XENERGY

1996 Agricultural Energy Efficiency Incentives Program
First Year Load Impact Evaluation
Final Report

Study ID No. 998

Prepared for

San Diego Gas & Electric
8306 Century Park Court
San Diego, California 92123-1593

Prepared by

XENERGY Inc.
16466 Bernardo Center Drive
Suite 250
San Diego, California 92128

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1 INTRODUCTION

1.1 INTRODUCTION

San Diego Gas & Electric (SDG&E) commissioned XENERGY Inc. to evaluate the first year load impacts of measures installed under its *1996 Agricultural Energy Efficiency Incentives (Ag. EEI) Program*. These measures were installed to provide resource value by improving the energy efficiency of the facilities that participated in the *Ag. EEI Program.*

The overall objectives of SDG&E's *1996 Agricultural Energy Efficiency Incentives Program First Year Impact Evaluation* were to:

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

These objectives were accomplished using the following methodology:

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

1.2 REPORT ORGANIZATION

The remainder of this report is organized as follows:

Section 2	Results
Section 3	Lighting Measures
Section 4	Site specific analysis reports for Pumping Measures
Appendix A	*"Retroactive Waiver for 1996 Agricultural Energy Efficiency Incentives Program"*
Appendix B	Table 6: Pumping Measures: Protocols for Reporting of Results of Impact Measurement Studies Used to Support an Earnings Claim
Appendix C	Table 6: Lighting Measures: Protocols for Reporting of Results of Impact Measurement Studies Used to Support an Earnings Claim
Appendix D	Table 7: Documentation Protocols for Data Quality and Processing

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RESULTS

This section presents summary tables showing the results of the first year load impact evaluation of SDG&E's PY96 Agricultural Energy Efficiency Incentives Program for pumping and interior lighting measures.

Table 2-1 shows the first year load impacts for pumping measures.

Table 2-1
Summary of *Ex Post* Net Realization Rates
Pumping Measures
1996 Agricultural Energy Efficiency Incentives Program

		Ex Ante Gross Load Impacts			*Ex Post* Gross Load Impacts			*Ex Ante* Net Load Impacts		*Ex Post* Net Load Impacts		*Ex Post* Net Realization Rate	
On-Site Visit?	**Quantity**	**Net-to-Gross**	**kWh Savings**	**kW Red.**	**Net-to-Gross**	**kWh Savings**	**kW Red.**	**kWh Savings**	**kW Red.**	**kWh Savings**	**kW Red.**	**kWh Savings**	**kW Red.**
Yes	21		1,685,191	139.00	0.75	1,401,194	180.00	1,516,672	125.10	1,050,896	135.00	0.69	1.08
No	24		68,426	54.18	0.75	56,794	70.16	53,767	47.295	42,671	52.62	0.79	1.11
Total	45		1,753,617	193.18		1,457,988	250.16	1,570,439	172.40	1,093,566	187.62	0.70	1.09

Table 2-2 shows the first year kWh savings for lighting measures and Table 2-3 shows the first year kW reduction for lighting measures.

Table 2-2
***Ex Post* kWh Impacts**
PY96 Agricultural EEI Program
Lighting Measures

Ex Ante kWh Savings	2,709,920
Adjustment Factor - Hours of Operation	0.368
Adjustment Factor - Measure Installation	1.006
Adjustment Factor - Fixture Wattage	0.701
***Ex Post* Gross kWh Savings**	**703,267**
Net-to-Gross	0.75
***Ex Post* Net kWh Savings**	**527,450**
Gross Realization Rate	**0.260**
Ex Ante Net kWh Savings	2,320,920
Net Realization Rate	**0.227**

Table 2-3
***Ex Post* kW Impacts**
PY96 Agricultural EEI Program
Lighting Measures

***Ex Ante* kW**	**628.73**
Ex Ante Coincidence Factor	0.76
Total *Ex Ante* kW	827.2763
Adjustment Factor - Connected Watts	0.701
Ex Post kW Coincidence Factor	0.423
***Ex Post* Gross kW**	**245.089**
Ex Post Net-to-Gross	0.75
Net kW Impacts	**183.817**
Gross Realization Rate	**0.390**
***Ex Ante* Net kW**	**538.5**
Net Realization Rate	**0.341**

3 LIGHTING MEASURES

3.1 OVERVIEW

During PY96 San Diego Gas & Electric installed indoor lighting measures as part of its *Agricultural Energy Efficiency Incentives Program (Ag. EEI Program)*. This section presents a first year *ex post* load impact evaluation of the lighting measures installed through the Ag. EEI Program during PY96. Table 3-1 shows an *ex ante* summary of the program. This shows that almost 22,000 individual measures were installed saving an estimated 2,709,920 kWh per year at the sites of 13 participants. For these participants, there were a total of 15 separate projects as identified in subsequent sections as ID No. There were two participants that had two projects represented by separate ID No.

Table 3-1
Program Summary
PY96 Agricultural EEI Program
Lighting Measures

Participant	Measure Quantity	*Ex Ante* kWh Savings	*Ex Ante* kW Reduced
1	495	23,525	6.52
2	4,100	565,367	130.87
3	1,180	128,766	29.82
4	7,440	835,508	193.4
5	2,352	256,668	59.4
6	114	27,708	10.88
7	120	13,001	3.01
8	980	205,922	47.67
9	250	39,809	9.22
10	720	111,104	25.72
11	194	62,389	10.33
12	2,604	283,052	65.52
13	1,450	157,101	36.37
Total	**21,999**	**2,709,920**	**628.73**

Table 3-2 shows a profile of the lighting measures installed during PY96. Small compact fluorescents, those rated between five and ten watts, were the most widely installed measure, representing about 90 percent of the measures installed and close to 90 percent of the *ex ante* load impacts.

This *ex post* evaluation was implemented under the *Retroactive Waiver for 1996 Agricultural Energy Efficiency Incentives Program* approved by CADMAC on June 18, 1997. The waiver is in Appendix A. This waiver approved the evaluation of lighting measures to be evaluated as a separate end use using on-site verification of engineering estimates.

Table 3-2
Measure Summary
PY96 Agricultural EEI Program
Lighting Measures

		Ex Ante Values By Measure Description			*Ex Ante* Values By Measure Category			Share By Measure Category		
	Measure Description	Measure Quantity	*Ex Ante* kWh Savings	*Ex Ante* kW Reduced	Measure Quantity	*Ex Ante* kWh Savings	*Ex Ante* kW Reduced	Measure Quantity	*Ex Ante* kWh Savings	*Ex Ante* kW Reduced
Small CFL	CF-7 Hardwire Fxtr	2,050	343,258	79.46	19,756	2,374,092	549.56	0.90	0.88	0.87
	CF-9 Hardwire Fxtr	1,105	232,188	53.75						
	5-10W CFL	7,048	763,620	176.76						
	5-10W Replacement CFL	9,553	1,035,026	239.59						
Medium CFL	CF-13Q Hardwire Fxtr	2	467	0.13	1,501	234,532	53.68	0.07	0.09	0.09
	1CFQE13S	1	32	0.03						
	11-15W CFL	728	112,135	26.01						
	11-15W Replacement CFL	770	121,898	27.51						
Large CFL	1CE22H	3	90	0.05	147	51,684	8.59	0.01	0.02	0.01
	21-25W Replacement CFL	144	51,594	8.54						
T8/Electronic Ballast	2FO32/.5B4T8-4L	4	283	0.11	594	46,639	15.71	0.03	0.02	0.02
	2FO32/1B4T8-2L	27	2,158	0.91						
	2FO32/1B4T8-2L/1R4-D2	46	10,645	3.98						
	2FO32/1B4T8-2L/2R4-D1	10	2,770	1.15						
	32 Watt lamp	252	1,384	0.39						
	4FO32/1B4T8-4L	10	1,314	0.63						
	4FO32/1B4T8-4L/2R4-D2	12	7,443	2.83						
	Opt Refl(4ft/1dlamp)	46	4,610	1.28						
	Opt Refl(4ft/2dlamp)	61	12,227	3.38						
	T-8 El Bal (4ft/2la)	126	3,805	1.05						
Other	Motion Detector	1	2,973	1.19	1	2,973	1.19	0.00	0.00	0.00
		21,999	2,709,920	628.73	21,999	2,709,920	628.73	1.00	1.00	1.00

To evaluate the lighting measures the on-site verification visits were conducted at each of the 13 participant sites. During these visits:

- the installation of the measures was verified and quantified;
- light loggers were installed and remained in place for a period of time to estimate hours of operation; and
- spot measurement of a sample of fixtures were taken to estimate *ex post* connected watts.

During the course of the study the primary types of business the participant sites were engaged in was chicken farming for the purpose of producing eggs for the retail market.

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

- measure installation

- hours of operation
- post-retrofit connected watts

3.2 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.

3.2.1 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 each site through the installation of light loggers at each facility. In most cases several loggers were installed throughout the facility. The percent of time the lights are on were calculated for each logger and then annualized. The average annualized hours of operation were calculated for each facility. A site-specific weighted average hours of operation for each participant was calculated for both *ex ante* and *ex post*, using *ex ante* gross kWh savings as the weight, to account for the magnitude of impacts of the individual measures. 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 realization rates, using the gross *ex ante* energy savings as the weight. The results are shown in Table 3-3.

Table 3-3 shows the adjustment factor for hours of operation of 0.368. This is interpreted as the fraction of the *ex ante* hours of operation that was observed through the *ex post* evaluation. The low value for this adjustment factor is explained by the inclusion of a sizable portion of the measures being used as replacement lamps and are in storage. Table 3-4 shows that 48 percent of the measures installed were replacement compact fluorescent lamps. These lamps were in storage and not being used. These measures were assigned an annual hours of operation of zero, i.e., they were not operating. The primary reason for the replacement lamps is because egg ranchers are very risk averse. They need to have the lights operating properly for the hens to lay eggs on a regular schedule. As lights burn out, they are immediately replaced Since these ranches are typically located in remote areas, a supply is maintained in storage for as the need arises.

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

	Ex Ante		*Ex Post*	
ID No.	**kWh Savings**	**Average Hours**	**Hours**	**Realization Rate by ID No. (*Ex Ante/Ex Post*)**
41707	23,527	3,613	3,347	0.926
42336	62,388	6,044	3,650	0.604
42406	27,708	2,437	2,257	0.926
42748	275,789	4,320	587	0.136
42771	111,103	4,320	993	0.230
42779	157,101	4,320	677	0.157
43185	39,809	4,320	1,405	0.325
43381	289,578	4,320	892	0.206
43728	256,667	4,320	1,039	0.240
43729	283,051	4,320	2,063	0.477
43730	128,767	4,320	1,411	0.327
43762	273,031	4,320	3,078	0.712
44877	205,922	4,320	2,965	0.686
45197	562,478	4,320	1,302	0.301
45611	13,001	4,320	2,377	0.550
Adjustment Factor for Hours of Operation (Weighted by kWh Savings per ID No.)				**0.368**

Table 3-4
Share of Measures Hardwired versus Replacement Lamps
PY96 Agricultural EEI Program
Lighting Measures

	Ex Ante Gross					
Type	**Measure Quantity**	**Percent**	**kWh Savings**	**Percent**	**kW Reduced**	**Percent**
Hardwired	11,532	52%	1,501,402	55%	353.09	56%
Replacement	10,467	48%	1,208,518	45%	275.64	44%
Total	21,999	100%	2,709,920	100%	628.73	100%

3.2.2 Measure Installation

Measure installations were verified and quantified. Table 3-5 shows the *ex ante* and *ex post* measure quantities for each ID No. A realization rate was calculated for each measure for each ID No. A weighted average of these realization rates was taken to estimate the adjustment factor for measure installations.

As shown in Table 3-5 the adjustment factor was slightly over 1.0, indicating that, for all practical purposes, all measures were installed. The reason for the adjustment factor close to 1.0 is that SDG&E has a post-installation inspection requirement that helps to ensure the installation of the measure, prior to payment of the program incentive. In addition, there was no turnover of participants and no renovation or remodeling activity performed that would have altered the lighting installations.

Table 3-5
Adjustment Factor for Measure Installation
PY96 Agricultural EEI Program
Lighting Measures

ID No.	Ex Ante Quantity	Ex Post Quantity	(Ex Post Quantity divided by Ex Ante Quantity)	Ex Ante kWh Savings
41707	8	8	1.0000	1,032
41707	2	2	1.0000	467
41707	46	41	0.8913	4,610
41707	46	41	0.8913	1,389
41707	92	82	0.8913	505
41707	19	19	1.0000	574
41707	38	38	1.0000	209
41707	61	61	1.0000	12,227
41707	61	61	1.0000	1,842
41707	122	122	1.0000	670
42336	50	50	1.0000	10,795
42336	144	144	1.0000	51,594
42406	45	45	1.0000	10,366
42406	1	1	1.0000	32
42406	10	10	1.0000	1,314
42406	5	5	1.0000	250
42406	3	3	1.0000	90
42406	22	22	1.0000	1,908
42406	10	10	1.0000	2,770
42406	12	12	1.0000	7,443
42406	1	1	1.0000	279
42406	4	4	1.0000	283
42406	1	1	1.0000	2,973
42748	1,000	1,000	1.0000	167,443
42748	1,000	1,000	1.0000	108,346
42771	360	360	1.0000	55,552
42771	360	360	1.0000	55,552
42779	500	504	1.0080	54,173
42779	950	950	1.0000	102,928
43185	125	124	0.9920	26,266
43185	125	125	1.0000	13,543
43381	1,050	1,040	0.9905	175,815
43381	1,050	1,050	1.0000	113,763
43728	1,156	1,140	0.9862	125,248
43728	20	20	1.0000	3,086
43728	1,156	1,156	1.0000	125,248
43728	20	20	1.0000	3,086
43729	1,292	1,288	0.9969	139,983
43729	10	10	1.0000	1,543
43729	1,292	1,292	1.0000	139,983
43729	10	10	1.0000	1,543
43730	580	580	1.0000	62,840
43730	580	580	1.0000	62,840
43730	10	10	1.0000	1,543
43730	10	10	1.0000	1,543
43762	1,260	1,280	1.0159	136,515
43762	1,260	1,260	1.0000	136,515
44877	980	976	0.9959	205,922
45197	2,140	1,820	0.8505	231,860
45197	2,140	2,140	1.0000	231,860
45197	320	640	2.0000	49,379
45197	320	320	1.0000	49,379
45611	120	160	1.3333	13,001
Total	**21,999**	**22,008**		**2,709,920**
Measure Installation Adjustment Factor (Weighted by kWh Savings)				**1.006**

3.2.3 Post -Retrofit Connected Fixture Watts

As part of the industrial protocols for M&V, the measurement of end use connected loads is required in estimating the 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.

Due to the nature of the facilities, measurements at the fixture level were feasible. Volts and amps were measured, while power factor was taken from the nameplate data on the fixture for compact fluorescent lamps. Typically, the power factor for T-8 fixtures was assumed to be 1.0. Table 3-6 shows the measurements and calculated watts per fixture.

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 factor for the individual fixtures were weighed by the *ex ante* kWh savings aggregating by type of fixture, as defined by the measure description in the program tracking system. As shown in Table 3-6, the adjustment factor for fixture wattage is 0.701. This value indicates that the *ex post* measurements were higher than the *ex ante* assumptions for the post-retrofit fixture.

Table 3-6
Adjustment Factor for Fixture Wattage
PY96 Agricultural EEI Program
Lighting Measures

	Ex Ante			*Ex Post*							
ID No.	Measure Code	Measure Description	Watts	Lamp Mfr/Model	Volts (V)	Amps (A)	Power Factor (PF)	*Ex Post* Watts (VxAxPF)	Raw Watts Adjustment Factor (Ex Ante/Ex Post)	Weight (Based on Savings)	Weighted Adj. Factor
42748	CF02	CF-7 Hardwire Fxtr	9.0	Phillips CFL7	120.1	0.14	0.65	10.9	0.82	0.063	0.052
43381	CF02	CF-7 Hardwire Fxtr	9.0	Phillips CF7	117.4	0.14	0.65	10.7	0.84	0.063	0.053
44877	CF03	CF-9 Hardwire Fxtr	11.0	Phillips CF9	120.0	0.16	0.65	12.5	0.88	0.043	0.038
43185	CF03	CF-9 Hardwire Fxtr	11.0	Sylvania CFL9	123.3	0.15	0.65	12.0	0.92	0.043	0.039
42779	CF40	5-10W CFL	7.0	Phillips CFL9	122.3	0.15	0.65	11.9	0.59	0.095	0.056
45611	CF40	5-10W CFL	7.0	Phillips CFL10	118.4	0.15	0.65	11.5	0.61	0.095	0.057
43762	CF40	5-10W CFL	7.0	Phillips CFL11	119.4	0.14	0.65	10.9	0.64	0.095	0.061
43728	CF40	5-10W CFL	7.0	Phillips CF7	120.7	0.14	0.65	11.0	0.64	0.095	0.060
45197	CF40	5-10W CFL	7.0	Sylvania CFL9	114.1	0.16	0.65	11.9	0.59	0.095	0.056
43729	CF40	5-10W CFL	7.0	Phillips CFL9	120.1	0.11	0.85	11.2	0.62	0.095	0.059
43730	CF40	5-10W CFL	7.0	Phillips CFL9	118.2	0.16	0.65	12.3	0.57	0.095	0.054
42771	CF41	11-15W CFL	13.0	Sylvania CFL13	114.0	0.19	0.65	14.1	0.92	0.053	0.049
45197	CF41	11-15W CFL	13.0	Sylvania CF13	116.3	0.19	0.65	14.4	0.91	0.053	0.048
42406	LI00	2FO32/1B4T8-2L	58.0	General Electric	120.2	0.52	0.95	59.4	0.98	0.009	0.009
41710	LI00	2FO32/1B4T8-2L	58.0	Sylvania F32	120.7	0.51	0.95	58.5	0.99	0.009	0.009
Weighted Average Adjustment Factor for Fixture Watts											**0.701**

These values are interesting in that other, similar studies have shown that measured fixture wattages for the typical T-8 fixture with electronic ballasts are within a fairly tight range of the *ex ante* wattage, perhaps a few percent of the assumed value. This can be seen in the measurements for ID Nos. 42406 and 41710 for T-8 fixtures with electronic ballasts, where the raw adjustment factors are 0.98 and 0.99, respectively. However, with CFLs there is a larger discrepancy between the *ex ante* and *ex post* wattages. This is due, in part, to the fact that the measures may be defined in ranges, e.g., "5-10W CFL," as well as a more specific definition, e.g., "CF-9 Hardwire Fxtr." When a range is used to define the fixture in the tracking system, the midpoint wattage was used as the *ex ante* post-retrofit fixture. For example, for measures described as "5-10W CFL" the *ex ante* wattage was 7.0. Similarly, for an "11-15W CFL" measure 13 watts was used. If the installed lamps fell in the lower end of the range then the difference between the *ex ante* and measured watts probably wouldn't be very large. On the other hand, if the lamps were on the upper end of the range, the *ex ante* watts would be consistently lower than what was actually measured. A final thought is whether the ballast was included when estimating the *ex ante* watts for the range of CFLs. For example, "5-10W CFL" were rated at 7.0 watts. If the midrange CFL were selected as representative of the 5 to 10 watt CFLs, and that would be a 7 watt CFL, the ballast must be included in the wattage. This would add as much as 4 watts to the total fixture wattage. It appears that the ballast was included in the *ex ante* wattage when a specific wattage lamp was indicated in the *ex ante* fixture description. For example, for ID No. 42748 a "CF-7 Hardwire Fxtr" was installed. Rather than having an *ex ante* wattage of 7.0 watts, the *ex ante* value was 9.0. The difference of 2.0 watts due to the ballast.

3.3 NET-TO-GROSS

The *Retroactive Waiver for 1996 Agricultural Energy Efficiency Incentives Program* approved by CADMAC on June 18, 1997 approved a default net-to-gross ratio of 0.75 for the program, in lieu of using a comparison group.

3.4 *EX POST* KWH IMPACTS

Equation 3-1 shows the calculation for the *ex post* gross kWh savings. Table 3-7 shows the *ex post* load impacts for SDG&E's PY96 Agricultural EEI Program.

$$\text{(Eq. 3-1)} \quad \text{Gross kWh Savings}_{\text{Ex post}} = \left(\text{kWh}_{\text{Ex ante}}\right) \text{x} \left(\text{Adj. Factor}_{\text{Hours of operation}}\right) \text{x} \left(\text{Adj. Factor}_{\text{Measure installation}}\right) \text{x} \left(\text{Adj. Factor}_{\text{Fixture wattage}}\right)$$

Table 3-7
***Ex Post* kWh Impacts**
PY96 Agricultural EEI Program
Lighting Measures

Ex Ante kWh Savings	2,709,920
Adjustment Factor - Hours of Operation	0.368
Adjustment Factor - Measure Installation	1.006
Adjustment Factor - Fixture Wattage	0.701
Ex Post Gross kWh Savings	703,267
Net-to-Gross	0.75
Ex Post Net kWh Savings	527,450
Gross Realization Rate	0.260
Ex Ante Net kWh Savings	2,320,920
Net Realization Rate	0.227

3.5 *EX POST* KW IMPACTS

The *ex post* kW impact estimate was based on the TOU loggers that were in the field at the time of SDG&E summer peak, September 4, 1997 at 15:30, or a proxy date of August 27, 1997, if the logger was not in place on September 4. The average of the percentage of time the loggers were on during the period of 14:00 to 16:00 was used to determine the peak coincidence factor. This 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 3-8.

Table 3-8
***Ex Post* kW Impacts**
PY96 Agricultural EEI Program
Lighting Measures

***Ex Ante* kW**	**628.73**
Ex Ante Coincidence Factor	0.76
Total *Ex Ante* kW	827.2763
Adjustment Factor - Connected Watts	0.701
Ex Post kW Coincidence Factor	0.423
***Ex Post* Gross kW**	**245.089**
Ex Post Net-to-Gross	0.75
Net kW Impacts	**183.817**
Gross Realization Rate	**0.390**
***Ex Ante* Net kW**	**538.5**
Net Realization Rate	**0.341**

3.6 *Ex Post* Building Square Footage

The *ex post* building square footage of the lighting installations was verified through the on-site verification visits. The verification was completed through review of site plans, measurement of the facilities and interviews with site personnel.

Table 3-9 shows a summary of the verified square footage.

Table 3-9
***Ex Post* Verified Building Square Footage**
PY96 Agricultural EEI Program
Lighting Measures

ID No.	No. Buildings	Verified SF
41707	1	8,000
42406	1	22,000
42748	17	108,800
42771	10	96,818
42779	12	54,000
43185	2	12,800
43381	16	104,000
43728	30	108,000
43729	14	151,312
43730	11	83,384
43762	4	64,000
44877	8	52,000
45197	19	191,520
45611	2	12,800
Total		1,069,434

4 PUMPING MEASURES

4.1 INTRODUCTION

This section provides the site specific analyses for the pumping measures installed under San Diego Gas & Electric's *1996 Agricultural Energy Efficiency Incentives (EEI) Program.*

4.2 SUMMARY OF LOAD IMPACTS OF PUMPING MEASURES

Table 4-1 provides an overview of the Agricultural EEI Program's 1996 measures and impacts. Twenty two participants installed 45 measures that saved over 1.75 million kWh (*ex ante* estimate).

Table 4-1
***Ex Ante* Program Summary**
Pumping Measures
1996 Agricultural Energy Efficiency Incentives Program

End Use	Pumping
Participants	22
Measures	45
kWh Savings	1,753,617
kW Reduced	193.18
Motor Horsepower (HP)	2,460

Table 4-2 shows the measures installed under the Agricultural EEI Program and the measures included in the *ex post* load impact evaluation. This table shows that the *ex ante* load impacts of the evaluation participants comprised 96 percent and 72 percent of the *ex ante* kWh and kW load impacts.

Table 4-2
Overview of Program Participants and *Ex Post* Evaluation Participants
Pumping Measures
1996 Agricultural Energy Efficiency Incentives Program

				Ex Ante Gross Load Impacts			
				Program Participants		*Ex Post* Evaluation Participants	
On-Site Visit Conducted?	ID No.	Measure Description	Quantity	kWh Savings	kW Reduced	kWh Savings	kW Reduced
Yes	14176	VFD for High Lift Sewer Pump	1	302,532	34.00	302,532	34.00
Yes	45081	Pumps with Reduced Stages	2	292,389	20.00	292,389	20.00
Yes	14176	VFD for Reclaimed water pump	1	222,450	25.00	222,450	25.00
Yes	45148	VFDs for 2x100hp & 1x50 hp	3	206,979	19.50	206,979	19.50
Yes	44226	VFDs on Water Pumps	2	191,545	3.20	191,545	3.20
Yes	14176	VFD for Low Lift Sewage Pumps	3	144,162	20.20	144,162	20.20
Yes	44225	VFDs Potable Water Pumps	2	118,033	2.00	118,033	2.00
Yes	14176	VFD for Tertiary Influent Pump #1	1	44,490	5.00	44,490	5.00
Yes	14176	Nitrified Recycle Pumps	2	35,592	4.00	35,592	4.00
Yes	45347	VFDs for 2x50HP Pumps	2	30,814	4.10	30,814	4.10
Yes	45082	Pumps w/Trimmed Impellers	2	96,205	2.00	96,205	2.00
Subtotal			**21**	**1,685,191**	**139.00**	**1,685,191**	**139.00**
No	45346	VFDs on 2x75HP	2	55,617	14.40		
No	43157	US/Model # H333A Motor 15HP - 50HP	2	7,260	1.36		
No	21490	Motor 60HP - 200HP	2	5,364	1.01		
No	19342	Motor 15HP - 50HP	1	3,630	0.68		
No	20379	Motor 15HP - 50HP	1	3,630	0.68		
No	20379	Motor 15HP - 50HP	1	3,630	0.68		
No	20379	TEFC	1	3,630	0.68		
No	19200	Motor 60HP - 200HP	1	3,352	0.63		
No	19200	Motor 60HP - 200HP	1	3,352	0.63		
No	19200	Motor 60HP - 200HP	1	3,352	0.63		
No	19200	Motor 60HP - 200HP	1	3,352	0.63		
No	21321	Motor 60HP - 200HP	1	3,352	0.63		
No	41144	Motor 60HP - 200HP	1	2,682	0.50		
No	42516	Baldor AEM41044Motor 15HP - 50HP	1	2,178	0.41		
No	20606	Motor 3HP - 10HP	1	1,260	0.24		
No	21981	Motor 3HP - 10HP	1	630	0.12		
No	20608	Motor 3HP - 10HP	1	630	0.12		
No	21984	Motor 1HP - 2HP	1	330	0.06		
No	40938	Motor 1HP - 2HP	1	330	0.06		
No	45399	US/Model # C072B Motor 1HP	1	165	0.03		
No	19241	VFD on Lift Pump	1	-39,300	30.00		
Subtotal			**24**	**68,426**	**54.18**	**0**	**0.00**
Total			**45**	**1,753,617**	**193.18**	**1,685,191**	**139.00**
Percent of Program Participants Evaluated *Ex Post*						**96%**	**72%**

Table 4-3 shows the *ex post* first year load impacts of the 1996 Agricultural EEI Program. Realization rates of 0.83 and 1.29 for gross kWh and kW load impacts were estimated.

Table 4-3
Summary of *Ex Post* Gross First Year Load Impacts
Pumping Measures
1996 Agricultural Energy Efficiency Incentives Program

			Ex Ante Gross Load Impacts		*Ex Post* Gross Load Impacts		Gross Realization Rates	
ID No.	**Measure Description**	**Quantity**	**kWh Savings**	**kW Reduced**	**kWh Savings**	**kW Reduced**	**kWh Savings**	**kW Reduced**
14176	VFD for High Lift Sewer Pump, VFD for Reclaimed water pump, VFD for Low Lift Sewage Pumps, VFD for Tertiary Influent Pump #1, Nitrified Recycle Pumps	8	749,226	88.20	549,592	59.80	0.73	0.68
45081	Pumps with Reduced Stages	2	292,389	20.00	308,393	49.40	1.05	2.47
45148	VFDs for 2x100hp & 1x50 hp	3	206,979	19.50	62,628	8.70	0.30	0.45
44226	VFDs on Water Pumps	2	191,545	3.20	115,031	15.00	0.60	4.69
44225	VFDs Potable Water Pumps	2	118,033	2.00	31,856	4.10	0.27	2.05
45082	Pumps w/Trimmed Impellers	2	96,205	2.00	281,030	35.60	2.92	17.80
45347	VFDs for 2x50HP Pumps	2	30,814	4.10	52,664	7.40	1.71	1.80
Total		**21**	**1,685,191**	**139.00**	**1,401,194**	**180.00**	**0.83**	**1.29**

Table 4-4 shows the net load impacts, both *ex ante* and *ex post*. These results show realization rates for the net load impacts of 0.69 and 1.08 for kWh and kW, respectively. A default net-to-gross ratio of 0.75 was used to estimate the net impacts as allowed under the *Retroactive Waiver for 1996 Agricultural energy Efficiency Incentives Program* approved by CADMAC on June 18, 1997.

Table 4-4
Summary of *Ex Post* Net Load Impacts
Pumping Measures
1996 Agricultural Energy Efficiency Incentives Program

				Ex Ante Gross Load Impacts			*Ex Post* Gross Load Impacts			*Ex Ante* Net Load Impacts		*Ex Post* Net Load Impacts		*Ex Post* Net Realization Rate	
On-Site Visit?	ID No.	Measure Description	Quantity	Net-to-Gross	kWh Savings	kW Red.	Net-to-Gross	kWh Savings	kW Red.	kWh Savings	kW Red.	kWh Savings	kW Red.	KWh Savings	kW Red.
Yes	14176	VFD for High Lift Sewer Pump, VFD for Reclaimed water pump, VFD for Low Lift Sewage Pumps, VFD for Tertiary Influent Pump #1, Nitrified Recycle Pumps	8	0.90	749,226	88.20	0.75	549,592	59.80	674,303	79.38	412,194	44.85	0.61	0.57
Yes	45081	Pumps with Reduced Stages	2	0.90	292,389	20.00	0.75	308,393	49.40	263,150	18.00	231,295	37.05	0.88	2.06
Yes	45148	VFDs for 2x100hp & 1x50 hp	3	0.90	206,979	19.50	0.75	62,628	8.70	186,281	17.55	46,971	6.53	0.25	0.37
Yes	44226	VFDs on Water Pumps	2	0.90	191,545	3.20	0.75	115,031	15.00	172,391	2.88	86,273	11.25	0.50	3.91
Yes	44225	VFDs Potable Water Pumps	2	0.90	118,033	2.00	0.75	31,856	4.10	106,230	1.80	23,892	3.08	0.22	1.71
Yes	45347	VFDs for 2x50HP Pumps	2	0.90	30,814	4.10	0.75	52,664	7.40	27,733	3.69	39,498	5.55	1.42	1.50
Yes	45082	Pumps w/Trimmed Impellers	2	0.90	96,205	2.00	0.75	281,030	35.60	86,585	1.80	210,773	26.70	2.43	14.83
Subtotal			**21**		**1,685,191**	**139.00**		**1,401,194**	**180.00**	**1,516,672**	**125.10**	**1,050,896**	**135.00**	**0.69**	**1.08**
No	19200	Motor 60HP - 200HP	1	0.75	3,352	0.63	0.75	2,787	0.82	2,514	0.4725	2,090	0.61	0.83	1.29
No	19200	Motor 60HP - 200HP	1	0.75	3,352	0.63	0.75	2,787	0.82	2,514	0.4725	2,090	0.61	0.83	1.29
No	19200	Motor 60HP - 200HP	1	0.75	3,352	0.63	0.75	2,787	0.82	2,514	0.4725	2,090	0.61	0.83	1.29
No	19200	Motor 60HP - 200HP	1	0.75	3,352	0.63	0.75	2,787	0.82	2,514	0.4725	2,090	0.61	0.83	1.29
No	19241	VFD on Lift Pump	1	0.9	-39,300	30.00	0.75	-32,677	38.85	-35,370	27	-24,508	29.14	0.69	1.08
No	19342	Motor 15HP - 50HP	1	0.75	3,630	0.68	0.75	3,018	0.88	2,723	0.51	2,264	0.66	0.83	1.29
No	20379	TEFC	1	0.75	3,630	0.68	0.75	3,018	0.88	2,723	0.51	2,264	0.66	0.83	1.29
No	20379	Motor 15HP - 50HP	1	0.75	3,630	0.68	0.75	3,018	0.88	2,723	0.51	2,264	0.66	0.83	1.29
No	20379	Motor 15HP - 50HP	1	0.75	3,630	0.68	0.75	3,018	0.88	2,723	0.51	2,264	0.66	0.83	1.29
No	20606	Motor 3HP - 10HP	1	0.75	1,260	0.24	0.75	1,048	0.31	945	0.18	786	0.23	0.83	1.29
No	20608	Motor 3HP - 10HP	1	0.75	630	0.12	0.75	524	0.16	473	0.09	393	0.12	0.83	1.29
No	21321	Motor 60HP - 200HP	1	0.75	3,352	0.63	0.75	2,787	0.82	2,514	0.4725	2,090	0.61	0.83	1.29
No	21490	Motor 60HP - 200HP	2	0.75	5,364	1.01	0.75	4,460	1.31	4,023	0.7575	3,345	0.98	0.83	1.29
No	21981	Motor 3HP - 10HP	1	0.75	630	0.12	0.75	524	0.16	473	0.09	393	0.12	0.83	1.29
No	21984	Motor 1HP - 2HP	1	0.75	330	0.06	0.75	274	0.08	248	0.045	206	0.06	0.83	1.29
No	40938	Motor 1HP - 2HP	1	0.75	330	0.06	0.75	274	0.08	248	0.045	206	0.06	0.83	1.29
No	41144	Motor 60HP - 200HP	1	0.75	2,682	0.50	0.75	2,230	0.65	2,012	0.375	1,673	0.49	0.83	1.29
No	42516	Baldor AEM41044Motor 15HP - 50HP	1	0.75	2,178	0.41	0.75	1,811	0.53	1,634	0.3075	1,358	0.40	0.83	1.29
No	43157	US/Model # H333A Motor 15HP - 50HP	2	0.75	7,260	1.36	0.75	6,037	1.76	5,445	1.02	4,527	1.32	0.83	1.29
No	45346	VFDs on 2x75HP	2	0.9	55,617	14.4	0.75	46,244	18.65	50,055	12.96	34,683	13.99	0.69	1.08
No	45399	US/Model # C072B Motor 1HP	1	0.75	165	0.03	0.75	137	0.04	124	0.0225	103	0.03	0.83	1.29
Subtotal			**24**		**68,426**	**54.18**		**56,794**	**70.16**	**53,767**	**47.295**	**42,671**	**52.62**	**0.79**	**1.11**
Total			**45**		**1,753,617**	**193.18**		**1,457,988**	**250.16**	**1,570,439**	**172.40**	**1,093,566**	**187.62**	**0.70**	**1.09**

Table 4-5 shows the *ex post* net load impacts for the 1996 Agricultural EEI Program pumping measures.

Table 4-5
***Ex Post* Net Load Impacts**
Program Level
Pumping Measures
1996 Agricultural Energy Efficiency Incentives Program

	kWh Savings	kW Reduced
Ex Ante Gross Load Impacts	1,753,617	193.18
Ex Post Gross Realization Rate	0.83	1.29
Ex Post Gross Load Impacts	1,457,988	250.16
Net-to-gross	0.75	0.75
Net Impacts	1,093,566	187.62

4.3 ID No. 14176 - Adjustable Speed Drives on Eight Pumps

4.3.1 Pre-Installation Equipment and Operation

Eight adjustable speed drives (ASD) were installed on pumps at this water treatment facility. The plant operates 24 hours per day, year round. The ASD's were installed on the five pumping processes as follows:

- One ASD on High Lift Sewage Pump - 150 hp
- Three ASDs on Low Lift Sewage Pumps - 50 hp
- One ASD on Tertiary Influent Pump #1 - 30 hp
- Two ASDs on Nitrified Recycle Pumps - 15 hp
- One ASD on Reclaimed Water Pump - 100 hp

Although more ASDs were installed on the backup pumps of these processes, this is the amount that was incentivised because it is the maximum that would be operating at any given time.

The low lift pumps bring sewage from the city to the high lift pumps. The high lift pumps can only take 2.0 million gallons per day (MGD). If the low lift pumps are receiving more than 2.0 MGD from the city the excess is pumped by the low lift pumps to another plant. Flow data shows that the high lift pumps are pumping a constant 2.0 MGD for 20 hours/day and at a lesser load for 4 hours/day. The low lift pumps vary quite significantly throughout the day.

The Tertiary Influent, Nitrified Recycle, and Reclaimed Water pumps are new installations.

4.3.2 Energy Efficiency Improvement

The installation of ASD's to the various pumps has significantly reduced the overall energy consumption of these processes. By allowing the motors to slow their speed to match the load imposed by the process reduces the energy required to pump the volume of water. The brake horsepower of a motor is reduced by the cube of the speed (standard engineering principals).

4.3.3 Source of Savings

Reduced horsepower required to match low pumping demand situations.

4.3.4 Ex Ante Load Impact Estimates

The *ex ante* load impacts were estimated for each pump using an engineering method. These results were then aggregated and reported under a single ID No. Basic operating assumptions for the pumps were formulated and initial hourly load impacts were estimated through a software program called the *Allen Bradley Energy Savings Comparison Program.* The hourly result from the program was then put into a spreadsheet that calculated the annual impacts.

ASD on One High Lift Sewer Pump

Capacity at a water reuse facility was increased. One high lift sewer pump was added and was to operate at an average of 80 percent capacity. The base case used to estimate the load impacts assumed the pump would be controlled at 80 percent by pump discharge throttling. An adjustable speed drive will be used to control the pumps at the 80 percent level, thereby reducing energy use.

The *Allen Bradley Energy Savings Comparison Program* was used to estimate the *ex ante* load impacts attributed to the ASDs. The hourly impacts were estimated through the Allen Bradley program were used in a spreadsheet to estimate the annual savings for the pump. Key assumptions used to estimate the load impacts of the ASDs are shown in Table 4-6.

Table 4-6
Key Assumptions for *Ex Ante* Load Impact Estimates
ASD on High Lift Sewer Pump
ID No. 14176

Pump efficiency	75%
Motor efficiency	95.2%
Average percent of operating capacity	80%
Motor rated horsepower	150
Head, ft	200
Flow, gpm	1,740

The *ex ante* load impacts for the ASDs are shown in Table 4-7.

Table 4-7
***Ex Ante* kW and kWh Impacts**
ASD on High Lift Sewer Pump
ID No. 14176

Time-of-Use Period	kWh Savings	kW Reduced
Summer On-peak	26,180	
Summer Semi-peak	33,660	
Summer Off-peak	66,640	
Winter On-peak	15,198	
Winter Semi-peak	65,858	
Winter Off-peak	94,996	
Total Impacts	302,532	34.0

ASDs on Three Low Lift Sewage Pumps

Capacity at a water reuse facility was increased. Three 50 hp low lift sewage pumps were added. Pump No. 1 was to operate continuously at 90 percent capacity. Pump No. 2 was to operate intermittently at 60 percent capacity. Pump No. 3 was to operate intermittently at 20 percent capacity. The base case used to estimate the load impacts assumed the three pumps would be controlled by pump discharge throttling. Adjustable speed drives will be used to control the pumps at the normal operating level, thereby reducing energy use.

The *Allen Bradley Energy Savings Comparison Program* was used to estimate the *ex ante* load impacts attributed to the ASDs. The hourly impacts were estimated through the Allen Bradley program were used in a spreadsheet to estimate the annual savings for each pump. Key assumptions used to estimate the load impacts of the ASDs are shown in Table 4-8.

Table 4-8
Key Assumptions for *Ex Ante* Load Impact Estimates
ASDs on Three Low Lift Sewage Pumps
ID No. 14176

Pump efficiency	71%
Motor efficiency	93.6%
Rated motor horsepower	50
Average percent of operating capacity	90%, 60%, 20%
Head, ft	54 ft.
Flow capacity, gpm	1,850

The *ex ante* load impacts for the ASDs are shown in Table 4-9.

Table 4-9
***Ex Ante* kW and kWh Impacts**

ASDs on Three Low Lift Sewage Pumps
ID No. 14176

Time-of-Use Period	kWh Savings	kW Reduced
Summer On-peak	16,860	
Summer Semi-peak	18,370	
Summer Off-peak	24,940	
Winter On-peak	10,357	
Winter Semi-peak	37,043	
Winter Off-peak	36,622	
Total Impacts	144,162	20.2

ASD on One Tertiary Influent Pump

Capacity at a water reuse facility was increased. One tertiary influent pump was added and was to operate at an average of 80 percent capacity. The base case used to estimate the load impacts assumed the pump would be controlled at 80 percent by pump discharge throttling. An adjustable speed drive will be used to control the pumps at the 80 percent level, thereby reducing energy use.

The *Allen Bradley Energy Savings Comparison Program* was used to estimate the *ex ante* load impacts attributed to the ASDs. The hourly impacts were estimated through the Allen Bradley program were used in a spreadsheet to estimate the annual savings for each pump. Key assumptions used to estimate the load impacts of the ASDs are shown in Table 4-10.

Table 4-10
Key Assumptions for *Ex Ante* Load Impact Estimates
ASD on One Tertiary Influent Pump
ID No. 14176

Pump efficiency	80%
Motor efficiency	92.7%
Average percent of operating capacity	80%
Rated total head, ft	32
Capacity at rated head, gpm	1,720
Operating head range at max rpm, ft	16 to 32

The *ex ante* load impacts for the ASDs are shown in Table 4-11.

Table 4-11
***Ex Ante* kW and kWh Impacts**
ASD on One Tertiary Influent Pump
ID No. 14176

Time-of-Use Period	kWh Savings	kW Reduced
Summer On-peak	3,850	
Summer Semi-peak	4,950	
Summer Off-peak	9,800	
Winter On-peak	2,235	
Winter Semi-peak	9,685	
Winter Off-peak	13,970	
Total Impacts	44,490	5.0

ASDs on Two Nitrified Recycle Pumps

Capacity at a water reuse facility was increased. Two nitrified recycle pumps were to be added and operated at an average of 80 percent capacity. The base case used to estimate the load impacts assumed the two pumps would be controlled at 80 percent by pump discharge throttling. Adjustable speed drives will be used to control the pumps at the 80 percent level, thereby reducing energy use.

The *Allen Bradley Energy Savings Comparison Program* was used to estimate the *ex ante* load impacts attributed to the ASDs. The hourly impacts were estimated through the Allen Bradley program were used in a spreadsheet to estimate the annual savings for each pump. Key assumptions used to estimate the load impacts of the ASDs are shown in Table 4-12.

Table 4-12
Key Assumptions for *Ex Ante* Load Impact Estimates
ASDs on Nitrified Recycle Pumps
ID No. 14176

Pump efficiency	71%
Motor efficiency	90.8%
Average percent of operating capacity	80%
Rated total head, ft	7
Capacity at rated head, gpm	2,800
Operating head range at max rpm, ft	6 to 8

The *ex ante* load impacts for the ASDs are shown in Table 4-13.

Table 4-13
***Ex Ante* kW and kWh Impacts**
ASDs on Nitrified Recycle Pumps
ID No. 14176

Time-of-Use Period	kWh Savings	kW Reduced
Summer On-peak	3,080	
Summer Semi-peak	3,960	
Summer Off-peak	7,840	
Winter On-peak	1,788	
Winter Semi-peak	7,748	
Winter Off-peak	11,176	
Total Impacts	35,592	4

ASD on One Reclaimed Water Pump

Capacity at a water reuse facility was increased. One reclaimed water pump was added and was to operate at an average of 80 percent capacity. The base case used to estimate the load impacts assumed the pump would be controlled at 80 percent by pump discharge throttling. An adjustable speed drive will be used to control the pumps at the 80 percent level, thereby reducing energy use.

The *Allen Bradley Energy Savings Comparison Program* was used to estimate the *ex ante* load impacts attributed to the ASDs. Key assumptions used to estimate the load impacts of the ASDs are shown in Table 4-14.

Table 4-14
Key Assumptions for *Ex Ante* Load Impact Estimates
ASD on Reclaimed Water Pump
ID No. 14176

Pump efficiency	82%
Motor efficiency	94.8%
Average percent of operating capacity	80%
Motor rated horsepower	100
Head, ft	200
Flow, gpm	1,400

The *ex ante* load impacts for the ASDs are shown in Table 4-15.

Table 4-15
***Ex Ante* kW and kWh Impacts**
ASD on Reclaimed Water Pump
ID No. 14176

Time-of-Use Period	kWh Savings	kW Reduced
Summer On-peak	19,250	
Summer Semi-peak	24,750	
Summer Off-peak	49,000	
Winter On-peak	11,175	
Winter Semi-peak	48,425	
Winter Off-peak	69,850	
Total Impacts	222,450	25.0

4.3.5 Ex Post Load Impact Estimates

The *ex post* load impacts for this project were estimated using an engineering based methodology. Spot measurements were taken and data loggers installed to evaluate the operating characteristics of the installed measures. Each measure was evaluated separately and then aggregated and reported for the total project.

ASDs on Three Low Lift Pumps

There are a total of four low lift pumps. Each pump has Adjustable speed drives were installed on three of the four pumps through the Agricultural EEI Program. The fourth pump serves as a backup role. Typical operation includes two or three of the four pumps at one time. As the flow decreases the speed of all pumps is reduced to match. To determine the savings, spot measurements of the control frequency were taken and correlated with flow readings from the customer's SCADA system. A power versus flow curve was developed using the relationship of flow and power defined in standard pump laws as shown in Eq. 4-1.

$$\text{(Eq. 4-1)} \quad \frac{(GPM_1)}{(GPM_2)} = \frac{(kW_1)^3}{(kW_2)^3}$$

Flow history was obtained from the SCADA system and a model of flow versus power was built to estimate annual energy consumption. Both pre- and post-retrofit energy use was based on the flow history from the SCADA system. The energy usage was calculated at the various flow levels using the percent of full gpm as the load factor of the baseline,´constant speed, pumps.

The *ex post* pre- and post-retrofit energy use calculations are shown in Table 4-16.

Table 4-16
Low Lift Pumps
***Ex Post* Load Impacts**
ID No. 14176

Hour	GPM	GPM per Pump	Hz	RPM	No. Pumps	Pre kW	Post kW	kW Reduced
Full[a]	1,850	1,850	60.0	1,185	1.0	28.2	31.1	-2.9
Base[b]	2,830	1,415	54.4	1,074	2.0	45.8	27.8	18.0
1	1,700	850	32.7	645	2.0	27.5	6.0	21.5
2	1,700	850	32.7	645	2.0	27.5	6.0	21.5
3	1,285	1,285	49.4	976	1.0	20.8	10.4	10.4
4	1,285	1,285	49.4	976	1.0	20.8	10.4	10.4
5	1,285	1,285	49.4	976	1.0	20.8	10.4	10.4
6	1,285	1,285	49.4	976	1.0	20.8	10.4	10.4
7	2,400	1,200	46.1	911	2.0	38.9	17.0	21.9
8	2,400	1,200	46.1	911	2.0	38.9	17.0	21.9
9	3,230	1,077	41.4	818	3.0	52.3	18.4	33.9
10	3,230	1,077	41.4	818	3.0	52.3	18.4	33.9
11	2,800	1,400	53.8	1,063	2.0	45.4	26.9	18.4
12	2,800	1,400	53.8	1,063	2.0	45.4	26.9	18.4
13	2,535	1,268	48.7	962	2.0	41.1	20.0	21.1
14	2,535	1,268	48.7	962	2.0	41.1	20.0	21.1
15	2,465	1,233	47.4	936	2.0	39.9	18.4	21.6
16	2,465	1,233	47.4	936	2.0	39.9	18.4	21.6
17	2,800	1,400	53.8	1,063	2.0	45.4	26.9	18.4
18	2,800	1,400	53.8	1,063	2.0	45.4	26.9	18.4
19	3,125	1,042	40.0	791	3.0	50.6	16.6	34.0
20	3,125	1,042	40.0	791	3.0	50.6	16.6	34.0
21	3,370	1,123	43.2	853	3.0	54.6	20.9	33.7
22	3,370	1,123	43.2	853	3.0	54.6	20.9	33.7
23	2,600	1,300	50.0	987	2.0	42.1	21.6	20.6
24	2,600	1,300	50.0	987	2.0	42.1	21.6	20.6

TOU Period	Operating Schedule	Hours per Year	Avg kW Reduced	kWh Savings
Summer On	12:00-18:00	742	20.1	14,895
Summer Semi	7:00-11:00 & 19:00-22:00	954	29.5	28,149
Summer Off	23:00-24:00 & 1:00-6:00	1,976	15.7	31,056
Winter On	18:00-20:00	441	28.8	12,698
Winter Semi	7:00-17:00 & 21:00-22:00	1,911	24.6	46,994
Winter Off	23:00-24:00 & 1:00-6:00	2,736	15.7	43,001
Total				**176,793**

Notes: (a) Rated full load operation.
(b) Spot measurement of actual operations.

High Lift Pump

There are two identical high lift pumps. Each has an adjustable speed drive. However, only one pump operates at a time. The pumps are cycled to keep the run hours balanced.

Flow data was collected for this pump as well. The high lift pumps continuously pump 2.0 MGD, except for about four hours during the middle of the night. The reduced load is approximately the same every night. The reduced pumping occurs from about 1:30 a.m. to 6:00 a.m. seven days/week.

Monitoring equipment was installed on the active ASD to record kW. These data were input into an hourly model plotting kW versus Flow. The pre-retrofit hourly energy consumption was calculated using the same methodology used for the low lift pumps. The hourly full as a percent of full or rated gpm was used as a load factor of the baseline or constant speed pump.

The *ex post* gross load impacts are shown in Table 4-17.

Table 4-17
High Lift Pumps
***Ex Post* Load Impacts**
ID No. 14176

Hour	GPM	GPM per Pump	Hz	RPM	No. Pumps	Pre kW	Post kW	kW Reduced
Base[(a)]	1,740	1,740	60.0	1,785	1.0	90.9	90.9	0.0
1	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
2	1,320	1,320	45.5	1,354	1.0	71.8	39.7	32.2
3	1,075	1,075	37.1	1,103	1.0	58.5	21.4	37.1
4	975	975	33.6	1,000	1.0	54.2	16.0	38.2
5	900	900	31.0	923	1.0	50.0	12.6	37.4
6	1,180	1,180	40.7	1,211	1.0	64.2	28.4	35.9
7	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
8	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
9	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
10	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
11	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
12	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
13	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
14	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
15	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
16	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
17	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
18	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
19	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
20	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
21	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
22	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
23	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4
24	1,389	1,389	47.9	1,425	1.0	75.6	46.3	29.4

TOU Period	Operating Schedule	Hours per Year	Avg kW Reduced	kWh Savings
Summer On	12:00-18:00	742	29.4	21,779
Summer Semi	7:00-11:00 & 19:00-22:00	954	29.4	28,002
Summer Off	23:00-24:00 & 1:00-6:00	1976	33.6	66,393
Winter On	18:00-20:00	441	29.4	12,944
Winter Semi	7:00-17:00 & 21:00-22:00	1911	29.4	56,092
Winter Off	23:00-24:00 & 1:00-6:00	2736	33.6	91,929
Total				**277,141**

Tertiary Influent Pumps

The tertiary influent pumps were installed in December 1996, but did not begin normal operation until Aug. 1997. Therefore, the true first year savings is only 5/12th of the annual savings. The annual profile is fairly constant so a linear deduction is appropriate. The savings presented in the overall site savings are annualized savings (12 months). The estimated 12 month savings are 55,440 kWh. The estimated five month impacts are 23,262 kWh.

There are two tertiary influent pumps. Each has an ASD. The pumps were originally designed for one pump to handle the load and the second would be backup. The operation verified during the site visit indicated that typical operation was both pumps operating at part load. This is because the capacity was just over the capacity of one pump. Therefore, two pumps operating at fairly low loads is the common operation. Savings were determined for both of the ASDs since they operate as a "pumping system."

Monitoring equipment was installed on both tertiary pumps for approximately two weeks. The data loggers recorded true kW and power factor. They were installed on the source side of the ASD's. The average hourly profile was developed from the monitoring data. Also the average hourly profile for the system flow was developed with flow data provided by the customer's SCADA system. The post-retrofit energy consumption was then determined by extrapolating the daily consumption annually.

The pre-retrofit energy consumption was calculated using the design conditions for full load and calculating the head pressure at the partial flows using Equation 4-2.

$$\text{(Eq. 4-2)} \quad Hp_2 = Hp_1 * \left(\frac{Flow_1^2}{Flow_2^2} \right)$$

where:

Hp_1 = Head pressure of system at full load (rated Hp)

Hp_2 = Head pressure of system at partial flow

$Flow_1$ = Full flow (rated gpm)

$Flow_2$ = Partial flow (rated gpm)

After calculating the head pressure at the various partial flows, the kW was calculated using Equation 4-3.

(Eq. 4-3) $$BHP = \frac{(GPM) \times (s) \times (Hp)}{(3{,}960) \times (h_p)}$$

where:

GPM = Flow (gpm)

s = specific gravity (= 1 for water)

Hp = Head pressure at the specified GPM

3,960 = a constant

η_p = Pump efficiency

The energy savings was determined as the sum of the hourly pre-retrofit kW minus the hourly post-retrofit kW for the average daily profile for weekdays and weekends. The daily savings was extrapolated to an annual basis by multiplying by the number of weekend days and weekday days. The profile obtained by the monitoring was representative of the annual profile according to the operation explained by the customer. Table 4-18 shows the results of these calculations.

Table 4-18
Tertiary Influent Pumps
***Ex Post* Load Impacts**
ID No. 14176

Day Type	Weekdays				Weekends			
Hour	Avg. GPM	Post Avg. kW	Pre Avg. kW	kW Reduced	Avg. GPM	Post Avg. kW	Pre Avg. kW	kW Reduced
1:00	1,495	9.33	15.9	6.57	1,495	9.61	15.9	6.30
2:00	1,495	9.45	15.9	6.45	1,495	9.85	15.9	6.05
3:00	1,285	8.04	18.6	10.56	1,495	9.94	15.9	5.96
4:00	1,285	7.10	18.6	11.50	1,285	8.85	18.6	9.75
5:00	1,285	7.27	18.6	11.33	1,285	7.59	18.6	11.01
6:00	1,285	7.88	18.6	10.72	1,285	7.63	18.6	10.97
7:00	1,495	9.67	15.9	6.23	1,285	8.22	18.6	10.38
8:00	1,805	9.49	13.3	3.81	1,495	9.60	15.9	6.30
9:00	1,805	12.66	13.3	0.64	1,495	10.05	15.9	5.85
10:00	1,805	10.05	13.3	3.25	1,495	9.83	15.9	6.07
11:00	1,495	9.42	15.9	6.48	1,495	10.31	13.3	2.99
12:00	1,495	9.62	15.9	6.28	1,495	10.76	13.3	2.54
13:00	1,495	9.49	15.9	6.41	1,495	10.57	13.3	2.73
14:00	1,495	9.66	15.9	6.24	1,495	10.65	13.3	2.66
15:00	1,495	9.39	15.9	6.51	1,495	9.42	15.9	6.48
16:00	1,495	9.60	15.9	6.30	1,495	9.70	15.9	6.20
17:00	1,495	9.32	15.9	6.58	1,495	8.86	15.9	7.04
18:00	1,495	10.24	15.9	5.66	1,495	9.62	15.9	6.28
19:00	1,495	9.66	15.9	6.24	1,495	9.58	15.9	6.32
20:00	1,495	9.64	15.9	6.26	1,495	9.54	15.9	6.36
21:00	1,495	9.68	15.9	6.22	1,495	9.63	15.9	6.27
22:00	1,495	9.68	15.9	6.22	1,495	9.67	15.9	6.23
23:00	1,495	9.67	15.9	6.23	1,495	9.48	15.9	6.42
24:00	1,495	9.70	15.9	6.20	1,495	9.60	15.9	6.30

TOU Period	Operating Schedule	Hours per Year	Avg. kW Reduced	kWh Savings
Summer On	12:00-18:00	742	6.28	4,662
Summer Semi	7:00-11:00 & 19:00-22:00	954	5.04	4,807
Summer Off	23:00-24:00 & 1:00-6:00	1,976	6.97	13,771
Winter On	18:00-20:00	441	6.05	2,669
Winter Semi	7:00-17:00 & 21:00-22:00	1,911	5.48	10,463
Winter Off	23:00-24:00 & 1:00-6:00	2,736	6.97	19,067
Total				**55,440**

Nitrified Recycle Pumps

The installation of the nitrified recycle pumps were verified. The savings were given the same realization rate as determined for the other similar ASD applications at this site. The realization rate for annual kWh savings for the tertiary influent, low lift, and high lift pumps is 1.17. The average realization rate for those pumps during each time-of-use period was calculated and applied to the *ex ante* energy savings for each time-of-use period for the nitrified recycle pumps.

Table 4-19
Nitrified Recycle Pumps
***Ex Post* Load Impacts**
ID No. 14176

	***Ex Ante* kWh Savings**	**Avg Realization Rate (Note 1)**	***Ex Post* kWh Saving**	**Hours per Year**	**Avg. kW**	**Coin kW**
Summer On	3,080	0.98	3,006	742	4.1	4.1
Summer Semi	3,960	1.11	4,403	954	4.6	
Summer Off	7,840	1.22	9,530	1,976	4.8	
Winter On	1,788	1.09	1,950	441	4.4	4.4
Winter Semi	7,748	1.07	8,266	1,911	4.3	
Winter Off	11,176	1.17	13,064	2,736	4.8	
Total	**35,592**		**40,219**	**8,760**		
Note 1.	Average *ex post* realization rate for Low Lift, High Lift and Tertiary Pumps.					

Reclaimed Water Pumps

The reclaimed water pumps are part of the plant expansion. They are new pumps added to the system. The new pumps were installed with ASD's. There are two 100 hp pumps that are designed to operate with one pump on-line and the other 100 percent backup.

However, the new addition to the plant had not received the required permits from the Department of Health and therefore this portion of the new system has not been in operation. The pumps and ASD's were installed by the end of 1996 but have sat idle. The permits were granted during the fourth quarter of 1997, but the associated distribution system (pipes) was not completed, so the pumps continue to be unused as of November 1997.

Because of the reclaimed water pumps were not in operation during 1997 the first year load impacts from the installation of ASDs on these pumps is zero. There should be savings in future years when the system is in operation.

Summary of Ex Post Load Impacts

Table 4-20 presents a summary of the total load impacts of the ASDs installed at this site by time-of-use period.

Table 4-20
Ex Post kW and kWh Savings by Time-of-Use Period
ID No. 14176

	kWh Savings	Avg. kW	Coin kW
Summer On	44,342	59.8	59.8
Summer Semi	65,361	68.5	
Summer Off	120,751	61.1	
Winter On	30,262	68.6	68.6
Winter Semi	121,816	63.7	
Winter Off	167,061	61.1	
Total	549,592		

4.3.6 Comparison with Ex Ante Estimated Impacts

Comparison of the *ex ante* and *ex post* estimates of demand saving show a realization rate of 0.68 and annual energy saving realization rate of 0.73. The main reasons for the differences are:

- Reclaimed water pumps have not been in operation. They are part of the new addition to the plant that has not received certification to begin operation. This accounts for approximately 30 percent of the estimated kWh savings, thus skewing the realization rates.
- The load profiles estimated prior to the ASD installations were slightly on the high side or conservative which would generally provide lesser savings.
- The *ex ante* savings estimates were calculated using the using an Allen Bradley software program. It is difficult to determine the methodology and calculations performed by this program to produce the savings estimate.

Table 4-21 shows the realization rate for each of the individual measures and the aggregate project.

Table 4-21
Comparison of *Ex Ante* and *Ex Post* Total Site Demand and Energy Impacts
ID No. 14176

	Ex Ante		Ex Post		Realization Rate	
Pump	kW	kWh	kW	kWh	kW	kWh
Nitrified Recycle Pumps	4.00	35,592	4.05	40,219	1.01	1.13
Low Lift Sewage Pumps	20.20	144,162	20.07	176,793	0.99	1.23
High Lift Sewage Pumps	34.00	302,532	29.35	277,141	0.86	0.92
Tertiary Influent Pump	5.00	44,490	6.28	55,440	1.26	1.25
Reclaimed Water Pump	25.00	222,450	0.00	0	0.00	0.00
Project Total	88.20	749,226	59.76	549,592	0.68	0.73

4.3.7 *Persistence of the Measure*

All of the variable speed drives are an integral part of the plant and pumping operation. There is no reason to believe that they will not operate the expected life of the equipment as specified in the project file, 15 years for each measure.

4.4 ID No. 44226 - Adjustable Speed Drives on Two 60 HP Pumps

4.4.1 *Pre-Installation Equipment and Operation*

This project involves the installation of adjustable speed drives (ASD's) on pumps at a municipal water district pumping station. This station consists of three (3) 60 hp pumps. The station demand is dependent on the water demand in that area. The area is mainly a residential subdivision.

The station operates 24 hours/day, 365 days/year. The pumps are set up to operate in a lead/lag sequence. Pump #1 typically acts as the lead pump. The other two pumps are each staged on as demand requires. It is rare that there is ever more than two pumps on-line at the same time. The greatest loads can typically be handled by the two of the three pumps.

4.4.2 *Energy Efficiency Improvement*

The installation of ASD's on each of the three pumps has significantly reduced the total energy consumption of the station. The installation of the ASD's has allowed the discharge throttling valves ("Cla" valves) to be removed and thus reducing the head pressure of the pumps. The ASD's reduce energy consumption by slowing the speed of the motors to match the flow demand rather than throttling the flow with a "Cla" valve. By reducing the speed of the motors the brake horsepower is reduced by the cube of the speed (standard engineering principals).

4.4.3 *Source of Savings*

Reduced horsepower required to match low pumping demand situations.

4.4.4 *Ex Ante Load Impact Estimates*

Variable frequency drives were installed on two of three motors at a water pump station. The station has three (3) 60 hp. Each pump has a capacity of 800 gpm.

The *ex ante* load impact estimates were calculated using an engineering based methodology. The Bell & Gossett Centrifugal Pump Selection Guide Software was used to calculate the energy savings. Bell & Gossett compares pump operation with variable frequency drives versus constant speed drives. An operational profile was developed based on billing data and usage curves from Bell & Gossett. The results are shown in Table 4-22.

Table 4-22
***Ex Ante* Energy Savings Estimates**
ID No. 44226

	kWh
Pre-Retrofit	255,001
Post-Retrofit	63,456
Energy Savings	191,545

Ex ante demand impacts were estimated by taking the input horsepower from the Bell & Gossett run for the pre- and post-retrofit scenarios. These horsepower levels were converted to kW by the standard motor conversion factors, assuming motor efficiency of 1.0. The *ex ante* demand impacts are shown in Table 4-23.

Table 4-23
***Ex Ante* Demand Reduction Estimates**
ID No. 44226

	kW
95% flow with a constant speed drive	74.3
95% flow with a variable speed drive	71.1
Demand Reduction	3.2

4.4.5 Ex Post Load Impact Estimates

The main approach to the analysis utilized pre- and post-retrofit billing data. The billing analysis was possible because the pump station is on a dedicated utility electric meter. There are minimal miscellaneous loads other than the pumps and there have been no changes to those loads. Hence, the billing data represent essentially end-use metered data.

The billing analysis utilized billing history from 1994 through 1997. The average monthly consumption for each month of the year from 1994 through 1996 was calculated based on kWh/day. The actual start-up date was obtained for the VSD's in order to identify the starting month in 1997 that valid post-retrofit data could be used. The ASD's at this station started in May 1997, so the billing analysis includes five months of post-retrofit data. The billing data indicates little seasonal or monthly variation. The summer/winter consumption broke down to 48 percent/52 percent respectively. Given this, the May through October period is closely representative of the annual profile. Therefore, annualizing the savings was performed linearly by month (extrapolated by 12/5^{ths}). The period of October 1996 through April 1997 was used as a "blockout" period since this period would not be representative of normal operation due to the construction/installation that took place during that period.

Historical flow data was not available for the station or the individual pumps. The customer indicated that the monthly and annual flow should be consistent with previous years because there has not been much construction or changes to other conditions that would affect the demand on the pump station.

To help validate the billing analysis run time data from manual log sheets and ASD displays were obtained. The run hours of each pump indicate that the customer's report on the operating controls during pre- and post-retrofit periods were accurate. When an average load factor is assumed for each pump based on the pump's operation, the calculated kWh using the run hour information collaborates the billing data analysis results.

A summary of the billing history of this pump station is shown in Table 4-24.

Table 4-24
Billing Data (kWh/Day)
ID No. 44226

Month	1994/1995	1995/1996	Daily Avg.	1996/1997	Savings per Day	No. Days	Savings per Month
10	1,461	1,123	1,292			30	
11	1,292	951	1,122			31	
12	1,120	943	1,032			30	
1	893	793	843			31	
2	833	644	739			31	
3	865	612	739			28	
4	996	807	902			31	
5	1,119	1,040	1,080	889	191	30	**5,715**
6	1,189	1,089	1,139	780	359	31	**11,129**
7	1,384	1,133	1,259	848	411	30	**12,315**
8	1,366	1,251	1,309	848	461	31	**14,276**
9	1,289	1,329	1,309	1,164	145	31	**4,495**
Total kWh	418,920	355,360		293,920			
Five-Months Energy Savings							**47,930**
Annualized Energy Savings							**115,031**

Table 4-25 shows the *ex post* kW and kWh load impact estimates by time-of-use period.

Table 4-25
***Ex Post* kW and kWh Savings by Time-of-Use Period**
ID No. 44226

Time-of-Use Period	Hours	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742	11,101	15.0	15.0
Summer Semi-peak	954	14,273	15.0	
Summer Off-peak	1,976	29,563	15.0	
Winter On-peak	441	5,209	11.8	11.8
Winter Semi-peak	1,911	22,570	11.8	
Winter Off-peak	2,736	32,314	11.8	
Total	8,760	115,031		

4.4.6 Discussion

All of the VSD's were installed in 1996. However, the drives were not commissioned and put into operation until May 1997. The savings were determined for 1st year impact as well as annualized values. The values presented in the table below and in the program analysis represent the annualized savings estimates.

4.4.7 Comparison with Ex Ante Estimated Impacts

The realization rates for energy and demand for this project are shown in Table 4-26. Comparison of the *ex ante* and *ex post* estimates of demand reduction show a realization rate of 4.69 and annual energy saving realization rate of 0.60. The main reasons for the differences are:

- *Ex ante* savings estimation as a percent of the total bill were extraordinarily high. For this site the *ex ante* savings estimate was 65 percent of the total energy bill. The *ex post* results indicate 39 percent of the total energy was saved through the installation of the measure. This percentage of total energy is more reasonable for this technology.
- *Ex ante* savings calculations were developed using a manufactures (Bell & Gossett) software program. The input variables could not be confirmed or disputed.
- Load profile of each pump was provided by the customer. There was no evidence of hard data that supported how these profiles were developed. It is uncertain how accurate they are. This is a key variable to the software program that calculated the savings.

Table 4-26
Comparison of *Ex Ante* and *Ex Post* Demand and Energy Impacts
ID No. 44226

	Demand		Energy		Gas	
Ex Ante Load Impacts	3.2	Peak kW	191,545	kWh	-	Therm
Ex Post Load Impacts	15.0	kW	115,031	kWh	-	Therm
Difference	11.8	kW	-76,514	kWh	-	Therm
Realization Rate	4.69		0.60		n/a	

4.4.8 Persistence of the Measure

Although the savings are not as much as anticipated, the customer is very much an advocate of these retrofits. The persistence of this measure should be the rated equipment life as indicated in the project file, 15 years.

4.5 ID No. 45081 - Two 30 HP Pumps With Reduced Stages

4.5.1 Pre-Retrofit Equipment and Operation

This project involves of one of two municipal water supply pumping stations that had the impellers removed from two of the pumps. This station includes two (2) 30 horsepower (hp) pumps, of which at least one pump is running 24 hours/day. There are also four (4) 150 hp pumps that operate in a lag sequence. The total pumping capacity was designed far above and beyond immediately foreseeable requirements. The distribution system likely could not handle the pumping capacity of this station if it operated at maximum output. The baseline operation of the station was the two 30 hp pumps handling the capacity with the additional operation of one of the 150 hp pumps cycling on when demand was high. It was estimated by the customer that one of the four 150 hp pumps operated a significant amount of the time. The other three 150 hp pumps remain as backup and rarely operate.

All pumps at the station take suction from a common header. Each pump discharges through a pressure regulating valve ("PRV") to a common discharge header. This header feeds a surge tank with another "PRV" before it goes to the street main. The measured total pumping head for each pump was an average of 380 feet.

4.5.2 Energy Efficiency Improvement

The pumps were providing more total dynamic head than required. The two 30 hp pumps had one stage, or set of impellers, removed. Also, the PRV's at the main were modified to reduce the head pressure. The pumps were operating many hours of the day at an inefficient point on their performance curve. The retrofit and upgrade of the system has reduced the head pressure of the system and allowed optimization of the pumping station and thus reduced the energy consumption significantly. The retrofit results in savings during the customer's off-peak (pumping demand) hours by reducing the horsepower requirements of one or two of the 30 hp pumps and not requiring the operation of the 150 hp pumps.

4.5.3 Source of Savings

Energy and demand savings are a direct result of reduction in head pressure the pumps are required to overcome and the optimization of the pumping station as a whole.

4.5.4 Ex Ante Load Impact Estimates

The *ex ante* load impact estimates were based on an engineering analysis. The total dynamic head requirements were estimated, then the energy use was estimated through engineering calculations. The calculations were presented in a spreadsheet format as shown in Tables 4-27 through 4-30.

Table 4-27
***Ex Ante* Basic Operating Assumptions**
ID No. 45081

Pumps operate as needed (i.e., no control problems)		
Suction pressure	10 psi	design criteria
System operating pressure	125 psi	design criteria
Valve control & piping loss	14.70 psi	consulting engineer's estimate
Required pump head	129.70 psi	calculated
Motor Efficiency	2 @ 30 hp pumps	0.88
	4 @ 100 hp pumps	0.916

Table 4-28
***Ex Ante* Pre-Retrofit Load Estimates**
ID No. 45081

PRE-RETROFIT			
Pump	**P-1, P-2 (2-30 hp)**	**P3-P6 (4-150 hp)**	**Source**
Suction pressure	32 psi	32 psi	on-site measurement
Discharge pressure	200 psi	235 psi	on-site measurement
Pump head	168 psi	203 psi	calculated
Pump Energy Demand			
Flow	75 gpm	630 gpm	(from pump curve)
Head	388 feet	469 feet	(from above)
Pump Efficiency	0.55	0.4	(from pump curve
Motor Efficiency	0.88	0.916	(standard efficiency motor)
Pump Demand	13 bhp	187 bhp	calculated
Motor Demand	11 kW	152 kW	calculated
Maximum Energy Use	99,240 kWh/year	1,330,580 kWh/year	calculated @ 8,760 hours/year)
Equivalent Full Load Pump Operation, Average Year			
Assumes the two small pumps operate prior to the large pump operating.			
Pump	**Annual kWh**	**Annual Gallons**	
P-1	99,240		
P-2	99,240		
P-3	299,334		
Total Energy Use	497,814		
Total Water Pumped, Average Year		153,332,000	

The *ex ante* post-retrofit energy use was characterized by the worksheet shown in Table 4-29.

Table 4-29
***Ex Ante* Post-Retrofit Energy Use Estimates**
ID No. 45081

POST-RETROFIT			
Required pump total dynamic head (TDH)	300 feet		
Pump Energy Demand at New TDH			
Pump	**P-1, P-2 (2-30 hp)**	**P-3 through P-6 (4-150 hp)**	**Source**
Flow	250 gpm	1550 gpm	(from pump curve)
Head	300 feet	300 feet	(from above)
Pump Efficiency	0.798	0.836	(from pump curve)
Motor Efficiency	0.88	0.916	(standard efficiency motor)
Pump Demand	24 bhp	140 bhp	calculated
Motor Demand	20 kW	114 kW	calculated
One pump capacity	131,400,000 gallons per year	814,680,000 gallons per year	
Equivalent Full Load Pump Operation, Average Year			
Assumes the two small pumps operate prior to the large pump operating.			
Pump	**Gallons per Year**		
P-1	131,400,000		
P-2	21,932,000		
P-3	0		
Total Water Pumped, Average Year	153,332,000		
Pump Average Annual Energy Use	205,426 kWh/year		

The *ex ante* load impact estimates are shown in Table 4-30.

Table 4-30
***Ex Ante* Load Impact Estimates**
ID No. 45081

Ex Ante Energy Impacts				
	kWh per Year			
Pre-retrofit	497,814			
Post-retrofit	205,426			
Savings	292,388			
Distribution of Energy Savings per TOU Period				
Season	**Seasonal Distribution Share**	**TOU Period**	**Seasonal Distribution Share**	**kWh Saved**
Summer	0.42	On-peak	0.19	23,357
		Semi-peak	0.28	34,934
		Off-peak	0.53	64,512
Winter	0.58	On-peak	0.08	13,624
		Semi-peak	0.38	65,103
		Off-peak	0.54	90,859
Total				292,388
***Ex Ante* Demand Impacts**				
	kW			
Pre-retrofit	175			
Post-retrofit	155			
Reduction	20			

4.5.5 Ex Post Load Impact Estimates

Periodically pump tests are performed on each of the city's pumping stations. The results of the tests were obtained for periods before and after the retrofit of the pumps. In conjunction with the billing history and run time log sheets for each pump (provided by customer), the station pre- and post-retrofit consumption were estimated. The pump test results show an average measured total head pressure reduction of 125 feet, from 380 to 255 feet.

Table 4-31 shows the spot measurement and pump test data obtained for the 30 hp pumps.

Table 4-31
***Ex Post* Pump Test Results**
ID No. 45081

	Pump #1			**Pump #2**			
	Post		**Pre**	**Post**			**Pre**
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 4
Head (ft)	250.6	249.5	399.6	249.5	251.8	274.9	360.4
kW	19.3	20.2	14.6	19.4	20.9	20.8	21.0
GPM	258.4	271.6	62.1	260.9	278.5	247.4	130.7
kW/Gpm	0.07	0.07	0.24	0.07	0.08	0.08	0.16

The run hours of the pre- and post-retrofit pumps are shown in Table 4-32.

Table 4-32
***Ex Post* Run Hour Estimates**
ID No. 45081

		Run Hours					
	Month	**Pump #1**	**Pump #2**	**Pump #3**	**Pump #4**	**Pump #5**	**Pump #6**
Pre-Retrofit	Feb-96	0	273	359	97	187	18
	Mar-96	0	420	132	247	327	106
	Apr-96	334	638	17	144	156	61
	May-96	627	453	0	22	27	1
	Jun-96	482	449	37	232	100	75
	Jul-96	797	776	336	576	3	0
	8/1/1996-11/30/96	2,401	1,899	1,996	576	122	0
	10 Month Subtotal	4,641	4,908	2,877	1,894	922	261
	Annualized	**5,569**	**5,890**	**3,452**	**2,273**	**1,106**	**313**
Post-Retrofit	Dec-96	622	585	7	3	0	0
	Jan-97	442	843	0	0	0	0
	Feb-97	364	767	1	0	0	0
	Mar-97	498	628	1	1	0	0
	Apr-97	0	565	64	41	2	2
	May-97	624	562	90	65	3	0
	Jun-97	443	403	26	112	5	24
	Jul-97	445	495	40	128	44	13
	Aug-97	799	249	54	4	0	0
	9 Month Subtotal	4,237	5,097	283	354	54	39
	Annualized	**5,649**	**6,796**	**377**	**472**	**72**	**52**

Pre-retrofit consumption was estimated using the annual run hours estimated from 10 months of log sheet data for the year previous to the retrofit. These hours and the measured load (kW) of the pumps determined the annual kWh. The pre-retrofit measured load was provided by the pre-retrofit pump tests. The pump test data were obtained for the 30 hp pumps only, and thus the pre-retrofit kW of the 150 hp pumps was not available. The equivalent full load hours of the 150 hp pumps was determined from the run time data and the bill history to estimate the average load factor of the 150 hp pumps in order to achieve the station consumption as shown in the bill history. The total station consumption is the sum of the 30 hp and 150 hp pumps consumption. Equation 4-4 shows the pre-retrofit consumption calculations.

$$\text{(Eq. 4-4)}\quad kWh_{\text{Pre-retrofit}} = \left[\begin{array}{l}\text{Average of } (\text{Pre-kW}_{\text{Motor 1}} \,\&\, \text{Pre-kW}_{\text{Motor 2}}) \\ \text{x (Run hours / year}_{\text{Motor 1}} + \text{Run hours / year}_{\text{Motor 2}})\end{array}\right] + \left[(\text{Estimated load for 150 hp motor x Load factor}) \text{ x (Run hours / year)}\right]$$

$$= \left[\left(\frac{14.6\text{ kW} + 21.0\text{ kW}}{2}\right) \text{x } (5{,}569 + 5{,}890 \text{ hours})\right] + \left[(111.9\text{ kW x } 0.55) \text{ x } (7{,}145 \text{ hours})\right]$$

$$=$$

$$= 643{,}709 \text{ kWh / Year}$$

The post-retrofit consumption of the 30 hp pumps was calculated from the post-retrofit pump test measured kW and the run time data provided by the customer. The consumption of the 150 hp pump was estimated using the run hours and the same load as the pre-retrofit condition. A slight seasonal variance in the billing history indicated that the annualization of the post-retrofit consumption should be adjusted +10 percent for the remaining months of 1997. Equation 4-5 shows the calculations for the post-retrofit consumption.

$$\text{(Eq. 4-5)}\quad kWh_{\text{Post-retrofit}} = \left[\begin{array}{l}\text{Average of } (\text{Post-kW}_{\text{Test 1}} \text{ through Post-kW}_{\text{Test 5}}) \\ \text{x } (\sum_{i=1}^{5} \text{Run hours / year}_{\text{Motor i}}) \text{ x (Seasonal Adjustment Factor)}\end{array}\right] + \left[((\text{Estimated load for 150 hp motor}) \text{ x (Load factor)}) \text{ x (Run hours / year)}\right]$$

$$= \left[\left(\frac{19.3 + 20.2 + 19.4 + 20.9 + 20.8\text{ kW}}{5}\right) \text{x } (5{,}649 + 6{,}796 \text{ hours}) \text{ x } (1.1)\right] + \left[(111.9\text{ kW x } 0.55) \text{ x } (973 \text{ hours})\right]$$

$$= 335{,}316 \text{ kWh / year}$$

Equation 4-6 shows the *ex post* energy impact.

$$\text{(Eq. 4-6)}\quad \text{Ex Post kWh Saved} = kWh_{\text{Pre-retrofit}} - kWh_{\text{Post-retrofit}}$$

$$= 643{,}709 \text{ kWh} - 335{,}316 \text{ kWh}$$

$$= 308{,}393 \text{ kWh / year}$$

Billing data for 1996 showed that almost 59 percent of the consumption for the facility occurred during the summer season, i.e., May through September. The time-of-use savings values were based on the seasonal share of savings, which was allocated to the time-of-use period based on the hours for each period. The average kW reduced for each period was obtained by dividing the kWh saved by the number of run hours for the period. Table 4-33 shows the calculations for the time of use periods.

Table 4-33
***Ex Post* Load Impacts by Time-of-Use Period**
ID No. 45081

	Time-of-Use Period	Hours	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer	Summer On-peak	742	36,682.0	49.4	49.4
1996 Consumption	Summer Semi-peak	954	47,162	49.4	
372,960 kWh	Summer Off-peak	1,976	97,686.7	49.4	
Winter	Winter On-peak	441	10,996	24.9	24.9
1996 Consumption	Winter Semi-peak	1,911	47,648	24.9	
260,640 kWh	Winter Off-peak	2,736	68,218	24.9	
Total		8,760	308,393		

4.5.6 Comparison with Ex Ante Estimated Impacts

The run hours of the pre- and post-retrofit pumps are shown in Table 4-34. Comparison of the *ex ante* and *ex post* estimates of demand reduction show a realization rate of 2.47 and realization rate of 1.05 for energy savings. The main reasons for the differences are:

- Lower load factor observed for 30 hp pumps than estimated in the *ex ante* estimates; and
- The significant reduction in the operation of the 150 hp pumps was difficult to estimate in the *ex ante* estimates and, thus, was under estimated. The relatively high *ex post* demand impact estimate resulted in a high realization rate for demand.

Table 4-34
Comparison of *Ex Ante* and *Ex Post* Demand and Energy Impacts
ID No. 45081

	Demand	Energy	Gas
Ex Ante Load Impacts	20 Peak kW	292,389 kWh	- Therm
Ex Post Load Impacts	49.4 kW	308,393 kWh	- Therm
Difference	29.4 kW	16,004 kWh	- Therm
Realization Rate	2.47	1.05	n/a

4.5.7 Persistence of the Measure

The pumps have been permanently de-staged. The measure will continue to provide the savings for the estimate life of the measure, 15 years. The actual savings will be determined by the capacity requirements of that pumping station which are weather and population variant.

4.6 ID No. 45082 - Trimmed Impellers On Two Pumps

4.6.1 Pre-Retrofit Equipment and Operation

This project involves of one of two municipal water supply pumping stations that had the impellers trimmed from two of the pumps at the station. The station includes four (4) 100 horsepower pumps rated at 1,600 gallons per minute (gpm) each. The flow is regulated by a pressure regulating valve ("PRV") on each pump. Pump #1 is the lead pump and #2 cycles on and off as the lag pump. Pumps #3 & #4 are backups.

All pumps at the station take suction from a common header. Each pump discharges through a "PRV" to a common discharge header

4.6.2 Energy Efficiency Improvement

The pumps were providing more total dynamic head (TDH) than required to meet the demand for water. The impellers on pumps #1 & #2 were trimmed allowing the pressure regulating valve to operate in a more open position. This reduces the head pressure the pump must work to overcome. The pumps were operating many hours of the day at an inefficient point on their performance curve. The retrofit and upgrade of the system has reduced the head pressure of the system and has allowed optimization of the pumping station, thus, reducing energy consumption significantly. The retrofit results in savings during the customer's off peak (pumping demand) hours by reducing the total horsepower required to deliver the same volume of water at the system pressure.

4.6.3 Source of Savings

Energy and demand savings are a direct result of reduction in head pressure the pumps are required to overcome and the optimization of the pumping station as a whole. The lower head pressure results in reduced horsepower required to maintain the same volume of water at the required system pressure. The savings are seen both in the lower load factor and a reduction in the operation of the lag pump. Therefore, the savings is seen as reduction in equivalent full load hours of the system.

4.6.4 Ex Ante Load Impact Estimates

The *ex ante* load impact estimates were based on an engineering analysis. The total dynamic head requirements were estimated, then the energy use was estimated through engineering calculations. The calculations were presented in a spreadsheet format as shown in Tables 4-35 through 4-38.

Table 4-35
***Ex Ante* Basic Operating Assumptions**
ID No. 45082

Pumps operate as needed (i.e., no control problems)		
Suction pressure	40 psi	design criteria
System operating pressure	85 psi	design criteria
Valve control & piping loss	16.50 psi	consulting engineer's estimate
Required pump head	61.50 psi	calculated

Table 4-36
***Ex Ante* Pre-Retrofit Load Estimates**
ID No. 45082

PRE-RETROFIT		
Pump	**P-1**	**Source**
Suction pressure	50 psi	on-site measurement
Discharge pressure	123 psi	on-site measurement
Pump head	73 psi	calculated
Pump Energy Demand		
Flow	1,400 gpm	(from pump curve)
Head	167 feet	(from above)
Pump Efficiency	0.845	(from pump curve
Motor Efficiency	0.916	(standard efficiency motor)
Pump Demand	70 bhp	calculated
Motor Demand	57 kW	calculated
Maximum Energy Use	499,889 kWh/year	calculated @ 8,760 hours/year)
Equivalent Full Load Pump Operation, Average Year	1.22 pumps	calculated
Total Water Pumped, Average Year	899,730,000 gallons/year	calculated

The *ex ante* post-retrofit energy use was characterized by the worksheet shown in Table 4-37.

Table 4-37
***Ex Ante* Post-Retrofit Energy Use Estimates**
ID No. 45082

POST-RETROFIT		
Required pump total dynamic head (TDH)	300 feet	
Pump Energy Demand at New TDH		**Source**
Flow	1,640 gpm	(from pump curve)
Head	142 feet	(from above)
Pump Efficiency	0.850	(from pump curve)
Motor Efficiency	0.916	(standard efficiency motor)
Pump Demand	69 bhp	calculated
Motor Demand	56 kW	calculated
Equivalent Full Load Pump Operation, Average Year	1.04 pumps	calculated
Total Water Pumped, Average Year	861,984,000 gallons per year	
Pump Average Annual Energy Use	515,022 kWh/year	

The *ex ante* load impact estimates are shown in Table 4-38.

Table 4-38
***Ex Ante* Load Impact Estimates**
ID No. 45082

Ex Ante Energy Impacts				
	kWh per Year			
Pre-retrofit	611,227			
Post-retrofit	515,022			
Savings	96,205			
Distribution of Energy Savings per TOU Period				
Season	**Seasonal Distribution Share**	**TOU Period**	**Seasonal Distribution Share**	**kWh Saved**
Summer	0.42	On-peak	0.13	5,435
		Semi-peak	0.32	12,774
		Off-peak	0.55	22,118
Winter	0.58	On-peak	0.07	3,658
		Semi-peak	0.38	21,018
		Off-peak	0.56	31,202
Total				96,205
***Ex Ante* Demand Impacts**				
	kW			
Pre-retrofit	114			
Post-retrofit	112			
Reduction	2			

4.6.5 Ex Post Load Impact Estimates

Periodic pump tests are performed on each of the pumping stations operated by this municipal entity. The results of these tests were obtained for periods before and after the retrofit of the pumps. In conjunction with the bill history and run time log sheets for each pump (provided by customer), the station pre-retrofit and post-retrofit consumption were estimated.

The pre-retrofit consumption was estimated using the annual run time hours estimated from six months of log sheet data for the year previous to the retrofit. These hours and the measured load (kW) of the pumps determined the annual kWh. The pre-retrofit measured load was provided by the pump tests.

The post-retrofit consumption was calculated from the post-retrofit pump test measured kW and the run time data provided by the customer. The pump test results show an average measured total head pressure reduction of 21 feet, from 169 to 148 feet.

Ex post spot measurement and pump test data obtained for the 100 hp pumps, and extracts of the pump tests are shown in Table 4-39.

Table 4-39
***Ex Post* Pump Test Results**
ID No. 45082

	Pump #1		Pump #2	
	Post	Pre	Post	Pre
	Test 1	Test 2	Test 1	Test 2
Head (ft)	147.8	169.8	147.8	168.6
kW	41.4	50.6	41.4	52.5
GPM	505.6	548.4	515.5	573.1
kW/Gpm	0.0803	0.09226	0.0803	0.0916

The run hours of the pre- and post-retrofit pumps are shown in Table 4-40.

Table 4-40
***Ex Post* Run Hour Estimates**
ID No. 45082

		Run Hours				
	Month	**Pump #1**	**Pump #2**	**Pump #3**	**Pump #4**	**Total**
Pre-Retrofit	Apr-96	19	240	568	223	1,050
	May-96	106	31	577	222	936
	Jun-96	406	580	204	15	1,205
	Jul-96	39	0	671	325	1,035
	Subtotal	570	851	2,020	785	4,226
	Annualized	**1,710**	**2,553**	**6,060**	**2,355**	**12,678**
Post-Retrofit	Dec-96	742	4	0	0	746
	Jan-97	1	862	0	0	863
	Feb-97	467	11	0	6	484
	Mar-97	654	120	4	1	779
	Apr-97	387	516	130	2	1,035
	May-97	0	767	0	0	767
	Jun-97	0	1,075	0	0	1,075
	Jul-97	269	1	0	0	270
	Aug-97	643	145	3	0	791
	Sep-97	724	0	0	0	724
	Subtotal	3,887	3,501	137	9	7,534
	Annualized	**4,664**	**4,201**	**164**	**11**	**9,040**
Difference between Pre-Retrofit and Post-Retrofit						3,638

Equations 4-7 through 4-9 show the calculations for the pre- and post-retrofit kWh and *ex post* kWh savings, respectively.

$$\text{(Eq. 4-7)} \quad kWh_{\text{Pre-retrofit}} = \text{Average of } (\text{Pre-}kW_{\text{Motor 1}} \,\&\, \text{Pre-}kW_{\text{Motor 2}}) \times (\text{Equivalent full load hours}_{\text{Pre-retrofit}})$$

$$= \left[\left(\frac{50.6\text{ kW} + 52.5\text{ kW}}{2}\right) \times (1{,}710 + 2{,}553 + 6{,}060 + 2{,}355 \text{ hours})\right]$$

$$= 653{,}551 \text{ kWh / Year}$$

$$\text{(Eq. 4-8)} \quad kWh_{Post\text{-}retrofit} = \left[\begin{array}{l}\text{Average of } (\text{Pre-}kW_{Motor\,1} \,\&\, \text{Pre-}kW_{Motor\,2}) \\ x\ (\text{Run hours/year}_{Motor\,1} + \text{Run hours/year}_{Motor\,2})\end{array}\right] + \left[\text{Average of } (\text{Pre-}kW_{Motor\,3} \,\&\, \text{Pre-}kW_{Motor\,4})\ x\ (\text{Run hours/year})\right]$$

$$= \left[(41.4\ kW)\ x\ (4{,}464 + 4{,}201\ hours)\right] + \left[(51.55\ kW)\ x\ (164 + 11\ hours)\right]$$

$$= 372{,}521\ kWh/Year$$

$$\text{(Eq. 4-9)} \quad \text{Ex Post kWh Saved} = kWh_{Pre\text{-}retrofit} - kWh_{Post\text{-}retrofit}$$

$$= 653{,}551\ kWh - 372{,}521\ kWh$$

$$= 281{,}030\ kWh/year$$

Billing data for 1996 showed that just over 46 percent of the consumption for the facility occurred during the summer season, i.e., May through September. The time-of-use savings values were based on the seasonal share of savings, which was allocated to the time-of-use period based on the hours for each period. The average kW reduced for each period was obtained by dividing the kWh saved by the number of run hours for the period. Table 4-41 shows the calculations for the time of use periods.

Table 4-41
***Ex Post* kW and kWh Savings by Time-of-Use Period**
ID No. 45082

	Time-of-Use Period	Hours	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer	Summer On-peak	742	26,395	35.6	35.6
1996 Consumption	Summer Semi-peak	954	33,937	35.6	
357,120 kWh	Summer Off-peak	1,976	70,292	35.6	
Winter	Winter On-peak	441	13,036	29.6	29.6
1996 Consumption	Winter Semi-peak	1,911	56,491	29.6	
411,200 kWh	Winter Off-peak	2,736	80,878	29.6	
		8,760	281,030		

4.6.6 Comparison with Ex Ante Estimated Impacts

The realization rates for energy and demand for this project are shown in Table 4-42. Comparison of the *ex ante* and *ex post* estimates of demand reduction show a realization rate of 17.8 and annual energy savings realization rate of 2.92. The main reasons for the differences are:

- A majority of the inputs to the *ex ante* calculations were estimates based on design criteria and average annual billing data. We have no means of validating or rebuking these inputs and they may or may not be accurate;
- The measurements of pump head were taken only as instantaneous or "spot" and the load on the system can change throughout the day and year. Again, we can only identify this as a possible source of discrepancy;
- The calculated average load of the motors was 57 kW. Two measurements at separate occasions indicate a load of approximately 51.5 kW for the pre-retrofit operation; and
- No demand savings were estimated for the reduction in operation of the number of pumps operating at one given time.

Table 4-42
Comparison of *Ex Ante* and *Ex Post* Demand and Energy Impacts
ID No. 45082

	Demand		Energy		Gas	
Ex Ante Load Impacts	2.0	Peak kW	96,205	kWh	-	Therm
Ex Post Load Impacts	35.6	kW	281,030	kWh	-	Therm
Difference	33.6	kW	184,825	kWh	-	Therm
Realization Rate	17.80		2.92		n/a	

4.6.7 Persistence of the Measure

The pumps have been permanently de-staged. The measure will continue to provide the savings for the estimate life of the measure, 15 years. The actual savings will be determined by the capacity requirements of that pumping station which are weather and population variant.

4.7 ID No. 45148 - Adjustable Speed Drives on Three Pumps

4.7.1 Pre-Retrofit Equipment and Operation

This project involves the installation of adjustable speed drives (ASD's) on pumps at a municipal water district pumping station. This station consists of one (1) 50 hp and three (3) 100 hp pumps. The station demand is dependent on the demand for water in the area. The area is mainly a residential subdivision.

The station operate 24 hours/day, 365 days/year. The pumps are set up to operate in a lead/lag sequence. Pump #2, the 50 hp pump, is always the lead pump. The (3) 100 hp pumps are each staged on as demand requires. Typically, the 100 hp pumps only operate during summer months. It is rare that there is ever more than one 100 pumps on-line at the same time. The greatest loads can typically be handled by the 50 hp and one 100 hp pump.

4.7.2 Energy Efficiency Improvement

The installation of ASD's on each of the four pumps has significantly reduced the total energy consumption of the pump station. The installation of the ASD's allowed the discharge throttling valves ("Cla" valves) to be removed, thus reducing the head pressure of the pumps. The ASD's reduce energy consumption by slowing the speed of the motors to match the flow demand rather than throttling the flow with a "Cla" valve. By reducing the speed of the motors the brake horsepower is reduced by the cube of the speed (common engineering principals).

4.7.3 Source of Savings

Reduced horsepower is required to match low pumping demand situations.

4.7.4 Ex Ante Load Impact Estimates

Variable frequency drives were installed on three motors on two 100 hp water pumps and one 50 hp water pump. Each 100 hp pump has a capacity of 1,500 gpm with 150 ft head. The 50 hp pump had a capacity of 750 gpm with 150 ft. head.

The *ex ante* load impact estimates were calculated using an engineering based methodology. The Bell & Gossett Centrifugal Pump Selection Guide Software was used to calculate the energy savings. Bell & Gossett compares pump operation with variable frequency drives versus constant speed drives. An operational profile was developed based on billing data and usage curves from Bell & Gossett. Runs were made for the single 50 hp pump and for the two 100 hp pumps combined for the pre-retrofit and post-retrofit cases. The results are shown in Table 4-43.

Table 4-43
***Ex Ante* Energy Savings Estimates**
ID No. 45148

	Energy Use		
	1 50-hp	**2 100-hp**	**Total**
Pre-Retrofit	77,932	230,777	308,709
Post-Retrofit	46,370	55,360	101,730
Energy Savings			206,979

Ex ante demand impacts were estimated by assuming that there will be no demand reduction from the 50 hp pump, while the two 100 hp pumps will be operating at 90 percent of capacity. Motor horsepower at the 90 percent level was taken and converted to kW using a motor efficiency of 1.0. The results are shown in Table 4-44.

Table 4-44
***Ex Ante* Demand Reduction Estimates**
ID No. 45148

2 100-HP Pumps	kW
90% flow with a constant speed drive	128.0
90% flow with a variable speed drive	108.5
Demand Reduction	19.5

4.7.5 Ex Post Load Impact Estimates

The main approach to the analysis utilized pre- and post-retrofit billing data. The billing analysis was possible because the pump station is on a dedicated utility electric meter. There are minimal miscellaneous loads other than the pumps and there have been no changes to those loads. Hence, the billing data represent essentially end-use metered data.

The billing analysis utilized billing history from 1994 through 1997. The average monthly consumption for each month of the year from 1994 through 1996 was calculated based on kWh/day. The actual start-up date was obtained for the ASD's in order to identify the starting month in 1997 that valid post-retrofit data could be used. The drives at this station started in May 1997, so the billing analysis includes five months of post-retrofit data. The billing data indicates little seasonal or monthly variation. Therefore, annualizing the savings was performed linearly by month (extrapolated by $12/5^{ths}$). The billing period from Oct. 1996 through April 1997 was used as a "block-out" period, where the data were not used in the analysis because they would not be representative of normal operation due to the construction/installation taking place at the time.

Historical flow data was not available for the station or the individual pumps. The customer indicated that the monthly and annual flow should be consistent with previous years because there has not been much construction or changes to any factors that would affect the demand on the station. Also, to help validate the billing analysis, run time data from manual log sheets and ASD displays were obtained. The run hours of each pump indicate that the customer's operating controls both pre- and post-retrofit were accurate. When an average load factor is assumed for each pump based on the pump's operation, the calculated kWh using the run hour information collaborates the billing data analysis results.

A summary of the billing history of this pump station is shown in Table 4-45.

Table 4-45
Billing Data (kWh/Day)
ID No. 45148

Month	94/95	95/96	Avg.	96/97	Savings per Day	No. Days	Savings per Month
10	919	883	901	880	21	31	
11	833	739	786	690	96	28	
12	619	683	651	577	74	31	
1	524	514	519	397	122	30	
2	375	474	425	381	44	31	
3	405	411	408	570	-162	30	
4	490	532	511	601	-90	31	
5	679	789	734	663	71	31	**2,201**
6	704	872	788	663	125	30	**3,750**
7	810	945	878	704	174	31	**5,379**
8	932	982	957	734	223	30	**6,690**
9	955	1,020	988	727	261	31	**8,076**
Total kWh	249,920	271,040		231,360			
Five-Month Savings							26,095
Annualized Impacts							**62,628**

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

Table 4-46
***Ex Post* kW and kWh Savings by Time-of-Use Period**
ID No. 45148

Time-of-Use Period	Hours	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak		6,434	8.7	8.7
Summer Semi-peak		8,272	8.7	
Summer Off-peak		17,134	8.7	
Winter On-peak		2,669	6.1	6.1
Winter Semi-peak		11,564	6.1	
Winter Off-peak		16,556	6.1	
Total	8,760	62,628		8.7

4.7.6 Comparison with Ex Ante Estimated Impacts

The realization rates for energy and demand for this project are shown in Table 4-47. Comparison of the *ex ante* and *ex post* estimates of demand reduction show a realization rate of 0.45 and annual energy saving realization rate of 0.30. The main reasons for the differences are:

- *Ex ante* impact estimates as a percent of the total bill were extraordinarily high. For this site the *ex ante* savings estimate was 89 percent of the total energy bill. This was recognized in the *ex ante* analysis and the energy savings was de-rated by factor of 0.88. However, this was not the value reported in program tracking system. The full energy savings was report instead of the de-rated energy savings. The *ex post* estimates indicate a total of 27 percent of total energy was saved during the first year. This is far more reasonable for this technology.

- The *ex ante* savings calculations were developed using a manufacturer's (Bell & Gossett) software program. The calculations of this program are unknown. The input variables could not be confirmed or disputed.
- The load profile of each pump was provided by the customer. There was no evidence of hard data that these profiles were developed. It is uncertain how accurate they are. This is a key variable to the software program that calculated the savings.

Table 4-47
Comparison of *Ex Ante* and *Ex Post* Demand and Energy Impacts
ID No. 45148

	Demand	Energy	Gas
Ex Ante Load Impacts	19.5 Peak kW	206,979 kWh	- Therm
Ex Post Load Impacts	8.7 kW	62,628 kWh	- Therm
Difference	- 10.8 kW	-144,351 kWh	- Therm
Realization Rate	0.45	0.30	n/a

4.7.7 Persistence of the Measure

The persistence of this measure should be the rated equipment life as indicated in the project file, 15 years.

4.8 ID No. 44225 - Adjustable Speed Drives on Two 40 HP Pumps

4.8.1 Pre-Installation Equipment and Operation

This project involves the installation of adjustable speed drives (ASD's) on pumps at a municipal water district pumping station. This station consists of three (3) 40 hp pumps. The station demand is dependent on the water demand in that area. The area is mainly a residential subdivision.

The station operate 24 hours/day, 365 days/year. The pumps are set up to operate in a lead/lag sequence. Pump #1 typically acts as the lead pump. The other pump is each staged on as demand requires.

4.8.2 Energy Efficiency Improvement

The installation of ASD's on each of the two pumps has significantly reduced the total energy consumption of the station. The installation of the ASD's has allowed the discharge throttling valves ("Cla" valves) to be removed and thus reducing the head pressure of the pumps. The ASD's reduce energy consumption by slowing the speed of the motors to match the flow demand rather than throttling the flow with a "Cla" valve. By reducing the speed of the motors the brake horsepower is reduced by the cube of the speed (standard engineering principals).

4.8.3 Source of Savings

Reduced horsepower required to match low pumping demand situations.

4.8.4 Ex Ante Load Impact Estimates

Variable frequency drives were installed on two of three motors at a water pump station. The station has three (3) 40 hp. Each pump has a capacity of 500 gpm.

The *ex ante* load impact estimates were calculated using an engineering based methodology. The Bell & Gossett Centrifugal Pump Selection Guide Software was used to calculate the energy savings. Bell & Gossett compares pump operation with variable frequency drives versus constant speed drives. An operational profile was developed based on billing data and usage curves from Bell & Gossett. The results are shown in Table 4-48.

Table 4-48
***Ex Ante* Energy Savings Estimates**
ID No. 45225

	kWh
Pre-Retrofit	161,979
Post-Retrofit	43,946
Energy Savings	118,033

Ex ante demand impacts were estimated by taking the input horsepower from the Bell & Gossett run for the pre- and post-retrofit scenarios. These horsepower levels were converted to kW by the standard motor conversion factors, assuming motor efficiency of 1.0. Table 4-49 shows the *ex ante* demand reduction estimates.

Table 4-49
***Ex Ante* Demand Reduction Estimates**
ID No. 45225

	kW
95% flow with a constant speed drive	49.6
95% flow with a variable speed drive	47.6
Demand Reduction	2.0

4.8.5 Ex Post Load Impact Estimates

The main approach to the analysis utilized pre- and post-retrofit billing data. The billing analysis was possible because the pump station is on a dedicated utility electric meter. There are minimal miscellaneous loads other than the pumps and there have been no changes to those loads. Hence, the billing data represent essentially end-use metered data.

The billing analysis utilized billing history from 1994 through 1997. A summary of the billing history of this pump station is shown in Table 4-50. The average monthly consumption for each month of the year from 1994 through 1996 was calculated based on kWh/day. The monthly average was adjusted to account for growth that occurred since 1996. The addition of new subdivisions increased the demand by about 10% according to plant personnel. Thsu, the monthly average was adjusted upwards by 10% to ensure the appropriate baselines were used. The actual start-up date was obtained for the VSD's in order to identify the starting month in 1997 that valid post-retrofit data could be used. The drives at this station started in January 1997, so the billing analysis includes 10 months of post-retrofit data. The period of Nov. through Dec. 1996 was used as a "blockout" period since this period would not be representative of normal operation due to the construction/installation that took place during that period. The billing data indicates very little seasonal or monthly variation. The summer/winter consumption broke down to 47 percent/53 percent, respectively. Given this, the January through October period is closely representative of the annual profile. Therefore, annualizing the savings was performed linearly by month (extrapolated by 12/10^{ths}). The variation of summer and winter was used in allocating the savings to the six time-of-use periods as shown in Table 4-51.

Historical flow data was not available for the station or the individual pumps. The customer indicated that the monthly and annual flow should be consistent with previous years because there has not been much construction or anything to change the demand on the station.

To help validate the billing analysis run time data from manual log sheets and ASD displays were obtained. The run hours of each pump indicate that the customer's report on the operating controls during pre- and post-retrofit periods were accurate. When an average load factor is assumed for each pump based on the pump's operation, the calculated kWh using the run hour information collaborates the billing data analysis results.

Table 4-50
Billing Data (kWh/Day)
ID No. 45225

Month	1994/1995	1995/1996	Avg. (Adjusted for Growth)	1996/1997	Savings per Day	No. Days	Savings per Month
11	552	549	606			30	
12	485	490	536			31	
1	454	423	482	381	101	31	**3,142**
2	400	403	442	375	67	28	**1,866**
3	416	387	442	400	42	31	**1,291**
4	458	417	481	465	16	30	**488**
5	554	524	593	480	113	31	**3,500**
6	488	582	589	550	39	30	**1,155**
7	565	621	652	553	99	31	**3,078**
8	637	676	722	577	145	31	**4,500**
9	667	661	730	577	153	30	**4,602**
10	629	588	669	575	94	31	**2,925**
Total Annual kWh	178,360	192,240		181,680			
10 Month Savings							28,755
Annualized Savings							31,856

Table 4-51
Ex Post Load Impacts by Time-of-Use Period
ID No. 45225

Time-of-Use Period	Hours	kWh Savings	Average kW Reduced	Coincident kW Reduced
Summer On-peak	742	3,046	4.1	4.1
Summer Semi-peak	954	3,917	4.1	
Summer Off-peak	1,976	8,112	4.1	
Winter On-peak	441	1,454	3.3	3.3
Winter Semi-peak	1,911	6,303	3.3	
Winter Off-peak	2,736	9,024	3.3	
Total	8,760	31,856		

4.8.6 Comparison with Ex Ante Estimated Impacts

The realization rates for energy and demand for this project are shown in Table 4-52. Comparison of the *ex ante* and *ex post* estimates of demand saving show a realization rate of 2.05 and annual energy saving realization rate of 0.27. The main reasons for the differences are:

- *Ex ante* savings estimation as a percent of the total bill were high. For this site the *ex ante* savings estimate was 65 percent of the total energy bill. The *ex post* estimates indicate 18 percent of the total energy consumed was saved.

- The *ex ante* savings calculations were developed using a manufacturer's (Bell & Gossett) software program. The calculations of this program are unknown. The input variables could not be confirmed or disputed.
- The load profile of each pump was provided by the customer. There was no evidence of hard data that supported how these profiles were developed. It is uncertain how accurate they are. This is a key variable to the software program that calculated the savings.

Table 4-52
Comparison of *Ex Ante* and *Ex Post* Demand and Energy Impacts
ID No. 45225

	Demand		Energy		Gas	
Ex Ante Load Impacts	2.0	Peak kW	118,033	kWh	-	Therm
Ex Post Load Impacts	4.1	kW	31,856	kWh	-	Therm
Difference	2.1	kW	-86,177	kWh	-	Therm
Realization Rate	2.05		0.27		n/a	

4.8.7 Persistence of the Measure

Although the savings are not as much as anticipated, the customer is very much an advocate of these retrofits. The persistence of this measure should be the rated equipment life as indicated in the project file, 15 years.

4.9 ID No. 45347 - Adjustable Speed Drives on Two 50 HP Pumps

4.9.1 Pre-Installation Equipment and Operation

This project involves the installation of adjustable speed drives (ASD's) on pumps at a municipal water district pumping station. This station consists of three (3) 50 hp pumps. The station demand is dependent on the water demand in that area. The area is mainly a residential subdivision.

The station operates 24 hours/day, 365 days/year. The pumps are set up to operate in a lead/lag sequence. They rotate the lead pump in order to keep the run times balanced between the three pumps. The other pumps are staged on as demand requires.

4.9.2 Energy Efficiency Improvement

The installation of ASD's on each of the three pumps has significantly reduced the total energy consumption of the station. The installation of the ASD's has allowed the discharge modulating valves ("Cla" valves) to be removed, thus reducing the head pressure of the pumps. The ASD's reduce energy consumption by slowing the speed of the motors to match the flow demand rather than throttling the flow with a "Cla" valve. By reducing the speed of the motors the brake horsepower is reduced by the cube of the speed (standard engineering principals).

4.9.3 Source of Savings

Reduced horsepower required to match low pumping demand situations.

4.9.4 Ex Ante Load Impact Estimates

Variable frequency drives were installed on two of three motors at a water pump station. The station has three (3) 50 hp.

The *ex ante* load impact estimates were calculated using an engineering based methodology. The Bell & Gossett Centrifugal Pump Selection Guide Software was used to calculate the energy savings. Bell & Gossett compares pump operation with variable frequency drives versus constant speed drives. An operational profile was developed based on billing data and usage curves from Bell & Gossett. The results are shown in Table 4-53.

Table 4-53
***Ex Ante* Energy Savings Estimates**
ID No. 45347

	kWh
Pre-Retrofit	211,663
Post-Retrofit	180,849
Energy Savings	30,814

Ex ante demand impacts were estimated by taking the input horsepower from the Bell & Gossett run for the pre- and post-retrofit scenarios for average flow conditions. These horsepower levels were converted to kW by the standard motor conversion factors, assuming motor efficiency of 1.0. Table 4-54 shows the *ex ante* demand reduction estimates.

Table 4-54
***Ex Ante* Demand Reduction Estimates**
ID No. 45347

	HP	kW
Average flow with a constant speed drive	32.83	24.4911
Average flow with a variable speed drive	27.38	20.4254
Demand Reduction		4.0657

4.9.5 Ex Post Load Impact Estimates

The main approach to the analysis utilized pre- and post-retrofit billing data. The billing analysis was possible because the pump station is on a dedicated utility electric meter. There are minimal miscellaneous loads other than the pumps and there have been no changes to those loads. Hence, the billing data represent essentially end-use metered data.

The billing analysis utilized billing history from 1994 through 1997. The average monthly consumption for each month of the year from 1994 through 1996 was calculated based on kWh/day. The actual start-up date was obtained for the VSD's in order to identify the starting month in 1997 that valid post-retrofit data could be used. The drives at this station started in January 1997, so the billing analysis includes 10 months of post-retrofit data. The period of November through December 1996 was used as a "blockout" period since this period would not be representative of normal operation due to the construction/installation that took place during that period. The billing data indicates very little seasonal or monthly variation. The summer/winter consumption broke down to 47 percent/53 percent, respectively. Given this, the January through October period is closely representative of the annual profile. Therefore, annualizing the savings was performed linearly by month (extrapolated by $12/10^{ths}$).

The variation of summer and winter was used in allocating the saving into the six costing periods as shown in Table 4-55.

Historical flow data was not available for the station or the individual pumps. The customer indicated that the monthly and annual flow should be consistent with previous years because there has not been much construction or changes of other factors that would affect the demand on the station.

To help validate the billing analysis run time data from manual log sheets and ASD displays were obtained. The run hours of each pump indicate that the customer's report on the operating controls during pre- and post-retrofit periods were accurate. When an average load factor is assumed for each pump based on the pump's operation, the calculated kWh using the run hour information collaborates the billing data analysis results.

A summary of the billing history of this pump station is shown in Table 4-55.

Table 4-55
Billing Data (kWh/Day)
ID No. 45347

Month	1994/1995	1995/1996	Avg.	1996/1997	Savings per Day	No. Days	Savings per Month
9	1,857	2,010	1,934	1,825	109	30	3,255
10	1,575	1,840	1,708	1,495	213	31	6,588
11	1,335	1,426	1,381	1,392	-12	30	-345
12	1,115	1,259	1,187	948	239	31	7,409
1	994	1,069	1,032	743	289	31	8,944
2	844	899	872	800	72	28	2,002
3	868	855	862	1,255	-394	31	-12,199
4	1,145	1,321	1,233	1,503	-270	30	-8,100
5	1,363	1,708	1,536	1,668	-133	31	-4,108
6	1,469	1,888	1,679	1,685	-7	30	**-195**
7	1,571	2,008	1,790	1,720	70	31	**2,155**
8	1,870	1,923	1,897	1,535	362	31	**11,207**
Total Annual kWh	487,040	554,300		505,600			
10-Month Energy Savings							13,166
Annualized Energy Savings							52,664

Table 4-56 shows the *ex post* load impacts by time-of-use period.

Table 4-56
***Ex Post* Load Impacts by Time-of-Use Period**
ID No. 45347

Time-of-Use Period	Hours	kWh Savings	Average kW Savings	Coincident kW Reduction
Summer On-peak	742	5,495	7.4	7.4
Summer Semi-peak	954	7,066	7.4	
Summer Off-peak	1,976	14,635	7.4	
Winter On-peak	441	2,207	5.0	5.0
Winter Semi-peak	1,911	9,566	5.0	
Winter Off-peak	2,736	13,695	5.0	
Total	8,760	52,664		

4.9.6 Comparison with Ex Ante Estimated Impacts

The realization rates for energy and demand for this project are shown in Table 4-57. Comparison of the *ex ante* and *ex post* estimates of demand saving show a realization rate of 2.05 and annual energy savings realization rate of 0.27. The main reasons for the differences are:

- *Ex ante* savings estimation as a percent of the total bill were extraordinarily high. For this site the *ex ante* savings estimate was 65 percent of the total energy bill. The evaluation results indicate a 18 percent of total energy saved. This is far more reasonable for this technology.

- The *ex ante* savings calculations were developed using a manufactures (Bell & Gossett) software program. The calculations of this program are unknown. The input variables could not be confirmed or disputed.
- The load profile of each pump was provided by the customer. There was no evidence of hard data that supported how these profiles were developed. It is uncertain how accurate they are. This is a key variable to the software program that calculated the savings.

Table 4-57
Comparison of *Ex Ante* and *Ex Post* Demand and Energy Impacts
ID No. 45347

	Demand	Energy	Gas
Ex Ante Load Impacts	4.1 Peak kW	30,814 kWh	- Therm
Ex Post Load Impacts	7.4 kW	52,664 kWh	- Therm
Difference	3.3 kW	21,850 kWh	- Therm
Realization Rate	1.81	1.71	n/a

4.9.7 Persistence of the Measure

The persistence of this measure should be the rated equipment life as indicated in the project file, 15 years.

SAN DIEGO GAS & ELECTRIC
Retroactive Waiver for
1996 AGRICULTURAL ENERGY EFFICIENCY INCENTIVES PROGRAM

Approved by CADMAC on June 18, 1997

REQUEST

This waiver requests that SDG&E be allowed to do the following evaluation for the PY96 Agricultural EEI Program:

1. In lieu of using a comparison group to estimate the net load impacts, SDG&E will use a default net-to-gross ratio of 0.75 to determine net load impacts for all end uses, water pumping, indoor lighting and miscellaneous, in the program.
2. Change reporting the results for the AEEI Program designated unit of measurement (DUOM) for the motors that were installed from "load impacts per acre foot of water pumped" to "load impacts per horsepower." These motors were purchased through the motor retail program and as such it is not possible to acquire the necessary information to satisfy the Protocols-established DUOM.
3. Evaluate the lighting measures (normally classified as miscellaneous measures) as a separate end use using on-site verification of engineering estimates. The designated unit of measurement will be "load impacts per square foot per thousand hours of operation."
4. Treat process and exterior lighting end uses as miscellaneous measures per Table C-9.

BACKGROUND

SDG&E has identified 37 participants who installed various measures in the 1996 AEEI Program with resource benefits, net (RBn) of $2,016,382 and an associated earnings claim of $431,874.

END USE	PARTICIPANTS	RBn	EARNINGS
Pumping	22	$951,401	$210,251
Indoor Lighting	14	$1,005,253	$207,069
Exterior Lighting	1	$2,525	$638
Process	1	$57,203	$13,916
TOTALS		**$2,016,382**	**$431,874**

The pumping measures will be studied under Table C-6 using a simplified engineering model. This will involve the use of premise-specific engineering models that are adjusted to reflect post-installation hours of operation and other related equipment characteristics. SDG&E proposes to use the verification method similar to that described in Table C-5 for Industrial Motors, instead of direct end use metering.

In order to meet the requirements of Protocols Table C-9 of having no more than 15 percent of the program's RBn evaluated as miscellaneous measures, SDG&E created a lighting end use category. SDG&E proposes to evaluate this end use with on-site verification of installation and using the *ex ante* engineering models adjusted to reflect post-installation premise specific hours of operation and related equipment characteristics using light loggers.

The remaining measures, the compressor (process end use) and exterior lighting, would then be classified as miscellaneous and account for less than 3 percent of the PY96 AEEI Program's RBn and will not be subject to further verification.

B

TABLE 6 - PUMPING MEASURES

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY96 SECOND EARNINGS CLAIM FOR AGRICULTURAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, February 1998, STUDY ID NO. 998

Designated Unit of Measurement: Load Impacts per Horsepower
End Use: Pumping

				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	11.37	8.53	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. ii. Load Impacts - kWh	66,272	49,704	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	0.1017	0.0763	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. ii. Load Impacts/designated unit - kWh	592.7	444.5	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	1.29	1.09	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. ii. Load Impacts - kWh, realization rate	0.83	0.70	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	0.48	0.40	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	0.31	0.26	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	0.75		N/A	N/A			N/A	N/A		
	A. ii. Average Load Impacts - kWh	0.75		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	0.75		N/A	N/A			N/A	N/A		
	B. ii. Avg Load Impacts/designated unit of measurement - kWh	0.75		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	21									
	B. Number of measures installed by all program participants in the 12 months of the program year	45									
	C. Number of measures installed by Comp Group	N/A									
7. Market Segment Data		SIC	Percent								
	Distribution by 3 digit SIC	018	3%								
		019	13%								
		494	84%								

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TABLE 6 - LIGHTING MEASURES

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY96 SECOND EARNINGS CLAIM FOR AGRICULTURAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, FEBRUARY 1998, STUDY ID NO. 998

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	18,853	14,140	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. ii. Load Impacts - kWh	54,097	40,573	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. i. Load Impacts/designated unit - kW	0.0001	0.0001	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. ii. Load Impacts/designated unit - kWh	0.414	0.341	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	0.390	0.341	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. ii. Load Impacts - kWh, realization rate	0.260	0.227	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	0.000	0.000	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	0.182	0.144	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			N/A	N/A			N/A	N/A		
	A. ii. Average Load Impacts - kWh	0.75		N/A	N/A			N/A	N/A		
	B. i. Avg Load Impacts/designated unit of measurement - kW	0.75		N/A	N/A			N/A	N/A		
	B. ii. Avg Load Impacts/designated unit of measurement - kWh	0.75		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
6. Measure Count Data		NUMBER									
	A. Number of measures installed by participants in Part Group	21,999									
	B. Number of measures installed by all program participants in the 12 months of the program year	21,999									
	C. Number of measures installed by Comp Group	N/A									
7. Market Segment Data		SIC or CZ	PERCENT								
	Distribution by 3 digit SIC - Commercial/Industrial	019	3.8								
		025	56.6								
		404	39.6								

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TABLE 7

M&E PROTOCOLS TABLE 7
DATA QUALITY AND PROCESSING DOCUMENTATION
For 1996 Agricultural Energy Efficiency Incentives Program
First Year Load Impact Evaluation
February 1998
Study ID No. 998

A. OVERVIEW INFORMATION

1. **Study Title and Study ID:** 1996 Agricultural Energy Efficiency Incentives Program: First Year Load Impact Evaluation, February 1997, Study ID No. 998.

2. **Program, Program Year(s), and Program Description (design):** 1996 Agricultural Energy Efficiency Incentives Program for the 1996 program year. The Program is designed to help agricultural 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 pumping, interior lighting and miscellaneous.

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

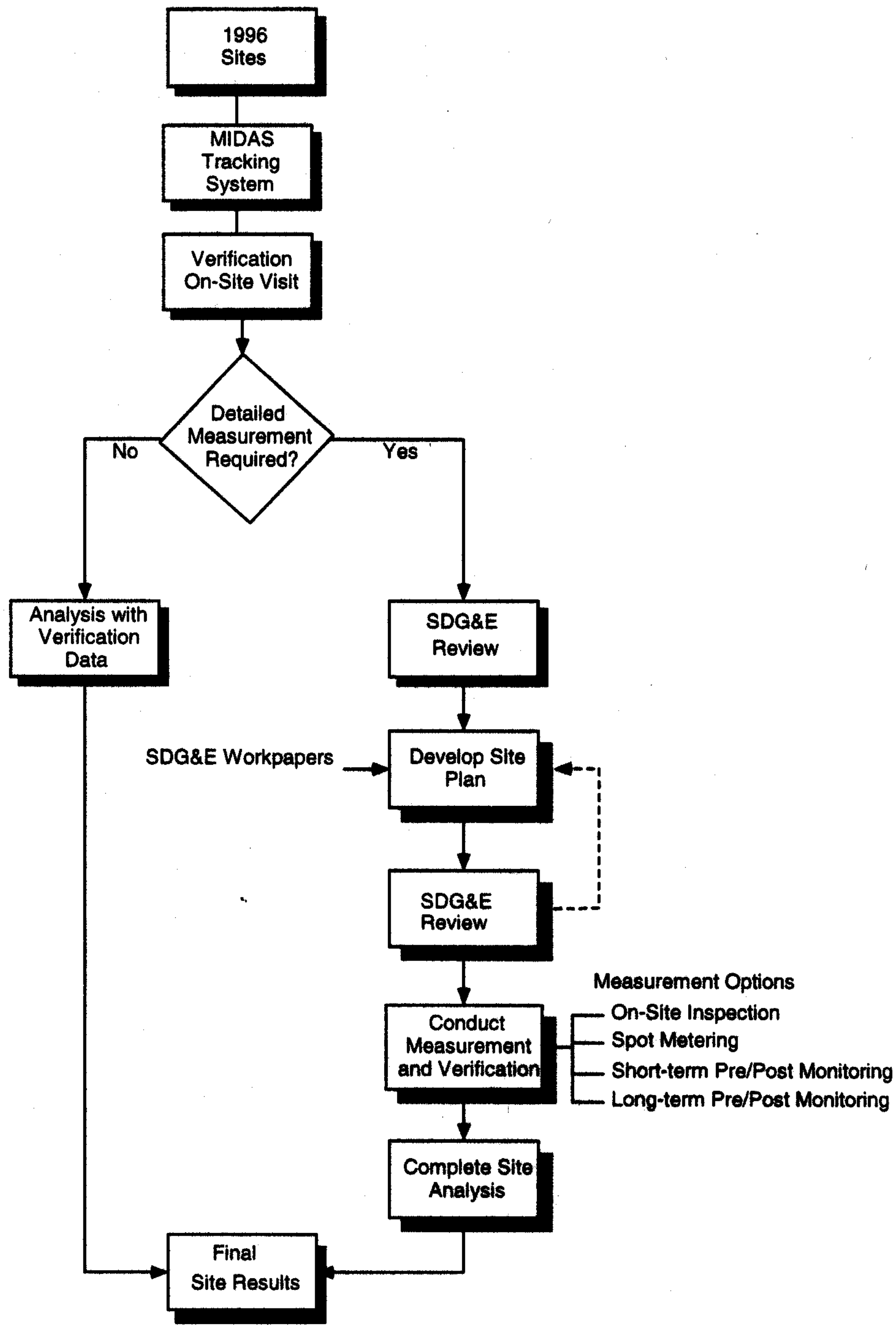
5. **Participant and comparison group definition:** For the load impact analysis, the participants in the 1996 Agricultural Energy Efficiency Incentives Program are defined as having at least one of the aforementioned measures installed. Per SDG&E's retroactive waiver a comparison group was not required for this evaluation.

6. **Analysis sample size:**

Electric Participant Sample for 1996 Agricultural Energy Efficiency Incentives Program			Gas Participant Sample for 1996 Agricultural 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	13	21,999	**Interior Lighting**	0	0	0
Pumping	11	21	**Pumping**	0	0	0
Miscellaneous	0	0	**Miscellaneous**	0	0	0
Total	24	22,020	**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:** A census of participants was conducted for interior lighting was conducted. Participants comprising the top 70 percent of load impacts were included in the survey for pumping measures.

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. <u>DATA SCREENING AND ANALYSIS</u>

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.