ITRC

moving water in new directions

IRRIGATION TRAINING & RESEARCH CENTER

SCE Pump Testing Program

Pump Repair Attitudes and Behavior

CALMAC Study ID SCE0373.01

Final Report

January 2013

IRRIGATION
TRAINING &
RESEARCH
CENTER

Prepared by
Dr. Stuart W. Styles
Kyle Feist
Sierra Orvis
Kerilyn Ambrosini
Technical Editor – Monica Holman
Irrigation Training & Research Center (ITRC)
California Polytechnic State University
San Luis Obispo, CA 93407-0730
805.756.2434
www.itrc.org

Disclaimer:

Reference to any specific process, product or service by manufacturer, trade name, trademark or otherwise does not necessarily imply endorsement or recommendation of use by either California Polytechnic State University, the Irrigation Training & Research Center, or any other party mentioned in this document. No party makes any warranty, express or implied and assumes no legal liability or responsibility for the accuracy or completeness of any apparatus, product, process or data described previously.

Irrigation Training & Research Center
January 2013

EXECUTIVE SUMMARY

The Cal Poly Irrigation Training & Research Center (ITRC) conducted an assessment of Overall Plant Efficiency (OPE) values generated by the Pump Testing Services Program offered by Southern California Edison (SCE). This report evaluates specific aspects of the Pump Testing Program results and provides informative market research regarding program participant practices and behaviors relating to OPE values. The market research presented in this report attempts to determine the frequency and level of relationships between pump system management characteristics and energy consumption.

It is well-known and was verified again in discussions with pump customers and pump repair companies that the pump tests completed by the SCE program offer vital efficiency and performance information to managerial staff of entities that have participated in the program. Furthermore, the pump test findings often trigger actions by participating entities, resulting in decreases in energy and water consumption. Therefore, pump tests that result in increases in client efficiency via system upgrades produce a return on SCE's investment in the program. Pump tests were also identified that do not result in direct increases in pump customer efficiency, but still provide valuable opportunities for client education, performance benchmarking and long-term trending.

Although many Pump Test Program participants indicated that they use the results of their pump tests to help them decide when to replace or repair pumps, it was clear that the majority of the customers interviewed do not recognize a specified minimum OPE as an "industry-standard" value that triggers a decision on major replacement or repairs. Survey participants also cited the flow rate evaluation performed by pump testers as another determinant for action. Although this value does not directly link to the OPE value, there is a definite awareness of the linkage between flow rate, volume of water pumped, and the annual energy requirements.

The results of the investigation found the following key points:

- An overwhelming number of **program participants described the pump test results as a valuable tool**. They provide benchmarking of vital pump performance information, water depths in wells, and pump flow rates
- **There was no indication of an industry standard of threshold/trigger OPE levels from either pump dealers or program participants.** Furthermore, historical pump test records did not reflect that an industry standard for minimum OPE is being used or could be readily identified/established.

Large public entities (e.g., public water agencies with hundreds of pumps) are very pleased with the Pump Testing Program, and indicate that their staff often rely heavily on the OPE data from the pump tests for decision making. As a result, some of these agencies have extremely high threshold OPE values. For example, one SCE city has a target OPE of 72% while another replaces any pumps that test with efficiencies below 65%.

Some private entities also indicated that high target values are used to trigger a repair project. For example, staff at a private entity aim for optimal values in the 70-75% range, and do not let OPE values drop below 60%. This claim is backed up by the SCE OPE database, which lists their average OPE test results at 68%. In this case, high OPE values are desired in order to reduce power bills.

Survey results indicate that larger entities focus more on pump efficiencies than smaller ones, and are more likely to factor in OPE values when deciding whether to remove a pumping unit for repair. Several users even reported using SCE pump testing in combination with a private pump tester in order to obtain 6-month OPE data.

On the other hand, smaller entities are more inclined to use the pump test results as an informational asset, rather than a key trigger for action. For example, before determining pump replacement, a small dairy consults with its pump dealer to discuss the pump test's overall efficiency results as well as how much the pump is used, how long payback would take, and how old a pump is. It has been found that smaller entities are more likely to wait until a pump has failed to replace it, instead of looking at efficiencies. Several of the smaller customers even reported that they really don't look too hard at the OPE, and that they could easily wait two years between tests.

Project Purpose

The purpose of this project was to investigate whether SCE customers have a minimum trigger Overall Plant Efficiency (OPE) value used for decision-making purposes on pump replacement or repairs. Specifically, this report was designed to evaluate whether there is a clear difference between <u>routine maintenance</u> as opposed to <u>complete retrofit/replacement/renovation</u> activities. The first mode of operation is to simply address pump repair as routine maintenance. This mode of operation is repair work that might be done on pumping units as a manner of preventive maintenance procedures. It was found that the larger organizations are migrating towards this approach. Complete retrofit/replacement/renovation activities are typically done when the pump performance is deficit and action must be taken. The majority of the customers surveyed operate in the second mode. A typical response by customers is that they tend to be more reactive to pump problems than proactive.

Through discussions between SCE and ITRC staff, priorities for this report were identified. The project was created to evaluate the assumptions made in the Pump Testing Program specifically related to how customers make a decision for action on their pumping units. The following is from the Statement of Work:

> For SCE's pump test program, savings are currently calculated based on pump test results. After each test, a report is generated which provides various operational parameters (such as flow rate, head, annual water requirement etc.) and pumping plant's OPE and potential energy savings strictly due to changing the impeller/bowl efficiency. When pump tests reveal inefficient operations, customers are encouraged to renovate/replace their pumping systems.
>
> An impact evaluation study conducted by Equipoise consulting in 2006 analyzed reported OPEs for various pumping technologies. While this earlier work is useful for establishing average OPEs by pump class it is does not determine how far below these OPEs customers will reach before taking action.
>
> The primary hypothesis is that many customers would, in the absence of SCE pump test data, make a predictable decision when to improve their pumping plant performance.

Survey Design

SCE provided their pump test database for the last six years (from January 2006 through December 2011). There are over 34,000 pump tests in the database with an average of over <u>**5,600**</u> pump tests performed per year. ITRC created a survey to evaluate SCE customer responses and reaction to the OPE results. The survey was vetted by SCE staff and a focus group of eight selected customers (identified in this report as Group 1). Initial observations were based on numerous phone interviews and the first questionnaires to be completed. Modifications to the questionnaires were made based on feedback from SCE.

ITRC selected 50 of SCE's private customers and 50 of SCE's public customers to be interviewed for the "Overall Plant Efficiency Survey". Customers were selected to represent the matrix of service accounts in Table 1. Based on a review of the database, ITRC determined that about **11,000 unique service accounts** have participated in the pump testing program over the last six years.

Table 1. Distribution of private/public customer service accounts by Megawatt-Hour and pump type

SCE Pump OPE Database - Private Distribution Sorted by Service Account - All Data

	Private				
mWh	Centrifugal Booster	Submersible Booster	Submersible Well	Turbine Booster	Turbine Well
<50	268	16	1335	173	2522
50-100	64	11	140	113	787
100-200	46	8	70	105	715
200-300	9	10	24	63	334
300-400	5	2	25	31	192
400-800	17	9	20	43	232
>800	74	3	25	44	98
Total	**483**	**59**	**1639**	**572**	**4880**

SCE Pump OPE Database - Public Distribution Sorted by Service Account - All Data

	Public				
mWh	Centrifugal Booster	Submersible Booster	Submersible Well	Turbine Booster	Turbine Well
<50	147	36	209	256	279
50-100	40	15	61	121	86
100-200	55	15	66	136	149
200-300	29	4	26	89	126
300-400	16	10	20	45	119
400-800	47	10	37	138	308
>800	41	3	37	158	320
Total	**375**	**93**	**456**	**943**	**1387**

The selected survey customers are also spatially distributed across SCE territory (see Figure 1). The pins on the map represent the customer locations. Surveys were completed by a total of 38 program participants, 2 program non-participants (outside of SCE's territory) and 17 pump dealers. The SCE pump test customers are composed of two market actors: public entities (approximately 550 customers) and private customers (approximately 2,500).

Table 2. List of SCE OPE customer types

Public	Private
▪ Cities ▪ Counties ▪ Community Service Districts ▪ Waste Water ▪ Sanitation ▪ Mutual Water Companies ▪ Irrigation Districts ▪ Schools, Cemeteries, Parks	▪ Golf Courses ▪ Property and Housing Groups ▪ Fisheries ▪ Irrigation and Ag Management ▪ Energy Corporations ▪ Farm and Ranch Management ▪ Horticulture ▪ Food and Beverage ▪ Healthcare Service Groups

Figure 1. Spatial distribution of SCE customers selected for survey. Note: The yellow pins represent the private agencies and the pink represent the public agencies.

SCE Pump Testing Program Participant Key Findings

- Numerous participants have identified other benefits of the Pump Test Program beyond the OPE value. For example, one water agency near Oxnard requires customers to test flow meters for accuracy; SCE customers get the benefit of the OPE plus a verification that their meter is accurate. Other regions, such as the east side of the San Joaquin Valley, have large fluctuations in the pumping water level. Several customers have reported that the pumping water level information they received from the OPE testing on their wells is invaluable. Among customers that reported that they do not use the OPE directly to determine a trigger value for pump repair, most indicated that they use other information from the pump test to help with the economic decision to repair, replace, or renovate pumps.

- Although ITRC has identified patterns in OPE levels that result in action (with customer behavior patterns emerging with an OPE below 50%), there exists no industry standard for minimum OPE levels.

- Very few of the SCE customers that were surveyed made note of the fact that different efficiencies should be expected out of varying pumps. One water agency customer said in an interview that they have different set points depending on the HP of the pumps, but most entities have only one threshold that they do not let their values drop below regardless of the pump type or size of the motor.

- There is very little OPE trending being done by SCE customers on specific pumps. It is recognized that all of the pump testers have easy access to the SCE OPE database. This allows the pump testers to easily pull up old tests and show the trend in a meeting with their client. However, it was apparent this feature was not being used often.

- Customers who repaired/replaced pumps typically did so based on overall pump performance, meaning that they were interested in the data provided by the OPE test. Figure 2 shows the number of respondents that cited their reasons for repairing/replacing a pump.

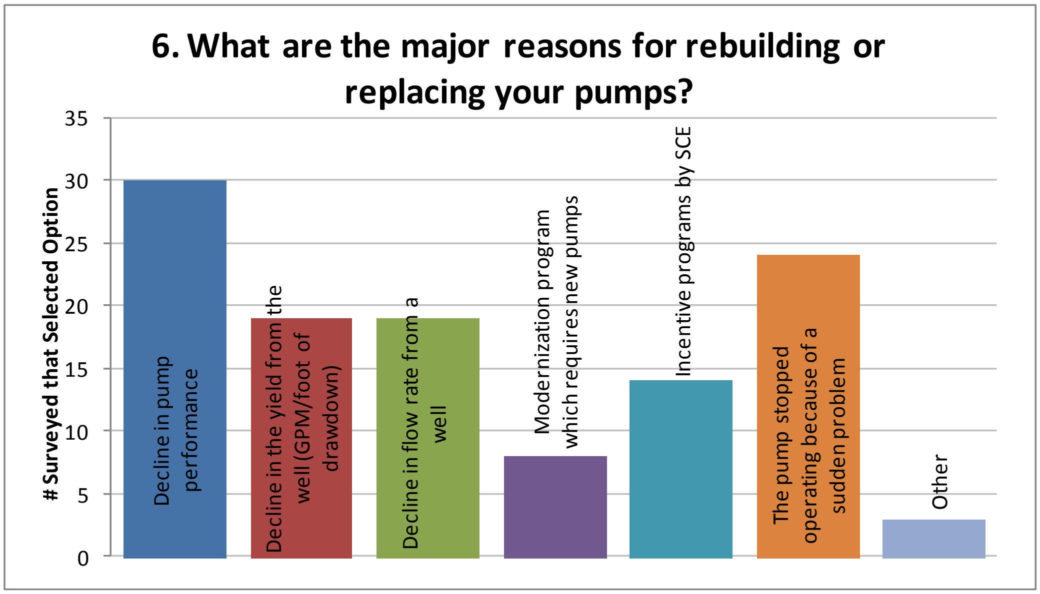


Figure 2. Survey Question 6 responses: Major reasons for rebuilding/replacing pumps

- Average OPE values were higher than the research team had expected to find. In addition, the number of pumps that tested over 70% was larger than expected. Figure 3 shows a summary of the OPE results that was reported for Group 1.

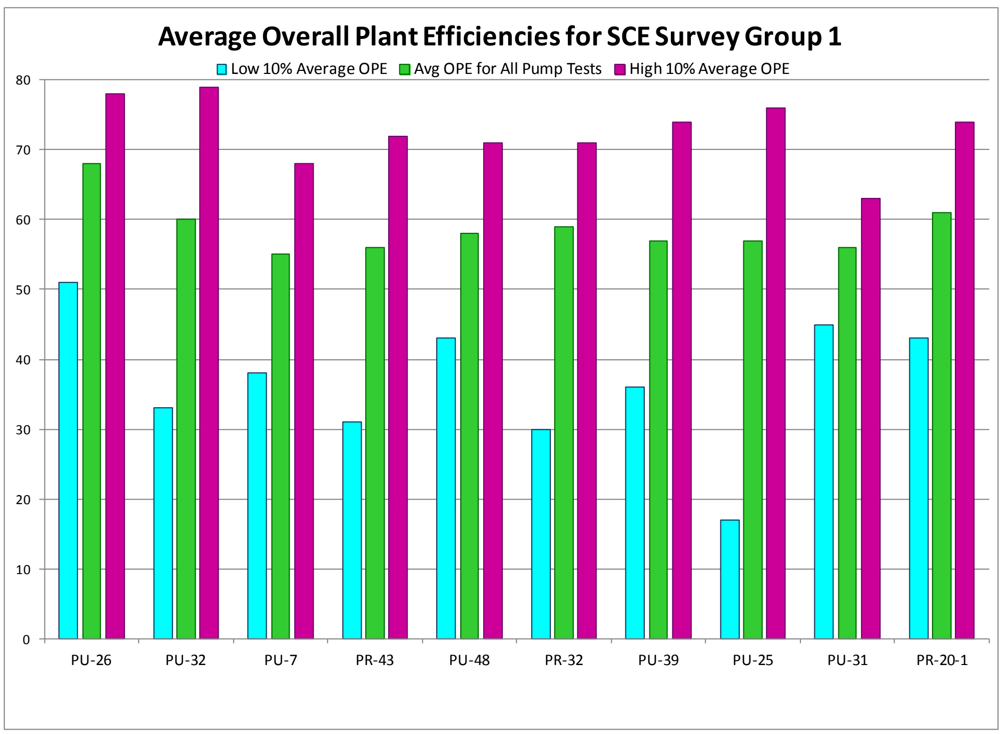


Figure 3. Evaluation of the OPE results for Group 1

- An initial assumption made by ITRC was that the low values in this SCE OPE database were a direct result of a poor performing pump that needed to be repaired. The assumption was that these values would provide a clear indicator of the minimum OPE values that were actually obtained by the pumps prior to repairs. **Unfortunately**, it was pointed out by one of the pump testers during a presentation of the preliminary data that low OPE tests can be generated by a system that operates at several Total Dynamic Head (TDH) values. In one year, the TDH may be very high (400 ft) and the OPE reported value at 70%. The next year the TDH may drop to a very low value (100 ft) and the OPE could drop to 30%. Or the OPE values could be flipped, meaning that there are pumps being used to cover a wide range of operating points. It should be noted that using the same pump for such a large TDH range is not recommended.

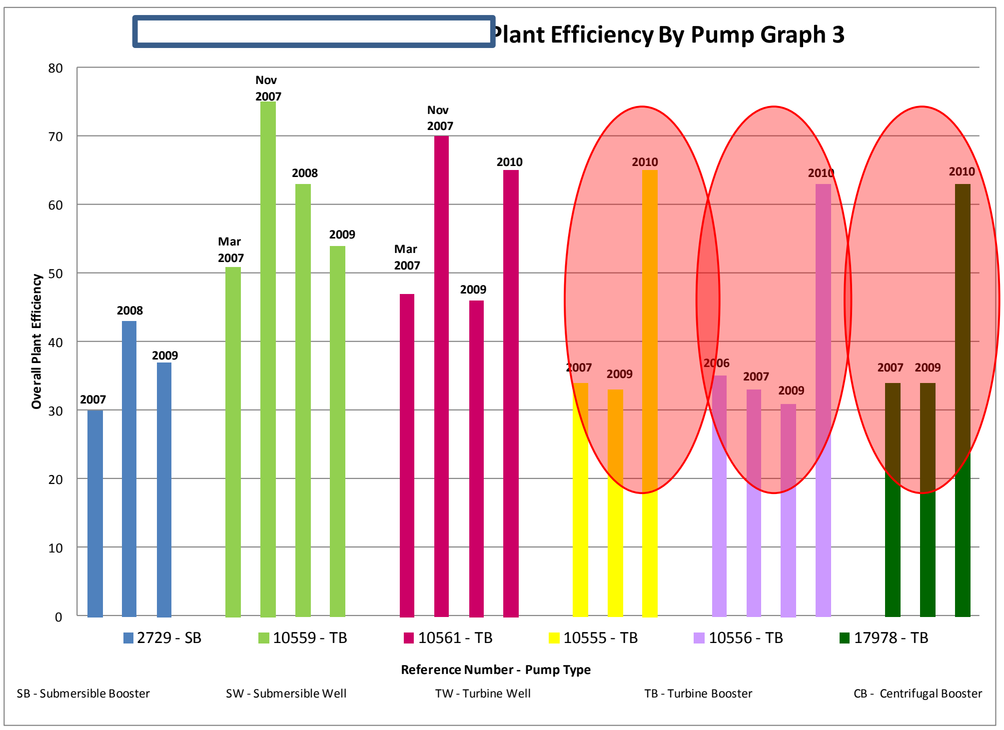


Figure 4. Evaluation of the OPE results for Los Angeles Customer

Program Participant Statistical Results

Twenty-seven unique hypotheses were developed and tested to categorize program participants by behavioral characteristics and pumping efficiency level. It was theorized that highly efficient pumping systems require substantial support on many fundamental levels. More specifically, intensive management practices such as subscribing to a trigger OPE could elicit higher average OPE levels. One or more appropriate statistical tests were applied to each of the twenty-seven hypotheses. Table 3 summarizes the results of the testing with the respective levels of statistical support.

Table 3. Summary of hypothesis testing results

No	Hypothesis	Strong	Moderate	Weak	None
1	Entities that reported prescribing to a set maintenance program operate more efficient pumps (mean OPE = 61.8%)	X			
2	Entities that rely solely on SCE test information operate more efficient pumps			X	
3	Entities that monitor using a SCADA or EMS system operate more efficient pumps (mean OPE = 63.9%)	X			
4	Entities that remove/repair one or more pump(s) per year, as a maintenance program, operate more efficient pumps				X
5	Entities that perform other pump testing for a maintenance program operate more efficient pumps				X
6	Entities that replace pumps upon failure operate more efficient pumps				X
7	Entities that have utilize other strategies for a maintenance program operate more efficient pumps				X
8	Entities that apply more person-hours towards a maintenance program operate more efficient pumps (mean OPE = 57%)		X		
9	Entities that invest more money in a maintenance program operate more efficient pumps (mean OPE = 65%)	X			
10	Entities that have a higher percentage of remotely monitored pumps operate more efficient pumps (mean OPE = 62.2%)	X			
11	Entities that operate SCADA-type monitoring operate higher efficiency pumps (mean OPE = 61.9%)		X		
12	Entities that employ a higher percentage of automatically controlled pumps operate more efficient pumps				X
13	Entities that employ a higher percentage of remotely controlled pumps operate more efficient pumps				X
14	Entities that have more pumps operate more efficient pumps (mean OPE = 62.1%)	X			
15	Entities that provide municipal water operate more efficient pumps (mean OPE = 63.6%)	X			
16	Entities that participate in trade/industry organizations and conferences operate more efficient pumps (mean OPE = 63.1%)	X			
17	Entities that reference magazine/news articles to make decisions operate more efficient pumps				X
18	Entities that reference emails and internet information, not used to make decisions, operate more efficient pumps				X
19	Entities reporting that participation in trade organizations had no impact operate more efficient pumps				X
20	Entities with no response to participation in trade organizations operate more efficient pumps				X
21	Entities reporting that an old pump as a major cause for pump repair operate more efficient pumps (mean OPE = 62.5%)		X		
22	Entities reporting that an incorrect pump installation as a major cause for pump repair operate more efficient pumps				X
23	Entities that reported sand wear is the major cause for pump repair operate more efficient pumps				X
24	Entities that reported bearing failure as a major cause for pump repair operate more efficient pumps				X
25	Entities that reported poor maintenance as a major cause for pump repair operate **less** efficient pumps	X			
26	Entities with other major causes for pump repair operate more efficient pumps				X
27	Entities that operate higher numbers of pumps utilize a trigger OPE for pump repair/replacement	X			

The resulting significance of each relationship can be summarized in the following major findings:

1. Larger, well-supported entities had significantly higher average OPE levels

This conclusion was derived from a combination of entity size indicators. These indicators are listed below along with a respective grouped mean OPE percentage.

a. The use of a SCADA or EMS monitoring system (mean OPE = 63.9%)
b. Spending more than $4,500 annually per pump on maintenance (mean OPE = 61.8%)
c. Operating more than 11 pumps (mean OPE = 62.1%)

2. Implementing automatic and remote control systems does not relate to higher OPEs

Entities that reported the capability to remotely or automatically control their pumps did not have significantly higher OPE levels. Although implementing complex pump controls may ease operational headaches, it did not ensure energy efficiency.

There were numerous examples provided where SCE customers are using some form of Supervisory Control and Data Acquisition System (SCADA). These included both the agricultural and municipal water agencies. Typically, these systems are being used to alarm a central location if there is a problem. There were only a few cases where SCADA or some type of remote monitoring is being used to determine the OPE automatically.

Of the twenty-seven hypotheses tested, there was strong support for #9 (95%+ confidence), moderate support for #3 (90%+ confidence), and weak support for #1 (85% confidence). Although many hypotheses were not supported to any substantial degree, many of the principle hypotheses were strongly supported. These primary hypotheses provide the support to identify multiple characteristics of efficient pumping systems.

Pump Dealer Key Findings

A total of 17 pump dealers were interviewed, representing an average of 7,651 pump repairs annually. These pump dealers serviced both program participants and non-participants. A number of critical conclusions were drawn from their responses using standard analytical methods, and are listed below.

Typical OPE Thresholds at Repair

Regardless of the cause of the action, pump dealers had a true sense of efficiency levels at the time of contracted service. The program participant frequencies are displayed in Table 4.

Table 4. Frequencies of OPE levels at the time of pump service

OPE (%)	Number of clients	Percent
25	450	9%
40	**3,545**	**70%**
45	104	2%
50	420	8%
55	215	4%
60	208	4%
70	140	3%
Total	5,082	100%

Some SCE customers may take action based on the performance of the pump rather than at a prescribed OPE value. However, in many cases cited by the participants, the SCE customers rely on the performance data that comes from the SCE OPE test in order to make that assessment. This pattern is reflected in Figure 5.

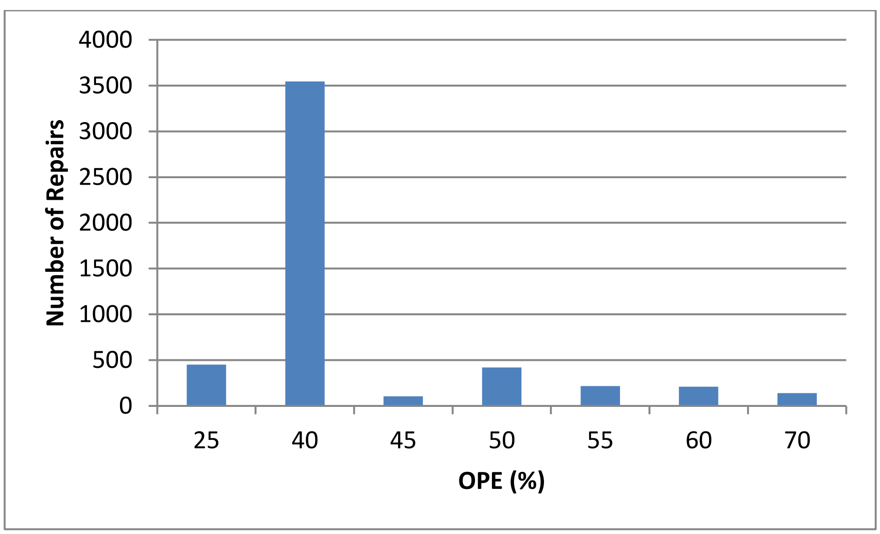


Figure 5. Comparison of OPE levels at the time of service

Pump Test Frequency

It is estimated that 5% of the 7,650 annual pump projects reported by pump dealers are completed on pumps that have consistent testing intervals. This equates to approximately 10% of the reported pump projects funded by Pump Testing Program participants. The remainder (65%) of these services is completed on pumps that receive sporadic testing at inconsistent intervals.

Key Recommendations and Findings by ITRC

Large Potential for Energy Savings

There is a large potential for energy and water savings in California. ITRC has published several reports documenting overall energy use and the potential for savings such as *California Agricultural Electrical Energy Requirements* (Burt et. al., 2003), which included a synopsis of average pumping plant efficiencies throughout central California's irrigation districts and growers. The average pumping plant efficiency for public water district pump tests was 64% (over large 900 pumps included). This high OPE value is similar to the public entities in this SCE study (average OPE ~57%).

However, the 2003 ITRC report noted a substantially lower value for on-farm pumps throughout California's San Joaquin Valley. An average pumping plant efficiency of 48% was calculated from over 2,800 on-farm pump test data points. This discrepancy indicates a large potential for energy conservation at the on-farm level.

Burt (2012) evaluated energy savings potential from a total of 15,000 pumps located throughout California. With similar average OPE findings presented in Burt (2012), potential savings was computed as **102,100 MWh/year**. Burt (2012) targeted the recommendations with an analysis which concluded that by **targeting only 2.5% of the larger pumping units, about 12% of the total potential savings could be achieved**. Relating this back to SCE's service area, this would tend to focus on the large pumps used by public agencies. It is highly recommended that these entities be supported to perform pump testing even if they have adopted a maintenance mode of operation. Figure 6 is a graphic summary of the results of the Burt (2012) evaluation. Note that this type of energy analysis could **only be done with OPE tests**.

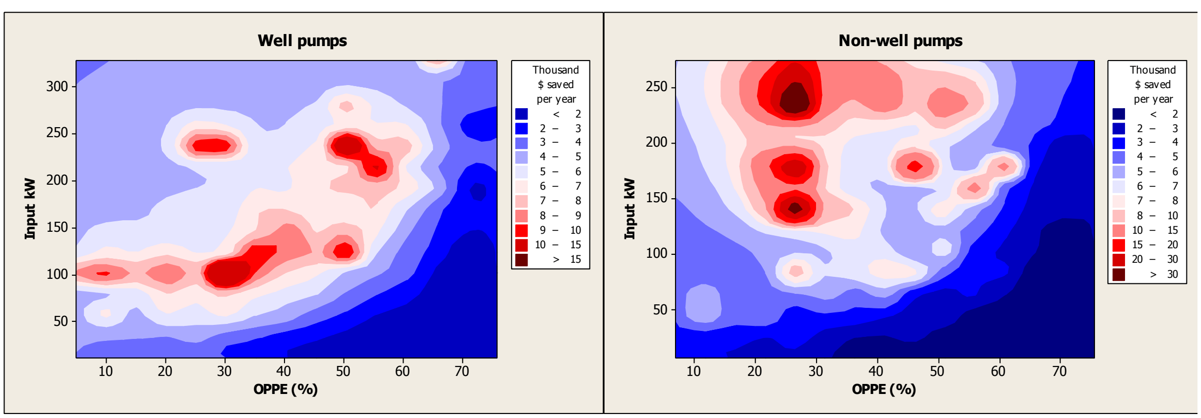


Figure 6. Contour plot of Input kW vs. OPE (%) arranged by money savings (thousand $/year) (Burt 2012)

Prioritized Approach to Pump Testing Services

In general, the majority of the SCE Pump Testing Program participants could be characterized into two groups:

Type 1 Customer. There were a number of respondents that stated that they would consider taking action on the repair/replacement/retrofit of a pumping unit at a relative OPE value below 50%, or at catastrophic failure. Typically, the OPE level was cited as only one of many determinants, including hours of operation, economic analysis and flow/pressure performance. All of the Type 1 customers contacted felt that the SCE Pump Testing Program was a **valuable service.**

Type 2 Customer. There were a smaller number of respondents that stated that they used a value as high as 65% as a point where they take action on the repair replacement/ retrofit of a pumping unit. Typically, the OPE was the key determinant in the decision making process.

Figure 7 illustrates the theoretical difference between a Type 1 and Type 2 SCE customer who participates in the pump test program, in terms of water/energy use on a single pumping unit. The time frame was expanded to 20 years to illustrate the temporal savings. It also illustrates that the OPE values are changing constantly and that a single year evaluation of benefits can be deceiving.

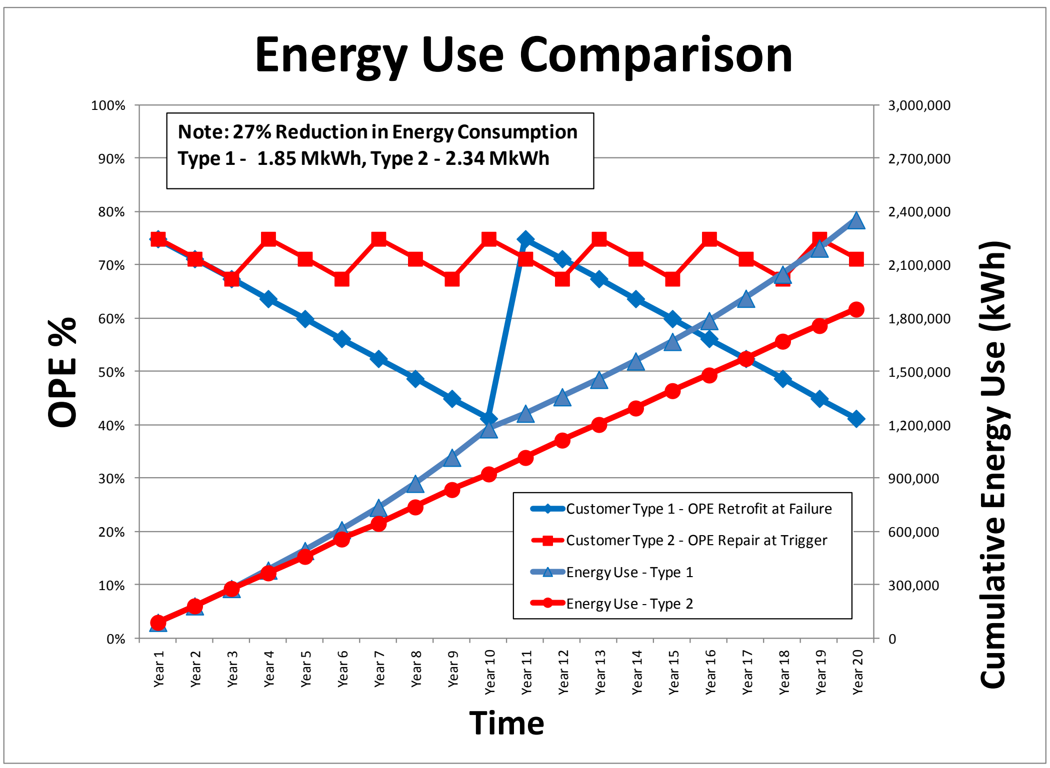


Figure 7. Theoretical energy use for two types of customers

The results of this example show that the Pump Testing Program is beneficial to both types of customers. Obviously, the Type 2 Customer is influenced heavily by the SCE Pump Testing and Rebate Incentives program. The result is a significant actual energy savings (27% energy over 20 years in this example). Although Type 1 Customers still benefit from pump test information, this example illustrates that influencing Type 1 Customers to act more like Type 2 Customers would be beneficial to SCE. The potential for ***future energy savings*** from <u>Type 1 Customers</u> is significant.

Recognizing that there are limited resources available and that every SCE customer cannot receive a pump test every year, there are other opportunities to aid SCE customers in the monitoring of the decline in pump performance. Coupled with adequate education, increased instantaneous performance monitoring has the *<u>potential to decrease the demand for short interval pump testing.</u>*

Option 1

Installation of state-of-the-art flow meters. Innumerable pump stations have poor hydraulic conditions for flow rate measurement. New advances in magnetic flow meter technology have provided a simple solution that has only recently become available. Research has demonstrated that these new electronic devices can work adequately in the poor hydraulic conditions existing in many pumping plants. In fact, some manufacturers have incorporated hydraulic conditioning into the measurement device for this reason. The key disadvantage to these meters is cost. Further analysis would be required to determine the feasibility and potential changes in behavior with the addition of instantaneous flow rate information for operational management.

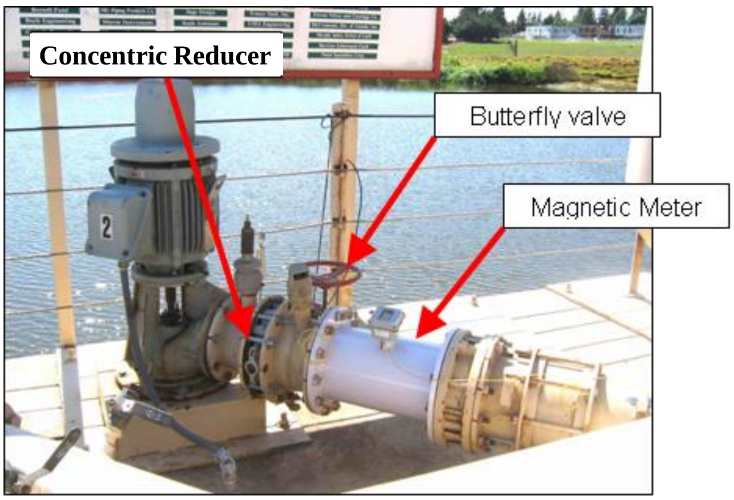


Figure 8. Photo showing the use of a magnetic flow meter in a poor hydraulic condition

Option 2

Installation of individual pump power meters. Most installations utilize only one device that meters the power consumption of multiple pumps. This makes pump performance monitoring problematic. New products have become available that provide inexpensive and non-intrusive metering of all circuit characteristics including power factor, kW, amperage and voltage. While a pump test report can separate the data to indicate the individual performance of pump units, the direct reading approach would aid SCE customers in the decision making process by helping with documenting the trend of the performance.

Figure 9. Direct display kilowatt meter

More specifically, combining both options would allow a customer to provide in-house trending of key performance characteristics and when supplemented with a longer interval testing schedule, has the potential to decrease pressure on SCE by providing instantaneous information.

Increase the OPE Education for Pump Testers

Pump testers should be provided with additional information on pump improvements that are beyond an OPE test. For example, the use of Variable Frequency Drives (VFDs) seems to be underutilized in the SCE service area.

Increase the OPE Education for SCE Customers

There needs to be an expanded effort on the education of the SCE customers on the Pump Testing Program. For example, there was a lack of awareness on how the OPE values vary based on the size of a pump. ITRC would be available to generate a list of topics that could be developed for future training.

Decrease the Use of Independent Surveys

More than one SCE customer complained about the number of questionnaires/surveys. ITRC has been involved with numerous surveys over the last 2 decades. It was unexpectedly difficult to get cooperation from the SCE customer base to get the surveys completed. The next phase of OPE evaluation should be done with site interviews/discussions and coordinated with the pump testers.

Minimum OPE

Although this study did not clearly identify a minimum OPE value, it was clear that the majority of pump retrofits/repairs occur after a pump has dropped below an OPE level of 50%.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Southern California Edison (SCE) provides utility services to the greater southern California area. A large portion of SCE's consumed energy is related to the transportation and pressurization of the state's water supply due to the intensive agriculture and municipal development present in a largely arid landscape. This relationship presents an increased potential for over-extending the electrical system's capabilities and occasionally results in black-outs and brown-outs. SCE has created a wide variety of programs and incentives to minimize these electrical shortages with the goal of reducing both peak electrical demand and overall electrical energy consumption within its service area.

With the large potential for energy conservation stemming from the agricultural industry, SCE has offered efficiency testing of water pumping systems for over 100 years. This program provides pumping efficiency reports including vital information to enable educated decision-making regarding the management and upgrades of electrically-driven pump systems.

In an attempt to minimize the financial burden of upgrading pump systems, SCE also offers incentive programs. The pump incentive programs provide cost-sharing for energy conservation projects such as pump replacements, automatic controls and off-peak pump operation.

SCE Program Background

SCE has offered pumping system evaluation as a free service since 1911. The technicians schedule and perform OPE evaluations throughout the SCE service area. A total of between 4,000 and 5,000 tests are performed each year. If a pump falls below an economic trigger value, a cost analysis is provided to customers that provides recommended upgrades, potential savings, and paybacks.

The pump test result below is from an SCE City customer and is an example of a pump test report as well as the use of the SCE incentive program to initiate a repair. The OPE test showed a pump test result of 38.7% for a vertical turbine pumping unit in a well application. It was recommended based on SCE threshold values that the efficiency could be improved to 70% with a potential energy savings of 331 MWh/year. Table 5 lists current SCE OPE threshold values.

Table 5. OPE Threshold Values based on pump type

Vertical Turbine Pump - Well

Motor HP	Trigger	Recommended	Minimum OPE Values
3 to 5	< 50%	55	17
7.5 - 10	< 53%	58	17
15 - 30	< 56%	61	18
40 - 60	< 60%	65	20
75 - up	< 64%	69	21

Vertical Turbine Pump - Booster

Motor HP	Trigger	Recommended	Minimum OPE Values
3 to 5	< 51%	55	17
7.5 - 10	< 56%	60	17
15 - 30	< 59%	63	18
40 - 60	< 62%	67	20
75 - up	< 65%	70-72	21

Centrifugal Booster

Motor HP	Trigger	Recommended	Minimum OPE Values
3 to 5	< 51%	55	17
7.5 - 10	< 54%	58	17
15 - 30	< 57%	61	18
40 - 60	< 61%	65	20
75 - up	< 65%	69	21

Submersible Pump

Motor HP	Trigger	Recommended	Minimum OPE Values
3 to 5	< 46%	51	15
7.5 - 10	< 49%	54	16
15 - 30	< 52%	57	17
40 - 60	< 56%	61	18
75 - up	< 60%	65	20

Fundamentally, the SCE Pump Testing Program is a service that produces informational packages for program participants. The package provides the participant with vital pumping system performance characteristics as well as various system upgrade options. These management recommendations are further combined with engineering economics in the form of potential payback periods for hardware and operational changes.

By comparison, third party pump efficiency tests commonly cost a consumer $500 per test, and lack the extensive analysis offered by SCE. Interviews with private pump testers were done as part of the study to get a better understanding of why some organizations use private testers. One of the key comments was that agencies that have heavily endorsed the use of OPE testing in their decision-making have now gone to testing every 6 months in order to maximize the energy efficiency of their large pumps. Since the formal guidelines on the SCE OPE testing are limited to every 2 years, this has created the opportunity for private pump testers to fill the void.

<u>Service Area</u>

The program assessment focused on pump dealers and service companies that operate inside of SCE's service area. Figure 10 shows the extent of the SCE service area as well as the locales on which the survey focused.

The service area includes a wide array of climates and levels of urbanization. SCE provides electrical power to a variety of pressurized water systems with a range of requirements, sizes and uses. The following lists some of the major categories of electrically-driven water pump users:

- Potable water systems
- Wastewater systems
- Agricultural irrigation
- Residential wells for irrigation and potable water

It is critical to acknowledge the large differences in expectations, operation, and levels of investment inherent in each of these system types. These characteristics will undoubtedly affect the level of program interest and participation throughout the service area.

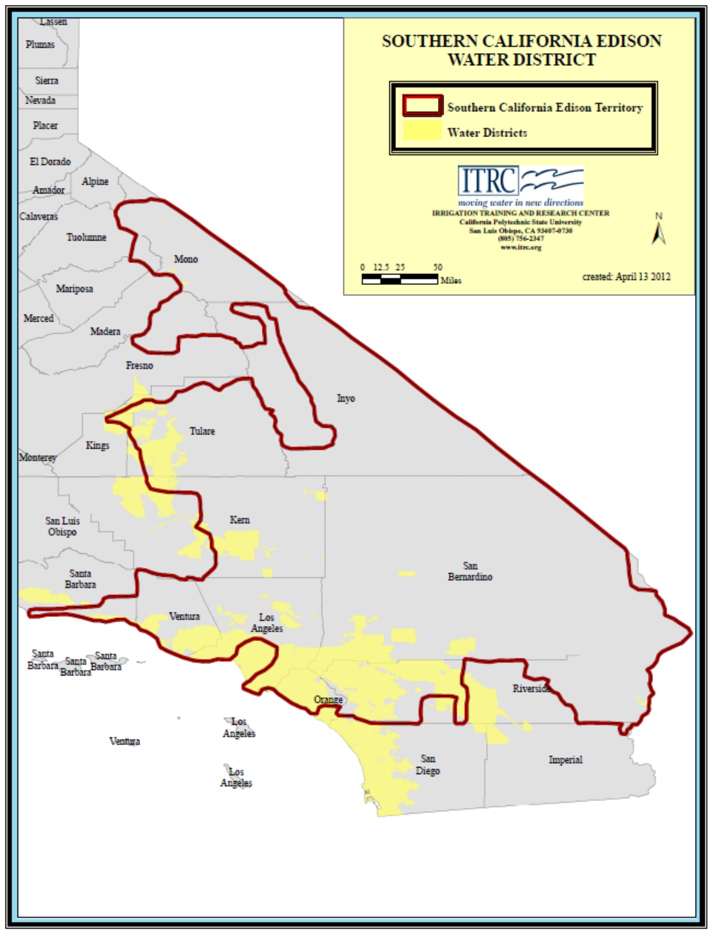


Figure 10. SCE service area throughout Southern California

PUMP TESTING PROGRAM EVALUATION

The Irrigation Training & Research Center (ITRC) located at the California Polytechnic State University, San Luis Obispo, completed an evaluation of agricultural pumping energy conservation programs offered by Southern California Edison (SCE). The major tasks of the evaluation are listed below:

1. Develop a method to gather data and commentary from program participants.
2. Complete a statistical analysis of program users (pump owners/operators) and program implementers (pump dealer/service companies).
3. Analyze the collected data for trends, patterns and practices.
4. Investigate the potential for improved targeting of focus groups.
5. Identify enhancements for future program design.

Evaluation Overview

Pressurized water system personnel will occasionally repair/replace pumps due to a number of well-known triggers. These triggers may include:

- Pump test records that show either a steady or sudden decline in pump performance (lower flow, pressure, or efficiency).
- Pump test records that show a serious decline in the yield from the well (GPM/foot of drawdown). The pump must be removed to physically renovate the well, and it is a logical time to refurbish or replace the pump.
- The significant decline over time of flow rate of a well to the point that irrigation operations are hindered or there is an obvious inefficiency. This lower flow rate may be due to a number of causes (lowered aquifer level, or pump problems), but in any case the pump will be removed and refurbished or replaced.
- The planning of a district modernization program which requires automation of the pumps and known pump performance characteristics. The automation will be put onto the pump with the highest efficiency. Therefore, a poor efficiency pump will be replaced with a newer, more efficient one that will be used as the automated pump.
- A pump that has stopped operating because of a sudden problem, such as:
  - It seized up due to mineral deposits after being off during the winter.
  - It seized up due to lineshaft bearings having improper lubrication or sand wear.
  - The motor burned up, or the motor bearings were damaged.
  - There is excessive vibration or overheating of the motor.

Although these cues are generally understood, the specific probabilities of each are unknown. Moreover, this information has not been historically available especially across the diverse industrial and geographical markets present in the SCE service area. The frequency of pump tests eliciting a renovation or repair response is of critical importance for the quantification of the SCE Pump Testing Program's success. This evaluation focuses on the examination and analysis of pump replacement trigger demographics as it applies to pump test data and other management characteristics.

Research Methods

A total of two questionnaires were developed by ITRC for use in this initiative: one for the customers and one for pump dealers. The surveys included both quantitative and qualitative inquiries, including current practices and open-ended market research. The surveys were aimed at culling responses to five questions:

1. What is used as a signal to replace or repair pumps?
2. Is there a "threshold" OPE that signals pump repair/replacement work?
3. What factors characterize entities with higher average OPEs?
4. Conversely, what factors characterize entities with low average OPEs?
5. With the goal of improving energy efficiency, how can the SCE Pump Testing Program be improved?

Client Research

The SCE Pump Testing Program provides a valuable service at a highly discounted rate with the goal of minimizing peak energy consumption inside the service area through energy conservation on a per-client basis. Conservation programs without direct revenue typically require not only diligent justification for their existence but also maximization of program efficiency. This report focuses on the latter. In terms of the SCE Pump Testing Program, maximizing program efficiency equates to minimizing the dollars invested per kW-hr conserved.

It can be assumed that individual pump tests result in different levels of energy conservation. It then follows that a practical method of increasing efficiency would be to prioritize the type and frequency of the pump tests using proven methods. The following outlines a logical market targeting approach:

1. Target entities that:
    - Refuse to pay for third party testing if the SCE service is unavailable
    - Require the recommendations and insight put forth by SCE representatives for conservation goals, planning and implementation
    - <u>Present energy conservation potential</u>
2. Minimize services to entities that:
    - Are motivated, willing and able to pay a third party for routine, frequent pump testing
    - Are unwilling to act upon system repair or upgrades regardless of the pump test results
    - <u>**Do not** present energy conservation potential</u>

Prior to this report, little information was available regarding the details of relationships between these two groups as well as a means to categorize pump test participants. The primary research presented in this section investigated the potential correlations between the types of Pump Test Program participants listed above and various entity characteristics. **It was posited that behavioral and managerial characteristics may have an influence on entity OPE levels.**

The specifics of this general hypothesis could then be used to identify market targeting strategies as a means to increase the program efficiency and energy conservation levels. Potential behavioral and managerial factors which may have a correlation with an entity's OPE level were listed by ITRC, such as:

- Maintenance intensity
- SCE program participation
- Entity operational budget
- Industry type
- Entity size

As these theories are yet unproven, the evaluation presented in this report targeted these factors when developing the 20 hypotheses outlined in Table 6.

Table 6. Research hypotheses

No.		Hypothesis
1	**The level of maintenance relates to an entity's OPE**	
a		Have a maintenance program
b		Rely solely on SCE pump test information
c		Monitoring using SCADA or EMS system
d		Removing/repairing at least one pump a year
e		Other pump testing
f		When a pump fails
g		Other maintenance program
2	**The level of annual investment in a maintenance program relates to an entity's OPE**	
a		The amount of person-hours per year
b		The amount of money invested annually
3	**The level and type monitoring and control relates to an entity's OPE**	
a		The percent of remotely monitored pumps
b		The type of monitoring
c		The percent of automatically controlled pumps
d		The percent of pumps remotely controlled
4	**The entity's size and type relates to an entity's OPE**	
a		The number of pumps
b		Industry type
5	**Participation in trade organizations relates to an entity's OPE**	
a		Follow and participate in trade/industry organizations including conferences
b		Reference issues in magazine/news articles, used to make decisions
c		Reference emails and internet information, not used to make decisions
d		No impact
e		No response
6	**Major causes for repair/replacement relates to an entity's OPE**	
a		Old pump
b		Incorrect installation
c		Sand wear
d		Bearing failure
e		Poor maintenance
f		No response
7	**The use of a threshold OPE relates to the size of the entity**	
		The number of pumps

OPE Calculation

Many of the statistical computations provided in this section compare survey responses to an "OPE" value. This overall plant efficiency (OPE) value is derived from computations with values from the program database, made available through SCE. The SCE program database provided a five-year history of individual pump tests for each of the selected entities, as well as other system information such as pump type and annual account energy use. In preparation for the statistical analysis, it was necessary to compute a representative OPE value for each entity.

A weighted-average computation was applied to the individual OPE data points across the entire database time scale. This approach properly weights each pump's contribution to overall entity efficiency based on factors such as relative size, energy consumption rate and average efficiency. Additionally, multi-year averaging accounts for OPE variance caused by temporal and systematic changes. The efficiency results from individual pump tests may temporarily vary due to total dynamic head changes caused by shifts in multiple pumping characteristics and could further vary permanently due to component upgrades. Although the weighted-average approach more adequately represents an entity's level of efficiency, it does minimize the presence of extremely low and high pumping efficiencies.

Hypothesis Testing

The analysis used to test the 20 hypotheses involved one or more appropriate statistical methods depending upon the response type, frequency and distribution. Table 7 lists the method(s) used for each hypothesis test.

Table 7. Statistical methods utilized for each hypothesis test

No.	T-test	Chi-Squared	ANOVA	Tukey
1a	X	X		
1b	X	X		
1c	X	X		
1d	*	*		
1e	*	*		
1f	*	*		
1g	X	*		
2a	X	X		
2b	X	X		
3a	X	X		
3b	*	*		
3c		X	X	
3d		X	X	
4a		*	X	X
4b			X	X
5a	X	X		
5b	X	X		
5c	*	*		
5d	*	*		
5e	X	X		
6a	X	X		
6b	X	*		
6c	X	X		
6d	X	X		
6e	X	X		
7	X	X		

(*) denotes a test with insufficient responses for analysis; however, the responses are still reported

Sample Design

Through conversations between SCE and ITRC staff, it was determined the analysis would include data from “a well-rounded” customer base. This approach provides key information on the market as a whole and can provide insight for future program design. Conversely, ITRC typically employs a more targeted strategy when focusing on conservation. This concept is described in detail in a later section.

ITRC developed a specific sample design approach to ensure that the analysis results were representative of the markets serviced by SCE. The required sampling data was extracted solely from the SCE Pump Testing Program database. The database made available to ITRC included 34,300 pump tests completed between January 2006 and December 2011, covering 10,887 individual pumps. The data was organized into a two-tiered sample selection spreadsheet to categorize the entries into the following subgroups: private and public entities.

Distribution percentages and target sample sizes for both private and public entities were calculated across all pump types and 12-month power consumption values. Table 8 shows the first-tier selection spreadsheet for private entities. A similar spreadsheet was compiled for the public entries as well.

Table 8. Preliminary sample selection spreadsheet

			Private Entities			
MW-hr / year	Centrifugal Booster	Submersible Booster	Submersible Well	Turbine Booster	Turbine Well	**Total**
< 50	268	16	1335	173	2522	4314
50-100	64	11	140	113	787	1115
100-200	46	8	70	105	715	944
200-300	9	10	24	63	334	440
300-400	5	2	25	31	192	255
400-800	17	9	20	43	232	321
> 800	74	3	25	44	98	244
Total	**483**	**59**	**1639**	**572**	**4880**	**7633**
Distribution	6%	1%	21%	7%	64%	100%
Target Sample Size	**3**	**1**	**10**	**4**	**32**	**50**

Using the calculated target values from Table 8, ITRC developed a selection weighting protocol to select **50 private and 50 public** sample entities using the following sample pool characteristics:

1. **Pump type**
   A well-rounded sample must include the range of pump types listed in Table 8, as each category has specific management requirements and system indicators. For example:
   - *Pump maintenance* – Most turbine and booster pumps and their motors require diligent and regular maintenance. Conversely, submersible pumps must be physically pulled in order to perform any maintenance.
   - *Initial investment* – Deep set vertical turbines require substantial investment relative to other pump types and also require an adequate three phase power supply and support structure.

   Once the pump type requirement was satisfied, secondary and tertiary conditions were applied to the screened sample pool before being selected.

2. **Power consumption**
   The magnitude of annual power consumption is a general indicator of entity size. The size of a given entity can directly influence pump management/operations by factors such as budget sizes, operations/management hierarchy and the number of pumps. As such, the matrix specifically targeted samples from multiple power consumption categories between 50 MW-hr/year to greater than 500 MW-hr/year.

3. **Spatial distribution**
   The matrix's final and tertiary condition was spatial distribution. It was prudent to verify the potential samples were well-distributed throughout the service area in order to negate regional and market specific practices. For example, metropolitan water districts in the greater Los Angeles area were selected alongside large and small agricultural growers in the southern San Joaquin Valley, Antelope Valley and Oxnard plain. Figure 11 and Figure 12 depict the variety of entity locations selected in each sector and combined.

Figure 11. Private entity spatial distribution (l.) and public entity special distribution (r.)

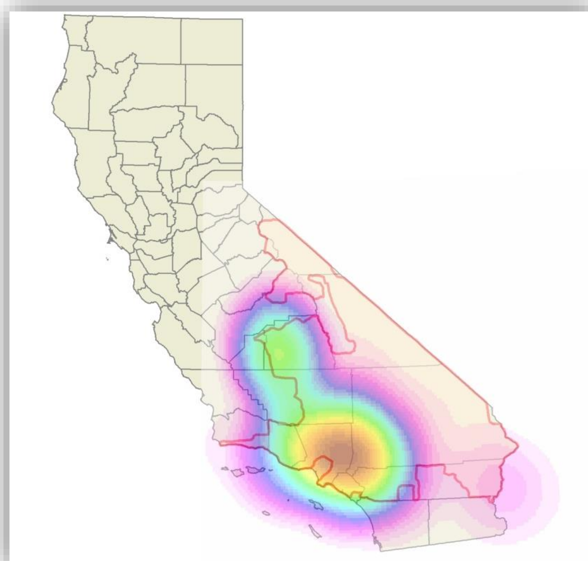


Figure 12. Combined customer spatial distribution (l.) and relative density of sample location s(r.)

The second tier of the selection protocol involved selecting entries based upon a best-fit analysis of the conditions listed until the computed target frequencies were met. Table 9 summarizes the sample categorization by pump type and power consumption.

Table 9. Private entity survey sample frequency

Categorical Frequencies for Private Entities					
MW-hr/yr	Centrifugal Booster (CB)	Submersible Booster (SB)	Submersible Well (SW)	Turbine Booster (TB)	Turbine Well (TW)
< 50	1		5	1	9
50-100	1	1	2		5
100-200			1	1	5
200-300			1	1	5
300-400			1		3
400-800				1	3
> 800	1				2
Total	**3**	**1**	**10**	**4**	**32**

Data Collection

ITRC contacted all one hundred (100) entities to solicit a request for participation in this research. The majority of phone calls and emails produced a positive response and a willingness to participate. The participating entities were then either sent a copy of the questions or polled over the phone, depending upon entity preference. Table 10 presents the sample population through the research process.

Table 10. Summary of entity participation levels

Entity Type	Sample Target	Entities Contacted	Entities Willing to Participate	Samples Achieved
Private	50	50	40	20
Public	50	50	34	18

ITRC staff experienced great difficulty in persuading most participating entities to commit to a 10-minute block of time to complete the survey, as shown in Table 11.

Table 11. Sample response

Response Description	Counts
Completed	38
Busy	17
No Response	39
Refused	3
Disconnected number	3
Total	100

Once the responses were received, the data was entered into an extensive spreadsheet format to conduct the testing and analysis. Using historical data from the SCE database, the average-weighted OPE value was calculated for each entity. Figure 13 displays the resulting range of OPE values for each of the 38 sample entities.

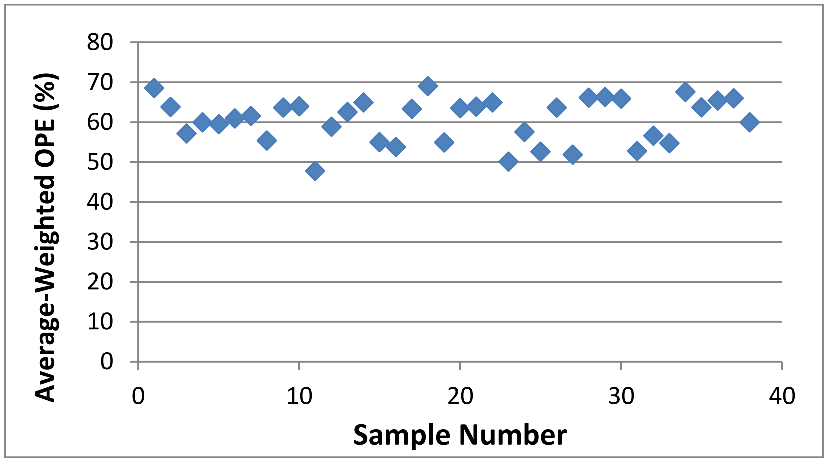


Figure 13. Average-weighted OPE values for each entity

The samples represented an OPE value range of 21%, with a maximum of 69% and a minimum of 48%. The mean OPE value for all entities was computed as 60%.

Pump Dealer Research

The pump dealer research conducted by ITRC focused on three concepts uniquely available from this sector:

1) Verification of common customer responses
2) Regional market information
3) The frequency of SCE program non-participants.

The questionnaires were conducted solely through over-the-phone conversation-based interviews. A total of 17 pump retail, repair and service companies completed surveys during this assessment. Cumulatively, these companies provide services to approximately **7,650 pumps** annually.

Pump Dealer Sample Design

Particular types of pump dealers were targeted in specific areas based upon the most energy-intensive local pump market. This approach inherently emphasizes predominant regional practices over atypical ones. For example, agricultural pump companies were selected in the lower San Joaquin Valley region to represent the increased concentration of agricultural producers, whereas municipal pump suppliers were targeted in the greater Los Angeles region.

The pump dealers interviewed represented all three major client sectors, including:

- Municipal
- Agricultural
- Wastewater

Table 12 lists the number and types of clients represented.

Table 12. Average annual pump repairs represented by pump dealer sample

Municipal	Agricultural	Wastewater	Total
1696	5854	100	**7650**

RESULTS

Customer Research Results

This section draws conclusions from the statistical analysis of the research responses as well as the hypothesis testing results provided earlier in **Attachment 2**.

1. Energy Conservation Prioritization

Although 72% of all respondents identified energy costs associated with water system operation as being *extremely important*, the frequency of relatively low OPE values persists. How can energy costs be *extremely important*, yet pumps remain in operation at known low efficiencies? A combination of various factors could be responsible for this situation:

- Changing system variables causing TDH fluctuations may be responsible for drops in OPE values.
- The operation schedule of the pump may prohibit economic justification for upgrades, repairs, or replacement.
- Energy costs may be deemed extremely important, but other projects take even higher priority.
- The entity may lack the budget to implement the required upgrades.
- System improvements may not be practical due to low power quality and reliability.

These factors create an environment that provides energy conservation opportunities if coupled with sufficient outreach, education and incentive support. Further analysis would be required to adequately quantify the energy conservation potential, which at this time is unavailable.

2. Large Entity Characteristics

Forty-eight percent of respondents reported the incorporation of a threshold OPE value in their management plan. Those entities that report its use had both a range of OPE thresholds as well as a range of actions triggered by the low reported OPE. Some entities had the same OPE value applied to all types and sizes of pumps, while others raised the threshold OPE relative to motor horsepower.

The results from the hypothesis testing indicated a relationship (p-value = 0.028) between the use of this management strategy and larger populations of pumps (45 on average). Furthermore, these larger entities were found to have significantly higher OPE values.

Entities operating 11-320 pumps had an average-weighted OPE of 62.1%, while entities operating 10 or fewer pumps had a lower OPE of 54.9 %. This statistically significant relationship (p-value = 0.001) confirms that larger entities operate and maintain higher overall pumping efficiencies.

3. Small Entity Characteristics

Smaller entities operating fewer than 10 pumps will on average maintain lower pumping efficiencies and will be less likely to include a trigger OPE into the management strategy. In lieu of a trigger OPE the management of pumps tends to be based on one of two options:

1) Pump repair/replacement is triggered by sudden failure.
2) Pump repair/replacement is triggered by an economic feasibility analysis based on current operating hours, current OPE level, initial investment and potential payback periods.

Because smaller entities typically have limited funding, pre-emptive repairs or upgrades are often waived until catastrophic failure occurs. Lower operational budgets also limit the time and resources available for an individual pump's economic analysis.

4. Variety of OPE Level Expectations

A small percentage of customers surveyed indicated that different efficiencies should be expected out of pumps of various sizes. Only 11 entities (29%) interviewed actually filled out a matrix relating various OPE targets to different levels of pump horsepower. Table 13 shows an example of this OPE matrix. Ten entities (26%) reported having a single OPE level that is applied to all pumps regardless of horsepower and operating hours. The remaining 27 entities did not report any level of expected OPE.

It has been observed that very few of the customers surveyed have knowledge that various pumps should be expected to run at various efficiencies. Most entities have one threshold that they do not let their values drop below.

Table 13. Customer matrix for trigger OPE values

Sizes (HP)	Turbine Well	Centrifugal Booster	Turbine Booster	Submersible Booster	Submersible Booster
3-5	35%	35%	35%	35%	35%
7.5-10	40%	40%	40%	40%	40%
15-30	45%	45%	45%	45%	45%
40-60	50%	50%	50%	50%	50%
75 - up	55%	55%	55%	55%	55%

5. Efficiency Prioritization

The analysis results indicated numerous correlations between various forms of efficiency investment and higher OPE levels. As expected, the OPE levels were substantially higher for entities that focused on the prioritization of pump efficiencies, including:

- Remote monitoring
- Developed maintenance program
- Participation in industry organizations

These examples show the importance of increased levels of monitoring, continuing education and staying abreast of appropriate technologies.

Graphical Results from Survey

The following graphs represent the graphical data collected from the survey. The results of these graphs and the tabular format of the data are discussed in **Attachment 2**.

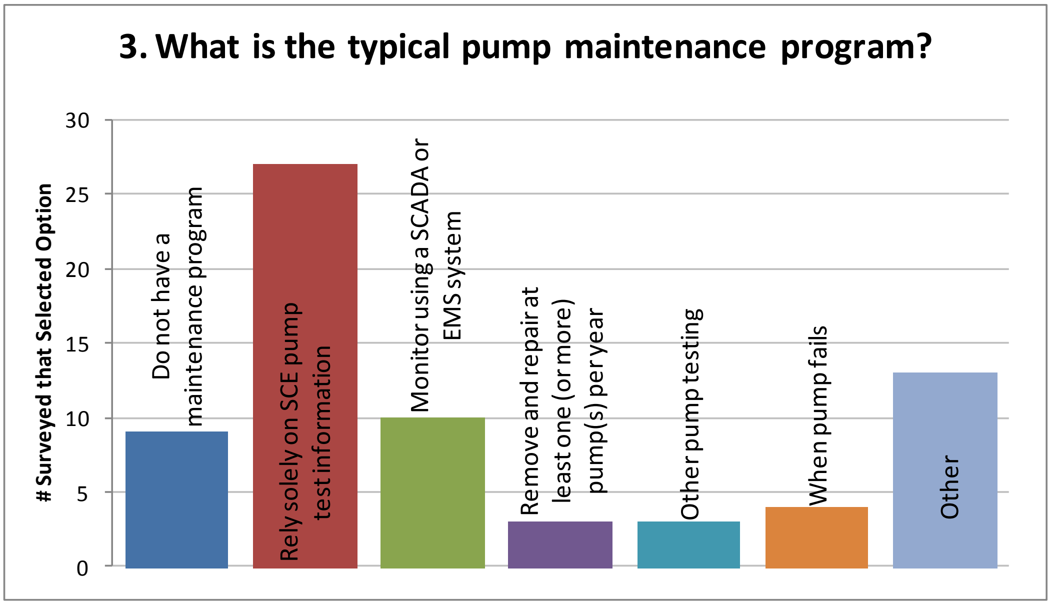


Figure 14. Question 3 responses: Typical pump maintenance programs

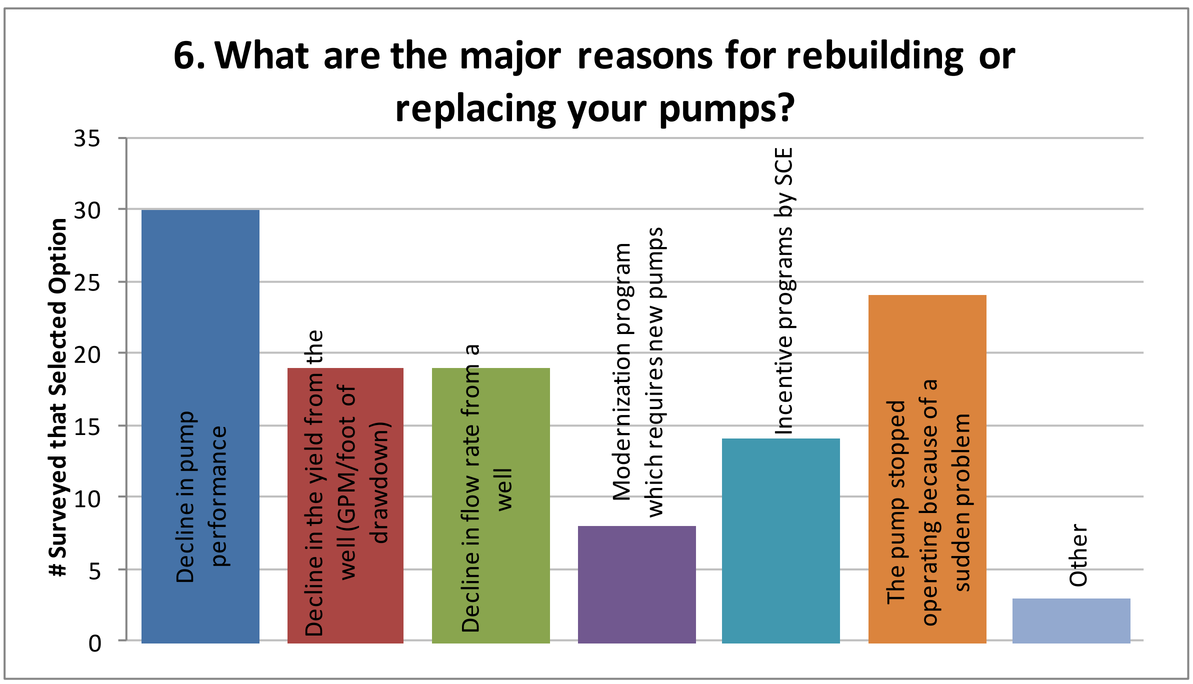


Figure 15. Question 6 responses: Major reasons for rebuilding/replacing pumps

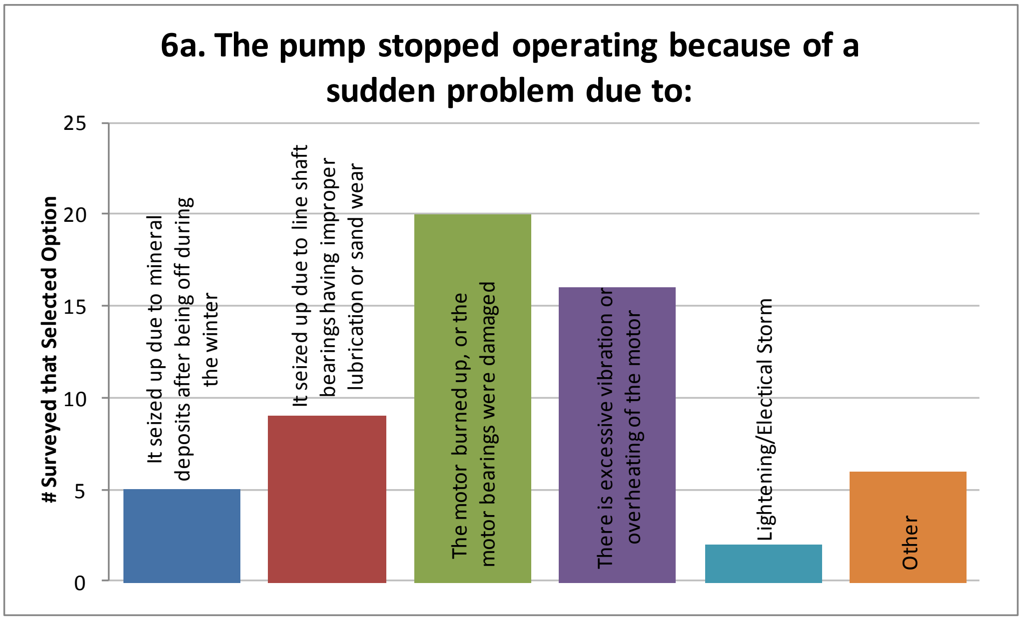


Figure 16. Question 6a responses: Pump problems

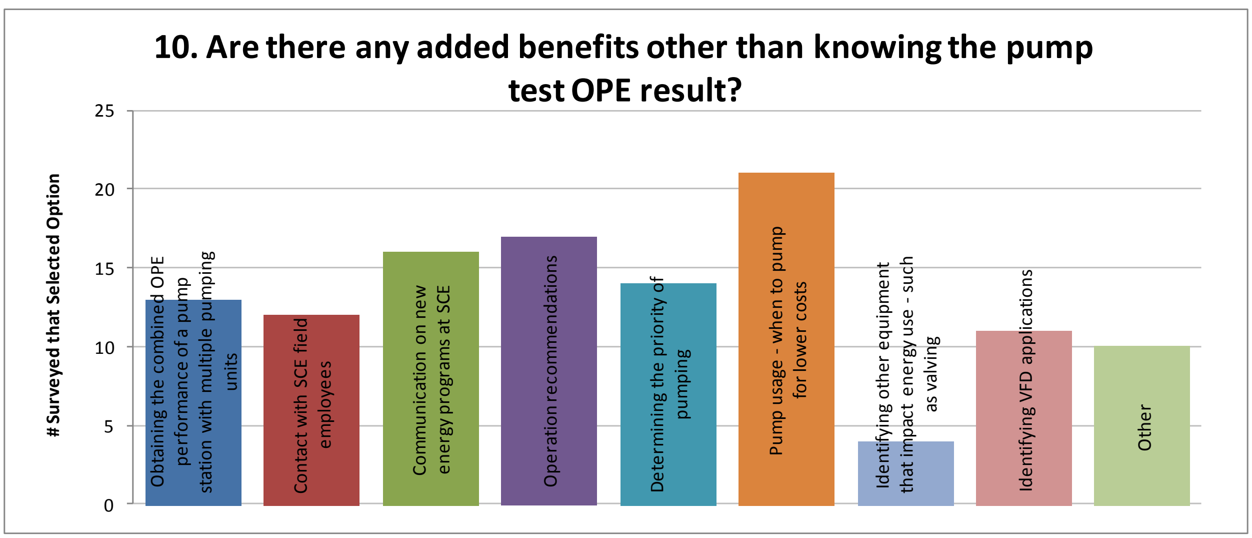


Figure 17. Question 10 responses: Added benefits

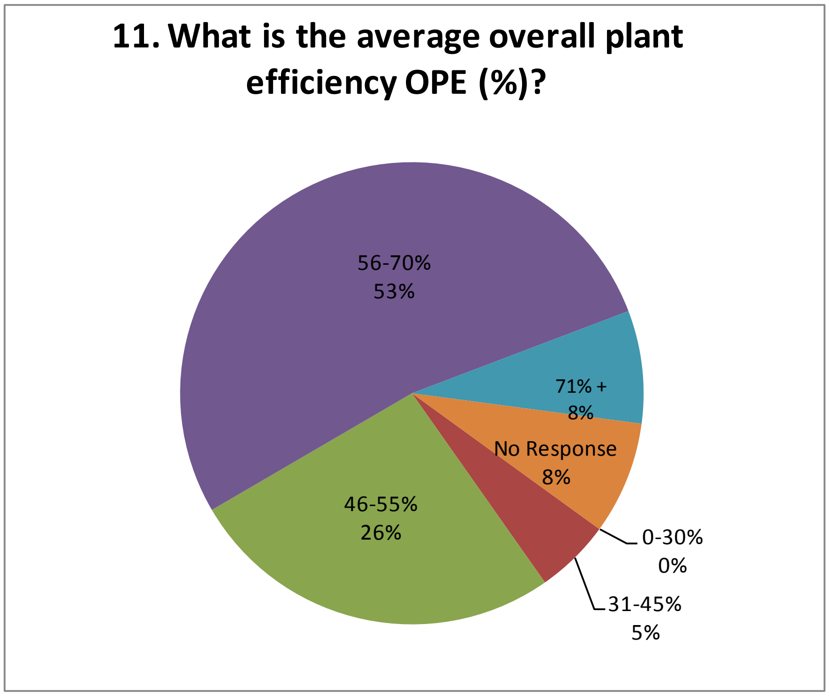


Figure 18. Question 11 responses: Average OPE

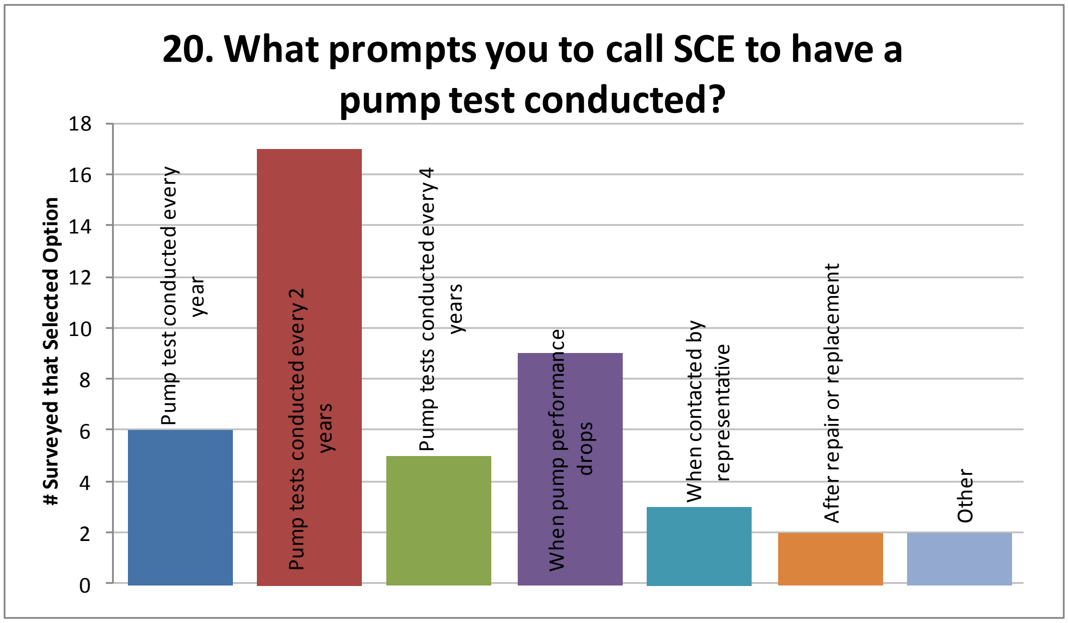


Figure 19. Question 20 responses: Reasons for testing

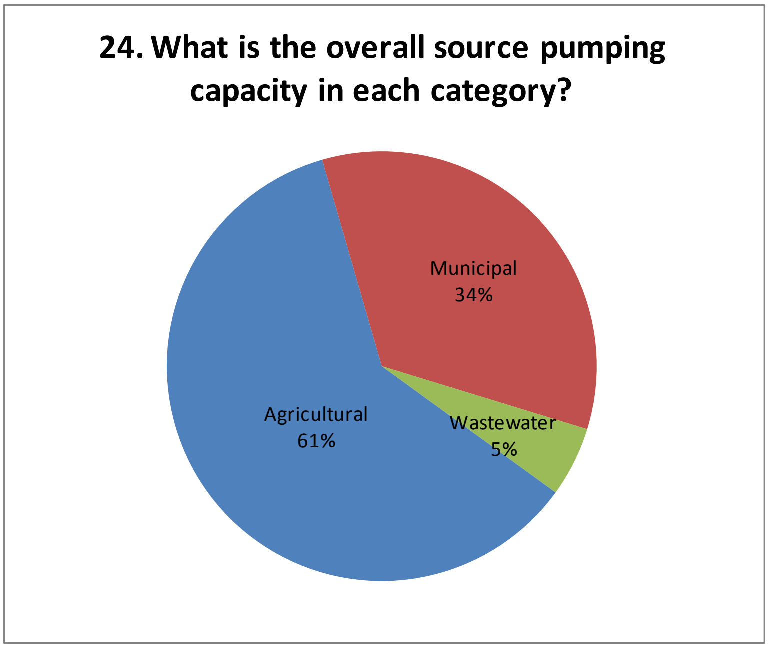


Figure 20. Question 24 responses: Overall source pumping capacity

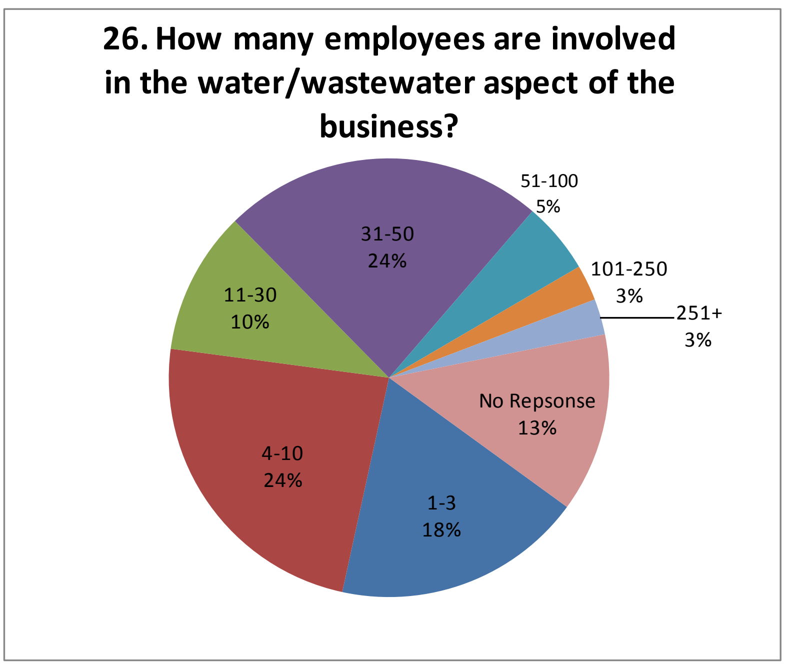


Figure 21. Question 26 responses: Water/wastewater employees

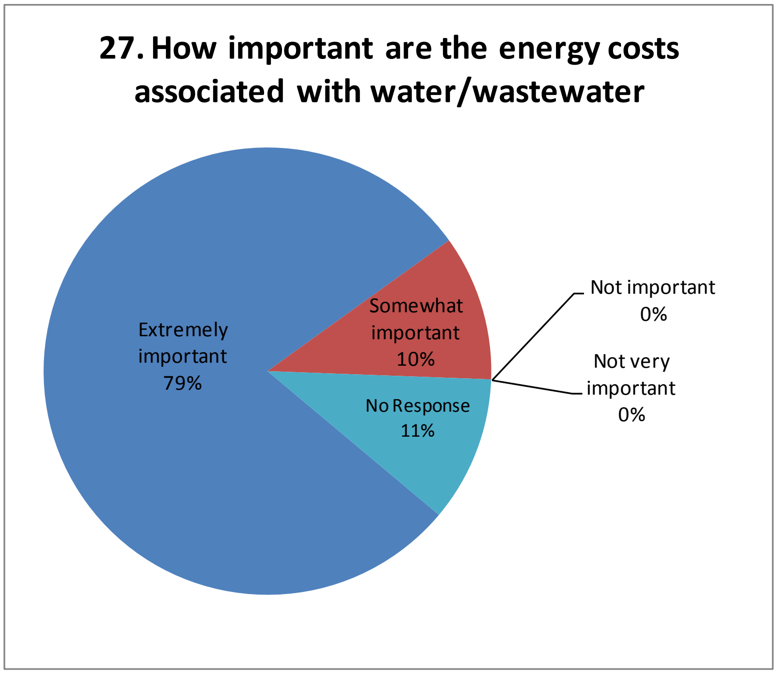


Figure 22. Question 27 responses: Energy cost importance

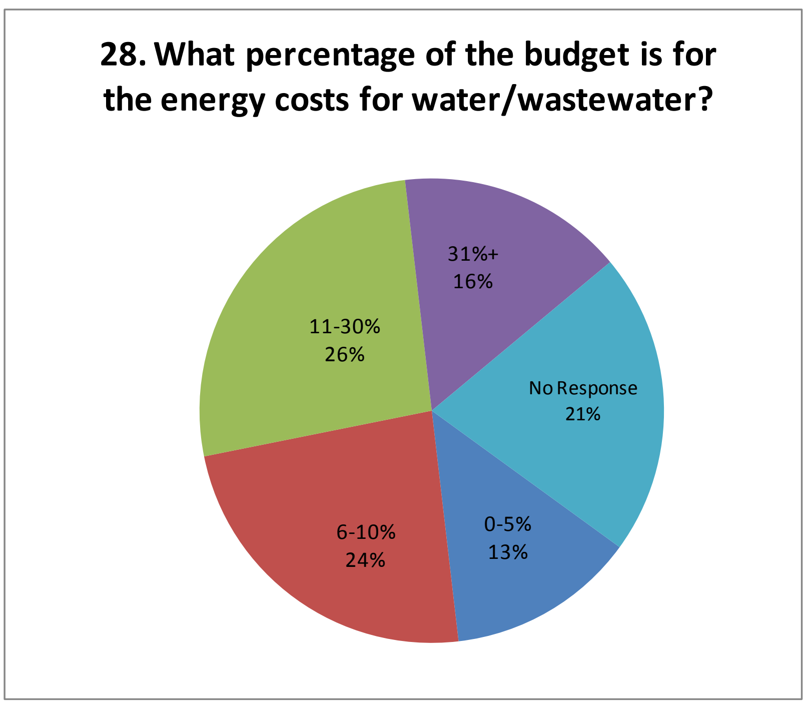


Figure 23. Question 28 responses: Energy costs as percentage of budget

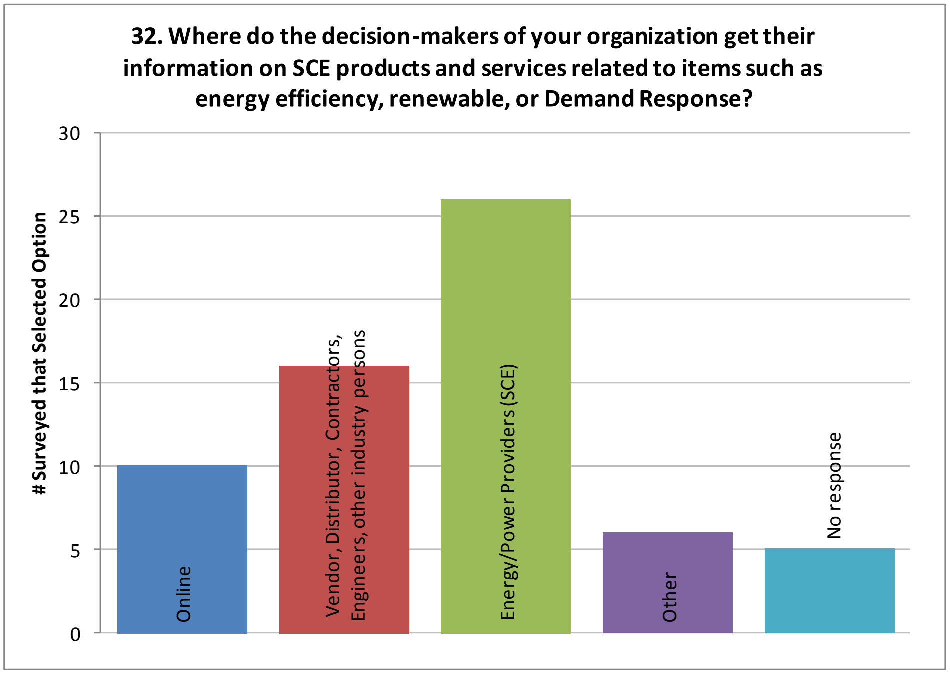


Figure 24. Question 32 responses: Sources of information about SCE

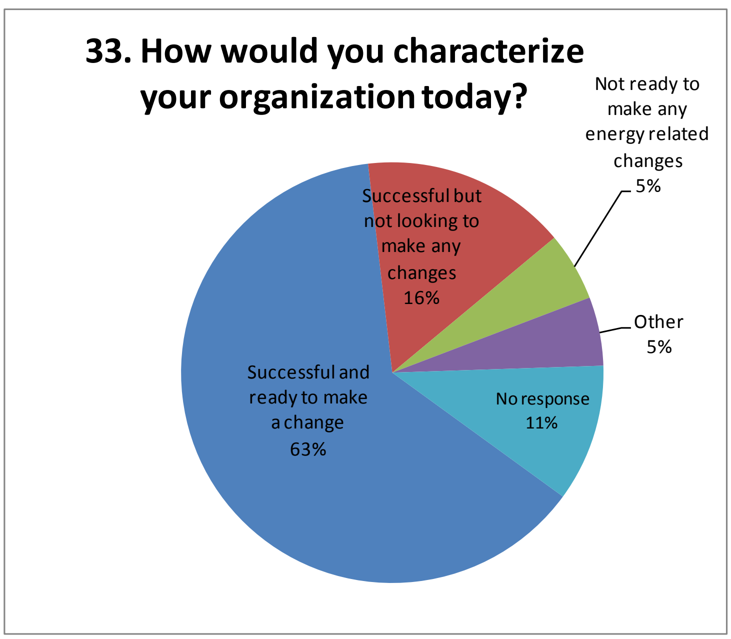


Figure 25. Question 33 responses: Organization characterization

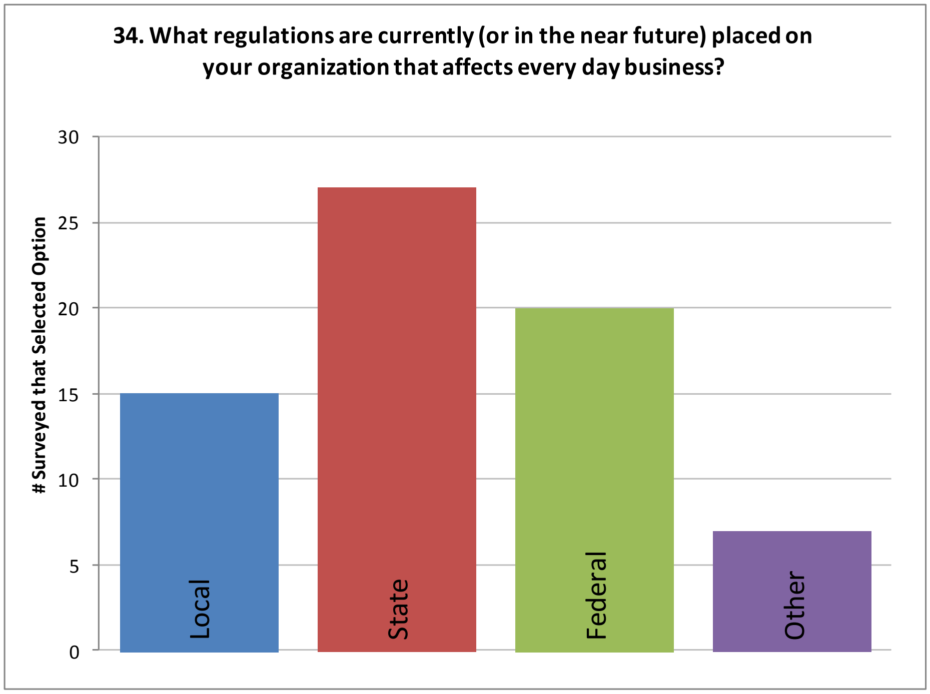


Figure 26. Question 34 responses: Current regulations

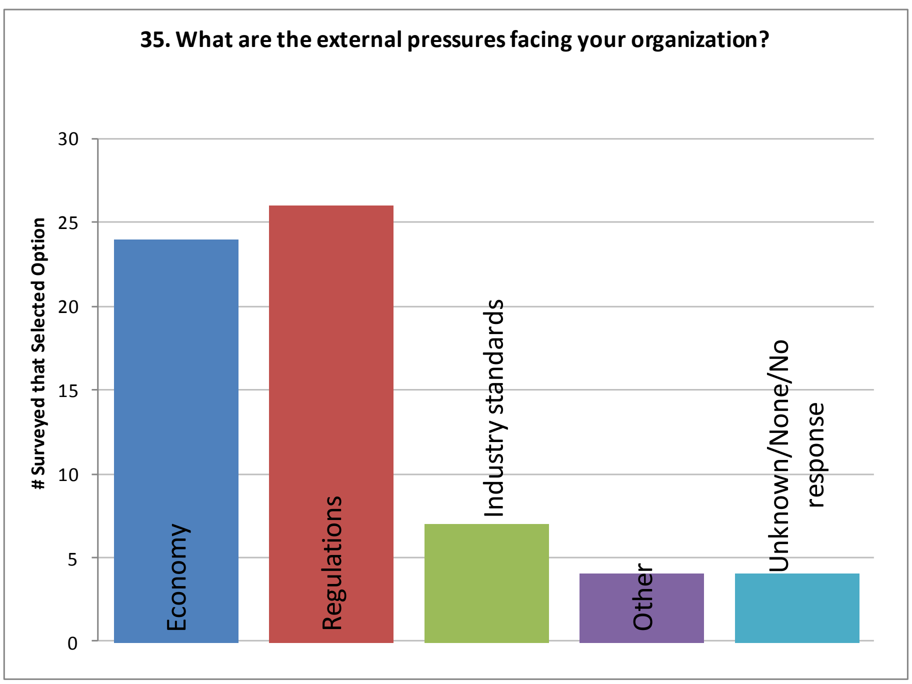


Figure 27. Question 35 responses: External pressures

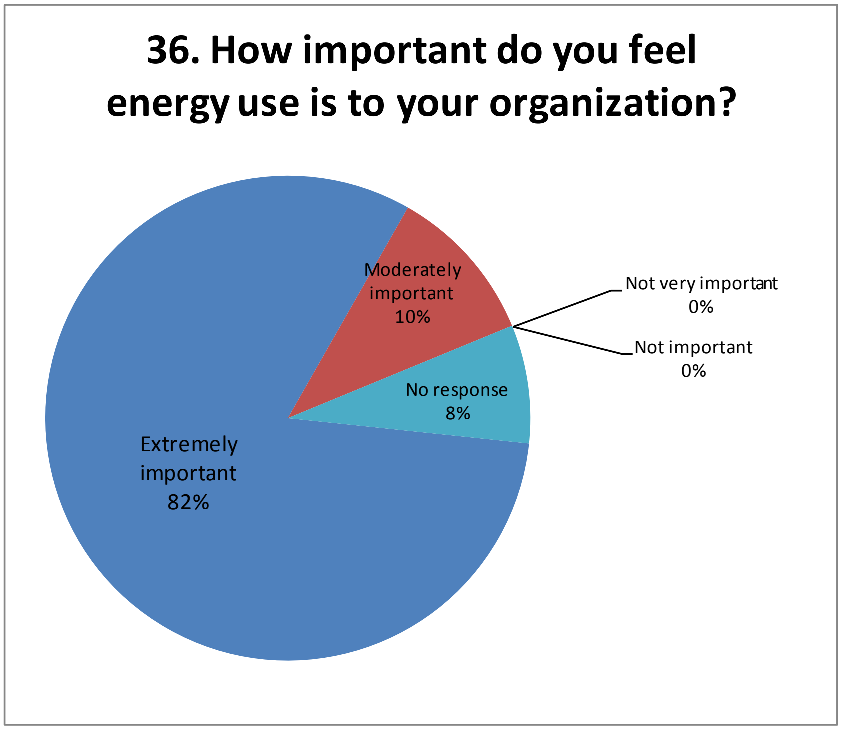


Figure 28. Question 36 responses: Importance of energy use

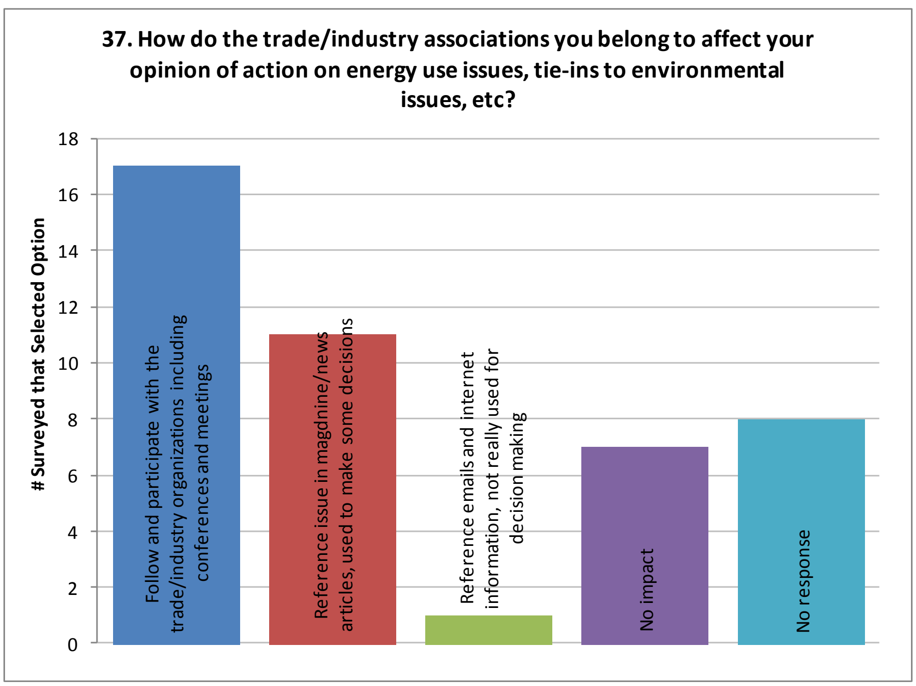


Figure 29. Question 37 responses: Influence of trade/industry associations

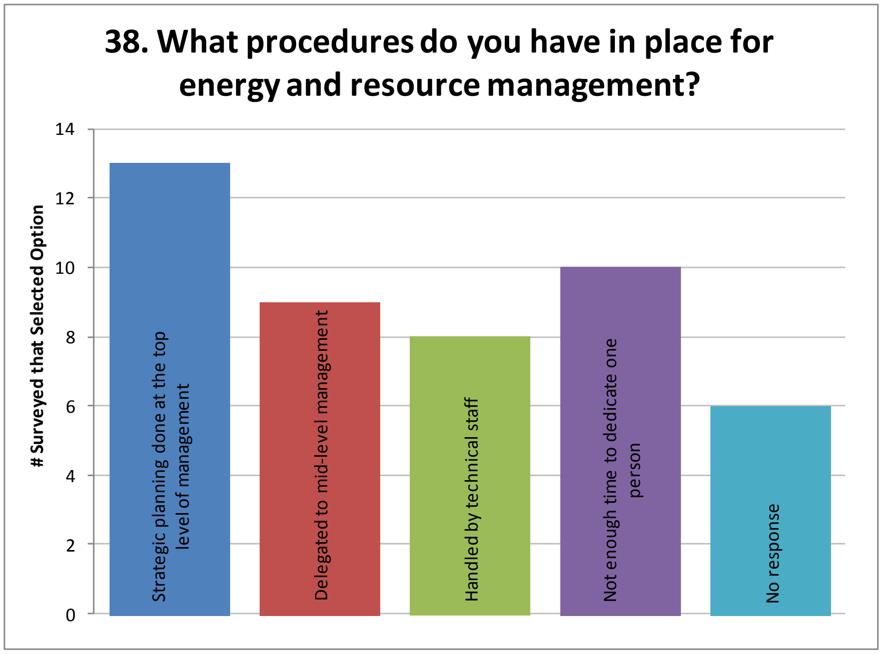


Figure 30. Question 38 responses: Energy and resource management

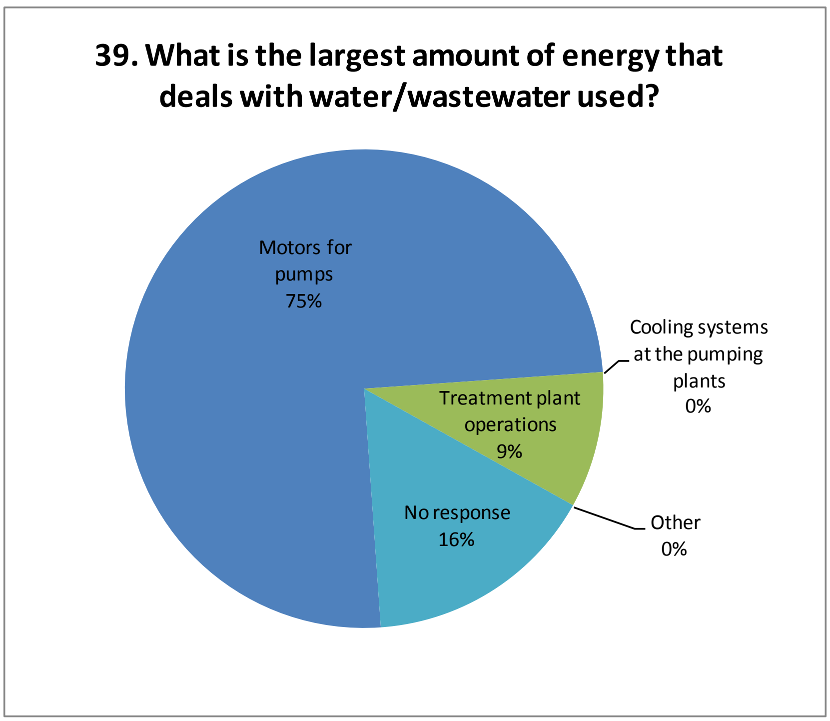


Figure 31. Question 39 responses: Energy consumption sources

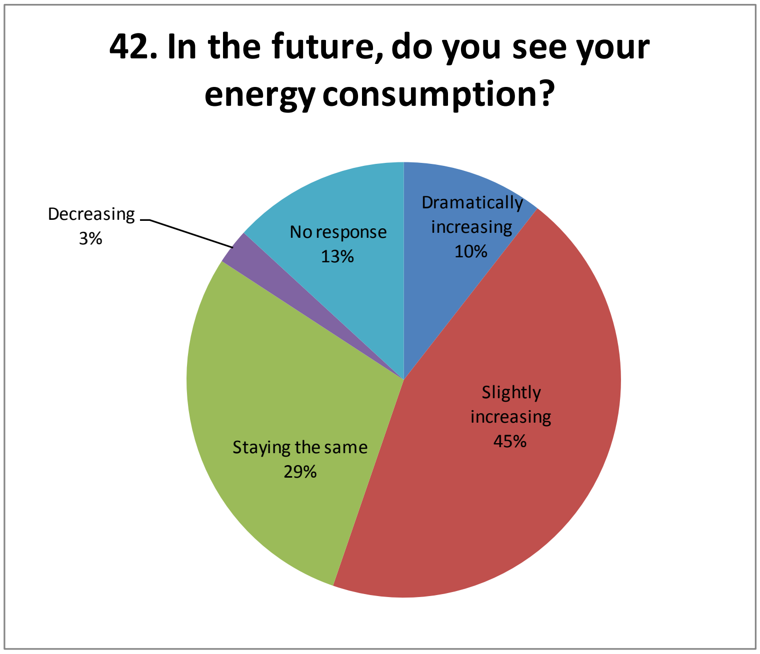


Figure 32. Question 42 responses: Future energy consumption predictions

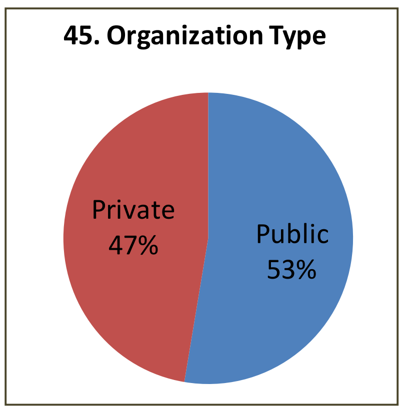


Figure 33. Question 45 responses: Organization type

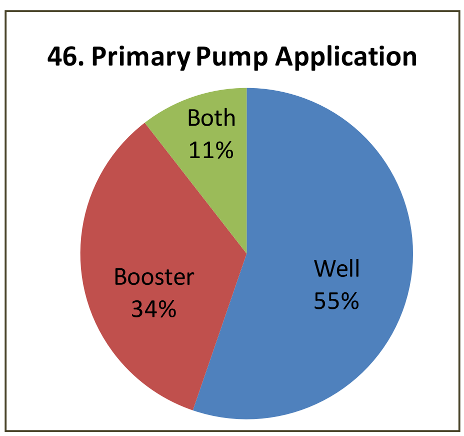


Figure 34. Question 46 responses: Primary pump applications

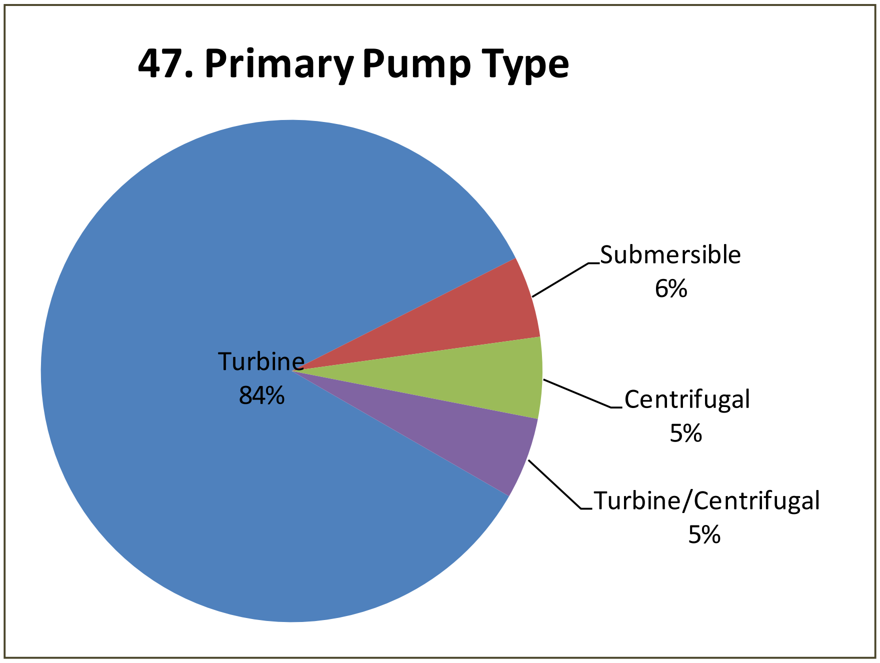


Figure 35. Question 47 responses: Primary pump type

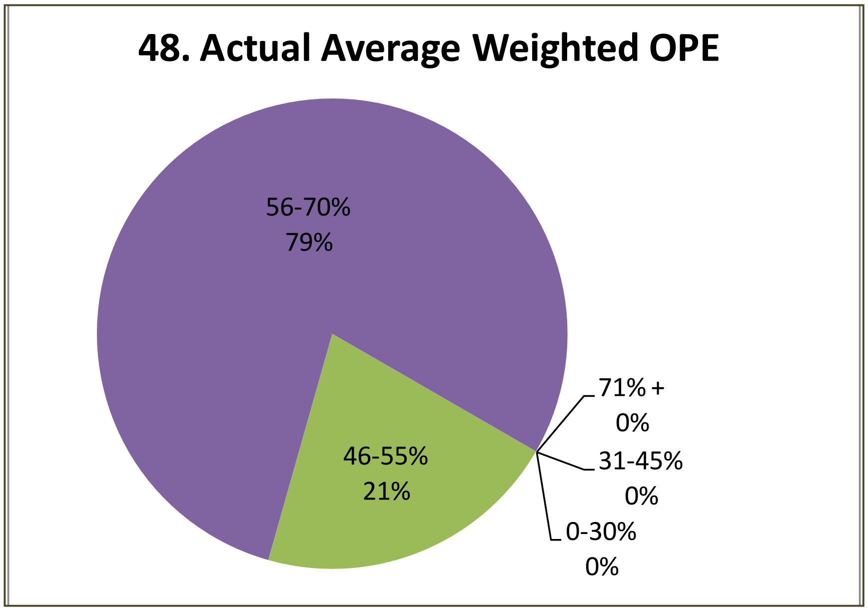


Figure 36. Question 48 responses: Actual average weighted OPE

Graphical Results from Database

The following graphs represent the graphical data collected from the database. An initial assumption made by ITRC was that the low values in this SCE OPE database were a direct result of a poor performing pump that needed to be repaired. The assumption was that these values would provide a clear indicator of the minimum OPE values that were actually obtained by the pumps prior to repairs.

Unfortunately, it was pointed out by one of the pump testers during a presentation of the preliminary data that low OPE tests can be generated by a system that operates at several Total Dynamic Head (TDH) values. In one year, the TDH may be very high (400 ft) and the OPE reported value at 70%. The next year the TDH may drop to a very low value (100 ft) and the OPE could drop to 30%. Or the OPE values could be flipped, meaning that there are pumps being used to cover a wide range of operating points.

ITRC created these graphs before it was found that they did not contain information on the minimum OPE. They are included in this report for informational purposes only. They do help provide a limited trending graph for the individual pumps.

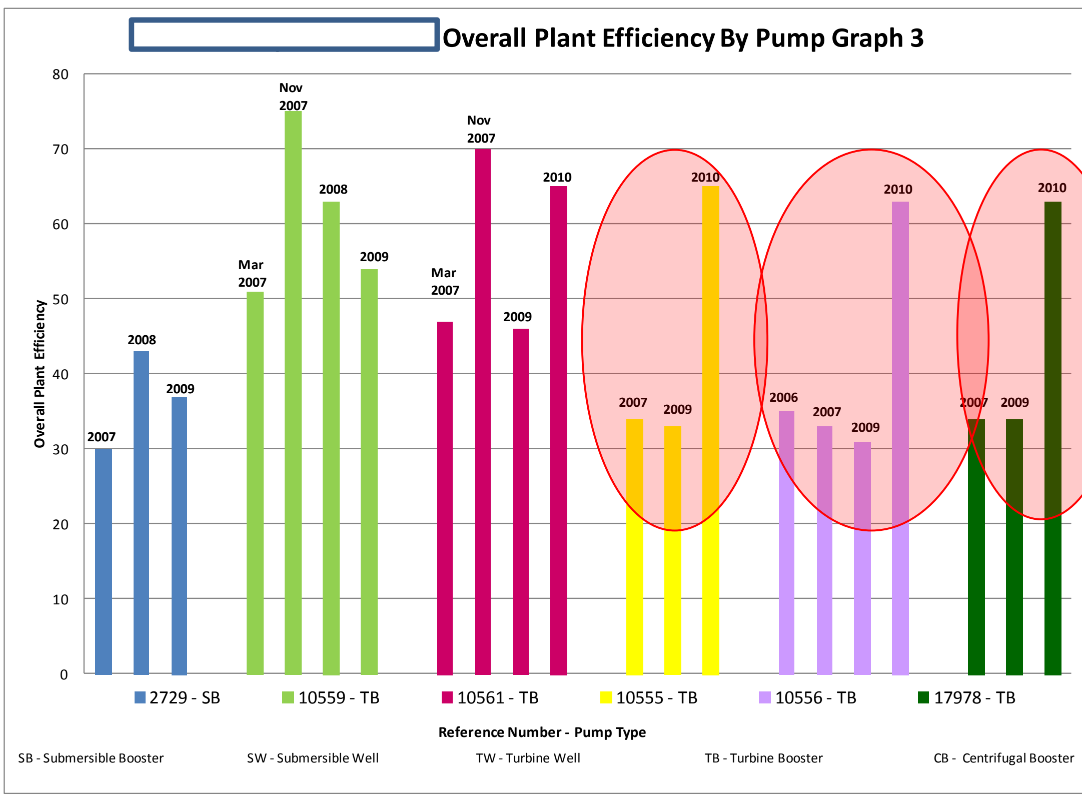
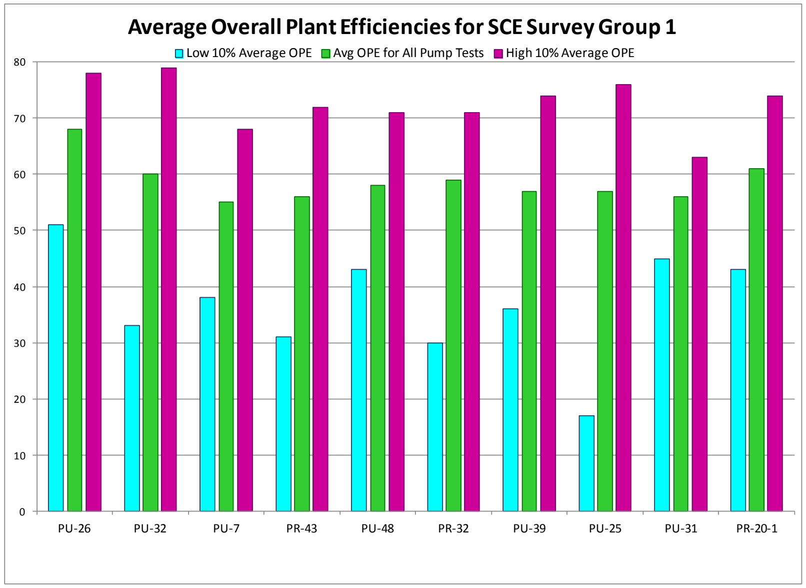


Figure 37. Evaluation of the OPE results for Los Angeles Water Customer

The following graphs provide a summary of the OPE values for the 38 participants in the OPE survey. Average OPE values were higher than expected by the research team. In addition, the amount of pumps that tested over 70% was not expected. Figure 38 shows a summary of the OPE results that was reported for Group 1.



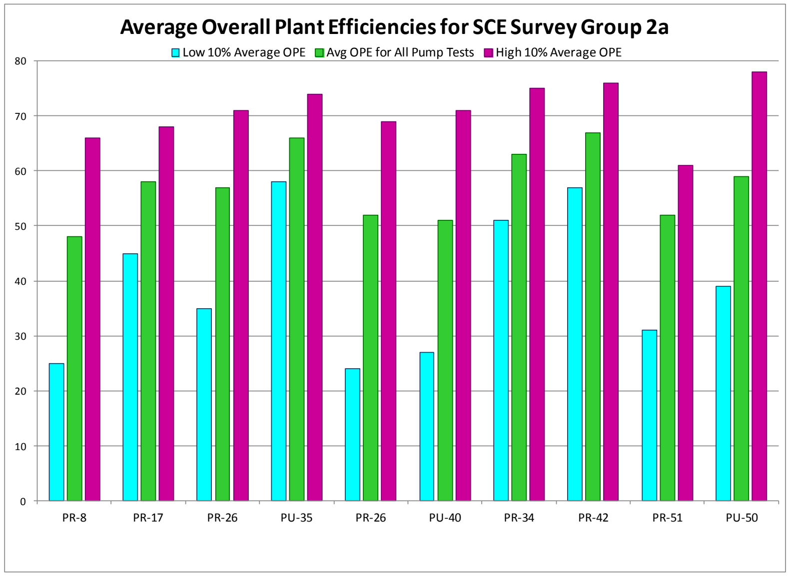
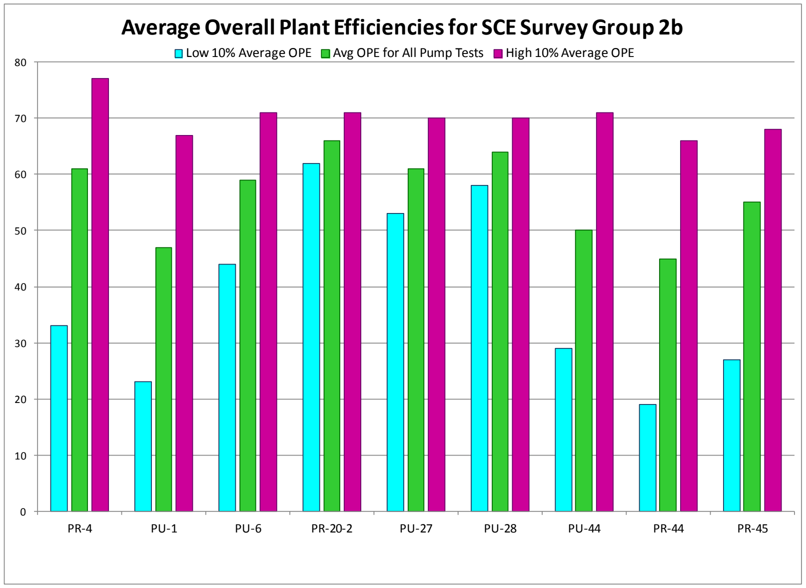


Figure 38. Evaluation of the OPE results for Group 1 (l.) and Group 2a (r.)



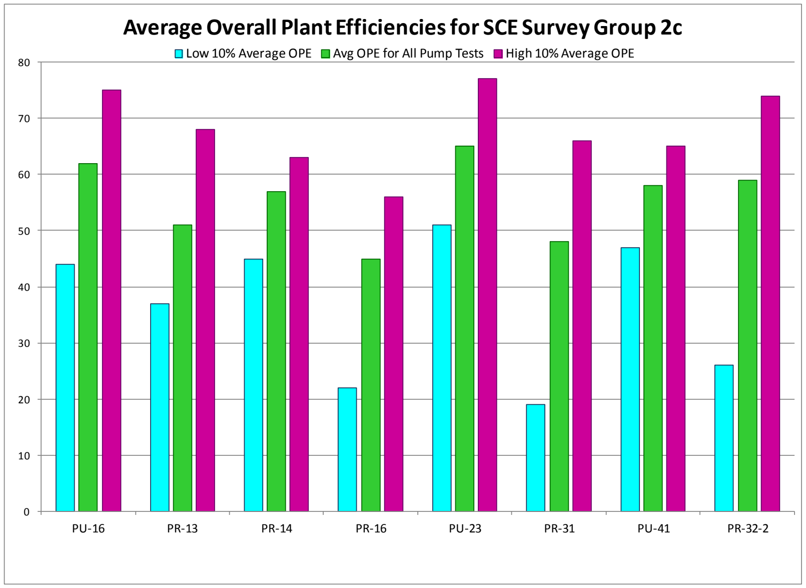


Figure 39. Evaluation of the OPE results for Group 2b (l.) and Group 2c (r.)

Control Group Results

Included in the primary research was a control group survey of entities outside of the SCE service area to investigate possible management and energy conservation alternatives. Two private entities, representing relatively small and medium sized operations, were queried with a similar survey instrument used for SCE clients. Due to the small control sample size, the control responses provided the study with informative anecdotal relationships.

The research found unanimous support for minimizing pumping power bills by rigorously maintaining high OPEs. In fact, both entities incorporated and paid full price for annual pump testing, despite the lack of a free pump testing service. The pump tests were also highly valued for additional benefits including operation scheduling and VFD recommendations. Furthermore, the entities reported that the frequency of pump testing was a sufficient alternative to remote pump performance monitoring.

Although investments in system control and monitoring were low, other investments were made to minimize power bills. For example, one entity had already installed a large scale solar panel array to offset electric utility bills and plans to expand in the future. Additionally, both entities utilized payback period analysis for all system improvements including pump repair and well rehabilitation.

Pump Dealer Results

The pump dealer survey results provided valuable data regarding the demographics of pump system operations and efficiency awareness. The shared clientele of SCE and the companies interviewed ensures directly relatable information. Furthermore, the pump dealer's third party perspective offers distinct unique advantages over direct surveys.

Pump Testing Participation

The frequency of pump test participation recorded during the surveys was a key indicator of the level of basic pump system management and energy efficiency awareness. For example, those clients utilizing pump test services considered appropriate design for new systems and economically feasible replacement thresholds for existing systems.

Without some form of pump performance benchmarking and/or monitoring, pump replacement is typically driven by mechanical failure. The cumulative survey results provided in Table 14 compare percentages of pump dealer clients that utilize pump testing in some form, including third party testing.

Table 14. Overall pump testing participation

Description	%	Number
Pump Test Participants	71	5438
Non-Participants	29	2213

The results indicate the majority of pump dealer clients do contract pump tests. The specific number of SCE pump tests compared to third party tests was not recorded by the pump dealers.

Pump Test Participants

Clients contracting pump tests generally utilize energy efficiency information in management decisions more often than those who opt out; however, the focus of this report is the client's actions based upon this performance data. The interviewed pump dealers identified various levels of efficiency commitment and management for pump system owners and operators. This hierarchy of action is shown in the diagram in Figure 40 with an estimate of category size based upon a fraction of the 7650 serviced pumps represented in this report.

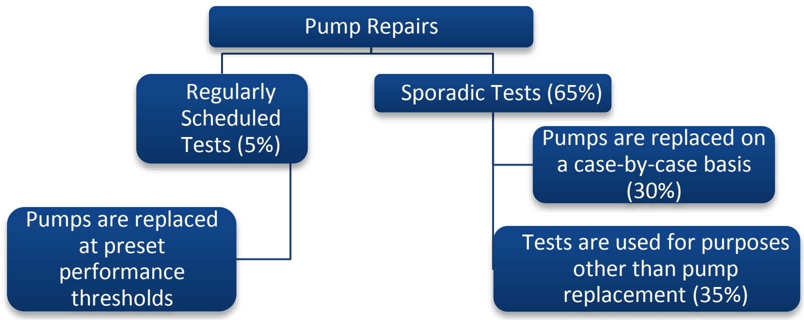


Figure 40. Client action levels with estimated population sizes

The categories depicted in Figure 40 are described in depth below.

Pumps replaced at preset performance thresholds

This category represents an estimated 3% of pump dealer clients with the following characteristics:

- These entities represent the model SCE client with a firm understanding of reducing energy over-consumption while simultaneously minimizing long-term operating costs.
- Typically comprised of well-managed large corporations and public works.
- Pumps are tested at short intervals to monitor performance.
- Pumps are replaced at pre-determined thresholds.
- Estimates of pump replacement intervals are integrated into the business's economic model and therefore adequate liquid funding is available to ensure long-term energy/cost savings.
- Although these entities may operate large numbers of pumps, they represent a small percentage of the pump dealer's clients.

Pumps are replaced on a case-by-case basis

This category represents an estimated 30% of pump dealer clients with the following characteristics:

- These entities represent a well-informed SCE client with a firm understanding of reducing energy over-consumption; however, short-term capital investments are limited .
- Typically comprised of moderately-sized public and private entities.
- Pump tests are contracted by the following considerations:
  - Lost or unknown records
  - Stretched or random intervals
- Pumps repair or replacements are signaled by one of the following:
  - System modifications create different pumping requirements
  - Noticeable loss in pressure or flow
- This notable portion of SCE clientele represents large potential energy savings and increased pump testing and incentive program availability.

Tests are used for purposes other than pump replacement

This category represents an estimated 35% of pump dealer clients with the following characteristics:

- Typically comprised of small residential or agricultural wells under 10 HP which are impractical for performance monitoring.
- Pump tests are contracted by the following considerations:
  - Well pump certifications during a transfer of real estate ownership
  - Changes in water table and water quality
- Pumps repair or replacements are signaled by one of the following:
  - Catastrophic pump failure
  - Noticeable loss in pressure or flow
  - Noticeable mechanical wear in bearings and seals
- This portion of SCE clientele represents potential energy savings through means other than the SCE pump testing or incentive program.

Participant Replacement/Repair Trigger

Pump test participants who were reported to take action based on the testing results did so at various OPE levels. This lower operating limit ranged from **25% to 70% with a weighted mean of 40%.** Table 15 summarizes the OPE trigger level compared to its frequency among pump test participators.

Table 15. Various action level OPE triggers

OPE (%)	Number of clients
25	450
40	3,545
45	104
50	420
55	215
60	208
70	140
Total	5,082

***NOTE: Some pump dealers were unable to comment on the OPE triggers; therefore the total shown is less than the 5,438 pump test participants.*

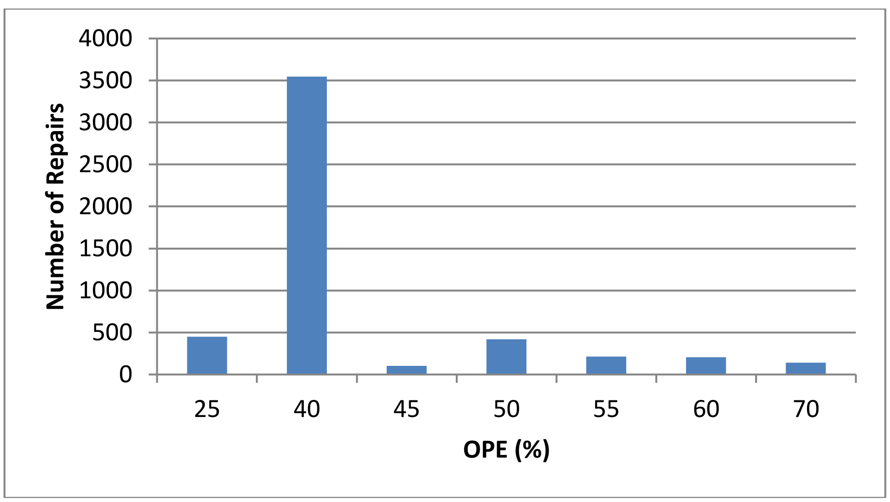


Figure 41. Comparison of OPE levels at the time of service

It must be noted that the concept of a threshold OPE was broadly regarded as an installation-specific value determined largely by the investment payback period. A common economic analysis, the payback period is dependent upon the following major factors:

- *Annual operating hours* determine the kW consumed per year
- *Motor horsepower* determines the consumed kW/hr

An example mentioned frequently in the interviews follows this guideline:

A 100 HP or larger motor operated everyday for over 12 hours is typically serviced or replaced when the OPE drops below 50%.

In this example, minimum guidelines referring to motor horsepower and annual operating hours were applied to an experienced-based analysis of payback period.

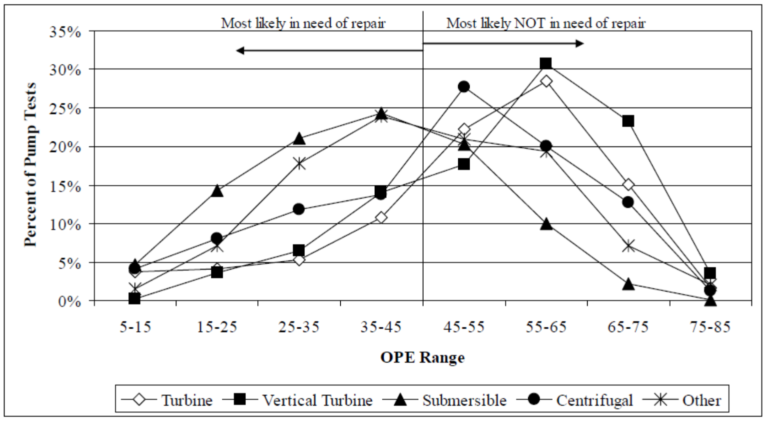


Figure 42. Use of 45% OPE as a point of need for pump repair (Equipoise 2006)

Other programs have noted a target value for pump repair. In Equipoise (2006), a recommended value of 45% was used as the cutoff for recommending a minimum value for pump repair.

Non-Participants

Non-participants were prevalent in all pump application sectors, but were more common in the private municipal (residential) sector. The survey results indicate the major causes responsible for the lack of pump test participation are **awareness** and **access**. In most cases, the pump owners as well as the local pump dealers were either unaware of the practicality of pump tests, or too remote to access the program.

This is most likely due to the percentage of non-participant installations between ½ - 5 HP where the cost-benefit ratio makes testing impractical. Furthermore, small pump manufacturers currently offer minimal options for smaller systems, as they are considered “disposable” for manufacturers, retailers, and buyers alike.

This mindset forces the responsibility of energy stewardship on the system designers. For small installations the pump dealers double as system designers as well as installation services. As this group lacks performance monitoring, operating efficiencies in such installations are then dependent on the appropriate design and initial recommendations offered by pump dealers.

In terms of basin-wide savings, this situation offers a great opportunity for educational outreach because of the centralization of the design, installation and repair of small pump systems. A program focusing on appropriate system design and product specification, based upon best engineering practices, could have a profound effect on basin-wide energy consumption. In order to more fully develop this potential, Table 16 provides the sector-based makeup of the non-participant group.

Table 16. Non-Participant levels by sector

Group Description	Municipal	Agricultural	Wastewater
Participants	**763**	4605	70
Non-Participants	**933**	1249	30

Non-Participant Replacement/Repair Trigger

Without the requisite information from any form of pump performance testing, replacements or repairs are typically triggered by **<u>mechanical failures</u>** or **<u>noticeable drops in performance</u>**. The frequently addressed triggers for the non-participant group include:

- Burnt motor
- Worn bowl/impeller
- Seized shaft
- Short-circuited wiring
- Lowered water table
- Decrease in well flow rate

It follows that there is a higher probability of low efficiency pumps operating in this group, due to the broad lack of awareness regarding critical pumping characteristics.

Terminology of the Pump Test

It was noted throughout the pump dealer interviews that the term "pump test" had a variety of meanings depending upon the pump dealer's typical pump application, geographic location and specific market. The focus of SCE's pump testing program and the topic of this report is the quantification of Overall Pump Efficiency (OPE).

OPE pump testing requires the accurate measurement of various performance indicators including flow rate, discharge pressure and electrical energy consumption. The value of a pump test result is directly related to the measurement accuracy of these parameters. As with any quantitative testing, multiple "testers" can induce systematic measurement error based upon a number of factors.

These factors include:

- Non-standard protocol
- Non-standard equipment with different accuracy specifications/certifications
- Various levels of pump experience

The majority of these are created from the <u>lack of a general adoption of standardized test procedures</u>. Further increasing the potential for systematic error is the multitude of non-OPE tests, which may also measure, but not focus on, pump performance. In some cases the test results from non-OPE tests can be wrongly compared to those performed by SCE and other certified contractors.

OPE pump tests provide a fundamental tool for long-term pump/well performance monitoring. As such, increased education outreach and the adoption of a standard test protocol may be a practical approach for further energy program outreach.

Table 17. Key recommendations to improve energy use by the pump repair companies

Recommendations by Pump Repair Companies

	Location	# of Annual Repairs	Percent of customers that use **any** Test Program	Minimum OPE Trigger %	Good system design	Rate structure	Time of use	Test every year	Test Every 3 years	Impeller material used	Well cleaning	Flow measurement	Maintenance	Recommends VFDs if appropriate	Premium Eff Motor	High Eff motor	Standard eff motor	Replacement only, not repair
1	Temecula	260	10%							Brnz, SS								
2	Visalia	600	70%	50%	X					Brnz, SS				X		X		
3	Camarillo	300	10%		X					SS	X			X	X			
4	Barstow	200	30%	40%	X					Brnz	X			X		X		
5	Shafter	225	70%	60%			X	X		Brnz	X		X	X			X	
6	Ojai	50	50%	55%				X		Brnz, SS	X	X		X		X	X	
7	Delano	100	50%	60%			X	X				X	X	X				X
8	Visalia	750	0.6	25%		X			X	Brnz, SS, Iron	X			X		X		
9	Corcoran	250	80%	40%				X		Brnz	X			X		X		
10	Bakersfield	3650	90%	40%	X			X						X			X	
11	Yucca Valley	75	0%		X						X						X	
12	Temecula	300	100%		X					SS	X			X			X	
13	Redlands	200	95%	55%						SS	X			X	X	X	X	X
14	Bakersfield	200								Brnz				X		X		
15	Coachella	30												X			X	
16	San Bernadino	260	40%	45%				X		Brnz, SS				X	X			
17	Paramount	200	70%	70%	X			X		Brnz, SS				X	X	X		
	Counts	**7650**			**7**	**1**	**2**	**7**	**1**		**9**	**2**	**2**	**15**	**4**	**8**	**7**	**2**
	Percentages				**41%**	**6%**	**12%**	**41%**	**6%**		**53%**	**12%**	**12%**	**88%**	**24%**	**47%**	**41%**	**12%**

RECOMMENDATIONS

Pump Testing Program

The survey results indicate that the Pump Testing Program offered by SCE has been generally accepted and widely used. Furthermore, minimal improvement recommendations were offered to ITRC staff during the interview process.

The **positive** aspects of the current state of the SCE Pump Testing Program include:

- There has been widespread acceptance and confidence in the program's findings. Little to no support was reported to the contrary. This is a good indicator that SCE clients trust the results as scientifically accurate.
- Many SCE clients include regularly scheduled SCE pump tests as part of their water management program. This fact indicates good management practices and energy stewardship, as well as adequate support from SCE staff.
- The lead time for SCE pump tests was reported to be between 3-7 days. This relatively short turnaround time means that there are currently an adequate number of trained SCE representatives. Additionally, the lack of *same-day* testing indicates the current staff is busy completing pump tests, and little down time is available. This is interesting to note since previous studies (Cullen et al 2009) reported that **one of the key problems was the 4-6 week wait** for a pump test to be performed.
- SCE pump tests are common precursors to incentive program applications. Not only are clients curious about pump performance, **but also** interested in improving their water infrastructure.
- The free service creates few reasons not to participate in the program. Although third parties charge a relatively low sum (up to $500 per pump test) for the same service, this cost can be insurmountable for some operations on tight budgets.

Areas of possible improvement include:

- Some rural areas receive less than adequate support and contact from SCE representatives, resulting in a lack of awareness or interest in energy savings. Therefore, these areas tend to have a lower savings potential than more developed areas. Some pump dealers indicated this concept has been a progression over the past 5 years.
- This program provides a free testing service, but lacks the educational outreach to bring in new clients, especially agricultural clients.

The following list offers **recommended improvements** to the SCE Pump Test Program to increase the participant base and its effectiveness as an energy conservation program.

- *Increased educational outreach*
    - The addition of an educational program has the potential to not only increase the client base, but also better improve the efficiency of new installations
    - Education and scientific progression can only help an industry that has typically relied on experience, gut feelings, and "rules of thumb"
    - Technological advances are exponentially more affordable and available to the general consumer. An educational program could provide information regarding new products, applications and services that increase energy efficiency.

- *Increasing the availability of pump tests to rural areas*
    - It may be practical to expand the pump test service area, or at minimum the educational aspect of the program, to currently inactive regions in southern California.

Pump Incentive Program

SCE also offers cost-sharing services through incentive programs for clients who decide to upgrade or repair degraded infrastructure. Although not the primary subject of this report, incentive programs provide key financial support in the energy conservation process. Timely, appropriate, and focused allocations of incentive funds are critical to true energy conservation success rates in California.

Because the Pump Testing Program is exclusively informative, there exists no pretense of participant action post-testing. No database relating pump test participation to frequency of recommendation follow-through was supplied to ITRC during this project. However, ITRC collected preliminary findings in this matter through numerous interviews. Figure 43 and Figure 44 show the participation of the respondents in other energy efficiency programs.

Participation in the SCE incentive program requires approval on any cost-sharing project before work can commence, and rightly so. Some level of oversight over project adequacy and suitability is crucial for the sustainability of the program. It is important for SCE to verify certain requirements are met, including a minimum $/kW-hr conserved. However, numerous customers reported a level of frustration regarding the participation in the incentive program due to the extended approval lead times.

Many pump dealers and some SCE clients referred to a pre-approval lead time range of 30-90 days between filing the necessary paperwork and receiving SCE approval. This relatively long time schedule eliminates many projects due to logistical infeasibility. For example, a pump that experiences an unexpected catastrophic failure during the peak growing season would need to be replaced within a week, if not sooner. Smaller entities as well may not have the budget for widespread pump redundancy and would require approval ASAP.

Although these examples represent cases where a new pump is installed regardless of participation in the program, the incentive would support the purchasing of higher-end and more efficient hardware. To increase the use of cost-sharing, the approval process period would need to be reduced considerably.

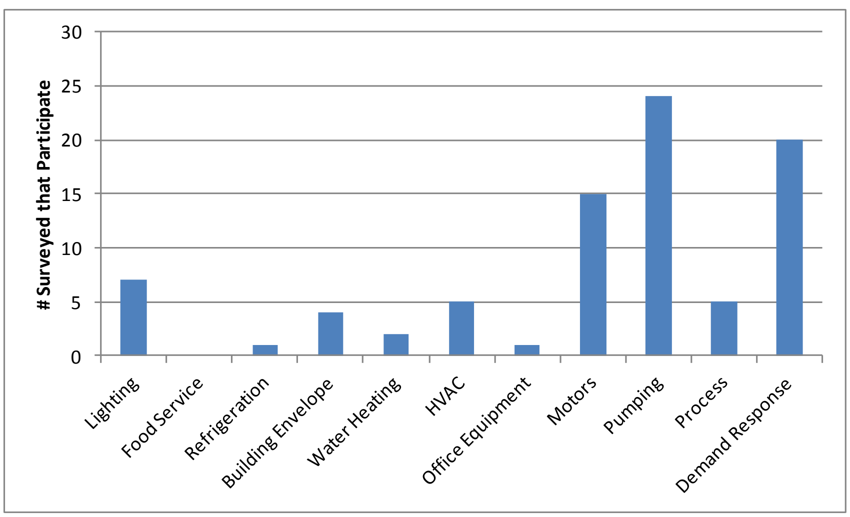


Figure 43. Question 30 responses: EE/DR incentive participation (summary)

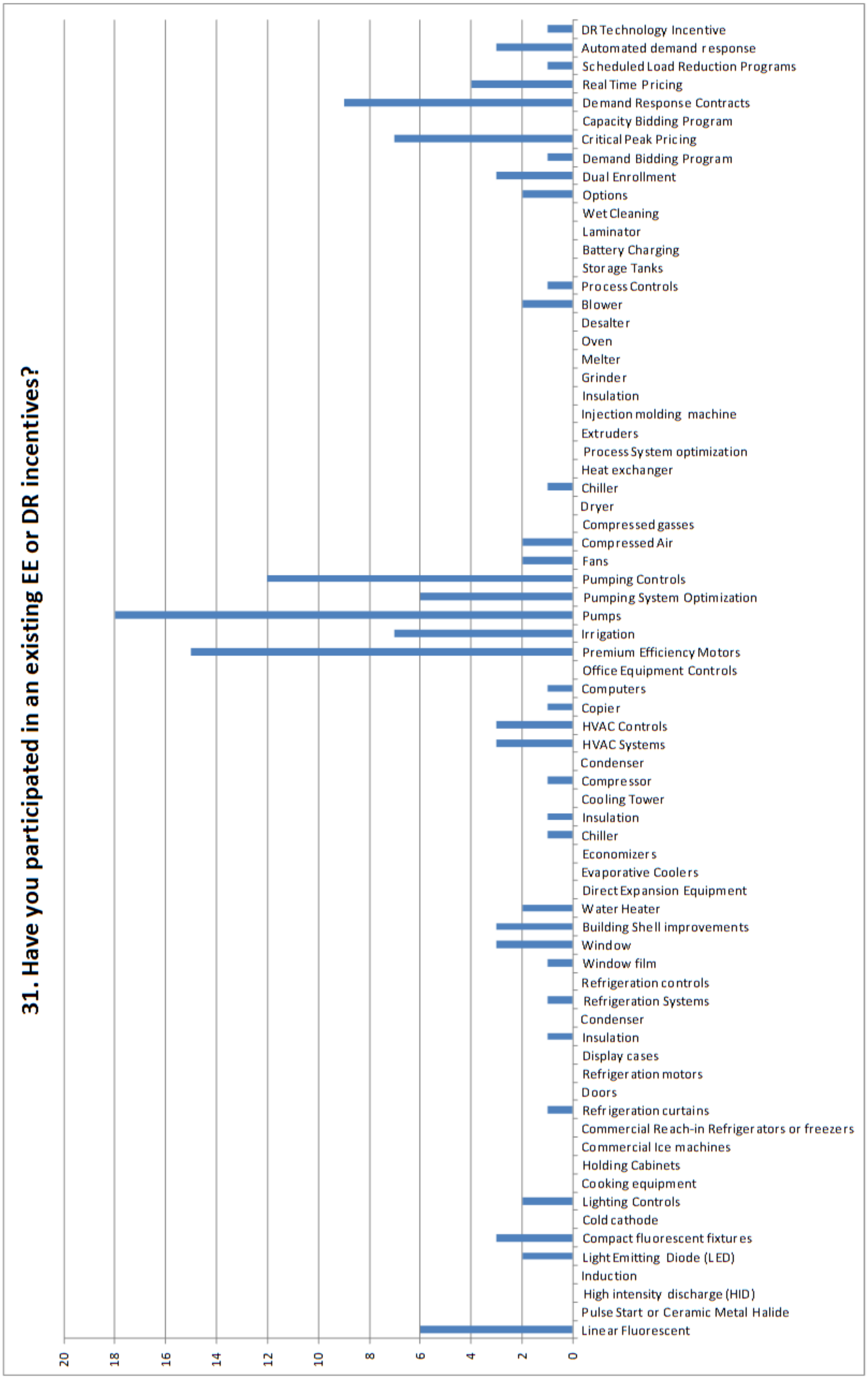


Figure 44. Question 31 responses: EE/DR incentive participation

Key Report Recommendations

Large Potential for Energy Savings

There is a large potential for energy and water savings in California. ITRC has published several reports documenting overall energy use and the potential for savings such as *California Agricultural Electrical Energy Requirements* (Burt et. al., 2003), which included a synopsis of average pumping plant efficiencies throughout central California's irrigation districts and growers. The average pumping plant efficiency for public water district pump tests was 64% (over large 900 pumps included). This high OPE value is similar to the public entities in this SCE OPE study (average OPE ~57%).

However, the 2003 ITRC report noted a substantially lower value for on-farm pumps throughout California's San Joaquin Valley. An average pumping plant efficiency of 48% was calculated from over 2,800 on-farm pump test data points. This discrepancy indicates a large potential for energy conservation at the on-farm level.

Burt (2012) evaluated energy savings potential from a total of 15,000 pumps located throughout California. With similar average OPE findings presented in Burt (2012), potential savings was computed as **102,100 MWh/year**. Burt (2012) targeted the recommendations with an analysis which concluded that by **targeting only 2.5% of the larger pumping units, about 12% of the total potential savings could be achieved**. Relating this back to SCE's service area, this would tend to focus on the large pumps used by public agencies. It is highly recommended that these entities be supported to perform pump testing even if they have adopted a maintenance mode of operation. Figure 45 is a graphic summary of the results of the Burt (2012) evaluation. Note that this type of energy analysis could **only be done with OPE tests**.

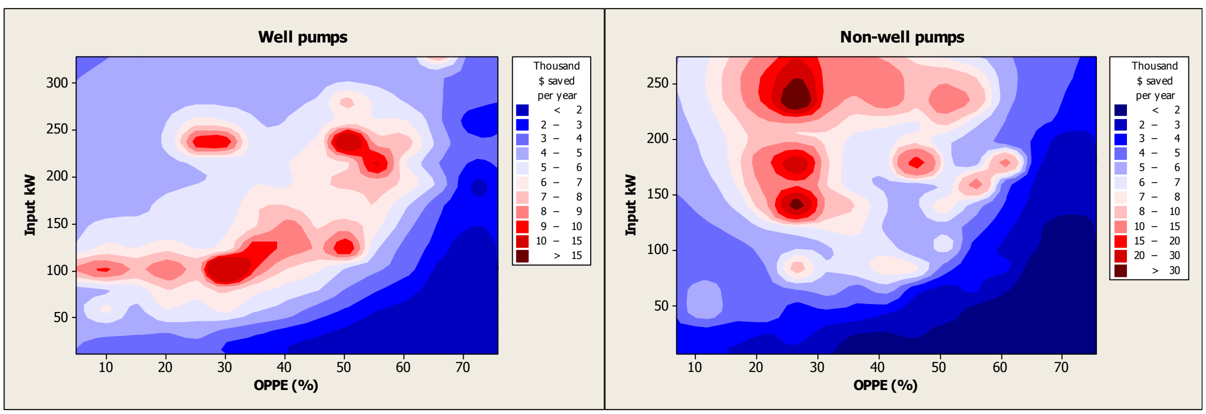


Figure 45. Contour plot of Input kW vs. OPE (%) arranged by money savings (thousand $/year) (Burt 2012)

It is highly recommended that entities that are pumping water in California be supported to perform pump testing even if they have adopted a maintenance mode of operation.

In general, the majority of the SCE Pump Testing Program participants could be characterized into two groups:

Type 1 Customer. There were a number of respondents that stated that would consider taking action on the repair/replacement/retrofit of a pumping unit at a relative OPE value below 50%, or at catastrophic failure. Typically, the OPE level was cited as only one of many determinants, including hours of operation, economic analysis and flow/pressure performance. All of the Type 1 customers contacted felt that the SCE Pump Testing Program was a **valuable service.**

<u>Type 2 Customer</u>. There were a smaller number of respondents that would state that they used a value as high as 65% as a point where they take action on the repair/replacement/retrofit of a pumping unit. These customers would cite the benefits of pump testing, the influence of the SCE Pump Testing Program, and that rapid pump evaluation is a key way to conserve energy and optimize resources. Typically, the OPE was the key determinant in the decision making process. There was significant concern that this evaluation of the program was being done to change the focus and direction of the SCE Pump Testing Program. All of the Type 2 customers contacted felt that the SCE Pump Testing Program **was a valuable service.**

Figure 46 illustrates the theoretical difference between a Type 1 and Type 2 SCE customer who participates in the pump test program, in terms of water/energy use on a single pumping unit. The time frame was expanded to 20 years to illustrate the temporal savings. It also illustrates that the OPE values are changing constantly and that a single year evaluation of benefits can be deceiving.

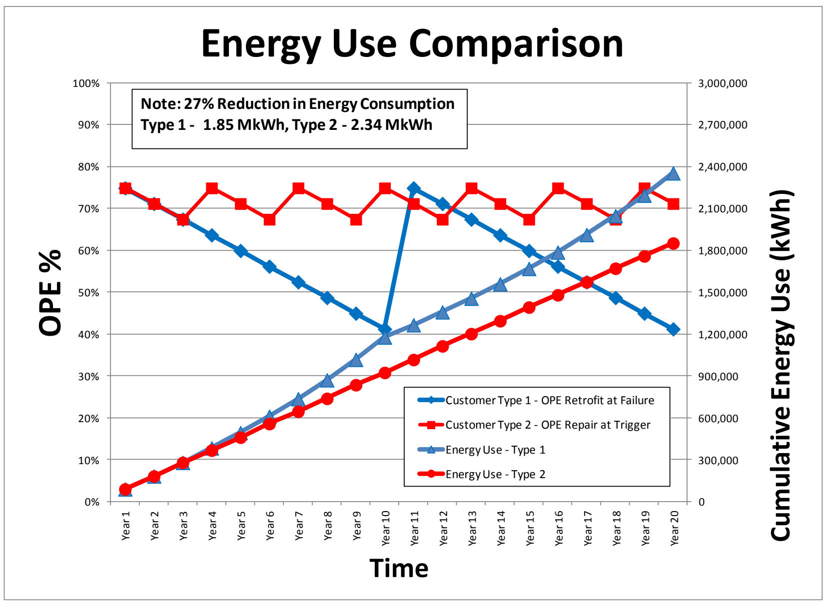


Figure 46. Theoretical energy use for two types of customers

The results of this example show that the Pump Testing Program is beneficial to both types of customers. Obviously, the <u>Type 2 Customer</u> is influenced heavily by the SCE Pump Testing and Rebate Incentives program. The result is a significant actual energy savings (27% energy over 20 years in this example). Although <u>Type 1 Customers</u> still benefit from pump test information, this example illustrates that influencing <u>Type 1 Customers</u> to act more like <u>Type 2 Customers</u> would be beneficial to SCE. The potential for ***future energy savings*** from <u>Type 1 Customers</u> is significant.

Recognizing that there are limited resources available and that every SCE customer cannot receive a pump test every year, there are other opportunities to aid SCE customers in the monitoring of the decline in pump performance. Coupled with adequate education, increased instantaneous performance monitoring has the *<u>potential to decrease the demand for short interval pump testing.</u>*

Option 1

Installation of state-of-the-art flow meters. Innumerable pump stations have poor hydraulic conditions for flow rate measurement. New advances in magnetic flow meter technology have provided a simple solution that has only recently become available. Research has demonstrated that these new electronic devices can work adequately in the poor hydraulic conditions existing in many pumping plants. In fact, some manufacturers have incorporated hydraulic conditioning into the measurement device for this reason. The key disadvantage to these meters is cost. Further analysis would be required to determine the feasibility and potential changes in behavior with the addition of instantaneous flow rate information for operational management.

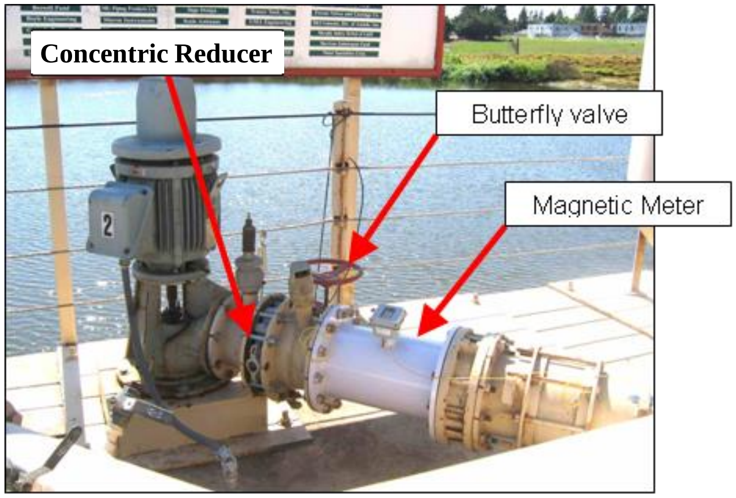


Figure 47. Photo showing the use of a magnetic flow meter in a poor hydraulic condition

Option 2

Installation of individual pump power meters. Most installations utilize only one device that meters the power consumption of multiple pumps. This makes pump performance monitoring problematic. New products have become available that provide inexpensive and non-intrusive metering of all circuit characteristics including power factor, kW, amperage and voltage. While a pump test report can separate the data to indicate the individual performance of pump units, the direct reading approach would aid SCE customers in the decision making process by helping with documenting the trend of the performance.

Figure 48. Direct display kilowatt meter

The installation of these devices has the potential to change each type of customer in the following ways:

Type 1 Customer

- Type 1 Customers have a firm grasp on external indicators such as pump discharge pressure and flow rate. Furthermore, it has been reported that a portion of these customers contract pump tests for a simple flow rate measurement rather than understanding the benefit of OPE values. The installation of a flow meter at these sites has the potential to inherently decrease this behavior as well as provide a primer for further education.
- At this time, Type 1 Customers may not benefit from the installation of an individual pump power meter unless intensive education is also provided.

Type 2 Customer

- Because of the interest in maintaining high OPE levels and having the resources follow through, the capability of monitoring both individual pump flow rates and power usage could greatly benefit Type 2 Customers. These devices provide the majority of required information to **continuously** monitor pump performance without the need to rely solely on SCE.

SCE pump tests could then be used to verify the daily monitoring afforded by these devices potentially decreasing the demand for short-term (6-month/annual) test scheduling.

Increase the OPE Education for Pump Testers

Pump testers should be provided with additional information on pump improvements that are beyond an OPE test. For example, the use of Variable Frequency Drives (VFDs) seems to be underutilized in the SCE service area. There are new techniques and ideas for pump repair that could be shared with customers. For example, there seems to be a lack of awareness of the different materials available for impellers for dealing with sand wear. The materials available can help extend the life of pumps. Another simple recommendation is to limit the use of pump screens that readily deteriorate due to corrosion. New materials should be specified that are non-corrosive and do not limit the flow area to the pump. New methods to impact water quality from wells are also being developed. Some pump dealers are using "packers" to try to improve the water quality. Burt (2008) covers a wide variety of some of the key components for obtaining and maintaining a good OPE.

Figure 49. Use of packers to limit zones of poor water quality in a well. The packers are installed to limit portions of the aquifer. Packers cause problems for pump testers by blocking the access to the pumping water level.

Increase the OPE Education for SCE Customers

There needs to be an expanded effort toward education SCE customers on the Pump Testing Program. For example, there was an obvious lack of awareness on how the OPE values vary based on the size of a pump. One of the survey questions dealt with how these customers get their information on energy-related topics. The highest response targeted SCE sources.

ITRC would be available to generate a list of topics that could be developed for future training that would target pump testers and SCE pump customers.

Decrease the Use of Independent Surveys

More than one SCE customer complained about the number of questionnaires/surveys. ITRC has been involved with numerous surveys over the last 2 decades. It was unexpectedly difficult to get cooperation from the SCE customer base to get the surveys completed. The next phase of OPE evaluation should be done with site interviews/discussions and coordinated directly with the pump testers.

Minimum Threshold for OPE

Although this study did not clearly identify a minimum OPE value, it was clear that the majority of pump retrofits/repairs occur after a pump has dropped below an OPE level of 50%.

REFERENCES

Burt, C.M., D.J. Howes, and G. Wilson. (2003). "California Agricultural Water Electrical Energy Requirements". ITRC Report No. 03-006, December 1, 2003. Irrigation Training & Research Center. Cal Poly. San Luis Obispo, CA.

Cullen, G., D. Swarts, and U. Mengelberg. (2009). PROCESS EVALUATION REPORT for the SCE Agricultural Energy Efficiency Program. Summit Blue Consulting Inc. CALMAC Study ID SEC0287.01 October 13, 2009

Equipoise Consulting, Inc. (2006). Evaluation of the Agricultural Pumping Efficiency Program (CPUC Project 230-02ABCD). March 2006.

KEMA. (2012). Industrial Sectors Market Characterization: Water and Wastewater Industry. Prepared for Pacific Gas & Electric and Southern California Edison. January 2012.

Orvis, S.A., C.M. Burt, and L. Perez Urrestarazu. (2011). "Characteristics of Irrigation Pump Performance in Major Irrigated Areas of California". ITRC Paper No. P11-010, November 2011. Irrigation Training & Research Center. Cal Poly. San Luis Obispo, CA.

Pérez Urrestarazu, L. and C.M. Burt. (2011). "Characterization of Pumps for Irrigation in Central California: Potential Energy Savings." *J. Irrig. Drain Eng.*, 138(9), 815–822.
doi: 10.1061/(ASCE)IR.1943-4774.0000463