimated post-retrofit heat exchanger cleaning downtime: 25 days per year
- reduced days of make-up steam requirement: = 65 days/year.
- for 170 gpm feed rate, the post-retrofit heat recovery would reduce reboiler load by 3,910,000 Btu/hour (3.91 MMBtu/hour).

Ex Ante Savings Due To Decreased Reboiler Duty of Unit #2

For 25 days of continuous steam requirement is shown in Equation 4-57.

$$\text{(Eq. 4-57)}\quad \text{Reduction in continuous steam requirement} = (3{,}910{,}000\ \text{Btu/hour}) \times (25\ \text{days}) \times (24\ \text{hours/day})$$

$$= 2{,}346{,}000{,}000\ \text{Btu}$$

$$= 2{,}346\ \text{MMBtu}$$

Ex Ante Savings Due To Reduced Heat Loss For Unit #2

Heat loss due to higher condensate discharge temperature of 218° F. The savings were calculated through Equation 4-58.

$$\text{(Eq. 4-58)}\quad \text{Steam required}_{\text{Post-retrofit}} = (30\ \text{MMBtu/hour}) - (3.91\ \text{MMBtu/hour})$$

$$= 26.09\ \text{MMBtu/hour}$$

$$= 26{,}090\ \text{lb. steam/hour}$$

Equation 4-59 shows the heat loss reduced due to higher condensate discharge temperature.

$$\text{(Eq. 4-59)}\quad \text{Heat loss reduced}_{\text{Post-retrofit}} = (26.09\ \text{MMBtu/hr}) \times (1\ \text{Btu/hr-degF}) \times (218^\circ\ \text{F} - 70^\circ\ \text{F}) \times (65\ \text{Days}) \times (24\ \text{Days})$$

$$= 6{,}024\ \text{MMBtu/hour}$$

Total Ex Ante Savings For Unit #2

The total *ex ante* energy savings for Unit #2 is shown in Equation 4-60.

$$\text{(Eq. 4-60)} \quad \text{Total therms saved for Unit \#2}_{\text{Ex ante}} = \frac{\left[\begin{array}{l}\text{Heat loss reduced}_{\text{Post-retrofit}} \\ \quad + \text{Reduction in continuous steam requirement}\end{array}\right]}{\text{Boiler efficiency}}$$

$$\times \text{ (1,000 therms / MMBtu)}$$

$$= \frac{[6{,}024 \text{ MMBtu} + 2{,}346 \text{ MMBtu}]}{0.9}$$

$$\times \text{ (1,000 therms / MMBtu)}$$

$$= 92{,}996 \text{ therms}$$

This result differs slightly from project files due to rounding errors.

Ex Ante Savings Unit #3

The second process line: Unit #3, has a capacity of 250 gpm versus 170 gpm for Unit #2. However, there is no need to change the supplemental heater, so only the waste condensate savings apply to this unit. Savings are calculated by ratio of sizes of the two units. From Equation 4-61 the Heat Loss Reduced$_{\text{Post-retrofit}}$ for Unit #2 is 60,237 therms for the output stream. The Heat Loss Reduced for Unit #3 is shown in Equation 4-62.

$$\text{(Eq. 4-61)} \quad \text{Heat loss reduced, unit \#3}_{\text{Post-retrofit}} = (\text{Heat loss reduced, unit \#2}) \times \left(\frac{\text{Capacity of Unit \#3}}{\text{Capacity of Unit \#2}}\right)$$

$$= (60{,}237 \text{ therms}) \times \left(\frac{250 \text{ gpm}}{170 \text{ gpm}}\right)$$

$$= 88{,}584 \text{ therms}$$

$$\text{(Eq. 4-62)} \quad \text{Energy savings, unit \#3} = \frac{(\text{Heat loss reduced, unit \#3})}{\text{Boiler efficiency}}$$

$$= \frac{(60{,}237 \text{ therms})}{0.90}$$

$$= 98{,}427 \text{ therms}$$

Total Ex Ante Savings for Unit #2 and Unit #3

Equation 4-63 shows the total energy savings of the retrofit measures installed on Units #2 and #3.

$$\text{(Eq. 4-63)} \quad \text{Total Energy savings}_{\text{Ex ante}} = \text{Energy savings, unit \#3}$$

$$= 92{,}996 \text{ therms} + 98{,}427 \text{ therms}$$

$$= 191{,}423 \text{ therms}$$

4.7.2 Ex Post Load Impact Estimation

The evaluation analysis was carried out by the same method as the *ex ante* estimates using the observed operating parameters and downtime values derived from interviews with operating personnel. It was found that the values used in the *ex ante* estimates have been achieved in practice. On review, the methodology is reasonable and sound. The *ex ante* savings estimates are therefor accepted as the *ex post* values.

4.7.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-30 summarizes the *ex ante* and *ex post* load impact estimates.

Table 4-30
Demand and Energy Impact Summary
Project ID No. 19400

	Demand Peak kW	Energy kWh/Year	Nat. Gas Therms/Year
***Ex Ante* Load Impact**	0	0	191,366
***Ex Post* Load Impact**	0	0	191,423
Difference	0	0	0
Realization Rate	N/A	N/A	1.00

4.7.4 Persistence of the Measure

The projected 20 year equipment life used in the *ex ante* estimate is reasonable with normal cleaning and maintenance.

4.7.5 Net-To-Gross

This measure was installed at the same site as ID No. 14200. In fact this measure is essentially the same as the heat exchanger installed under ID No. 14200. Thus, the net-to-gross assessment is the same.

SDG&E contributed to the technical analysis of the measures by sponsoring the in-depth study of the process that provided the basis for the recommendations adopted by the participant. It appears that the participant was, however, aware of the opportunity and probably helped direct the consultant to the problem. Thus, SDG&E offered a medium level of involvement. The financial incentives provided through the IEEI program provided the final impetus for the participant to adopt the measure. Thus, the net-to-gross value is 0.75.

4.8 ID No. 20411 - Improved Process Mixing

This is a organic materials processing facility in San Diego. The facility produces food admixtures through a variety of thermal, mechanical and biological production processes. This project involves a process improvement which reduces the amount of process raw materials and the energy required to heat these materials. The process modifications are a trade secret. The customer has requested that the nature of the project be kept strictly confidential.

The facility operates continuously, year-round. Thermal energy required for many processes is provided by steam generated in natural gas-fired boilers, rated at 90% overall efficiency. Electricity is also generated with steam from these boilers.

4.8.1 Ex Ante Load Impact Estimate

The *ex ante* load impact estimates were calculated using an engineering methodology based on assumptions provided by the customer. The savings are based on a reduction in certain raw materials and the resultant reduction in process input energy (natural gas fuel to produce steam) to heat the raw material.

The improvements resulted in a reduction of a key process input material. Additional "secondary" energy savings resulting from this improvement were calculated and claimed under Project ID No. 14200.

The *ex ante* load impacts were based on pilot studies which indicated that the process improvement resulted in:

- a decrease in raw material from about 61% of total mix to 50% of the total mix, or 18.33 percent (19% was the figure used.).
- the input energy required to heat the make up raw materials is also reduced by 19%.
- the pounds of steam per pound of product are 32 pounds of steam per pound of product.

For annual production of 13,000,000 pounds of product, and a boiler efficiency of 90%, the resulting *ex ante* savings are shown in Equation 4-64.

$$\text{(Eq. 4-64)} \quad \text{Therm savings}_{\text{Ex ante}} = (\text{Annual pounds of product}) \times (\text{Reduction in material required}) \times \left(\frac{\text{Steam required}}{\text{Boiler efficiency}}\right)$$

$$= (13{,}000{,}000 \text{ lb. product}) \times (0.19) \times \left(\frac{32 \text{ lb.}}{0.90}\right)$$

$$= 878{,}222 \text{ therms}$$

4.8.2 Ex Post Load Impact Estimation

The *ex post* analysis was carried out by the same method as the *ex ante* estimates using the actual observed reduction in raw material required. The site was visited on September 30, 1997. The improvements were observed in operation. Operating logs were visually reviewed with operating staff.

In this process, two products are mixed:

- CBM: A mixture of isopropyl alcohol and water (~85% IPA), and
- SPENT IPA: a similar mixture of materials with a concentration ranging from 55 to 65%

The Injection Ratio is defined in Equation 4-65.

$$\text{(Eq. 4-65)} \quad \text{Injection Ratio} = \frac{LB_{\text{cbm}}}{LB_{\text{beer}}}$$

$$= \frac{\%\text{SPENT}}{(\%\text{CBM} - \%\text{SPENT})}$$

The pre-retrofit Injection Ratio with Spent at 61% and CBM@85%, as shown in Equation 4-66.

$$\text{(Eq. 4-66)} \quad \text{Injection Ratio}_{\text{Pre-retrofit}} = \frac{61}{85-61}$$

$$= 2.54$$

It was observed from process log books that the raw CBM decreased from 61 percent of total mixture volume to 55 to 57 percent of total volume (depending on operating conditions and the operator). The post-retrofit Injection Ratio with spent reduced to 57% is calculated in Equation 4-67.

$$\text{(Eq. 4-67)} \quad \text{Injection Ratio}_{\text{Post-retrofit}} = \frac{57}{85-57}$$

$$= 2.036$$

The CBM reduction due to the retrofit is calculated in Equation 4-68.

$$\text{(Eq. 4-68) Reduction in I.R.} = \frac{2.54 - 2.036}{2.54}$$

$$= \frac{.504}{2.54}$$

$$= 0.1985$$

$$\equiv 19.85\%$$

The 1997 production was on target for approximately 25% increase above the 1996 level of 13,000,000 lb. Steam requirements have been measured as 32 lb. steam per lb. gum, and the boiler efficiency is estimated by the operator as 90%. The savings are calculated in Equation 4-69.

$$\text{(Eq. 4-69)} \quad \text{Savings} = \frac{(13{,}000{,}000 \text{ lb x } 1.25) \text{ x } (32 \text{ lbsteam / lb input}) \text{ x } (1000 \text{ Btu / lb. steam}) \text{ x } (0.1985\text{reduction})}{(0.90\text{Eff}) \text{ x } (100{,}000 \text{ Btu / therm})}$$

$$= 1{,}146{,}889 \text{ therms / year}$$

4.8.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-31 summarizes the *ex ante* and *ex post* load impact estimates.

Table 4-31
Demand and Energy Impact Summary
Project ID No. 20411

	Demand Peak kW	Energy kWh/Year	Nat. Gas Therms/Year
***Ex Ante* Load Impact**	0	0	878,222
***Ex Post* Load Impact**	0	0	1,146,889
Difference	0	0	-268,667
Realization Rate	N/A	N/A	1.31

The primary reason for the discrepancy is that the increase in plant output was not included in the *ex ante* estimates.

4.8.4 Persistence of the Measure

The 20 year equipment life is reasonable with normal maintenance and replacement of operating parts.

4.8.5 Net-To-Gross

This process modification was developed by the company at a pilot project at another site with great success. The participant representative explained that the project may have been installed without the incentive, but possibly deferred for some time. The IEEI Program incentive reduced the simple payback from 2.05 without the incentive to 1.77 with the incentive.

SDG&E's involvement in identifying the project is low, since, according to interviews, the participant tried the measure at its pilot plant and concluded that the measure provided the best results. The measure was then installed in another plant (located outside of California). The results at this second site confirmed the pilot results. It appears that the incentive was influential in the decision to install the measure in 1996. Thus, the net-to-gross ratio is 0.40.

4.9 ID No. 40514 - High Efficiency Air Compressors

This is a machinery component manufacturing facility in San Ysidro, CA. The plant typically operates three shifts per day, five days per week. Staff reports frequent single or double shifts on Saturdays and periodic Sunday operations as production requires.

SDG&E sponsored an in-depth consultant's study to identify energy saving opportunities and to quantify the potential load impacts of these opportunities. The current project involved replacement of six compressors with two new compressors. Most of the plant machinery is pneumatically driven. Compressed air is used to drive production machinery, for parts cleaning, blow-off, and control uses. Prior to the project, the plant's compressed air requirements were provided by four Joy 75 hp two-stage reciprocating compressors and two Joy 150 hp two stage, reciprocating compressors. According to plant staff the compressors were equipped with synchronous motors, each was capable of unloading to 50% capacity. The compressors were brought on line manually as required by air flow and pressure requirements. When on line, the compressors operated at line pressure according to automatic pressure controls. The compressors were more than thirty years old and had been moved from another facility.

The compressors were replaced with three Atlas-Copco, Model GA-75 screw compressors with 100 hp motors, rated at 487 cfm at 100 psi. In addition, a receiver tank, "demand expander" apparatus, a new air dryer, and sequencing controls were installed. The air dryer received a separate incentive as part of another project. In addition, improved traps were installed and a leak reduction program was carried out.

According to plant staff, only three of the former compressors would operate at a given time. Under high load conditions, two 150 hp compressors would be operated. Under average conditions, one 150 hp and one 75 hp compressor would run, with a second (and on rare occasions, a third) 75 hp compressor operating to provide "trim" air. Compressors were kept on line to maintain system pressure at all times, regardless of production.

In the post-retrofit operating condition, the three new GA75 compressors were connected to the air system and are operated in place of the Joy compressors. The Joy compressors have been retained as backups, but are expected to be removed soon. According to staff, they have not operated except during maintenance of the new compressors.

The new compressors are sequenced by an automatic sequencer. The compressors are operated to maintain a storage pressure of 105 psi, and system pressure downstream of the demand expander unit is maintained at 90 psi. The compressors are brought on line as required to maintain the required flow at the storage pressure.

Plant staff reports that two compressors are typically loaded during first and second shift operations, and a third is very rarely required. A single compressor typically handles the load during third shift and weekend operations.

4.9.1 Ex Ante Load Impact Estimate

The *ex ante* load impact estimates were calculated using an engineering methodology. According to file materials, the compressed air flow and pressure requirements for each shift and leakage rates during off hours were estimated from measurements taken over several days and interviews with plant staff. From this data a load profile was developed.

The hours of occurrence of each loading condition during each production shift were estimated. The compressor input power for each flow rate which occurred during each shift was estimated by multiplying the compressor rated power by the conversion factor 0.746 kW/hp and by a "loading factor" (part-load power) for the flow control strategy from a matrix provided by a compressor manufacturer. The resulting compressor power kW for each flow/pressure was then multiplied by the number of hours of occurrence of that flow condition during that shift to determine the annual kWh for the compressor plant during that shift. The kWh for each shift were then added to calculate the total annual pre-retrofit kWh. These operations are shown in Equations 4-70 and 4-71.

$$\text{(Eq. 4-70)} \quad kW_{Shift} = \frac{\left[\begin{array}{c}(\text{\# compressors}) \times (\text{compressor hp}) \times (0.746\ \text{kW/hp}) \\ \times\ (\text{\%Full Load Power at Part Load})\end{array}\right]}{\text{Motor efficiency}}$$

(Eq. 4-71) $\text{Total kWh} = \sum \text{kW}_{Shift} \times \text{Hours}_{Shift}$

The post-retrofit kWh was determined in a similar fashion. The anticipated post-retrofit air flow rate (after leaks and system pressure reduction were carried out) was estimated by subtracting 50% of the measured system leakage from the observed 300 cfm leakage rate (i.e., a 50% leakage reduction, or 150 cfm was projected).

The power input, in kW, to the new compressors under each post-retrofit flow condition was calculated from the "new" compressors' performance curves. The power was multiplied by the hours of operation at each flow condition during each operating shift to calculate the post-retrofit kWh for that shift. The kWh for all shifts were summed to calculate the total post-retrofit kWh.

The difference in the pre- and post-retrofit kWh was taken to calculate the estimated annual kWh savings. The time-of-use period kWh savings were determined by multiplying the total kWh by the ratio of the operating hours during each time-of-use period to 8,568.

The *ex ante* load impact calculations are shown in Equations 4-72 and 4-73, and summarized in Table 4-32. The total annual kWh savings was 675,792 kWh.

(Eq. 4-72) $\text{kWh savings}_{ex\ ante} = \text{kWh}_{Pre\text{-}retrofit} - \text{kWh}_{Post\text{-}retrofit}$

$= 1{,}149{,}245 \text{ kWh} - 473{,}453 \text{ kWh}$

$= 675{,}792 \text{ kWh}$

(Eq. 4-73) $\text{kW reduced}_{ex\ ante} = \text{kW(first shift)}_{Pre\text{-}retrofit} - \text{kW(first shift)}_{Post\text{-}retrofit}$

$= 211.92 \text{ kW} - 87.63 \text{ kW}$

$= 124.29 \text{ kW}$

- **Three Atlas-Copco GA75, 100 horsepower compressors (487 cfm@100psi)** were installed rather than **one-125 hp (GA90:640cfm@100psi) and one 75 hp compressor (GA55:75hp; 375cfm@100psi)** as described in the *ex ante* project files. In summary, a total of 300 compressor horsepower was installed and is operated regularly rather than 200 hp assumed in *ex ante* load impact estimates.
- The **observed compressor loading pattern based on *ex post* measured power input differed substantially from the loading profile used in the *ex ante* estimates**. The *ex post* profile matched much more closely to the compressor plant operating logs. The *ex post* compressor loading profile showed that two compressors typically operated at near full-load, and a third compressor operated at more than 75% loading during all three shifts, five days per week, rather than one compressor (either the 125 hp or 75 hp) assumed in the *ex ante* estimates. Two compressors operated for one shift on Saturday. Compressors were shut down for two shifts on Saturday and all day Sunday. According to staff, the weekend schedule varies monthly as required by production.

The *ex post* savings were calculated as follows:

- The amperage of each compressor was monitored at fifteen minute (averaged) intervals for a period of one week. Little variation was observed when a given compressor was in operation.
- Average total compressor plant input kW was calculated from the measured amps.
- Total plant airflow was calculated for the post-retrofit compressor plant using the manufacturer's rated airflow per input power.
- The airflow requirement was divided by the power per cfm estimated for the pre-retrofit compressor plant to estimate the compressor power which would have been required for the "old" plant for the same airflow requirement.
- The average kW for the old and new plants were multiplied by 8,760 hours per year to estimate the annual energy consumption. The difference is the *ex post* savings.

The load impact calculations are shown in Table 4-33. A sample of the monitoring data and the calculation of operating power for the monitoring period is shown in Appendix D.

Table 4-33
***Ex Post* Load Impacts**
Project ID No. 40514

PRE-RETROFIT kWh										
Shift	**# Com-pressors**	**Rated hp**	**CFM per Com-pressor**	**CFM required**	**Load Factor**	**Compr. %FL Power at Part Load**	**Shift Hours**	**Motor Eff.**	**kW**	**kWh**
Weekday1	3	150	600	1,400	0.78	93.7%	2,040	0.923	340.79	695,215
Weekday2	3	150	600	1,400	0.78	93.7%	2,040	0.923	340.79	695,215
Weekday3	3	150	600	1,400	0.78	93.7%	2,040	0.923	340.79	695,215
Sat1	1	150	600	0	0.00	0.0%	408	0.923	-	-
Sat2	1	150	600	480	0.80	94.0%	408	0.923	113.96	46,496
Sat3	1	150	600	0	0.00	0.0%	408	0.923	-	-
Sun	1	150	600	0	0.00	0.0%	1,224	0.923	-	-
							8,568	**Annual Pre-kWh**		**2,132,142**
								Average CFM/kW		**3.07**
POST-RETROFIT kWh										
Shift	**# Com-pressors**	**Rated hp**	**CFM per Com-pressor**	**CFM required**	**Load Factor**	**Compr. %FL Power at Part Load**	**Shift Hours**	**Motor Eff.**	**kW**	**kWh**
Weekday1	3	100	480	1,397	0.97	97.3%	2,040	0.945	230.51	470,241
Weekday2	3	100	480	1,397	0.97	97.3%	2,040	0.941	231.49	472,239
Weekday3	3	100	480	1,397	0.97	97.3%	2,040	0.941	231.49	472,239
Sat1	1	100	480	-	0.00	0.0%	408	0.941	-	-
Sat2	2	100	480	480	0.50	65.0%	408	0.941	103.06	42,049
Sat3	1	100	480	-	0.00	0.0%	408	0.941	-	-
Sun	1	100	480	-	0.00	0.0%	1,224	0.941	-	-
							8,568	**Annual Post-kWh**		**1,456,768**
								Average CFM/kW		**4.44**
***EX POST* LOAD IMPACTS**										
	Pre-Retrofit	**Post-Retrofit**	**Load Impact**							
Demand Reduction										
Energy Savings	2,132,142	1,456,768	675,374							

The demand kW impact is calculated in Table 4-34, which also calculates the savings by time of use period by prorating the operating hours during each time of use period. The system operates at near average loading during all operating periods except when shut down during the weekend off-hours. As a result, the peak-coincident demand impact is equal to the average demand impact during the on-peak periods.

Table 4-34
***Ex Post* kW and kWh Impacts by Time-Of-Use Period**
Project ID No. 40514

Time-of-Use Period	Total Hours	Weekend Off Hours	Site Operating Hours	kWh Adjustment Factor	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742	0	742	0.11845	78,168	105.3	105.3
Summer Mid-peak	954	0	954	0.15230	100,502	105.3	
Summer Off-peak	1,976	1,040	936	0.14943	98,606	49.9	
Winter On-peak	441	0	441	0.07040	46,458	105.3	105.3
Winter Mid-peak	1,911	0	1,911	0.30508	201,320	105.3	
Winter Off-peak	2,736	1,456	1,280	0.20434	134,845	49.3	
Total	8,760	2,496	6,264		659,898		

Savings were also calculated using the monitoring results directly. Monitoring data are shown in Appendix D. The result was 644,422 kWh. The average of the *ex post* methodology and the monitoring results to arrive at the evaluation result of 659,898 kWh per year.

4.9.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-35 summarizes the *ex ante* and *ex post* load impact estimates.

Table 4-35
Demand and Energy Impact Summary
Project ID No. 40514

	Demand Peak kW	Energy kWh/Year	Nat. Gas Therms/Year
***Ex Ante* Load Impact**	124.3	675,792	-
***Ex Post* Load Impact**	105.3	659,898	-
Difference	18.9	15,894	-
Realization Rate	0.85	0.98	n/a

The discrepancy in kWh impact is very small. However, the difference is a result of off-setting differences between the *ex ante* assumptions and calculations and the *ex post* findings.

- The post-retrofit system does not operate during off-hours, as was projected in the *ex ante* estimates.
- The *ex post* operating air flow requirements are greater (about twice) than those measured or calculated in the *ex ante* estimates.
- The compressor plant actually installed is very different from the plant assumed in the *ex ante* estimates. However the plant *efficiency*, as expressed in cfm per kW input, is approximately the same.
- The evaluation results do not verify reduction of leaks as assumed in the estimates.

4.9.4 Persistence of the Measure

The 20 year measure life is reasonable for these compressors with the level of service and assuming reasonable maintenance.

4.9.5 Net-To-Gross

Participant staff indicated that although they were aware of the age and inefficiency of their compressed air plant, the impact was not quantified until the consultant's in-depth study of the compressed air, funded by SDG&E, was conducted. Once the impact of the system improvements were identified and quantified, it was clearly a wise business decision to proceed with the compressor retrofits recommended in the study.

Since SDG&E sponsored the in-depth study that provided the basis for participant's decision to proceed with the compressed air system retrofits, SDG&E's level of involvement was high. Thus, the net-to-gross value is 1.00.

4.10 ID No. 40516 - AUTOMATED DIE CAST MACHINE

This is a machinery component manufacturing facility in San Ysidro, CA. The plant typically operates three shifts per day, five days per week. Staff reports frequent single or double shifts on Saturdays and periodic Sunday operations as production requires.

Small aluminum castings are a major component of the products fabricated at this facility. Five automatic continuous-casting machines operate nearly continuously to produce the castings. Each casting machine has an associated electric melting furnace. The casting process is fully automatic. The ingot carousel is loaded manually, but ingots are loaded into the horizontal furnaces automatically. Molten material is poured into the casting machines and castings are removed from the molds automatically.

This project involved the replacement of an existing casting machine and its associated furnace with a new high-capacity and improved-efficiency furnace and casting machine. A Buhler Model H400B continuous casting machine was installed to replace two LesterHP-700X-SF Machines.

There are numerous technological improvements in the Buhler machine versus the outdated Lester machine. Of most importance, the Lester machine has a connected load of 127 kW and the Buhler machine has a connected load of 111.64 kW. The Lester machines have a recorded production averaging 1,558 parts per machine per day. The Buhler machine has a rated output capacity of 3,500 parts per day, however, plant operating data for July 1997 indicates that the machine actual output averages 2,038 castings (parts) per 24 hour operating day.

4.10.1 Ex Ante Load Impact Estimate

The *ex ante* load impact estimates were calculated using an engineering methodology.

The calculations to estimate the *ex ante* power requirement of the pre-retrofit Lester machine are shown in Equations 4-74 through 4-78.

(Eq. 4-74) $kW_{Pre\text{-}retrofit}$ = 127.17 kW per machine (from manufacturer's data)

(Eq. 4-75) Output capacity $_{Pre\text{-}retrofit}$ = 1,558 parts / machine / 24 hours (from customer's operating data)

(Eq. 4-76) $$\text{Unit energy use}_{Pre\text{-}retrofit} = \frac{(kW_{Base\ Case}) \times (24 \text{ hours / day})}{(\text{Output capacity})}$$

$$= \frac{(127.17 \text{ kW}) \times (24 \text{ hours / day})}{(1{,}558 \text{ castings / 24 hours})}$$

= 1.959 kWh / part

(Eq. 4-77) Annual parts produced for two machines = (1,558 parts / machine / day) x (5.5 days / week) x (51 weeks) x (2 machines)

= 874,038 parts per year

(Eq. 4-78) Annual energy use $_{Pre\text{-}retrofit}$ = (874,038 parts) x (1.959 kWh / part)

= 1,712,217 kWh / year

Similarly, the *ex ante* post-retrofit energy use is calculated in Equations 4-79 through 4-81.

(Eq. 4-79) Operating power $_{Post\text{-}retrofit}$ = 111.64 kW (per manufacturer)

(Eq. 4-80) $$\text{Unit energy use}_{Post\text{-}retrofit} = \frac{(111.64 \text{ kW}) \times (24 \text{ hours/ day})}{3{,}500 \text{ parts / day}}$$

= 0.765531 kWh / part

(Eq. 4-81) Annual energy use $_{Post\text{-}retrofit}$ = (874,038 parts) x (0.765531 kWh / part)

= 669,104 kWh / year

The *ex ante* load impacts are shown in Equations 4-82 and 4-83.

$$\text{(Eq. 4-82)} \quad \text{kWh savings}_{\text{Ex ante}} = 1{,}712{,}217 \text{ kWh / year} - 669{,}104 \text{ kWh / year}$$

$$= 1{,}043{,}113 \text{ kWh}$$

$$\text{(Eq. 4-83)} \quad \text{Ex ante kW reduced} = \left[(127.17 \text{ kW / machine}) \times (2 \text{ machines})\right] - 111.64 \text{ kW}$$

$$= 142.7 \text{ kW}$$

4.10.2 Ex Post Load Impact

The *ex post* evaluation was carried out using the same engineering method used for the *ex ante* load impact estimates using documented production output for the period immediately prior to the *ex post* on-site visit. The site was visited on September 25 and again on October 1, 1997. Plant staff reported that this was a "typical" production week. The equipment was observed in operation and the operating characteristics of the enhanced-case equipment reported in the project file were verified. Because the energy savings rely primarily on the production output of the machine, production figures for the prior month were requested from plant operating staff.

The *ex post* evaluation used customer-reported actual production for the post-retrofit period of 2,038 castings (parts) per day for the post-retrofit case and 1,558 parts for the pre-retrofit case. These values are used to adjust the operating conditions for the pre-retrofit case through the Adjustment Factor for Differences in Production Capacity of 1.3. This effectively scales the output of the pre-retrofit casting machines to reflect the output reported during the *ex post* site visit. Equations 4-84 through 4-86 were used to calculate the *ex post* energy savings of the casting machine.

$$\text{(Eq. 4-84)} \quad \text{Parts / Year}_{\text{Casting Machine}} = (\text{Parts / Day}_{\text{Casting Machine}}) \times (5.5 \text{ day / week}) \times (51 \text{ wk / yr})$$

$$\text{(Eq. 4-85)} \quad \text{Adjustment Factor for Differences in Production} = \frac{\text{Parts / year}_{\text{Buhler Machine}}}{\text{Parts / year}_{\text{Lester Machine}}}$$

$$= \frac{1{,}039{,}380}{794{,}580}$$

$$= 1.3$$

(Eq. 4-86) $kWh_{Casting\ Machine} = (kW_{Casting\ Machine}) \times (24\ hours/day) \times (280.5\ day/year) \times (Adjustment\ Factor)$

The annual kWh savings is shown in Table 4-36.

Table 4-36
***Ex Post* Energy Impacts of New Die Casting Machine**
Project ID No. 40516

	Source	Lester HP-700X-SF (Pre-Retrofit)	Buhler H400 B (Post-Retrofit)
Casting Machine kW	SDG&E (*Ex Post* Verified)	127.17	111.64
Castings/Day/Machine	Customer Data	1,558	2,038
Adjustment Factor for Differences in Production Capacity (Post-Retrofit/Post-Retrofit Output)		1.3	1.0
Hours/Day		24	24
Annual Weeks/Year of Operation	Customer Data	51	51
Typical Operating Days/Week	Data	5.5	5.5
Average Operating Days/Year	Customer Data	280.5	280.5
kWh/Year (adjusted for production quantity)		1,112,941	751,561
kWh Savings/Year			361,381

Table 4-37 shows the *ex post* load impacts by time-of-use period. The facility production continues 24 hours per day except weekends, hence the savings are expected to occur in proportion to the number of production hours during each time-of-use period. The savings are allocated to the time-of-use periods by the following method:

1. The **total annual hours** occurring during each time-of-use period are calculated.
2. The **hours that production does not take place** during each time-of-use period are calculated. In this case, the facility will shutdown only on weekends.
3. The **operating hours during each time-of use period** are calculated by subtracting *hours that production does not take place* from *total annual hours* as shown in Equation 4-87.

(Eq. 4-87) $Operating\ hours_{TOU\ period} = Total\ annual\ hours_{TOU\ period} - hours\ that\ production\ does\ not\ take\ place_{TOU\ period}$

4. The **kWh savings** are allocated to each time-of-use period by multiplying the total kWh savings by the ratio of the operating hours during each time-of-use period to the total annual operating hours.
5. The **average kWh savings by TOU period** are calculated by dividing the total kWh saved during the time-of-use period by the total annual hours during the time-of-use period.

6. The **peak-coincident kW demand reduction** is calculated by dividing the total kWh savings during the summer on-peak period by the total operating hours during the period, as shown in Equation 4-88. In this case, because production continues during all peak period hours, the peak coincident demand savings are the same as the average peak period demand savings.

$$\text{(Eq. 4-88)} \quad \text{Peak coincident kW reduced} = \frac{\text{Total kWh saved}_{\text{on-peak}}}{\text{Total operating hours}_{\text{on-peak}}}$$

Table 4-37
***Ex Post* kW and kWh Impacts by Time-Of-Use Period**
Project ID No. 40516

TOU Period	Total hours	Hours w/ No Production	Annual Operating Hours	kWh Adjustment Factor	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742	0	742	0.11009	39,784	53.6	53.6
Summer Mid-peak	954	0	954	0.14154	51,151	53.6	
Summer Off-peak	1,976	800	1,176	0.17448	63,054	31.9	
Winter On-peak	441	15	426	0.06320	22,841	51.8	51.8
Winter Mid-peak	1,911	65	1,846	0.27389	98,978	51.8	
Winter Off-peak	2,736	1,140	1,596	0.23680	85,573	31.3	
Total	8,760	2,020	6,740		361,381		

4.10.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-38 summarizes the *ex ante* and *ex post* load impact estimates.

Table 4-38
Demand and Energy Impact Summary
Project ID No. 40516

	Demand Peak kW	Energy kWh/Year	Nat. Gas Therms/Year
***Ex Ante* Load Impact**	127.2	1,043,113	0
***Ex Post* Load Impact**	53.6	361,381	0
Difference	73.6	681,732	0
Realization Rate	0.42	0.35	N/A

The primary reasons for the discrepancy are:

- The evaluation used the actual production values for the pre- and post-retrofit production quantities: 3,116 and 4,076 parts per day, respectively. It appears that the *ex ante* estimates used the pre-retrofit value for castings (1,558 per day) for parts, and used the anticipated production value of 3,500 parts per day as the post-retrofit production value. The difference in pre- and post-retrofit production used in the *ex ante* estimates (but which did not actually occur) resulted in a greater difference in pre- and post-retrofit kWh per unit and hence larger savings than actually occurred.

- The *ex ante* estimates assumed that one "new" machine at full operating load would replace two "old" machines at full operating load. The *ex post* evaluation assumed that the kW reduction would be proportional to the savings which occurs during the peak time-of-use periods. Although two "old" machines had been removed when the retrofit machine was added, when considered over the multiple-year upgrade project, four of the "new" machines replaced five of the "old" machines with a 30 percent increase in total daily production. This difference is reflected in the *ex post* kW reduction value.

4.10.4 Persistence of the Measure

The 20 year equipment life claimed in the estimates is reasonable for major capital equipment of this type.

4.10.5 Net-To-Gross

This project involved replacement of an older die casting machine with a new, higher efficiency die cast machine with greater production output. Discussions with the participant staff revealed that this was the fourth of the new machines installed. Staff interviewed did not present a clear picture of the motivation for the project. It does appear that the technical awareness behind the equipment change originated with the customer and that the replacement was a part of a long-term capital equipment improvement program. However, the customer representative interviewed indicated that the incentive program did play a part in the decision to go ahead with the improvements during 1996 rather than deferring the work.

Since SDG&E appeared to play a relatively minor role in conceptualizing the recommendation for the equipment SDG&E's level of involvement was low. The incentive played a role in influencing the decision to implement the measures, thus the net-to-gross ratio is 0.40.

4.11 ID No. 40560 - Air Compressor Controls and Storage

This facility manufactures, assembles and tests components of power-production machinery. The facility occupies a large multi-building campus in San Diego. The manufacturing areas of the plant typically operate three shifts per day, five days a week.

The compressed air system at this facility initially consisted of two major systems:

- a general plant and control air system; and

- a high pressure/high flow testing air system.

The main plant compressed air was provided by a 400 hp Sullivan compressor, supplemented by a 200 hp Gardner/Denver compressor, and backed up by one 200 hp Worthington compressor and one 300 hp Sullivan compressor (which, according to file information, operated periodically to supplement the 400 hp and 200 hp compressors).

The separate test air plant consisted of one 1500 hp Atlas Copco (AC) compressor and two 300 hp Worthington booster units, that saw little service. Additional special purpose and isolated air was provided by one 25 hp, one 40 hp and several 5 hp local compressors.

This project was the second year of a two year compressed air system improvement program. The first year involved correction of leaks, and improvements to air quality. The second year project was intended to include:

- installation of a 5 hp compressor to provide air during periods of extremely low air requirements;
- a central control system with sensors and control logic; and
- additional storage tanks and "demand expanders" to stabilize plant air supply and pressure demand, and an intertie between the high and low-pressure systems to allow for excess air from the high pressure system to be supplied to the low pressure system.

The project changed significantly after the *ex ante* loading estimates were calculated. Table 4-39 lists the activities that were performed and those that were not or which were impaired in some way and not effective.

Table 4-39
Energy Efficiency Activities Undertaken
Project ID No. 40560

What Was Done	What Was Not Done
• Two large compressors, a 300 hp Sullivan and a 200 hp Worthington, failed (according to staff) and were removed from the plant; • the high pressure/low pressure system intertie is only used when the test system is in operation, rather than more frequently as was envisioned in the savings estimates • a new 250 hp Sullair screw compressor was installed. The compressor was included in the project costs, but not considered in the consultant's analysis which formed the basis of the estimates.	• A 5 hp high pressure/low flow compressor was not installed; • the proposed APT control system hardware was installed but was never successfully put into automatic service; the compressor plant operation remains in the manual mode and the envisioned control strategy was not fully implemented; • a suggested combustion waste-air recovery system was not implemented - (this was not included in the savings estimates, however.)

4.11.1 Ex Ante Load Impact Estimation

The *ex ante* load impact estimates were calculated using an engineering methodology, based on compressor operating and performance data provided by the compressed air system consultant. The air flow and pressure requirements for each shift over the year were estimated from measurements taken over several days. The hours of occurrence of each loading condition during each time-of-use period were estimated by interviews with operating staff.

The full load input power, and average load factor during operation was estimated for each compressor. The power requirement was multiplied by the annual hours of operation, based on short term observations and interviews with operating staff, to determine the pre-retrofit kWh. The post-retrofit kWh was determined by multiplying the compressor horsepower (converted to kW) by the projected load factor and annual operating hours after the recommended equipment was installed and control strategy were implemented.

The difference in the pre- and post-retrofit kWh, less the savings for the 1995, leak reduction portion of the project was reported as the savings. The total of the annual savings by time-of-use period was 956,507 kWh. A summary of the *ex ante* load impact estimates is shown in Table 4-40.

Table 4-40
***Ex Ante* Load Impact Estimate Summary**
Project ID No. 40560

Compressor	*Ex Ante* - Base Case					*Ex Ante* - Proposed Retrofit				*Ex Ante* Load Impacts	
	Rated HP	Hours per Year	Load Factor	kWh per Year	Avg. kW	Hours per Year	Load Factor	kWh per Year	Avg. kW	kWh Savings	kW Reduced
Sullair	400	8 ,760	0.95	2,826,718	322.7	1,100	0.95	354,953	322.7	2,471,765	0.0
Worthington	200	1,500	0.50	130,145	86.8	1,500	0.50	130,145	86.8	-	0.0
Sullivan	300	200	0.70	36,440	182.2	200	0.10	5,206	26.0	31,234	174.0
Gardner/Denver	200	6,000	0.95	989,099	164.8	7,400	0.95	1,219,888	164.8	(230,789)	0.0
Worthington Bstrs (2)	300	1,600	0.60	255,430	159.6	1,000	0.80	159,644	159.6	95,786	0.0
Atlas Copco	1,500	1,500	0.75	1,432,975	955.3	1,600	0.95	1,936,108	1,210.1	(503,133)	(254.8)
Sullair 25	25	6,000	0.95	130,743	21.8	6,000	0.95	130,743	21.8	-	0.0
Sullair 40	40	2,000	0.95	69,730	34.9	2,000	0.95	69,730	34.9	-	0.0
Subtotal				5,871,280	1,928.1			4,006,417	2,026.7	1,864,863	0.0
					Impacts for leak reduction accounted for in 1995					878,355	
					Projected Impacts for 1996					986,507	

4.11.2 *Ex Post* Load Impact Estimation

The site was visited on October 1, 1997. The compressors were observed in operation, and their control strategy and operation was discussed with operating staff regarding the pre- and post-retrofit air compressor plant operation. The *ex post* load impacts were estimated through a methodology similar to that used for the *ex ante* estimates, however the *ex post* impacts were based on site-observed compressor power (amps), and operating hours obtained from observation of analog meters on the equipment and operating logs and monitoring data provided by the customer.

Monitoring was considered and planned for this site, however, it was not carried out for several reasons:

- The high pressure plant was not in operation at the time of the visit and was not expected to be in operation for several weeks;
- The Atlas-Copco compressor was down for major maintenance;
- We were informed that the 250 hp Sullair was not likely to be in operation for several weeks due to limited activity in the test chamber
- The evaluator and customer electrician agreed that monitoring equipment could not be installed safely on the 400 hp Sullair compressor.
- Operating logs indicating operating hours for all the major compressors were found;
- It was discovered that two of the compressors originally expected to remain in operation had been removed.

- Compressor operating monitoring equipment was activated a few days after the initial visit, providing records of operating air flow and power for limited operating periods.

The pre-retrofit operating hours used in the *ex ante* estimates were adjusted to reflect current information provided by plant operating staff, site observations and information obtained from operating logs. Post-retrofit operating hours were observed or obtained from operating logs provided by the customer. kWh savings calculations are shown in Table 4-41.

Table 4-41
***Ex Post* kWh Savings Calculations**
Project ID No. 40560

	Pre-Retrofit						Post-Retrofit					*Ex Post* Load Impacts	
	Rated HP	Hours per year	Load Factor	kWh per year	Avg. kW	Coin. Peak. kW	Rated HP	Hours per Year	Load Factor	kWh per Year	Avg. kW	kWh Savings	kW Reduced
Sullair	400	8,760	0.95	2,699,223	308.1	308.1	400	5,952	0.75	1,447,889	165.3	1,251,334	142.8
Worthington	200	1,000	0.50	81,087	81.1	9.3	-	-	-	-	-	81,087	9.3
Sullivan	300	200	0.70	34,057	170.3	3.9	-	-	-	-		34,057	3.9
Gardner/Denver	200	4,037	0.95	621,961	154.1	71.0	200	400	0.95	61,626	7.0	560,335	64.0
Worthington Bstrs (2)	400	480	0.50	77,843	162.2		400	480	0.50	77,843	162.2	-	-
Atlas Copco	1,500	1,500	0.75	1,368,342	912.2		1,500	1,500	0.75	1,368,342	912.2	-	-
Sullair 25	25	6,000	0.95	115,549	19.3		25	6,000	0.95	115,549	19.3	-	-
Sullair 40	40	2,000	0.95	61,626	30.8		40	2,000	0.95	61,626	30.8	-	-
NEW Sullair 250	0	0	0	-	-		250	3,008	0.90	525,930	-	(525,930)	-
	3,065			5,059,688	1,838.04		2,815			3,658,806	1,297	1,400,883	
											kWh Impacts	**1,400,883**	

Table 4-42 shows the *ex post* load impacts by time-of-use period. Note that the kW savings are calculated as the kWh savings during the peak time-of-use period divided by the hours of the peak period. Site observations indicate that the on-peak period kW loading is consistent with periodic but random peaks and valleys. Thus, the average impacts during the on-peak period are most representative of the system peak period savings.

Table 4-42
kW and kWh Impacts by Time-Of-Use Period
Project ID No. 40560

Time-of-Use Period	Total Hours	Site Hours	kWh Adjustment Factor	kWh Savings	kW Adjustment Factor	Average kW Reduced	Peak Coincident kW Reduced
Summer On-peak	742	742	0.12077	169,182	1.00	228.0	228.0
Summer Mid-peak	954	954	0.15527	217,520	1.00	228.0	
Summer Off peak	1,976	930	0.15132	211,986	0.47	107.3	
Winter On-peak	441	391	0.06364	89,151	0.89	202.2	202.2
Winter Mid-peak	1,911	1,841	0.29964	419,763	0.96	219.7	
Winter Off peak	2,736	1,286	0.20935	293,280	0.47	107.2	
Total	**8,760**	**6,144**		**1,400,883**			

4.11.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-43 summarizes the *ex ante* and *ex post* load impact estimates. Comparison of the *ex ante* and *ex post* peak demand and energy values shows a realization rate of 0.406 and 1.42 , respectively.

Table 4-43
Demand and Energy Impact Summary
Project ID No. 40560

	Peak Coincident kW	kWh/Year	Nat. Gas Therms/Year
***Ex Ante* Load Impact**	561.5	986,507	0
***Ex Post* Load Impact**	228.0	1,400,883	0
Difference	333.5	-414,376	0
Realization Rate	0.406	1.42	N/A

The primary reasons for the discrepancy between the *ex ante* and *ex post* load impact estimates are:

- The *ex ante* kW impact estimates took the difference between the greatest highest loads of the pre- and post retrofit equipment, rather than attempting to identify the most likely peak-coincident kW Because production changes very little between first and second shifts, the average kW over the period probably is most representative of the system peak-coincident impact at this site. The average was calculated as the evaluation ex post value.
- Operating logs and monitoring data obtained during the *ex post* evaluation indicated a smaller difference in plant operating power over time (i.e. kWh) than was used in the *ex ante* estimates (which were based on short term operating observations conducted by the air compressor consultant).

- The high pressure and low pressure system operations were not integrated to the degree envisioned in the *ex ante* estimates.
- In the overall scheme of improving the compressed air system a comprehensive plan was implemented that spanned two year. Overall, these improvements yielded load impacts that could not be isolated in this evaluation. It is likely that the sum of the parts is greater than the individual components by themselves.

4.11.4 Persistence of the Measure

Project estimates use a life of 20 years for the air compressor system improvements. A 20 year life for the hardware elements is realistic and normal for equipment of this type with normal maintenance.

4.11.5 Net-To-Gross

SDG&E approached this customer during 1994 or 1995 to investigate compressor energy use and potential for efficiency modifications. The projects were identified by a consultant through a study sponsored by SDG&E. Customer staff commented that it is likely that no action would have been taken had it not been for the IEEI Program.

Since SDG&E sponsored the consultant's study that identified the efficiency improvements, SDG&E's level of involvement was high. Thus, the net-to-gross value is 1.00.

4.12 ID No. 40663 - Compressed Air System

This is a heavy manufacturing facility located in San Diego, CA. Staff reported that the facility operates three shifts per day, five days per week. However, monitoring indicates that second shift compressed air requirements are lower than first shift and that third shift and weekend compressed air requirements are even lower.

Compressed air is required to drive pneumatic machinery, controls, welding, cutting, cleaning and for periodic sand-blasting. The facility's compressed air requirements are provided by seven large compressors at three locations in the large complex. There are two standby compressors at a fourth location. Four of the compressors had been replaced and several improvements had been made to the plant's compressed air system in earlier SDG&E projects. This project involved the replacement of one Clark 800 hp, two stage reciprocating compressor with three new Gardner-Denver 200 hp, screw-type compressors. The project also involved installation of an enhanced air compressor control system with improved control logic to monitor plant operation, and to schedule and dispatch all the compressors according to demand. The installation of new drains in the air system, and continuing a leak reduction program begun in an earlier project were also part of the project.

4.12.1 Ex Ante Load Impact Estimation

The *ex ante* load impact estimates were based on air flow rates estimated for each operating shift for pre- and post-retrofit operation. The compressor power for the assumed post-project air demand and compressor power was subtracted from the power for the pre-project air compressor operation determined by visual observations, interview with operators and spot measurements. The estimates assumed a post-project control strategy in which two (of four total) 350 hp Le Roi compressors are removed from operation except as standby. The peak kW for each compressor building was estimated from the shift air requirements, and from the manufacturer's compressor performance data for both the pre- and post-retrofit operating control scenarios.

The kWh consumed by the compressors for each time-of-use period for both pre- and post-retrofit operation was estimated by multiplying the peak kW for the compressor plant by the estimated (or anticipated) number of hours of operation during each time-of use period.

The difference between the pre- and post-retrofit compressor kWh for each time of use period was summed to provide the total *ex ante* savings estimate. The *ex ante* kWh savings were calculated as the difference between the pre- and post-project total kWh. *Ex ante* savings estimates are summarized below in Table 4-44.

Table 4-44
Summary of *Ex Ante* Savings Estimates
Project ID No. 40663

BASE CASE																		
	SUMMER									WINTER								
	On-peak			Semi-peak			Off-peak			On-peak			Semi-peak			Off-peak		
Bldg.	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh
10&70	572.3	763	436,665	572.3	981	561,426	572.3	1928	1,103,394	572.3	462	264,403	572.3	2002	1,145,745	572.3	2534	1,450,208
26	396.7	763	302,682	279.7	981	274,386	174	101	17,574	279.7	462	129,221	396.7	2002	794,193	174	2534	440,916
12	408	153	62,424	0	0	-	0	0	-	92	0	-	0	0	-	0	0	-
			801,771			835,812		2029	1,120,968			393,624			1,939,938			1,891,124
Total Base Case Annual kWh																		6,983,238
RETROFIT																		
	SUMMER									WINTER								
	On-peak			Semi-peak			Off-peak			On-peak			Semi-peak			Off-peak		
Bldg.	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh
10	572.3	763	436,665	293	981	287,433	467	1928	900,376	572.3	462	264,403	293	2002	586,586	467	2534	1,183,378
26	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
12&70	171	763	130,473	232.3	981	227,886	0	0	-	171	462	79,002	232.3	2002	465,065	0	0	-
			567,138		1962	515,319		1928	900,376	743.3		343,405		4004	1,051,651		2534	1,183,378
Total Retrofit Annual kWh																		4,561,266
EX ANTE ENERGY IMPACT																		
Annual *Ex Ante* kWh Savings *																		2,421,971

Differences between the reported *ex ante* savings of 2,420,736 kWh and the results shown in Table 4-44 are due to rounding errors.

The demand impacts were estimated through Equation 4-89. It appears that anticipated full load kW during the maximum demand "event" were used as the pre-retrofit and post-retrofit kW used in the *ex ante* estimates. The source of the exact values used are not clear from the file information provided.

$$\text{(Eq. 4-89)} \quad \text{kW savings}_{\text{Ex Ante}} = 2{,}148 \text{ kW} - 1{,}148 \text{ kW}$$

$$= 1{,}000 \text{ kW reduced}$$

4.12.2 Ex Post Load Impact Estimation

The site was visited on September 23, 1997. Monitoring took place during the period October 1, through October 16, 1997. The installed equipment was observed. Three new Gardner Denver compressors, designated #184, #185, and #186 had been installed in Building 26. The 800 hp Clark compressor remained in place and is in use as standby only. New drains had been installed at each compressor station. It was observed that compressors in Buildings 26, 10 and 12 were in operation under the control of the new APT control system. Two compressors in building 70 remained in place and operable, but these were operated manually and they were not connected to the automatic control system.

Full load, part load and idling amperages were observed for each compressor via the APT control system. Readings were taken of the operating hour log for each of the compressors. Log books were reviewed.

Current transformers were installed on the electric service to each of the seven primary compressors in active operation (4 LeRoi units, #189, #190, #199, and #200; and the Gardner Denver units, #184, #185 and #186). Amperage was recorded at 15 minute intervals for a period of 16 days. The backup Clark and Joy compressors were not operated during the period and they were not monitored. From the amp readings, the power for each compressor was calculated. A power profile was developed for each individual compressor and for the total compressed-air plant for the monitoring period. Values of average and maximum power for each hour of the day during the monitoring period were calculated.

The *ex post* "post-retrofit" kWh for each time-of-use period were calculated by multiplying the average measured kW for all the compressors for each hour of operation, by the number hours in the corresponding time-of-use period.

The kWh for each time-of-use period calculated from the post-retrofit monitoring were subtracted from the kWh for each time-of-use period for the *ex ante* pre-retrofit equipment and control strategy which were provided in the project file.

The annual kWh savings are the sum of the individual seasonal time-of-use period savings.

The *ex post* kW reduction was calculated by adjusting the average kW savings by the Peak Coincidence Factor that represents the ratio of the peak-hour demand to the average on-peak time-of-use period demand as follows:

- the average kW saving value was obtained by dividing the kWh savings during the summer on peak period by the total hours during the period (742);
- the average kW which occur during the Summer between 2 to3 p.m. were calculated from the data obtained during the two week monitoring period;
- the ratio of the average 2 to 3 p.m. kW to the overall time-of use period average kW was calculated to produce the Peak Coincidence Factor; and
- the peak-coincident kW impacts were calculated by multiplying the average kW reductions by the Peak Coincident Factor. (At this site, this factor was 1.37 during the summer on-peak period).

The level of production activity had increased at the facility from 1995 to 1997. Although there is no discrete unit of production by which energy use can be normalized, construction labor hours provide a reasonably good indicator of the level of activity (hence demand for compressed air, and impacts of compressed air system changes) at this facility. As a result, a second calculation was performed to adjust the pre-retrofit kWh for the increase in construction activity.

This was done by increasing the pre-retrofit kWh by a linear factor which was the ratio of the 1997 construction labor (measured in millions of man-hours) divided by the 1995 construction labor. It was felt that this was reasonable in that the *ex ante* pre-retrofit observations (on which the pre-retrofit kWh used in both the *ex ante* and the *ex post* analysis were based) took place in early 1995, and the measurements on which the *ex post* analysis took place during a representative period in late 1997. The construction labor man-hours increased from 6.2 million to 6.52 million, an increase factor of 5.16 percent. This resulted in a Labor Adjustment Factor of 1.0516.

The unadjusted time-of-use and annual kWh impact calculations are shown in Table 4-45a. The Construction labor data provided is shown in Table 4-45b. The final *ex post*, adjusted kWh and time-of-use kWh impacts are shown in Table 4-45c.

Table 4-45a
Unadjusted *Ex Post* Time-of-Use Period Load Impacts
Project ID No. 40663

PRE-RETROFIT																		
	SUMMER									WINTER								
	On-peak			Semi-peak			Off-peak			On-peak			Semi-peak			Off-peak		
Bldg	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh
10&70	572.3	763	436,665	572.3	981	561,426	572.3	1928	1,103,394	572.3	462	264,403	572.3	2002	1,145,745	572.3	2534	1,450,208
26	396.7	763	302,682	279.7	981	274,386	174	101	17,574	279.7	462	129,221	396.7	2002	794,193	174	2534	440,916
12	408	153	62,424	0	0	-	0	0	-	92	0	-	0	0	-	0	0	-
		742	**801,771**		954	**835,812**		1970	**1,120,968**		441	**393,624**		1911	**1,939,938**		2736	**1,891,124**
Avg. kW	**1,081**			**876**			**569**			**893**			**1,015**			**691**		
Total Base Case Annual kWh																		**6,983,238**
POST-RETROFIT																		
	SUMMER									WINTER								
	On-peak			Semi-peak			Off-peak			On-peak			Semi-peak			Off-peak		
	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh
		742	-		954	-		1970	-		441	-		1911	-		2736	-
TOTAL:	826.4	742	613,179	800.9	954	764,085	404.2	1970	796,218	724.5	441	319,495	832.3	1911	1,590,484	404.2	2736	1,105,814
Avg. kW	**826**			**801**			**404**			**724**			**832**			**404**		
Total Retrofit Annual kWh																		**5,189,274**
***EX POST* LOAD IMPACTS**																		
Annual kWh Savings																		**1,793,963**
TOU Period kWh Savings			**188,592**			**71,727**			**324,750**			**74,129**			**349,454**			**785,310**
Average kW Reduced			**254.2**			**75.2**			**164.8**			**168**			**182.9**			**287**

Table 4-45b
Construction Labor Data and Adjustment Factor
Project ID No. 40663

	Man-Hours (millions)			
Labor Group	**1995**	**1996**	**1997**	**95-97 Increase**
Repair/Maintenance (A)	0.24	0.33	0.32	33.33%
New Construction (B)	5.96	6.95	6.2	4.03%
Engineering (C)	0.73	0.55	0.57	-21.92%
Total	6.93	7.83	7.09	2.31%
Total Construction Labor (A + B)	**6.20**	7.28	**6.52**	**5.16%**
Labor Adjustment Factor				**1.0516**

Table 4-45c
***Ex Post* Time-of-Use Period Load Impacts**
Adjusted by Labor Adjustment Factor
Project ID No. 40663

EX POST PRE-RETROFIT kWh - (Unadjusted kWh Multiplied by Labor Adjustment Factor)																		
	Summer									Winter								
	On Peak			Semi Peak			Off Peak			On Peak			Semi Peak			Off Peak		
Bldg	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh
10&70	572.3	763	459,197	572.3	981	590,396	572.3	1928	1,160,330	572.3	462	278,046	572.3	2002	1,204,865	572.3	2534	1,525,039
26	396.7	763	318,300	279.7	981	288,544	174	101	18,481	279.7	462	135,889	396.7	2002	835,174	174	2534	463,667
12	408	153	65,645	0	0	-	0	0	-	92	0	-	0	0	-	0	0	-
TOU Total		742	843,142		954	878,940		1970	1,178,810		441	413,935		1911	2,040,039		2736	1,988,706
Avg kW			1,136			921			598			939			1,068			727
Total Pre-Retrofit kWh																		**7,343,573**
EX POST POST-RETROFIT																		
	Summer									Winter								
	On Peak			Semi Peak			Off peak			On Peak			Semi Peak			Off peak		
	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh	kW	Hrs	kWh
		742	-		954	-		1970	-		441	-		1911	-		2736	-
Total	826.4	742	613,179	800.9	954	764,085	404.2	1970	796,218	724.5	441	319,495	832.3	1911	1,590,484	404.2	2736	1,105,814
		742	-		954	-		1970	-		441	-		1911	-		2736	-
		742	613,179		954	764,085		1970	796,218		441	319,495		1911	1,590,484		2736	1,105,814
Avg kW			826			801			404			724			832			404
Total Annual kWh																		**5,189,274**
Annual kWh Savings																		**2,154,298**
TOU Period kWh Savings																		
			229,963			114,855			382,592			94,440			449,555			882,893
Average kW Reduced																		
			309.9			120.4			194.2			214			235.2			322.7
Peak Coincidence Factor (Peak kW/Average)																		
			1.37															
Peak kW Reduced																		
			423.6															

Table 4-46 shows the *ex post* load impacts by time-of-use period.

Table 4-46
***Ex Post* kW and kWh Impacts by Time-Of-Use Period**
Project ID No. 40663

Time-of-Use Period	kWh Adjustment Factor	kWh Savings	Average kW Reduced	Peak Coincidence Factor	kW Reduced Coincident with System Peak
Summer On-Peak	0.10675	229,963	309.9	1.37	423.6
Summer Semi-Peak	0.05331	114,855	120.4		
Summer Off-Peak	0.17759	382,592	194.2		
Winter On-Peak	0.04384	94,440	214.1		
Winter Semi-Peak	0.20868	449,555	235.2		
Winter Off-Peak	0.40983	882,893	322.0		
Total		2,154,298			

4.12.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-47 summarizes the *ex ante* and *ex post* load impact estimates.

Table 4-47
Demand and Energy Impact Summary
Project ID No. 40663

	Demand Peak kW	Energy kWh/year	Nat. Gas Therms/Yr
***Ex Ante* Estimated Impact**	1,000.0	2,420,736	0
***Ex Post* Gross Impact**	423.6	2,154,298	0
Difference	576.4	(266,438)	0
Realization Rate	0.42	0.89	N/A

Comparison of the *ex ante* and *ex post* peak demand values shows a realization rate of 0.89 for kWh and 0.42 for kW.

The primary reason for the difference in the annual kWh values is that the system is not operated as was envisioned in the *ex ante* estimates. The *ex post* monitoring revealed that more compressors are operated for longer hours than was projected in the estimates. Specifically:

- The estimates projected that the capacity provided by compressors #189 and #190 in Building 26 would be replaced with air from the three new compressors in Building 12 and that #189 and #190 would not run at all after the project. These compressors operated nearly continuously with a load factor of 0.4 and 0.9 respectively during the monitoring period along with two of the three compressors in Building 12.

- It was projected in the *ex ante* that the new compressors in Building 12 would only be required to run at about one-third capacity during the on-peak and semi-peak periods, and not run at all during the off-peak periods. Monitoring indicates that these compressors operate continuously with an overall average load factor of 0.6, and an off-peak load factor of about 0.7.
- Reductions in Summer semi-peak and off-peak kWh and Winter off-peak kWh did not materialize to the extent predicted in the *ex ante* estimates. This is probably due to greater than expected air demand during those periods than was anticipated.

The large discrepancy between *ex ante* peak kW savings and the *ex post* result may be explained by significant differences in the method of estimating savings as well as large differences in operating kW values observed during the evaluation and the base case values used in the estimates. This is explained further below:

- The *ex ante* estimates for kW savings were based on the difference between the values for the maximum operating compressor kW (2,148) at the time of a peak air flow demand "event" in the pre-retrofit operating and control strategy and the expected peak compressor kW (1,148) during a peak demand event after the improvements and post-retrofit control strategy was implemented. The values used appear to reflect the total compressor connected load prior to the project and very limited compressor load under similar conditions in the post-retrofit case.
- The *ex post* values are calculated based on measured post-retrofit compressor loads and loading patterns. The post-retrofit monitoring indicates that there is significant diversity of loading and that short-term peak events occur randomly during the first and second shifts. As a result, the most representative kW impact at the time of the System Peak is the average kW savings value adjusted by a factor which relates the impact during the 1-3 p.m. peak period hours to the average impact as described previously.
- A portion of the kW savings discrepancy also results from the lower than expected overall kWh savings which occurred for the reasons described previously.

4.12.4 Persistence of the Measure

The 20 year measure life is reasonable and consistent with expectations for the hardware aspects of this project, including the three new air compressors, air dryers, receiver vessels, demand expanders, piping and drains. The savings resulting from leak reduction (other than leaks) will only be retained with an on-going program of inspection and maintenance. We understand from plant personnel that test equipment was purchased and that such a program is in place at the time of the evaluation. This must be continued for the leak reduction savings to continue.

4.12.5 Net-To-Gross

Discussions with participant's staff made it clear that no action would have been taken without the intervention of SDG&E at this site. Air compressors were identified as a major end use in a scoping study conducted by SDG&E's staff. SDG&E then arranged and sponsored a consultant's study to identify and quantify the benefits of efficiency opportunities in the compressed air system. Most of the study's recommendations were implemented.

Since SDG&E sponsored the consultant's study that identified the efficiency improvements, SDG&E's level of involvement was high. Thus, the net-to-gross value is 1.00.

4.13 ID No. 41453 - Optimized Air Cooled Compressed Air System

This facility is a metal products fabrication plant and warehouse located in San Diego, CA. The facility typically operates three shifts, 24 hours, per day, five days per week. However, there is frequently a one or two shift operation on Saturdays and sometimes on Sundays, depending on production requirements.

The facility has five production lines. Compressed air is required to drive pneumatic machinery, controls, and for cleaning. Prior to the project, the facility's compressed air requirements were provided by four water-cooled compressors, two 50 hp and two 100 hp units. Two 30 ton air-cooled chillers and their associated pumps and condenser fans were maintained on line at all times to provide cooling water to the compressors.

Typically, two of the 100 hp compressors would operate when air requirements were high, with trim air requirements provided by one or two of the 50 hp machines. During third shift or weekends when production requirements were low, either one 100 hp or one 50 hp unit was kept on line to maintain system pressure.

The retrofit consisted of the removal of two 50 hp compressors and one 100 hp compressor, with the installation of one new 125 hp air-cooled screw compressor. The 100 hp compressor and a vacuum pump were converted to air-cooling and the water chillers and their associated circulation pumps were removed from service. Additional improvements also included installation of a new 400 gal receiver tank, an improved air cooler and new low leakage moisture drains, repair of major air leaks and improved controls on the compressors.

4.13.1 Ex Ante Load Impact Estimation

The *ex ante* impact estimates were calculated on the basis of a consultant's spot flow and power measurements of the pre-retrofit equipment and engineering calculations. The estimates used the pre-retrofit equipment and operating strategy as the Base Case. The estimates were based on air flow rates observed during the first shift and estimated for each other operating shift. The estimates assumed constant full load, constant operation of the pre-retrofit compressors and cooling equipment. and of the post-retrofit compressor.

The key assumptions in the above analysis are:

1. chillers operate at full load during the facility operating hours;
2. the two 100 hp compressors operate at full load during all plant operating hours;
3. the 100 hp compressors have an average input power during operation of 72.3 kW and 81.7 kW respectively (based on short term spot measurements and operating observations);
4. there is no compressor load or operation during non-work hours;
5. the pumps have an 80% load factor;
6. the 50 hp compressors were not included in the calculation.

The load impacts were estimated on the bases of the difference in installed watts of the pre- and post-retrofit equipment. The difference in Watts is multiplied by the operating hours to estimate the kWh for each piece of equipment. Equations 4-90 and 4-91 show the basic calculations. The *ex ante* load impacts are shown in Table 4-48.

(Eq. 4-90) $$\Delta \text{Watts} = \text{Watts}_{\text{Pre-retrofit}} - \text{Watts}_{\text{Post-retrofit}}$$

(Eq. 4-91) $$\text{Annual kWh} = \sum_i \Delta \text{Watts}_i \times (\text{Annual Operating Hours}_i)$$

where,

ΔWatts_i = the difference in Watts for equipment i; and

$\text{Annual Operating Hours}_i$ = Annual Operating Hour for equipment i.

Table 4-48
***Ex Ante* Savings Estimates**
Project ID No. 41453

	Hours of Operation				Existing		Retrofit		Savings		
Unit	Start Hour	Stop Hour	Week-days	Week-ends	No. Units	Watts	No. Units	Watts	Hours per Year	kW	kWh per Year
Compr. #1	0	2400	5	0	1	72,286			6,120	72.29	442,390
Compr. #2	0	2400	5	0	1	81,730			6,120	81.73	500,188
125 hp Compr.	0	2400	5		0	0	1	110,296	6,120	-110.30	-675,010
N. Chiller	0	2400	5	0	1	35,216			6,120	35.22	215,522
S. Chiller	0	2400	5	0	1	33,862			6,120	33.86	207,233
CHW Pump	0	2400	5	0	1	3,591			6,120	3.59	21,976
CHW Pump	0	2400	5	0	1	1,465			6,120	1.46	8,963
7 Mix Motors	0	2400	5	0	1	0	1	839	6,120	-0.84	-5,136
Total											716,126

The total annual kWh is distributed among the time-of-use periods in proportion to the operating hours that occur during each TOU period.

The peak kW reduced is assumed to be the difference between the total pre-retrofit observed kW for the system (which includes the average compressor kW and the full load chiller kW) and the post-retrofit kW.

The *ex ante* assumptions were reviewed and appeared to be realistic estimates given the operating conditions observed at the site visit and confirmed by interviews with operating staff.

4.13.2 Ex Post Load Impact Calculation

The site was visited on September 24, 1997 and September 30, 1997. The installed equipment was observed. The 125 hp project compressor was observed in operation and two 50 hp compressors and the two chillers were observed to be in storage behind the plant. Other air system appurtenances were observed to be installed and in operation.

The *ex post* analysis was performed by two methods:

- Monitoring/engineering; and
- Unit Energy Intensity Analysis

Monitoring/Engineering Analysis

The compressor power and schedule used in the *ex ante* analysis was accepted as the base case operation. The power of the new 125 hp and 100 hp compressors was monitored at fifteen minute intervals for seven days. From this, the post-retrofit average compressor power, in Watts, was calculated. The observed power for each machine was multiplied by the annual hours of operation and load factor to estimate the annual kWh usage. A load factor of 0.25 is assigned to the 100 hp compressor because staff reported that its use was abnormally high during the monitoring period. These hours were also verified by the measured data for the monitoring period. The post-retrofit kWh and kW were subtracted from the pre-retrofit values to estimate the load impacts. Equations 4-92 and 4-93 show the calculations for estimating the pre- and post-retrofit energy use. A summary of the engineering analysis results is provided in Table 4-49.

(Eq. 4-92) $\text{Annual kWh}_{\text{Pre-retrofit}} = \sum_{\text{End Use i}} \text{Annual kWh}_i$

$= (\text{kW}) \times (\text{hours / day}) \times (\text{days / week}) \times (\text{weeks / year}) \times (\text{Load factor})$

$= 1{,}396{,}278 \text{ kWh / year}$

(Eq. 4-93) $\text{Annual kWh}_{\text{Post-retrofit}} = \sum_{\text{End Use i}} \text{Annual kWh}_i$

$= (\text{kW}) \times (\text{hours / day}) \times (\text{days / week}) \times (\text{weeks / year}) \times (\text{Load Factor})$

$= 764{,}015 \text{ kWh / year}$

Table 4-49
***Ex Post* Engineering/Monitoring Impact Results**
Project ID No. 41453

Unit	Capacity	Watts	Hours per Day	Days per Week	Weeks per Year	Load Factor	Annual Hours	Annual kWh
Pre-Retrofit								
Compr. #1	100	72,286	24	5	51	1	6,120	442,390
Compr. #2	100	81,730	24	5	51	1	6,120	500,188
Compr. #3	50	40,000	24	5	51	0	6,120	0
Compr. #4	50	40,000	24	5	51	0	6,120	0
N. Chiller	30T	35,216	24	5	51	1	6,120	215,522
S. Chiller	30T	33,862	24	5	51	1	6,120	207,235
CHW Pump	5 hp	3,591	24	5	51	1	6,120	21,977
CHW Pump	2 hp	1,465	24	5	51	1	6,120	8,966
Total		**308**	kW					**1,396,278**
Post-Retrofit								
125 hp Compr.	125 hp	106,000	24	5	51	1	6,120	648,720
100 hp Compr	100 hp	62,000	24	5	51	0.25	6,120	94,860
Air Cool Fan	3 hp	2,500	24	5	51	1	6,120	15,300
7 Mix Motors	1.5 hp	839	24	5	51	1	6,120	5,135
Total		**171**	kW					**764,015**
Load Impacts		**136.81 kW**						**632,263**

Unit Energy Intensity Analysis

The monthly electricity consumption kWh was divided by the units of production prior to and after the system modifications. From this, a value of kWh per unit of production was developed. The pre-retrofit unit savings were then multiplied by the post-retrofit production values to determine the annual savings. The savings were calculated as shown in Equations 4-94 through 4-96.

(Eq. 4-94) $$\text{Monthly Pre-Retrofit kWh / unit} = \frac{\text{Pre-Retrofit Monthly kWh}}{\text{Pre-Retrofit Monthly production (units)}}$$

(Eq. 4-95) $$\text{Monthly Post-Retrofit kWh / unit} = \frac{\text{Post-Retrofit Monthly kWh}}{\text{Post-Retrofit Monthly production (units)}}$$

(Eq. 4-96) $$\text{Annual kWh Savings} = \begin{bmatrix}\text{Average Monthly Pre-Retrofit kWh / Unit} \\ \text{- Average Monthly Post-Retrofit kWh / Unit}\end{bmatrix} \text{x (Total Annual Post-Retrofit Production)}$$

Because shift production data is not readily available, the demand component of the load impacts is determined by hours rather than units of production. The annual demand reduction was determined by estimating the proportion of annual production hours which the summer on-peak period represents. The summer on-peak production hours were divided into the on-peak kWh to estimate the average on-peak demand reduction, as shown in Equations 4-97 through 4-98.

(Eq. 4-97) $$\text{Peak period kWh savings} = (\text{Total Annual kWh Savings}) \text{ x} \left(\frac{\text{(Summer on-peak production hours)}}{\text{(Total annual production hours)}}\right)$$

(Eq. 4-98) $$\text{Peak kW reduced} = \frac{(\text{Peak Period kWh Savings})}{(\text{Total Peak Period hours})}$$

A summary unit energy intensity analysis results is shown in Tables 4-50 and 4-51.

Table 4-50
***Ex Post* Unit Energy Intensity Impact Analysis**
Project ID No. 41453

Month	Year	Days in Period	kWh in Billing Period	kWh per Day	Product A Units Produced	Product B Units Produced	Total Units (000s)	kWh per 1,000 Units
1	96	32	313,715	9,804	n/a	n/a	101,989	3.08
2	96	30	327,645	10,922	n/a	n/a	79,710	4.11
3	96	29	313,965	10,826	n/a	n/a	93,514	3.36
4	96	29	319,080	11,003	n/a	n/a	93,195	3.42
5	96	33	338,592	10,260	n/a	n/a	93,604	3.62
Average							92,402	3.52
3	97	31	254,704	8,216	55,316,886	47,066,448	102,383	2.49
4	97	29	246,514	8,500	53,360,795	47,849,980	101,211	2.44
5	97	31	204,052	6,582	26,838,959	31,064,011	57,903	3.52
6*	97	31	260,000	8,387	55,624,926	52,735,866	108,361	2.40
7	97	30	261,031	8,701	55,363,109	50,879,621	106,243	2.46
8	97	29	255,389	8,807	53,290,392	46,023,586	99,314	2.57
Average							95,902	2.57

Table 4-51
***Ex Post* Load Impact Estimated Through Unit Energy Intensity Approach**
Project ID No. 41453

***Ex Post* Load Impacts Based on Unit Energy Intensity**	
Pre-retrofit kWh per 1,000 units produced	3.52
Post-retrofit kWh per 1,000 units produced	2.57
kWh Savings per 1,000 units produced	0.95
Average units per month during post-retrofit period (000s)	95,902
Annualized production (unit/month 12) (000s)	1,150,829
Annual kWh savings	1,084,066

Ex Post Load Impacts Summary

The *ex post* load impacts were estimated as the average of the results of the Monitoring/Engineering and Unit Energy Intensity Analyses. The average kWh savings for the two methods is shown in Equation 4-99.

$$\text{(Eq. 4-99)} \quad \text{Average Ex Post kWh} = \frac{(\text{kWh Savings}_{\text{Monitoring/Engineering}}) + (\text{kWh Savings}_{\text{Unit Energy Intensity}})}{2}$$

$$= \frac{(1{,}084{,}066 + 632{,}263)}{2}$$

$$= 858{,}165 \text{ kWh / year}$$

The total annual kWh savings is distributed among the time-of-use periods in proportion to the operating hours that occur during each TOU period. Table 4-52 shows the *ex post* kWh and kW impacts by time-of-use period.

Table 4-52
***Ex Post* kW and kWh Impacts by Time-Of-Use Period**
Project ID No. 41453

Time-of-Use Period	Total Hours	Operating Hours	kWh Adjustment Factor	kWh Savings	kW Adjustment Factor	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742	742	0.12077	103,639	1.00	139.7	139.7
Summer Semi-peak	954	954	0.15527	133,250	1.00	139.7	
Summer Off-peak	1,976	930	0.15132	129,860	0.47	65.7	
Winter On-peak	441	391	0.06364	54,613	0.89	123.8	123.8
Winter Semi-peak	1,911	1,841	0.29964	257,142	0.96	134.6	
Winter Off-peak	2,736	1,286	0.20935	179,660	0.47	65.7	
Total	8,760	6,144		858,165			

4.13.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-53 summarizes the *ex ante* and *ex post* load impact estimates. Comparison of the *ex ante* and *ex post* peak demand values shows a realization rate of 1.20 for kWh and 1.20 for kW. The primary reason for the discrepancy appears to be more efficient post-retrofit plant operation than was anticipated in the *ex ante* estimates.

Table 4-53
Demand and Energy Impact Summary
Project ID No. 41453

	Demand Peak kW	Energy kWh/Year	Nat. Gas Therms/Year
***Ex Ante* Load Impact**	117.0	716,127	0
***Ex Post* Load Impact**	139.7	858,165	0
Difference	-22.7	-142,038	0
Realization Rate	1.19	1.20	N/A

4.13.4 Persistence of the Measure

The 20 year equipment life for the compressors, tank and dryer and air-coolers is reasonable and consistent with standard expectations with normal maintenance and periodic manufacturer's recommended service. A portion of the savings, however, are dependent on a reduction in air system leaks, which can only be maintained through an on-going maintenance program.

4.13.5 Net-To-Gross

The compressed air system at this plant was almost completely replaced. The project file demonstrated a long background of discussions with SDG&E's technical staff regarding the energy use and the impact of the compressed air system on the improvements. SDG&E sponsored a consultant's study to identify and quantify the energy savings opportunities in the compressed air system. Customer staff stated that none of the modifications would have taken place without the initial consulting study and the program's incentives.

Since SDG&E sponsored the consultant's study that identified the efficiency improvements, SDG&E's level of involvement was high. Thus, the net-to-gross value is 1.00.

4.14 ID No. 43166 - Optimized Compressed Air System

This is a large multi-building rotating machinery manufacturing and assembly facility located in San Diego, CA. The plant consists of engineering, production and testing, and administrative areas. The buildings are modern tilt-up structures. The plant typically operates three shifts per day, seven days a week. Occupancy and production during weekends, second and third shifts is generally lighter than first shift, but plant utilities are required at all times.

Compressed air is required at this facility for measuring devices, bubble mixing for part cleaning, open blowing, air tools and cooling of test equipment. Air is also consumed by leaks and leaking moisture drains.

This project involved the replacement of one 150 hp compressor with one 40 horsepower compressor and a 40 hp blower. In addition, major improvements to the compressed air distribution system included the addition of a 660 gallon receiver tank, replacement of five drain valves, replacement of nozzles with improved types, elimination of a desiccant dryer, and repair of leaks.

According to the project file, prior to the retrofit project, the 150 hp and 50 hp compressors operated continuously "at part load" to provide for plant air and testing air. Although the plant load could be provided by the 50 hp compressor, the 150 hp compressor was manually kept on line at all times so the air for test operations would always be available. Existing controls were not set up properly nor were they sufficiently reliable to assure that sufficient air would be available for test operations unless the 150 hp compressor was left on line at all times that testing might occur.

In addition, the file describes leaks, inefficient nozzles and air-driven equipment, and poor system controls and lack of capacity prior to the retrofit project.

The consultant report suggested several alternative improvements. The recommendations selected for implementation included:

- removal of the 150 hp compressor
- installation of a 40 hp high volume/low pressure blower with rapid-response controls to provide intermittent test cooling air requirements (not recommended but required for backup air, because the 150 hp compressor was removed)
- relocation of the 50 hp compressor and installation of a 40 hp compressor as backup or standby
- installation of new drain valves
- installation of a 660 gallon receiver tank
- repair controls and leaks
- elimination of a desiccant dryer

4.14.1 Ex Ante Load Impact Estimate

The *ex ante* impact estimates were calculated based on the summary findings of a study carried out by an air compressor specialist funded by the Industrial EEI program. The compressor loads and operating schedule were determined by short term observations and discussions with plant operating staff. From this information a projected compressor air flow and demand loading profile was projected. The details of the consultant's calculations and the supporting data were not provided in the project file. The summary *ex ante* savings calculations are summarized in Table 4-54.

Table 4-54
***Ex Ante* Estimated Impacts**
Project ID No. 43166

Unit	Operating kW	Hours per Day	Days per Week	Weeks per year	Load Factor	Annual Hours	Annual kWh
Pre-Retrofit Configuration	142.026	24	7	52	1.00	8,760	1,244,147
Post-Retrofit Configuration	41.012	24	7	52	1.00	8,760	359,266
***Ex Post* Load Impacts:**	**101.01**						**884,881**

Where:
(1) Existing kW = $58,906/yr /($0.0473465/kWh)/(8760 hrs/yr)
= 142.026 kW
(Source: "Compressed Air Audit," prepared at the request of SDG&E by Plant Air Technology, Audit conducted July 1996)

(2) Retrofit kW = ($17,010/yr)/$0.0473465/kWh)/(8,760 hrs/yr)
= 41.01213 kW
(Source: "Compressed Air Audit," prepared at the request of SDG&E by Plant Air Technology, Audit conducted July 1996)

4.14.2 Ex Post Load Impact

The site was visited on September 24 and September 30, 1997. At the time of the evaluation visit, the 150 hp compressor had been removed from the site. The 50 hp compressor was operating as the "base load" plant air compressor. The 40 hp compressor was on line in "automatic" mode available for standby but not operating. The 40 hp high volume blower was not operating at the time of the visit because testing was not in progress at the time.

Current transducers and a data logger were installed to record the operating characteristics of the 40 hp and 50 hp compressors during this period, approximately one week of operation. Plant staff reported that this was a "typical" production week. The equipment operation was observed and the operating staff was interviewed regarding the pre- and post-retrofit air compressor plant operations.

- The amperage of each compressor was monitored at fifteen minute (averaged) intervals for a period of one week (little variation was observed when a given compressor was in operation).
- Average compressor plant input kW was calculated from the measured amps.
- Compressor brake horsepower was derived from the calculated kW.
- Total plant airflow was calculated for the compressor plant using the manufacturer's rated airflow per input power.

- The airflow requirement was divided by the power per cfm estimated for the pre-retrofit compressor plant to estimate the compressor power which would have been required for the "old" plant for the same airflow requirement.
- The average kW for the old and new plants were multiplied by 8,760 hours per year to estimate the annual energy consumption. The difference is the *ex post* energy savings.

The kWh impact calculations based on the evaluation monitoring results are shown in Table 4-55.

Table 4-55
***Ex Post* kWh Impact Calculations**
Project ID No. 43166

Unit	Capacity HP	kW	Hours per Day	Days per Week	Weeks per Year	Load Factor	Annual hours	Annual kWh
PRE-RETROFIT								
Compr. #1-150 hp	150	121.6	24	7	40	1	7,000	851,413
Compr. #2-50 hp	50	40.5	24	7	52	1	8,760	355,161
Dryer for Test Air	5	4.3	24	7	52	1	8,760	37,557
Total		166.5			Avg. kW:	142.0		1,244,131
POST-RETROFIT								
40 hp Compr.	40	32.4	16	2	35	1.00	1,120	36,327
50 hp Compr	50	40.0	24	7	52	1.00	8,760	350,212
30 hp Blower	30	24.3	16	3	20	0.42	1,920	9,852
Total		96.7			Avg. kW:	45.3		396,391
***Ex Post* Load Impacts**						**96.8**		**847,740**

Table 4-56 shows the *ex post* kWh and demand impacts by time-of-use period. kWh impacts are determined by multiplying the ratio of the operating hours during each time-of-use period by the total air system operating hours. The average demand impacts are calculated by dividing the total kWh savings during each time of use period by the ratio of the total hours during the time-of-use period to the total annual hours (8,760). Because the system is in operation during all peak period hours, the peak-hour impact is the same as the average TOU period impact.

Table 4-56
kW and kWh Impacts by Time-Of-Use Period
Project ID No. 43166

Time-of-Use Period	Total Hours	Annual Operating Hours	kWh Adjustment Factor	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742	742	0.08470	71,806	96.8	96.8
Summer Semi-peak	954	954	0.10890	92,322	96.8	
Summer Off-peak	1,976	1,976	0.22557	191,225	96.8	
Winter On-peak	441	441	0.05034	42,677	96.8	96.8
Winter Semi-peak	1,911	1,911	0.21815	184,935	96.8	
Winter Off-peak	2,736	2,736	0.31233	264,774	96.8	
Total	8,760	8,760		847,740		

4.14.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-57 summarizes the *ex ante* and *ex post* load impact estimates.

Table 4-57
Demand and Energy Impact Summary
Project ID No. 43166

	Demand Peak kW	Energy kWh/Year	Nat. Gas Therms/Year
***Ex Ante* Load Impact**	101.0	894,890	0
***Ex Post* Load Impact**	96.8	847,740	0
Difference	4.2	47,150	0
Realization Rate	0.96	0.95	N/A

The cause for the small discrepancy is slight differences in the post-retrofit operation observed during the evaluation from the operating strategy which was assumed in the *ex ante* estimates.

4.14.4 Persistence of the Measure

The 20 year measure life is reasonable for the level of service of this equipment and assuming that recommended maintenance is carried out.

4.14.5 Net-To-Gross

A long and on-going interaction between the customer and SDG&E was demonstrated in the project file and during discussions with participant staff. SDG&E identified compressed air as a significant end use at this facility and then sponsored a consulting study to identify specific modifications that would reduce energy consumption. Participant staff was interviewed to determine the extent of SDG&E's influence in the improvements. He indicated that "all of the modifications were the ideas of the SDG&E consultant."

Since SDG&E conducted the initial screening survey and sponsored the in-depth consultant's study that provided the basis for the recommendations adopted by the participant, SDG&E's level of involvement was high. Thus, the net-to-gross value is 1.00.

4.15 ID No. 45635 - Efficient Die Case Machine

This is a machinery component manufacturing facility in San Ysidro, CA. The plant typically operates three shifts per day, five days per week. Staff reports frequent single or double shifts on Saturdays and periodic Sunday operations as production requires, averaging 5.5 days per week. According to the project file the customer needed a new die cast machine due to increased production.

Small aluminum castings are a major component of the products fabricated at this facility. Five automatic continuous-casting machines operate nearly continuously to produce the castings. Each casting machine has an associated electric melting furnace. The casting process is fully automatic. The ingot carousel is loaded manually, but ingots are loaded into the horizontal furnaces automatically. Molten material is poured into the casting machines and castings are removed from the molds automatically.

This project involved the replacement of an existing casting machine and its associated furnace with a new high-capacity and improved-efficiency furnace and casting machine. A Buhler Model SCD/42 continuous casting machine was installed rather than the standard (for the factory) Buhler Model H400B Machine.

According to the project file, the primary energy-saving differences between the machines included:

- an automatic ingot loading assembly which preheats the ingots to approximately 500° F with ambient and conductive heat from the furnace (the pre-retrofit scenario had the ingots loaded manually with no pre-heating, thus, the ingots go into the furnace at ambient temperature); and
- a slightly lower operating power requirement for the "high-efficiency" casting machine.

4.15.1 Ex Ante Load Impact Estimate

The *ex ante* load impact estimates were calculated by using an engineering methodology. The estimates were calculated in two parts: the savings for the reduced power requirement for the improved machine, and the savings resulting from automatic ingot loader versus the base case manual loading.

Ex Ante Load Impacts For High Efficiency Furnace

The pre-retrofit energy use was calculated through Equations 4-100 through 4-103. First, the unit energy use per part produced was estimated in Equations 4-100 through 4-102. Then production data were used to estimate total annual usage. This approach effectively controls for variation in production from year to year and adjusts the pre-retrofit consumption for a valid comparison with the production levels verified *ex post.*

$$\text{(Eq. 4-100)} \quad kW_{\text{Pre-retrofit}} = 79.49 \text{ kW (from manufacturer's data)}$$

$$\text{(Eq. 4-101)} \quad \text{Output capacity}_{\text{Pre-retrofit}} = 3{,}456 \text{ parts / 24 hour (manufacturer's data)}$$

$$\text{(Eq. 4-102)} \quad \text{Unit Energy Use}_{\text{Pre-retrofit}} = \frac{79.49 \text{ kW x 24 hours / day}}{3{,}456 \text{ parts / day}}$$

$$= 0.552 \text{ kWh per part}$$

From reported plant data, 836,352 parts per year are produced. Thus, the pre-retrofit annual kWh consumed is shown in Equation 4-103.

$$\text{(Eq. 4-103)} \quad kWh_{\text{Pre-retrofit}} = \left(\text{Unit Energy Use}_{\text{Pre-retrofit}}\right) \text{ x } \left(\text{No. parts produced}\right)$$

$$= \left(0.552 \text{ kWh per part}\right) \text{ x } \left(836{,}352 \text{ parts}\right)$$

$$= 469{,}229 \text{ kWh / year}$$

The post-retrofit energy use was calculated through Equations 4-104 through 4-107. The unit energy use per part produced is estimated in Equations 4-104 through 106.

$$\text{(Eq. 4-104)} \quad kW_{\text{Post-retrofit}} = 73.54 \text{ kW (from manufacturer's data)}$$

$$\text{(Eq. 4-105)} \quad \text{Output capacity}_{\text{Post-retrofit}} = 4{,}320 \text{ parts / 24 hour (manufacturer's data)}$$

$$\text{(Eq. 4-106)} \quad \text{Unit Energy Use}_{\text{Post-retrofit}} = \frac{73.54 \text{ kW x 24 hours / day}}{4{,}320 \text{ parts / day}}$$

$$= 0.408556 \text{ kWh per part}$$

From reported plant data, 836,352 parts per year are produced. Thus, the post-retrofit annual energy use is shown in Equation 4-107.

$$\text{(Eq. 4-107)} \quad kWh_{Post\text{-}retrofit} = (\text{Unit Energy Use}_{Post\text{-}retrofit}) \times (\text{No. parts produced})$$

$$= (0.408556 \text{ kWh per part}) \times (836{,}352 \text{ parts})$$

$$= 341{,}696 \text{ kWh / year}$$

The load impacts are shown in Equations 4-108 and 109.

$$\text{(Eq. 4-108)} \quad kW\ reduced_{Ex\ ante} = kW_{Pre\text{-}retrofit} - kW_{Post\text{-}retrofit}$$

$$= 79.49 \text{ kW} - 73.54 \text{ kW}$$

$$= 5.95 \text{ kW}$$

$$\text{(Eq. 4-109)} \quad kWh_{Ex\ ante} = kWh_{Pre\text{-}retrofit} - kWh_{Post\text{-}retrofit}$$

$$= 469{,}228 \text{ kWh} - 341{,}696 \text{ kWh}$$

$$= 127{,}532 \text{ kWh}$$

Ex Ante Load Impacts For Ingot Loader

For the ingot loader, the savings are calculated by multiplying the total weight of metal melted by the heat capacity of the metal. *Ex ante* operating assumptions for the ingot loader are shown in Table 4-58.

Table 4-58
***Ex Ante* Operating Assumptions**
Project ID No. 45635

Parts per day	4,320 parts per day
Scrap and waste melted w/o ingot loader	15% scrap and waste material melted
Pounds material per casting	2.7 lb. Aluminum per casting, with 2 parts for each casting
Operating schedule	Operating days = 6 days per week, 51 weeks per year.
Heat capacity of Aluminum	@72° F , h_l= 15.1 Btu/lb. @500° F, h_2 = 113.5 Btu/lb. @1,000° F, h_f= 242 Btu/lb.
Heat of fusion for Aluminum	h_x = 177 Btu/lb.
Furnace	Each furnace has five 16 kW electric resistance bands

The heat required to process the aluminum for the pre- and post-retrofit operations are shown in Equations 4-110 and 4-111, respectively.

$$\text{(Eq. 4-110)}\quad \Delta h_1 = h_f + h_x - h_1 = 242 + 177 - 15.1 = 403.9 \text{ Btu / lb.}$$

$$\text{(Eq. 4-111)}\quad \Delta h_2 = h_f + h_x - h_2 = 242 + 177 - 113.5 = 305.5 \text{ Btu / lb.}$$

Equation 4-112 shows the energy saved per pound of material due to the pre-heating of material through the ingot loader.

$$\text{(Eq. 4-112)}\quad \Delta H = \Delta h_1 - \Delta h_2 = 403.9 - 305.5 = 98.4 \text{ Btu / lb}$$

The annual kWh savings were calculated as shown in Equation 4-113.

$$\text{(Eq. 4-113)}\quad \text{Annual kWh savings} = [\text{Number of parts including scrap}] \times [\text{Amount of Aluminum per part}] \times [\Delta H] \times [51 \text{ weeks / year} \times 6 \text{ days / week}] \times \left[\frac{1 \text{ kWh}}{3{,}413 \text{ Btu}}\right]$$

$$= \left[\frac{4320 \text{ parts per day}}{0.85 \text{ scrap factor}}\right] \times \left[\frac{2.7 \text{ lb / casting}}{2 \text{ parts / casting}}\right] \times [98.4 \text{ Btu / lb}] \times [51 \text{ weeks / year} \times 6 \text{ days / week}] \times \left[\frac{1 \text{ kWh}}{3{,}413 \text{ Btu}}\right]$$

$$= 60{,}531 \text{ kWh / year}$$

The demand savings are calculated by assuming a 25 percent demand reduction for the furnace due to the pre-heating of the aluminum material, as shown in Equation 4-114.

$$\text{(Eq. 4-114)}\quad kW_{\text{ingot loader}} = (\text{No. electric resistance bands}) \times (\text{kW per band}) \times (0.25 \text{ reduction})$$

$$= (5 \text{ bands}) \times (16 \text{ kW / band}) \times (0.25)$$

$$= 20.0 \text{ kW}$$

Total Ex Ante Load Impacts

The total project load impacts are calculated by summing the two parts of the project as shown in Equations 4-115 and 4-116.

$$\text{(Eq. 4-115)} \quad kW_{Ex\ ante} = kW_{furnace} + kW_{ingot\ loader}$$

$$= 5.95\ kW\ -\ 20\ kW$$

$$= 25.95\ kW$$

$$\text{(Eq. 4-116)} \quad kWh_{Ex\ ante} = kWh_{furnace} + kWh_{ingot\ loader}$$

$$= 60127{,}532 + 60{,}531$$

$$= 188{,}063\ kWh$$

4.15.2 Ex Post Load Impact Estimation

The site was visited on September 25 and again on October 1, 1997. The equipment was observed in operation and the operating characteristics of the retrofit equipment reported in the file were verified. Air compressors were logged for the period at this site which also verify the continuous operation 5.5 days per week. Because the savings rely primarily on the production of the machine, production figures for a representative recent period during 1997 were requested and obtained from plant operating staff.

The *ex post* evaluation analysis was performed using the same method as the *ex ante* estimates using the annualized actual production for the post-retrofit period immediately preceding the *ex post* visit.

Continuous Casting Machine

Based on interviews of site staff and reviews of operating logs at the plant the following assumptions were made regarding the operation of the continuous casting machine:

- The operating kW values used in the *ex ante* analysis were confirmed.
- The casting machines are operated at the operating kW during the plant operating hours.
- The production output for the Buhler SCD42 machine is the same as that for the Buhler H400B, 2,038 castings per day
- Scrap rate is 15%, resulting in 85% of the heated material to be consumed in usable product (and 15% being recycled).

The energy use and savings are calculated in Equations 4-117 through 4-121. The results are summarized in Table 4-59.

(Eq. 4-117) $kW_{Post\text{-}retrofit} = 73.54\ kW$

(Eq. 4-118) $kW_{Pre\text{-}retrofit} = 79.49\ kW$

(Eq. 4-119) $kWh_{Pre\text{-}retrofit} = (\text{Operating } kW_{Pre\text{-}retrofit}) \times (\text{Annual weeks of operation}) \times (\text{Days / week}) \times (\text{Hours / day})$

$= (79.49\ kW) \times (51\ \text{weeks / year}) \times (5.5\ \text{day / week}) \times (24\ \text{hours / day})$

$= 535{,}127\ kWh$

(Eq. 4-120) $kWh_{Post\text{-}retrofit} = (\text{Operating } kW_{Post\text{-}retrofit}) \times (\text{Annual weeks of operation}) \times (\text{Days / week}) \times (\text{Hours / day})$

$= (73.54\ kW) \times (51\ \text{weeks / year}) \times (5.5\ \text{day / week}) \times (24\ \text{hours / day})$

$= 495{,}071\ kWh$

(Eq. 4-121) $\text{Ex Post kWh Savings}_{Casting\ machine} = kWh_{Pre\text{-}retrofit} - kWh_{Post\text{-}retrofit}$

$= 535{,}127\ kWh - 495{,}071\ kWh$

$= 40{,}055\ kWh$

Table 4-59
Annual Savings SCD42 versus H400B Casting Machine
Project ID No. 45635

		Operating kW	Annual Weeks of Operation	Days per Week	Hours per Day	Annual kWh	No. Castings per Machine per Day
Base Case	**Buhler H400B**	79.49	51	5.5	24	535,127	2,038
Retrofit	**Buhler SCD/42**	73.54	51	5.5	24	495,071	2,038
Annual kWh Savings						40,055	

The demand impacts are calculated in the time-of-use analysis in Table 4-57 in combination with the ingot loader .

Automatic Ingot Loader

Prior to installation of the automatic ingot loaders, the standard operating practice was to pre-heat the ingots as much as possible by laying them on the lip of the melting furnace. According to pyrometer readings taken on November 5, 1997 by plant operating staff, this results in an ingot temperature of about 200° F. With the electric ingot loader, the ingot temperature is raised from room temperature to about 800° F. The savings are calculated by multiplying the total weight of metal melted by the heat uptake of the metal over that temperature range. capacity of the metal converted to kWh. Using 2,038 parts per machine per day, 5.5 days per week for 51 weeks per year, 2.70 lb. melt per part, and 15% loss/scrap, the Btu savings are calculated in Table 4-60 and kWh savings are shown in Table 4-61.

Table 4-60
Automatic Ingot Loader Btu Savings
Project ID No. 45635

Automatic ingot loader heats ingot to 800° F. Manual placement on Furnace Rim resulted in heating ingot to about 200° F	
Heat capacity @ 200° F:	44.53 Btu/lb.
Heat Capacity @ 800° F (w/ingot loader)	190.60 Btu/lb.
Savings with Ingot Loader:	146.07 Btu/lb.

Table 4-61
***Ex Post* Annual kWh Savings**
Automatic Ingot Loader
Project ID No. 45635

Delta Heat/lb.	Weight	Production Actual 96/97	Usable Product Rate	Annual Working Days	Annual Heat Consumed	Annual kWh
Btu/lb.	lb./part	parts/day	1-(scrap rate)	days/year	Btu	Btu/(3413*.95)
146.07	2.7	2,038	0.85	280.5	265,245,942	**81,807**

Total Ex Post Load Impacts

The total kWh savings are shown in Equation 4-122.

(Eq. 4-122) $\text{Total Ex Post kWh Savings}_{\text{Casting machine}} = \text{Ex Post kWh Savings}_{\text{Casting machine}} + \text{Ex Post kWh Savings}_{\text{Ingot loader}}$

$= 36{,}414 \text{ kWh} + 74{,}350 \text{ kWh}$

$= 110{,}764 \text{ kWh}$

The demand impacts are calculated by assuming that the kWh reduction is averaged over the operating hours of the casting machine, due to the continuous operation of the machine. The kW impacts for the total projects, i.e., casting machine and ingot loader, are shown in Table 4-57.

Table 4-62 shows the *ex post* load impacts by time-of-use period.

Table 4-62
***Ex Post* kW and kWh Impacts by Time-Of-Use Period**
Project ID No. 45635

Time-of-Use Period	Total Hours	Weekend Hours Off	Annual Operating Hours	kWh Adjustment Factor	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742		742	0.11009	13,416	18.1	18.1
Summer Mid-peak	954		954	0.14154	17,249	18.1	
Summer Off-peak	1,976	800	1,176	0.17448	21,263	10.8	
Winter On-peak	441	15	426	0.06320	7,702	17.5	17.5
Winter Mid-peak	1,911	65	1,846	0.27389	33,376	17.5	
Winter Off-peak	2,736	1,140	1,596	0.23680	28,856	10.5	
Total	8,760	2,020	6,740		121,862		

4.15.3 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-63 summarizes the *ex ante* and *ex post* load impact estimates.

Table 4-63
***Ex Post* Demand and Energy Impact Summary**
Project ID No. 45635

	Demand Peak kW	Energy kWh/Year	Nat. Gas Therms/Year
Ex Ante Load Impact	26.0	188,063	0
Ex Post Load Impact	18.1	121,862	0
Difference	7.9	66,201	0
Realization Rate	0.70	0.65	N/A

The primary reasons for the discrepancy are:

- The *ex post* casting machine load impacts were lower than the *ex ante* estimates because the *ex ante* estimates used the rated production capacity figures for the machines (3,456 and 4,320 parts per day for the base and enhanced machines, respectively) to calculate the impacts. The *ex post* used the actual post-retrofit production output (2,038 parts per day) for both the pre- and post-retrofit load estimates.
- The ingot loader savings (81,807 kWh) exceeded the estimates (60,531 kWh) because the *ex post* post-retrofit measured ingot temperature rise (200° F to 800° F) was greater than the value used in the *ex ante* estimates (72° F to 500° F).

4.15.4 Persistence of the Measure

The 20 year equipment life is reasonable for this type of equipment under the observed level of service with normal maintenance and periodic replacement of moving parts.

4.15.5 Net-To-Gross

This project involved the installation of a new die cast machine and associated new melting furnace with an automatic ingot loader as a part of a production equipment upgrade program carried out by this manufacturing customer. It appears that the technical basis for the project originated with the customer, and that the equipment replacement was a part of a long-term capital improvement program. However, the participant representative acknowledged that the IEEI Program played a part in the decision to proceed with the upgraded, energy efficient equipment rather than standard efficiency equipment and to replace this equipment during 1996 rather than deferring it to a later year.

Since SDG&E appeared to play a relatively minor role in conceptualizing the recommendation for the equipment SDG&E's level of involvement was low. The incentive played a role in influencing the decision to implement the measures, thus the net-to-gross ratio is 0.40.

5 MOTOR MEASURES

5.1 OVERVIEW

The methodology used to estimate the load impacts for motors installed under the 1996 Industrial EEI Program was described in Section 3. Table 5-1 provides a summary of the program for PY96. The motor measures were separated into groups large and small. The three large motor measures were evaluated separately, much as was done for the process measures in Section 4. The smaller motor measures were evaluated by gathering installation and operating information through a telephone survey. The data were then processed as described in Section 2.3.

Table 5-1 shows that over 90 percent of the *ex ante* load impacts were included in the *ex post* evaluation.

Table 5-1
Summary by Motor Size
Motor Measures
PY96 Industrial EEI Program

Size	No. Participants	No. Measures	*Ex Ante* Gross kWh	*Ex Ante* Gross kW	No. Survey Participants	Surveyed *Ex Ante* Gross kWh	Surveyed *Ex Ante* Gross kW
Large	3	4	3,028,423	400.55	3	3,028,423	400.55
Small	94	197	541,444	78.52	54	203,357	48.12
Total	**97**	**201**	**3,569,867.00**	**479.07**	**57**	**3,231,780.00**	**448.67**
Percent Surveyed						**0.905**	**0.937**

Table 5-2 shows the total horsepower of the motors installed under the program.

Table 5-2
Total Horsepower of Motors Installed
Motor Measures
PY96 Industrial EEI Program

Total Horsepower of Large Motors Installed	1,175.00
Total Horsepower of Small Motors Installed	3,780.50
Total Horsepower of Motors Installed	4,955.50

5.2 SUMMARY OF IMPACTS

Table 5-3 shows a summary of the gross program load impacts. The table indicates a realization rate of 0.76 for kWh and 0.68 for kW.

Table 5-3
Summary of Gross Program Load Impacts
Motor Measures
PY96 Industrial EEI Program

	***Ex Ante* Gross**		***Ex Post* Gross**		**Gross Realization Rate**	
	kWh	**kW**	**kWh**	**kW**	**kWh**	**kW**
Large Motors	3,020,127	400.5	1,738,397	229.3	0.5756	0.5725
Small Motors	541,444	78.52	982,377	97.05	1.8144	1.2360
Program	**3,561,571**	**479**	**2,720,774**	**326.35**	**0.7639**	**0.6813**

Table 5-4 shows a summary of the net program load impacts.

Table 5-4
Summary of Net Program Load Impacts
Motor Measures
PY96 Industrial EEI Program

	***Ex Ante* Net**		***Ex Post* Net**		**Net Realization Rate**	
	kWh	**kW**	**kWh**	**kW**	**kWh**	**kW**
Large Motors	2,271,317	300.41	695,359	91.72	**0.3061**	**0.3053**
Small Motors	406,083	58.89	765,395	75.61	**1.8848**	**1.2840**
Program	**2,677,400**	**359**	**1,460,754**	**167.33**	**0.5456**	**0.4657**
Program Net-to-Gross			**0.5369**	**0.5127**		

5.3 LARGE MOTOR MEASURES

The three large motor measures were installed at the same multi-building campus facility for the same customer.

5.3.1 ID No. 40310 - Variable Frequency Drives

This facility is a multi-building campus that includes light manufacturing, warehousing, R&D, and offices. The measures installed affected one building of approximately 33,500 sq. ft. The customer installed two variable frequency drives (VFD) on separate dust collection fans. The two 400 horsepower fans are identical. The pre-retrofit operation of the fans was constant speed 24 hours per day during the week, 18 to 22 hours on Saturdays, and 2 hours on Sundays.

Energy Efficiency Improvement

The dust collectors were retrofit with variable frequency drives as a means of lowering the total cfm and energy usage of the original design. The drives are designed to operate at a "high" or "low" speed setting. They do not vary with a specific condition such as static pressure. The drives are manually switched to one of three settings (high, low, or off) when desired. However, even at the high setting they are only running the fans at 55 Hz versus full-load of 60 Hz. This produces significant savings since the power is reduced as a cube of decreasing the speed.

Energy and demand impacts are a direct result of slowing the speed of the fans. The operating hours of the equipment did not change.

Ex Post Load Impacts

The pre-retrofit kW load of the fans was measured *ex ante* and included in the project file. This was used as the baseline load of the fans. This profile was combined with the *ex post* operation schedule to determine the baseline energy usage. The verified hours of operation did not change from the *ex ante* profile. Equation 5-1 shows the calculations for pre-retrofit energy use.

$$\text{(Eq. 5-1)} \quad kWh_{\text{Pre-retrofit}} = (kW_{\text{Pre-retrofit}}) \times (\text{Annual hours of operation}) \times (\#\ \text{of fans})$$

$$= (208.5\ \text{kW}) \times (7{,}624\ \text{hours / year}) \times (2\ \text{fans})$$

$$= 3{,}179{,}208\ \text{kWh / year}$$

The post-retrofit demand and hours of operation were obtained by visiting the site, discussing the project and operation with site personnel, and installing monitoring equipment on one of the two variable speed drives. Spot measurements were taken on the other VSD. The monitoring equipment recorded true kW, current, voltage, kVa, kVar, and power factor in 15-minute intervals. The *ex post* monitoring collected data from October 9, 1997 through October 21, 1997. According to the site contact, this period was representative of the annual operating profile of the fans. The variation of load factor and hours of operation are consistent from one week to another. The short term data also verified this condition. The monitoring data clearly showed the demand and operation schedule of the fan. The trended data verified the schedule previously provided by the customer. An hourly energy usage profile was put together using the measurement data. Separate profiles were developed for weekdays, Saturdays, and Sundays (see Appendix F for data). This profile was extrapolated to an annual basis to determine the annual energy usage. The demand savings were calculated as the average kW during each of the time-of-use periods. Equation 5-2 shows the calculation for post-retrofit energy use.

(Eq. 5-2) $$kWh_{Post\text{-}retrofit} = \sum_{n} (kW_{Measured}) \times (\text{Annual hours of operation}) \times (\#\text{of fans})$$

$$= [(160.6\ kW \times 208\ hours/year) + (128.5\ kW \times 7{,}416\ hours/year)] \times (2\ fans)$$

$$= 1{,}972{,}722\ kWh/year$$

The demand savings were calculated as the *ex ante* measured demand minus the average demand measured *ex post* during the peak period. The energy and demand savings were calculated as shown in Equations 5-3 and 5-4.

(Eq. 5-3) $$kW\ Reduced_{Ex\ post} = kW_{Pre\text{-}retrofit} - kW_{Post\text{-}retrofit}$$

$$= [(208.5\ kW/fan) \times (2\ fans)] - [(128.5\ kW/fan) \times (2\ fans)]$$

$$= 160.0\ kW$$

(Eq. 5-4) $$kWh\ Savings_{Ex\ post} = kWh_{Pre\text{-}retrofit} - kWh_{Post\text{-}retrofit}$$

$$= (3{,}179{,}208) - (1{,}972{,}722)$$

$$= 1{,}206{,}486\ kWh/year$$

Table 5-5 shows the *ex post* load impacts by time-of-use period.

Table 5-5
***Ex Post* kW and kWh Impacts by Time-of-Use Period**
ID No. 40310
PY96 Industrial EEI Program
Motor Measures

Time-of-Use Period	Average kW Reduced	kW Savings Coincident with System Peak	kWh Savings
Summer On-peak	160.0	160.0	118,720
Summer Semi-peak	160.0		152,640
Summer Off-peak	118.6		234,350
Winter On-peak	160.0	160.0	70,560
Winter Partial-peak	160.0		305,760
Winter Off-peak	118.6		324,456
Total			1,206,486

Comparison with Ex Ante Estimated Impacts

The realization rates for energy and demand for this project are shown in Table 5-6. Comparison of the *ex ante* and *ex post* estimates of demand reduction show a realization rate of 0.60 and annual energy savings realization rate of 0.60. The main reason for the differences was the *ex ante* estimates were calculated based on estimates (supplied by the customer) of reducing the fan speed to 70% of the pre-retrofit condition. After the retrofit the customer was not able to achieve the required cfm at the 70% fan speed. The fan speed verified in the *ex post* site visit is approximately 82%.

Table 5-6
Comparison of *Ex Ante* and *Ex Post* Load Impacts
ID No. 40310
PY96 Industrial EEI Program
Motor Measures

	Demand kW	Energy kWh/Year	Gas Therms/Year
Ex Ante Load Impacts	268	2,020,791	-
Ex Post Load Impacts	160	1,206,468	-
Difference	108	814,323	-
Realization Rate	0.60	0.60	-

Persistence of the Measure

The customer seemed committed to the operation of the fans with variable frequency drives. They had some trouble with another drive on site and had installed a temporary VFD to operate the fan until the permanent drive is fixed or repaired. Therefore, the 15 year equipment life for this site is reasonable.

5.3.2 ID No. 40311 - Variable Frequency Drives

This facility is a multi-building campus that includes light manufacturing, warehousing, R&D, and offices. The measures installed affect one building of approximately 2,100 sq. ft. The customer installed a variable frequency drive to a 250 horsepower dust collection fan. The pre-retrofit operation of the fan was constant speed, 24 hours per day during the week and 18 to 22 hours on Saturdays and 2 hours on Sundays.

Energy Efficiency Improvement

The dust collector was retrofitted with a variable frequency drive as a means of lowering the total cfm and energy usage of the original design. The drive is designed to operate at a "high" or "low" speed setting. It does not vary with a specific condition such as static pressure. The drive is manually switched to one of three settings (high, low, or off) when desired. However, even at the high setting the fan is only running at 55 Hz versus full-load of 60 Hz. This produces significant savings since the power is reduced as a cube of decreasing the speed.

Energy and demand impacts are a direct result of slowing the speed of the fans. The operating hours of the equipment did not change.

Ex Post Load Impacts

Ex ante measurements of the fan's kW was obtained for the pre-retrofit engineering estimate of savings. This demand was used as the baseline demand. The hours of operation changed only slightly from the *ex ante* profile.

The post-retrofit demand and hours of operation were obtained *ex post* by visiting the site, discussing the project and operation with the customer, and installing monitoring equipment on the source side of the variable speed drive. The monitoring equipment recorded true kW, current, voltage, kVa, kVar, and power factor in 15 min intervals. The monitoring data clearly showed the demand and operation schedule of the fan. The trended data verified the schedule previously provided by the customer. An hourly energy usage profile was put together using the measurement data. This profile was extrapolated to determine the annual energy savings. The demand savings were calculated as the pre-retrofit measured demand minus the average demand measured during the peak period.

The *ex post* impacts were based on monitoring data collected from October 10, 1997 to October 12, 1997. This period is representative of the annual operating profile of the fans. The variation of load factor and hours of operation are consistent from one week to another. The short term data also verified this.

The pre-retrofit kW load of the fans was measured *ex ante* and included in the project file. This was used as the baseline load of the fans. This was combined with the post-retrofit operation schedule to determine the baseline energy usage, as shown in Equation 5-5.

$$\text{(Eq. 5-5)} \quad kWh_{\text{Pre-retrofit}} = (kW_{\text{Pre-retrofit}}) \times (\text{Annual hours of operation}) \times (\text{\# of fans})$$

$$= (179.0\ kW) \times (7{,}624\ \text{hours / year}) \times (1\ \text{fans})$$

$$= 1{,}364{,}696\ kWh / \text{year}$$

The post-retrofit demand and energy usage was determined from the *ex post* monitoring data. An hourly profile was developed for weekdays, Saturdays, and Sundays. This profile was extrapolated to an annual basis to determine the annual energy usage, as shown in Equation 5-6. The demand savings were calculated as the average kW during each of the utility costing periods. Refer to Appendix F for detailed information.

$$\text{(Eq. 5-6)} \quad kWh_{Post\text{-}retrofit} = \sum_{n} (kW_{Measured}) \times (\text{Annual hours of operation}) \times (\#\text{of fans})$$

$$= [(127.4\ kW \times 7{,}416\ hours/year) + (114\ kW \times 208\ hours/year)] \times (1\ fan)$$

$$968{,}510\ kWh/year$$

The demand savings were calculated as pre-retrofit - post-retrofit demand as shown in Equation 5-7.

$$\text{(Eq. 5-7)} \quad kW\ Reduced_{Ex\ post} = kW_{Pre\text{-}retrofit} - kW_{Post\text{-}retrofit}$$

$$= [179.0\ kW] - [127.4\ kW]$$

$$= 51.6\ kW$$

Equation 5-8 shows the calculations for the *ex post* energy savings.

$$\text{(Eq. 5-8)} \quad kWh\ Savings_{Ex\ post} = kWh_{Pre\text{-}retrofit} - kWh_{Post\text{-}retrofit}$$

$$= (1{,}364{,}696) - (968{,}510)$$

$$= 396{,}186\ kWh/year$$

The pre-retrofit kW load of the fans was measured *ex ante* and included in the project file. This was used as the baseline load of the fans. This profile was combined with the *ex post* operation schedule to determine the baseline energy usage. The verified hours of operation did not change from the *ex ante* profile. Equation 5-9 shows the calculations for pre-retrofit energy use.

$$\text{(Eq. 5-9)} \quad kWh_{Pre\text{-}retrofit} = (kW_{Pre\text{-}retrofit}) \times (\text{Annual hours of operation}) \times (\#\ \text{of fans})$$

$$= (208.5\ kW) \times (7{,}624\ hours/year) \times (2\ fans)$$

$$= 3{,}179{,}208\ kWh/year$$

Table 5-7 shows the *ex post* load impacts by time-of-use period.

Table 5-7
***Ex Post* kW and kWh Impacts by Time-of-Use Period**
ID No. 40311
PY96 Industrial EEI Program
Motor Measures

Time-of-Use Period	Average kW Reduced	kW Savings Coincident with System Peak	kWh Savings
Summer On-peak	51.6	51.6	38,287
Summer Semi-peak	51.6		49,226
Summer Off-peak	39.8		78,579
Winter On-peak	51.6	51.6	22,756
Winter Partial-peak	51.6		98,608
Winter Off-peak	39.7		108,730
Total			396,186

Comparison with Ex Ante Estimated Impacts

Comparison of the *ex ante* and *ex post* estimates of demand reduction show a realization rate of 0.51 and annual energy saving realization rate of 0.52, as shown in Table 5-8. The main reasons for the differences are:

- The *ex ante* estimates were calculated based on estimates (supplied by the customer) of reducing the fan speed to 75% of the pre-retrofit case. After the retrofit the customer was not able to achieve the required cfm at the 75% fan speed. The fan speed verified in the *ex post* site visit is approximately 85%.
- The *ex post* analysis is based on values measured on site.

Table 5-8
Comparison of *Ex Ante* and *Ex Post* Load Impacts
ID No. 40310
PY96 Industrial EEI Program
Motor Measures

	Demand kW	Energy kWh/Year	Gas Therms/Year
Ex Ante Load Impacts	100.3	756,548	-
Ex Post Load Impacts	51.6	396,186	-
Difference	48.7	360,362	-
Realization Rate	0.51	0.52	-

Persistence of the Measure

The customer seemed committed to the operation of the fans with variable frequency drives. They had some trouble with another drive on site during the time of the visit and had installed a temporary VFD to operate the fan until the permanent drive is fixed or repaired. Therefore, the 15 year equipment life given for this site is reasonable.

5.3.3 ID No. 40312 - Variable Frequency Drives

This facility is a multi-building campus that includes light manufacturing, warehousing, R&D, and offices. The measures installed affect one building of approximately 3,950 sq. ft. The participant installed a variable frequency drive (VFD) to a 125 horsepower dust collection fan. The pre-retrofit operation of the fan was constant speed, 24 hours per day during the week and 18 to 22 hours on Saturdays, and 2 hours on Sundays.

Energy Efficiency Improvement

The dust collector was retrofitted with a variable frequency drive as a means of lowering the total cfm and energy usage of the original design. The drive is designed to operate at a "high" or "low" speed setting. It does not vary with a specific condition such as static pressure. The drive is manually switched to one of three settings (high, low, or off) when desired. However, even at the high setting the fan is only running at 55 Hz. This produces significant savings since the power is reduced as a cube of decreasing the speed.

Energy and demand savings are a direct result of slowing the speed of the fan. The operating hours of the equipment did not change.

Ex Post Load Impacts

Projects for ID Nos. 40310 and 40311 were at the same facility involving the same measures. During the site visit the 125 hp dust collection fan under consideration for this project was temporarily out of commission. A temporary drive was installed to run the fan at reduced speeds. Since the other VFD's were being monitored, the average realization rate for energy and demand of ID Nos. 40310 and 40311 was applied to this project. The analysis for the other VFDs is described below.

Ex ante measurements of the fan's kW were obtained for the pre-retrofit engineering estimate of savings. This demand was used as the baseline demand. The hours of operation changed only slightly from the *ex ante* profile. The *ex post* post-retrofit demand and hours of operation were obtained by visiting the site, discussing the project and operation with the customer, and installing monitoring equipment on the source side of variable speed drives that were operating under the same schedule. The monitoring equipment recorded true kW, current, voltage, kVa, kVar, and power factor in 15 minute intervals. The monitoring data clearly showed the demand and operation schedule of the fan. The trended data verified the schedule previously provided by the customer. An hourly energy usage profile was put together using the measurement data. This profile was extrapolated to determine the *ex post* annual energy savings. The demand savings were calculated as the pre-retrofit measured demand minus the demand measured during the peak period.

The energy and demand savings for this project were developed from the average realization ratios for projects ID Nos. 40310 and 40311, as shown in Equations 5-10 and 5-11. Refer to Sections 5.3.1 and 5.3.2 for further analysis details.

$$\text{(Eq. 5-10)} \quad \text{kWh Realization Rate} = \frac{\left(\text{kWh Realization Rate}_{\text{ID No. 40310}} + \text{kWh Realization Rate}_{\text{ID No. 40311}}\right)}{\text{No. of Fan}}$$

$$= \frac{(0.59 + 0.59 + 0.50)}{3}$$

$$= 0.56$$

$$\text{(Eq. 5-11)} \quad \text{kWh Savings} = \left(\text{kWh}_{\text{Ex ante}}\right) \text{ x } (\text{kWh Realization Rate})$$

$$= (242{,}788 \text{ kWh}) \text{ x } (0.56)$$

$$= 135{,}743 \text{ kWh / year}$$

The demand impact of the project was calculated using Equation 5-12.

$$\text{(Eq. 5-12)} \quad \text{kW Reduced}_{\text{Ex post}} = \frac{(\text{Summer On-peak kWh Savings})}{\text{Summer On-peak Hours per Year}}$$

$$= \frac{13{,}118 \text{ kWh}}{742 \text{ hours}}$$

$$= 17.7 \text{ kW}$$

Table 5-9 shows the *ex post* load impacts by time-of-use period.

Table 5-9
***Ex Post* kW and kWh Impacts by Time-of-Use Period**
ID No. 40312
PY96 Industrial EEI Program
Motor Measures

Time-of-Use Period	Average kW Reduced	kW Savings Coincident with System Peak	kWh Savings
Summer On-peak	17.7	17.7	13,118
Summer Semi-peak	17.7		16,866
Summer Off-peak	13.6		29,923
Winter On-peak	17.7	17.7	7,797
Winter Partial-peak	17.7		33,785
Winter Off-peak	13.6		37,254
Total			135,743

Comparison with Ex Ante Estimated Impacts

Comparison of the *ex ante* and *ex post* estimates of demand reduction show a realization rate of 0.55 and annual energy saving realization rate of 0.56, as shown in Table 5-10. The main reasons for the differences are:

- The *ex ante* estimates were calculated based on estimates (supplied by the customer) of reducing the fan speed to 80% of the pre-retrofit. However, the customer was not able to achieve the required cfm at the 80% fan speed. The fan speed verified in the *ex post* site visit was approximately 90%.
- The *ex post* analysis is based on values measured on site.

Table 5-10
Comparison of *Ex Ante* and *Ex Post* Load Impacts
ID No. 40312
PY96 Industrial EEI Program
Motor Measures

	Demand kW	Energy kWh/Year	Gas Therms/Year
Ex Ante Load Impacts	32.2	242,788	-
Ex Post Load Impacts	17.7	135,743	-
Difference	14.5	107,045	-
Realization Rate	0.55	0.56	-

Persistence of the Measure

The customer seemed committed to the operation of the fans with variable frequency drives. They had some trouble with this drive at the time of the on-site visit and had installed a temporary VFD to operate the fan until the permanent drive is fixed or repaired. Therefore, the 15 year equipment life given for this project is reasonable.

5.3.4 Net-to-Gross: Large Motor Measures

San Diego Gas & Electric initiated the retrofit process through the identification and quantification of the energy savings opportunity represented by the three large motor measures. They provided engineering support and cost-justification support. However, the savings opportunities were so great that the paybacks without incentives were low, ranging from 0.29 to 0.63. When the incentives were included, the paybacks ranged from 0.23 to 0.51. Following the decision rules in Table 3-1 SDG&E had a Medium Level of Involvement. The unincentivized paybacks for the three measures in aggregate were less than 0.5 years, thus, the net-to-gross ratio is 0.40.

5.4 SMALL MOTOR MEASURES

The *ex post* load impacts of small motor measures were estimated using the approach described in Section 3.3.2. The results of the evaluation of small motors for evaluation participants is shown in Table 5-11. Program level kWh and kW impacts are shown in Tables 5-12 and 5-13, respectively.

Table 5-11
Summary of Load Impacts - Small Motor Measures
Evaluation Participants
PY96 Industrial EEI Program
Motor Measures

		Ex Ante		*Ex Post*				Net Impacts	
ID No.	Horsepower	Gross kW	Gross kWh	Gross kW	kWh	Installation Type	Net-to-Gross	kW	kWh
19215	80	1.08	5,808	2.16	10,778	RET	1.00	2.16	10,778
19224	30	0.82	4,356	1.01	7,499	NEW	1.00	1.01	7,499
19228	5	0.12	630	0.15	419	ROB	0.00	0.00	0
19233	50	0.68	3,630	1.96	17,187	NEW	1.00	1.96	17,187
19234	200	1.68	8,940	0.55	4,059	ROB	0.00	0.00	0
19329	75	0.63	3,352	0.92	4,017	NEW	1.00	0.92	4,017
19341	80	1.91	10,164	2.12	10,473	ROB	0.00	0.00	0
19437	20	0.27	1,452	0.92	4,017	ROB	0.00	0.00	0
19471	15	0.41	2,178	0.92	4,017	NEW	1.00	0.92	4,017
19507	200	1.68	8,940	4.72	23,341	NEW	1.00	4.72	23,341
20234	50	0.68	3,630	1.10	5,495	ROB	0.00	0.00	0
20236	10	10.00	10	0.39	1,790	ROB	0.00	0.00	0
20237	15	0.20	1,089	0.00	0	INV	0.00	0.00	0
20625	8	0.18	945	0.19	604	ROB	0.00	0.00	0
20676	15	0.41	2,178	1.30	7,587	ROB	0.00	0.00	0
20682	30	0.41	2,178	0.37	1,155	ROB	0.00	0.00	0
20683	20	0.27	1,452	0.53	2,188	INV	0.00	0.00	0
20709	40	0.54	2,904	0.00	0	ROB	0.00	0.00	0
20711	30	0.41	2,178	0.19	1,673	ROB	0.00	0.00	0
20757	50	2.72	14,520	2.16	18,890	RET	1.00	2.16	18,890

Table5-11 (continued)
Summary of Load Impacts - Small Motor Measures
Evaluation Participants
PY96 Industrial EEI Program
Motor Measures

		Ex Ante		*Ex Post*				Net Impacts	
ID No.	Horsepower	Gross kW	Gross kWh	Gross kW	kWh	Installation Type	Net-to-Gross	kW	kWh
20796	20	0.27	1,452	0.32	1,014	ROB	0.00	0.00	0
21202	20	0.27	1,452	0.67	2,449	ROB	0.00	0.00	0
21491	5	0.12	630	0.20	975	ROB	0.00	0.00	0
21492	1	0.03	165	0.55	4,059	ROB	0.00	0.00	0
21879	50	1.36	7,260	2.07	18,100	RET	1.00	2.07	18,100
21880	20	0.54	2,904	1.00	8,766	NEW	1.00	1.00	8,766
21881	30	0.82	4,356	1.55	13,568	RET	1.00	1.55	13,568
21979	40	0.54	2,904	0.00	0	RET	1.00	0.00	0
21980	20	0.27	1,452	0.33	2,880	ROB	0.00	0.00	0
39687	15	0.20	1,089	0.30	934	ROB	0.00	0.00	0
40374	20	0.27	1,452	0.55	4,059	RET	1.00	0.55	4,059
40917	10	0.24	1,260	0.31	932	ROB	0.00	0.00	0
41145	15	0.20	1,089	0.62	3,626	ROB	0.00	0.00	0
41602	30	0.82	4,356	1.08	2,767	NEW	1.00	1.08	2,767
42455	25	0.34	1,815	0.43	967	ROB	0.00	0.00	0
42494	40	0.54	2,904	1.40	4,152	NEW	1.00	1.40	4,152
42515	30	0.41	2,178	0.94	2,111	RET	1.00	0.94	2,111
42517	75	1.89	10,057	1.40	4,152	NEW	1.00	1.40	4,152
42518	8	0.18	945	0.25	568	ROB	0.00	0.00	0
42585	75	0.63	3,352	1.50	10,482	ROB	0.00	0.00	0
43580	3	0.07	378	0.56	1,397	ROB	0.00	0.00	0
43891	5	0.47	2,520	6.05	52,982	RET	1.00	6.05	52,982
44795	8	0.18	945	0.18	664	ROB	0.00	0.00	0
44866	20	0.27	1,452	0.43	1,263	RET	1.00	0.43	1,263
45084	50	0.68	3,630	0.64	1,998	ROB	0.00	0.00	0
45402	40	0.54	2,904	0.00	0	ROB	0.00	0.00	0
45459	75	0.63	3,352	1.36	9,518	NEW	1.00	1.36	9,518
45863	2	0.12	660	0.14	717	RET	1.00	0.14	717
46009	50	0.68	3,630	1.01	4,871	ROB	0.00	0.00	0
46010	30	0.82	4,356	0.88	4,219	ROB	0.00	0.00	0
46023	200	5.03	26,820	5.47	47,891	NEW	1.00	5.47	47,891
46044	200	1.68	8,940	3.54	21,220	NEW	1.00	3.54	21,220
19341.1	30	1.23	6,534	0.77	3,811	NEW	1.00	0.77	3,811
19341.2	50	0.68	3,630	1.35	6,662	NEW	1.00	1.35	6,662
		48.12	**203,357**	**59.48**	**368,964**			**42.91**	**287,469**
			Realization Rate	**1.24**	**1.81**			**Net-to-Gross**	**0.77913**

Table 5-12
Program kWh Impacts - Small Motor Measures
PY96 Industrial EEI Program
Motor Measures

Ex Ante kWh Savings	541,444
Realization Rate	1.814
***Ex Post* Gross kWh Savings**	**982,377**
Net-to-Gross	0.78
***Ex Post* Net kWh Savings**	**765,395**
Ex Ante Net kWh Savings	406,083
Net Realization Rate	1.885

Table 5-13
Program kW Impacts - Small Motor Measures
PY96 Industrial EEI Program
Motor Measures

***Ex Ante* kW**	78.52
Realization Rate	1.24
***Ex Post* Gross kW**	**97.05**
Net-to-Gross	0.78
Net kW Impacts	**75.61**
Gross Realization Rate	1.236
Ex Ante Net kW	58.89
Net Realization Rate	1.284

A

REVISED TABLE E-3 FOR THE PY96 IEEI PROGRAM

This section contains the revised Table E-3 for SDG&E's PY96 Industrial Energy Efficiency Incentives Program.

SAN DIEGO GAS & ELECTRIC

SDG&E Table E-3
Components of Resource Benefit Values
Program Year: 1996 First Earnings Claim
Program: INDUSTRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM [IEEI]
(in thousands of 1996 Dollars)

Average Load Impacts Per Unit (Gross)

	LIGHTING			MOTORS			PROCESS			MISC		
Year	kW	kWh	Therms	kW	kWh	Therms	kW	kWh	Therms	kW	kWh	Therms
1996	0.06	0.06	(0)	0.09	658.53		102.44	365,984.07	69,121.96	18.89	105,454.62	337.47
1997	0.06	0.06	(0)	0.09	658.53		102.44	365,984.07	69,121.96	18.89	105,454.62	337.47
1998	0.06	0.06	(0)	0.09	658.53		102.44	365,984.07	69,121.96	18.89	105,454.62	337.47
1999	0.06	0.06	(0)	0.09	658.53		102.44	365,984.07	69,121.96	18.89	105,454.62	337.47
2000	0.06	0.06	(0)	0.09	658.53		102.44	365,984.07	69,121.96	18.89	105,454.62	337.47
2001	0.06	0.06	(0)	0.09	658.53		102.44	365,009.45	69,121.96	18.89	98,031.41	337.47
2002	0.06	0.06	(0)	0.09	658.53		102.44	365,009.45	69,121.96	18.89	98,031.41	337.47
2003	0.06	0.06	(0)	0.09	658.53		102.44	364,561.09	69,121.96	18.89	98,031.41	337.47
2004	0.06	0.06	(0)	0.09	658.53		102.44	364,561.09	69,121.96	18.89	98,031.41	337.47
2005	0.06	0.06	(0)	0.09	658.53		102.44	364,561.09	69,121.96	18.89	98,031.41	337.47
2006	0.05	0.04	(0)	0.09	658.53		102.44	364,561.09	69,121.96	16.47	60,707.90	196.45
2007	0.05	0.04	(0)	0.09	658.53		102.44	364,561.09	69,121.96	16.47	52,305.33	196.45
2008	0.04	0.04		0.09	658.53		102.44	364,561.09	69,121.96	16.47	52,305.33	196.45
2009	0.04	0.04		0.09	658.53		102.44	364,561.09	69,121.96	16.47	52,305.33	196.45
2010	0.04	0.04		0.09	658.53		102.44	364,561.09	69,121.96	16.47	52,305.33	196.45
2011	0.04	0.03					99.57	332,010.72	66,090.55	10.49	30,051.51	196.45
2012	0.02	0.02					99.57	332,010.72	66,090.55	10.49	29,094.50	196.45
2013	0.02	0.02					99.57	332,010.72	66,090.55	10.49	29,094.50	196.45
2014	0.02	0.02					99.57	332,010.72	66,090.55	10.49	29,094.50	196.45
2015	0.02	0.02					99.57	332,010.72	66,090.55	10.49	29,094.50	196.45
2016												
2017												
2018												
2019												
2020												
SUM (Lifecycle)	0.06	0.89	(0.00)	0.09	9,877.88		102.44	7,136,481.54	1,367,282.21	18.89	1,433,788.84	5,339.20
PV	$ 0	$ 0	$ (0)	$ 0	$ 0		$ 104	$ 230	$ 250	$ 17	$ 49	$ 1

	LIGHTING			MOTORS			PROCESS			MISC		
	kW	kWh	Therms	kW	kWh	Therms	kW	kWh	Therms	kW	kWh	Therms
# of Units:	24,684	124,723,215	124,723,215	5,144	5,144		31	31	31	41	41	41
Resource Benefit ($000, gross):	$ 1,245	$ 3,791	$ (1)	$ 395	$ 1,753		$ 3,217	$ 7,118	$ 7,740	$ 706	$ 2,025	$ 41
Net-to-Gross Ratio:	0.84	0.86	0.90	0.75	0.75		0.99	0.98	0.90	0.75	0.75	0.75
Resource Benefit ($000, net):	$ 1,048	$ 3,276	$ (1)	$ 296	$ 1,314		$ 3,187	$ 6,958	$ 6,966	$ 530	$ 1,520	$ 31
Impact Study References:	Study ID #			Study ID #			Study ID #			Study ID #		
Study used for Forecast	903			N/A			N/A			N/A		
Required 1st Yr LI Study, 2nd Claim	995			995			995			N/A		
Required Persistence, 3rd Claim	996			996			996			N/A		
Required Persistence, 4th Claim	997			997			997			N/A		

Notes:
(1) This table was revised to account for measures that were reclassified from one end use to another.

B

TABLE 6

This section contains Table 6 for SDG&E's PY96 Industrial Energy Efficiency Incentives Program for Lighting, Process and Motor measures.

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY96 SECOND EARNINGS CLAIM FOR INDUSTRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, February 1998, STUDY ID NO. 995

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	55.93	53.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. ii. Load Impacts - kWh	353,649	335,627	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. iii. Load Impacts - therm	86,047	86,047	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. i. Load Impacts/designated unit - kW	55.9310	53.5517	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. ii. Load Impacts/designated unit - kWh	353,648.8	335,627.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. iii. Load Impacts/designated unit - therm	86,047	42,701	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	0.50	0.48	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. ii. Load Impacts - kWh, realization rate	0.88	0.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. iii. Load Impacts - therm, realization rate	1.15	0.63	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	0.50	0.49	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	0.88	0.84	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	1.15	0.63	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	0.95		N/A	N/A			N/A	N/A		
	A. ii. Average Load Impacts - kWh	0.96		N/A	N/A			N/A	N/A		
	A. iii. Average Load Impacts - therm	0.50		N/A	N/A			N/A	N/A		
	B. i. Avg Load Impacts/designated unit of measurement - kW	0.99		N/A	N/A			N/A	N/A		
	B. ii. Avg Load Impacts/designated unit of measurement - kWh	0.98		N/A	N/A			N/A	N/A		
	B. iii. Avg Net Load Impacts/designated unit of measurement therm	0.90		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	30									
	B. Number of measures installed by all program participants in the 12 months of the program year	131									
	C. Number of measures installed by Comp Group	N/A									

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY96 SECOND EARNINGS CLAIM FOR INDUSTRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, February 1998, STUDY ID NO. 995

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

7. Market Segment Data		SIC	Percent	5. A. 90% Confidence Level	5. B. 80% Confidence Level
	Distribution by 3 digit SIC	208	4.8		
		283	9.4		
		295	4.8		
		306	4.8		
		329	4.8		
		339	4.8		
		341	4.8		
		351	4.8		
		357	4.8		
		358	4.8		
		364	4.8		
		365	4.8		
		367	9.4		
		372	9.4		
		373	9.4		
		382	4.8		
		399	4.8		

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY96 SECOND EARNINGS CLAIM FOR INDUSTRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, February 1998, STUDY ID NO. 995

Designated Unit of Measurement: Load Impacts per Horsepower
End Use: Motors

				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	3.36	1.73	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. ii. Load Impacts - kWh	28,049	15,059	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. iii. Load Impacts - therm	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. i. Load Impacts/designated unit - kW	0.0863	0.0443	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. ii. Load Impacts/designated unit - kWh	719.7	386.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. iii. Load Impacts/designated unit - therm	N/A	N/A	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	0.68	0.47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. ii. Load Impacts - kWh, realization rate	0.76	0.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. iii. Load Impacts - therm, realization rate	N/A	N/A	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	0.96	0.66	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	1.09	0.78	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	N/A	N/A	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	0.51		N/A	N/A			N/A	N/A		
	A. ii. Average Load Impacts - kWh	0.54		N/A	N/A			N/A	N/A		
	A. iii. Average Load Impacts - therm	N/A		N/A	N/A			N/A	N/A		
	B. i. Avg Load Impacts/designated unit of measurement - kW	0.51		N/A	N/A			N/A	N/A		
	B. ii. Avg Load Impacts/designated unit of measurement - kWh	0.54		N/A	N/A			N/A	N/A		
	B. iii. Avg Net Load Impacts/designated unit of measurement - therm	N/A		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	57									
	B. Number of measures installed by all program participants in the 12 months of the program year	201									
	C. Number of measures installed by Comp Group	N/A									

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY96 SECOND EARNINGS CLAIM FOR INDUSTRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, February 1998, STUDY ID NO. 995

Designated Unit of Measurement: Load Impacts per Horsepower

End Use: Motors

7. Market Segment Data		SIC	Percent
	Distribution by 3 digit SIC	144	7.3
		161	3.1
		162	1.0
		179	2.1
		204	1.0
		243	2.1
		251	2.1
		254	1.0
		265	2.1
		267	2.1
		271	1.0
		275	1.0
		281	1.0
		308	6.2
		323	1.0
		327	6.2
		328	1.0
		341	1.0
		342	1.0
		343	1.0
		347	1.0
		351	2.1
		354	2.1
		355	2.1
		356	2.1
		357	2.1
		358	4.1
		359	3.1
		365	2.1
		366	1.0
		367	2.1
		369	1.0
		371	1.0
		372	8.2
		373	9.3
		376	1.0
		381	2.1
		382	2.1
		384	1.0
		385	1.0
		394	4.1
		399	1.0
		399	1.0

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY96 SECOND EARNINGS CLAIM FOR INDUSTRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, FEBRUARY 1998, STUDY ID NO. 995

Designated Unit of Measurement: LOAD IMPACTS PER AFFECTED SQUARE FOOT PER 1000 HOURS OF OPERATION.
End Use: Interior Lighting

				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 GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP
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	7.0995	5.9636	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. ii. Load Impacts - kWh	21,891	18,389	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. i. Load Impacts/designated unit - kW	0.4019	0.3376	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. ii. Load Impacts/designated unit - kWh	0.2159	0.1814	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
Realization Rate:	D.A. i. Load Impacts - kW, realization rate	1.1181	1.1181	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. ii. Load Impacts - kWh, realization rate	1.2182	1.1899	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	6.6988	6.6989	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	3.5989	3.5152	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	0.84		N/A	N/A			N/A	N/A		
	A. ii. Average Load Impacts - kWh	0.84		N/A	N/A			N/A	N/A		
	B. i. Avg Load Impacts/designated unit of measurement - kW	0.84		N/A	N/A			N/A	N/A		
	B. ii. Avg Load Impacts/designated unit of measurement - kWh	0.84		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		
4. Designated Unit Intermediate Data		PART GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP
	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
5. Measure Count Data		NUMBER									
	A. Number of measures installed by participants in Part Group	48,795									
	B. Number of measures installed by all program participants in the 12 months of the program year	52,605									
	C. Number of measures installed by Comp Group	N/A									

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY96 SECOND EARNINGS CLAIM FOR INDUSTRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, FEBRUARY 1998, STUDY ID NO. 995

Designated Unit of Measurement: LOAD IMPACTS PER AFFECTED SQUARE FOOT PER 1000 HOURS OF OPERATION.
End Use: Interior Lighting

7. Market Segment Data		SIC or CZ	PERCENT
	Distribution by 3 digit SIC - Commercial/Industrial	152	5.5
		153	0.4
		154	1.2
		171	0.4
		172	0.4
		173	1.2
		174	1.2
		179	1.6
		203	0.8
		205	0.8
		208	2.4
		209	0.4
		228	0.4
		232	0.8
		238	0.4
		239	0.4
		251	0.4
		253	0.4
		271	2.4
		272	0.8
		274	2
		275	7.1
		278	0.4
		279	0.8
		281	0.8
		282	0.4
		283	3.2
		285	0.8
		289	0.4
		305	0.4
		306	0.8
		308	4.3
		317	0.4
		322	0.4
		327	0.4
		328	0.4
		329	0.4
		339	0.4
		341	0.4
		342	1.2
		344	4
		345	0.4
		347	0.8
		349	0.8
		352	0.4
		354	2
		356	1.2
		357	5.5
		358	1.2
		359	2.8
		361	0.4
		362	1.2
		364	0.4
		365	0.4
		366	2
		367	7.9
		369	1.6
		371	0.4
		372	0.8
		376	1.6
		381	0.8
		382	3.2
		384	4.3
		386	1.2
		394	3.2
		396	0.4
		399	2.8
		504	0.4
		506	0.4
		737	0.4

C

TABLE 7

M&E PROTOCOLS TABLE 7
DATA QUALITY AND PROCESSING DOCUMENTATION
For 1996 Industrial Energy Efficiency Incentives Program
First Year Load Impact Evaluation
February 1998
Study ID No. 995

A. OVERVIEW INFORMATION

1. **Study Title and Study ID:** 1996 Industrial Energy Efficiency Incentives Program: First Year Load Impact Evaluation, February 1997, Study ID No. 995.

2. **Program, Program Year(s), and Program Description (design):** 1996 Industrial Energy Efficiency Incentives Program for the 1996 program year. The Program is designed to help industrial customers control energy costs by providing incentives for the installation of energy efficient equipment at their facilities.

3. **End Uses and/or Measures Covered:** All end uses combined disaggregated by process, interior lighting and motors.

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

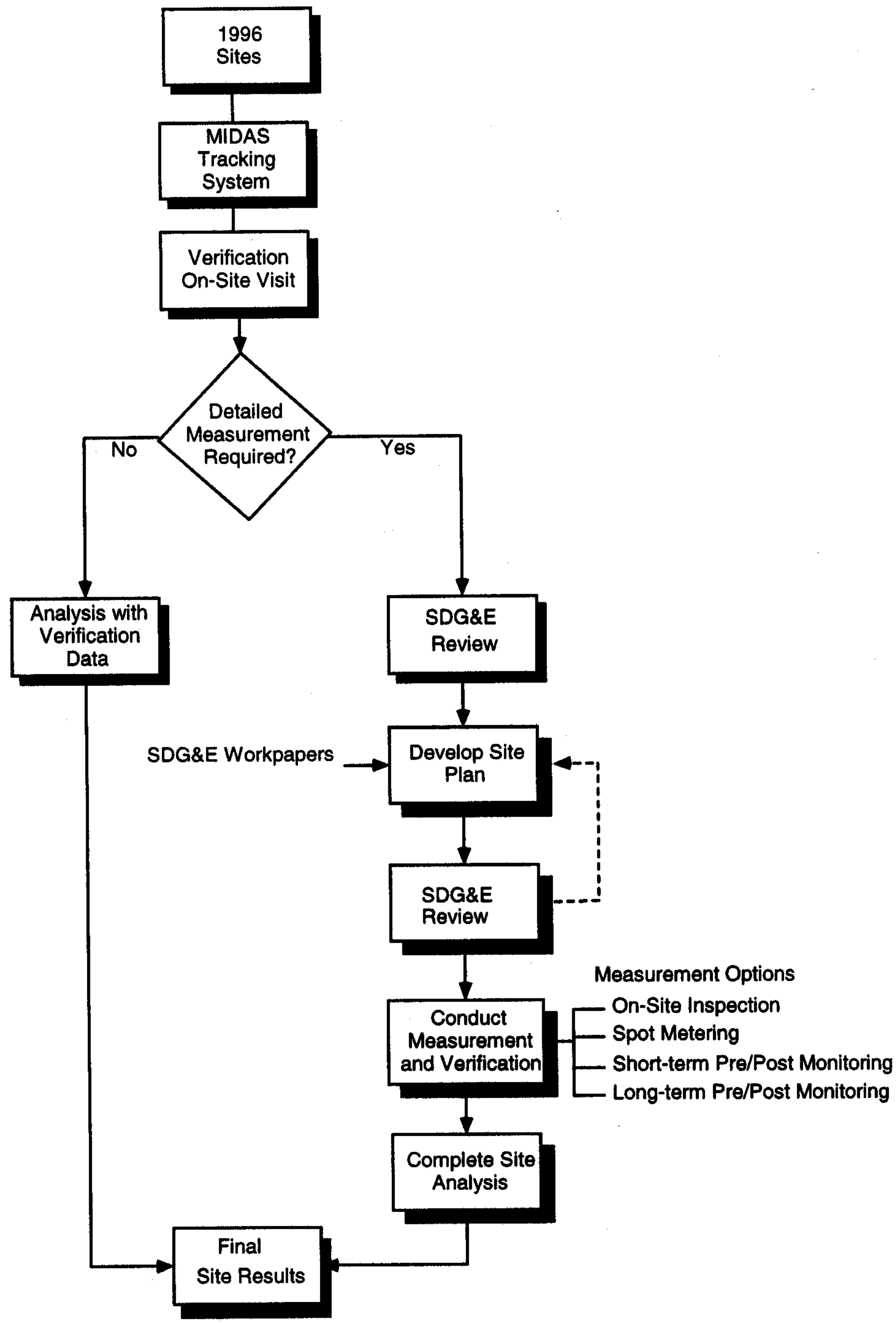
5. **Participant and comparison group definition:** For the load impact analysis, the participants in the 1996 Industrial Energy Efficiency Incentives Program are defined as having at least one of the aforementioned measures installed.

6. **Analysis sample size:**

Electric Participant Sample for 1996 Industrial Energy Efficiency Incentives Program			Gas Participant Sample for 1996 Industrial Energy Efficiency Incentives Program			
Measure Type	No. of Participants	No. of Measures	Measure Type	No. of Participants	No. of Projects	No. of Measures
Interior Lighting	57	48,795	Interior Lighting	0	0	0
Process	8	22	Process	2	4	12
Motors	57	57	Motors	0	0	0
Total			Total	0	0	0

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: participants comprising the top 70 percent of load impacts were included in the survey for process measures. Lighting: a stratified sample based on kWh savings. The Dalenius-Hodges stratification protocol with the Neyman Allocation was employed. Motors: participants comprising the at a minimum the top 70 percent of load impacts were included in the survey for motors.

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.