Producing More with Less: Evaluating the Impact of a T&D Agricultural DSM Program

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In 1990, Idaho Power Company was facing potential overload transmission and distribution conditions in an area where irrigation drives the critical peak and accounts for 70 percent of the total load. Idaho Power determined that an energy conservation audit and rebate program targeting irrigation systems could reduce peak demand in the area and delay the installation of costly transmission upgrades.

The evaluation of this program began by examining load research data from 1989 to determine if demand readings from customer revenue meters would serve as reliable proxies for coincident peak reductions. The analysis confirmed that the load shapes from the customers closely matched the load shapes from the two substations feeding the area, and that reductions in customer demand would help relieve the burden in the targeted area.

Applying this information to estimate program savings, billing demand data from the initial 21 participants were compared to a sample of 94 nonparticipants who had recently requested irrigation system audits. Because the program targeted the largest, most inefficient systems first, a weighting scheme was used to adjust for energy consumption and type of crop harvested. In addition, substantial differences in temperature and precipitation between 1991 and 1992 required that the data be weather-adjusted.

The impact evaluation determined that the program significantly reduced demand for participants by almost 25 percent during the peak day in 1992 and significantly reduced energy consumption by over 25 percent during the post installation year. Measured savings closely matched the engineering estimates made at the time of the energy audits.

Introduction

In 1990, Idaho Power Company identified potential summer overload conditions in the Blackfoot-Pingree area of its service territory.[1] The company was faced with a decision to invest millions of dollars to upgrade the current transmission system or reduce the load on the system through energy conservation. After examining the customer makeup of the affected area and assessing the potential to reduce demand, Idaho Power identified significant conservation opportunities in the irrigation sector. The company then decided to develop the Blackfoot Irrigation Pilot project. The objective of the pilot was to permanently reduce pumping horsepower by promoting energy efficiency improvements in irrigation systems throughout the affected area. By providing a rebate to encourage energy efficient upgrades, Idaho Power projected a one megawatt reduction in loads coincident with the area peak. Irrigation audits were conducted by Idaho Power engineers during the 1991 growing season and efficiency improvements were made in the fall/winter between the 1991 and 1992 growing seasons.

In the fall of 1992, Idaho Power Company contracted with a consulting firm to conduct an impact evaluation of the Blackfoot Irrigation Pilot project for the 1992 growing season. The purpose of the evaluation was to determine actual demand and energy savings resulting from energy efficient upgrades in irrigation pumping equipment. The method of analysis was a statistical analysis of billing demand and electricity.[2] Specifically, three analyses were conducted: an implementation analysis, a load research analysis, and an impact analysis.

Methodology

The implementation analysis tabulated information on the rates of measure recommendations and installations and engineering estimates of demand and energy savings. The load research analysis verified that noncoincident billing demand was an appropriate proxy for the demand coincident with the area peak. It should be noted that Idaho Power derived the engineering estimates as part of the program audits. The impact analysis estimated the energy and peak demand savings attributable to the program using bill comparisons. A conditional demand analysis of the savings was also performed to examine program impacts from customer participation, categories of measures, types of crops, and amount of irrigation acreage.

Implementation Analysis

The first component of the study, the implementation analysis, examined the patterns of measure recommendations, measure installations, and engineering-based projections that were developed as part of program implementation. The analysis was based on pre- and post-installation audit information that Idaho Power tracked in Lotus 1-2-3 spreadsheets. This information was collected for all 21 irrigation sites that received a complete audit and applied for rebates. For each irrigation site, the spreadsheets contain the analysis and participant information, including types of crops, irrigated acreage, irrigation systems, and efficiency improvements.

Load Research Analysis

The load research approach was developed based on the assumption that irrigation systems operated in such a manner that the demand readings from the revenue meters were reliable proxies for coincident peak.

The consulting firm examined the load research data of irrigation accounts by comparing it to the billing data. The purpose was two-fold. The first was to verify that the maximum demand from the load research data compared to the monthly billing demand from the revenue meters. The second, and most important reason, was to determine that the maximum demand from the load research data compared to demand coincident with the area peak. If maximum demand from the load research data and the billing data were equal, and the maximum demand coincided with the area peak, then billing demand was an appropriate proxy for coincident demand.

Impact Analysis

The objective of the third analysis aimed at using a billing comparison to estimate coincident demand and energy savings. Customer billing data were used to estimate the peak demand reduction.

For the billing comparison, billing data were obtained and prepared for the 21 program participants and a group of 94 nonparticipants who were signed up to receive an audit for the following year. The billing analysis included data from the spring of 1991 through the fall of 1992. Due to the timing of the analysis, the 1992 billing data extended only through October. Some of the irrigation systems did continue to operate in November, which was not captured in the billing data.

The consulting firm estimated the net demand reduction by comparing changes in billing demand of program participants for the same monthly billing periods before and after the installation of the measures *relative* to the changes for a comparison group of nonparticipants. The basic concept underlying billing demand comparisons was straightforward. The changes in billing demand of the program participants are not only attributed to the effects of the measures but also to the effects of other variables (e.g., variations in weather, crop rotation, and other economic factors). The changes in demand for the control group are attributed to the effects of the other variables, including measures that were installed at the initiative of some of the members of the control group but *excluding* the incremental effects of the program on the installation of measures. The difference in the change in billing demand between the two groups was attributed to the single factor that varies systematically between them, namely, program participation. Thus, the effects of weather differences and other factors on changes in consumption and demand are accounted for in the billing analysis through the use of the control group.

The billing comparison needed to address one major issue in the characteristics of the comparison group. It concerned the significant difference between the participants and nonparticipants. This was apparent from the tabulations of average consumption and demand for the two groups in the period immediately preceding the installation of the measures. From participant data, it was known that only approximately one-sixth of the audit recipients would install measures. Thus, the comparison sample exhibited a self selection bias. It was also determined that participants consume more energy per acre than nonparticipants. One contributing factor was that participants grew mostly potatoes in 1991 compared to nonparticipants who grew grain. Potato crops require more irrigation than grain crops.

To minimize this self selection bias, customer data were stratified and nonparticipants were weighted to correct for differences in characteristics compared to those of the participants. The treatment and comparison samples were stratified by crop type and consumption (for the kWh billing analysis) and demand (for the kW billing analysis).

Two additional components of the impact analysis were the implementation of a customer survey and regression analysis. The objective of the customer survey was to collect information about the type of crops grown, the number of acres irrigated, and whether equipment was operated differently in 1991 compared to 1992. The objective of the regression analysis was to identify the effects of program participation and individual measures on changes in electricity consumption and demand after controlling for the effects of other factors such as weather and economic conditions.

Results

The results of the Blackfoot Irrigation Pilot project evaluation consisted of an implementation analysis, a load research analysis, and an impact analysis.

Implementation Analysis

The purpose of the analysis was to provide information on customer characteristics, the rates of recommendation and installation by measure, and to tally the engineering estimates of savings from the pre- and postinstallation audits.

Characteristics of Participant Irrigation Systems. Of the 122 irrigation systems that Idaho Power audited, 21 irrigation systems received energy conservation improvements. In the season prior to measure installation, irrigation systems had an average demand of 170 kW and consumed an average of 214 MWh. The characteristics that follow are based on information from the preinstallation audit. In the 1991 growing season, the 21 irrigation systems used a total of 3,864 horsepower to operate and water over 4,326 acres, which were mostly planted with potatoes and some grain. The average field size for participants was 206 acres. Participant acreage ranged from 80 to 340 acres. The average irrigation system uses 184 horsepower. Table 1 summarizes this information.

Table 1. Characteristics of Participants

Number of participant irrigation systems	21 systems
Number of farmers	15 farmers
Average system motor size	184 horsepower
Minimum system motor size	30 horsepower
Maximum system motor size	450 horsepower
Total system motor size	3,864 horsepower
Average acres	206 acres
Minimum acres	80 acres
Maximum acres	340 acres
Total acres	4,326 acres
Typical 1991 crop	potatoes (67%)
Typical 1992 crop	grain (76%)

The participants rotate their crops from one year to the next. The majority of participants grew potatoes in 1991. To avoid soil problems and disease with potato crops, farmers rotated to another crop the following year. In 1991, 14 irrigation systems (67 percent of all systems) were used to irrigate 2,979 acres of potatoes (68 percent of all acres). In 1992, because of crop rotation, 16 irrigation systems (76 percent of all systems) were used to irrigate 3,351 acres of grain (77 percent of all acres).

Audit Measure Installation Patterns. The 21 irrigation systems that participated in the program installed the recommended improvements. The improvements included: low-pressure pivot and nozzle packages, motor and/or pump modifications, and motor and/or pump replacements. Table 2 lists the individual measures by number of installations.

Engineering Estimates from the Audits. The consultant selected information from the pre- and post-installation audits and tallied the estimates of demand and energy savings. Idaho Power used Lotus spreadsheets to record inputs and to derive engineering estimates. The spreadsheets contain the engineering calculations used to assess demand and energy savings of recommendations and improvements.

The preinstallation engineering estimates projected that the program would reduce total demand by 717 kW, while postinstallation engineering estimates projected a reduction in demand of 672 kW. Thus, the initial projections were fairly close. The preinstallation engineering estimates also predicted an average demand reduction of 34 kW, or 28 percent.

Load Research Analysis

The evaluation approach was based on the premise that billing demand readings from the revenue meters were

Table 2. List of Recommended and Installed Measures

Measure	Number of Systems Installing the Measure
Low-pressure pivot and nozzle package	12
Pump modifications	9
Pump replacement	8
Motor modifications	5
Motor replacement	2
Booster pump removal	5
New pivot installation	3
Main-line replacement	1
Linear installation	1
Stage removal on well pump	1

reliable proxies for coincident peak. As part of the evaluation, the consulting firm examined load research data and verified the validity of this premise.

The first step in the analysis was to confirm that the irrigation systems operate as Idaho Power stated. For each site, the consulting firm determined that the peak demand is equal to the average demand when the system is operating. The load research analysis determined that the peak demand from load research data compares to the monthly demand from the billing data. Then, the analysis determined that the peak demand from the load research data was coincident with the area.

Specifically, the consultant examined 1989 load research data on irrigation accounts. The load research analysis included 27 metered sites in the Eastern Division of Idaho Power. Ten of the 27 sites were located in the Blackfoot service area—the area of interest. Idaho Power provided hourly load research data, which were averages of the 15-minute-interval data. With this information the consultant verified that the maximum demand from the load research data compared to the monthly billing demand from the revenue meters. Figure 1 shows a load profile for one of the irrigation systems operated on the peak day. The consultant visually inspected the load profiles for each of the 27 irrigation systems. The load is constant when the systems are operated. In addition, the consultant generated load profiles for a typical day and the peak summer day. Figure 2 presents the load profile for the 27 irrigation systems on a typical day.

Hourly load data from 1989 for the Blackfoot area were also examined. The consultant aggregated these data into hourly kilowatts for an average summer day and for the peak summer day. Figure 3 shows the area load profile for a typical day.

In 1989, the area peaked on June 27. We compared this load profile to the hourly load data for each of 27 sites on this day. The load shapes of the irrigation systems match

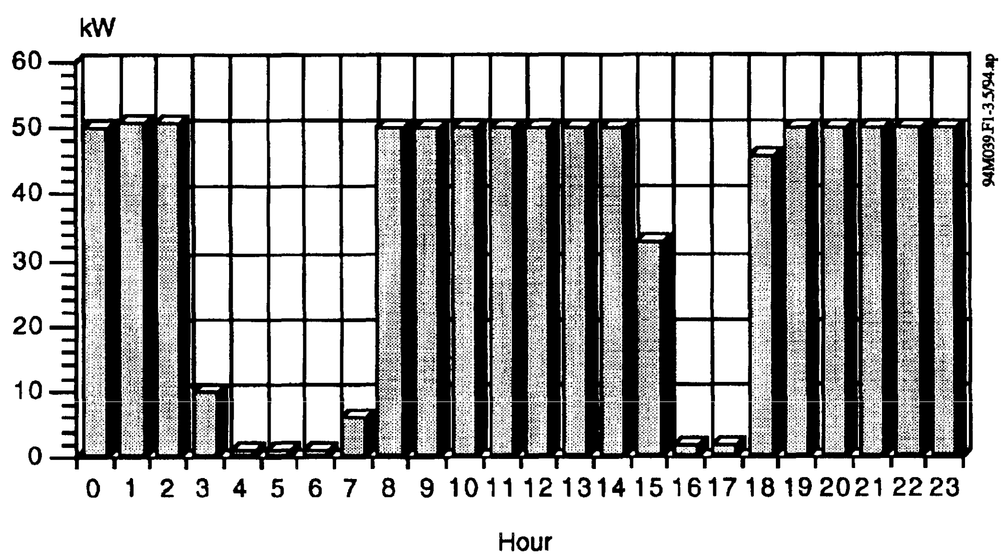

Figure 1. Load Profile for an Irrigation System on the Peak Day

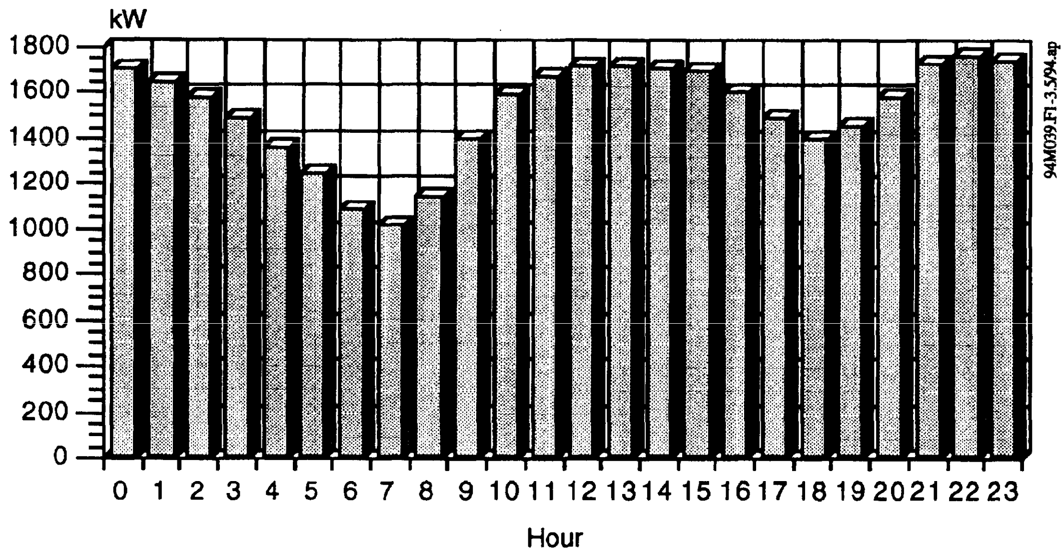

Figure 2. Load Profile of 27 Irrigation Systems on a Typical Day

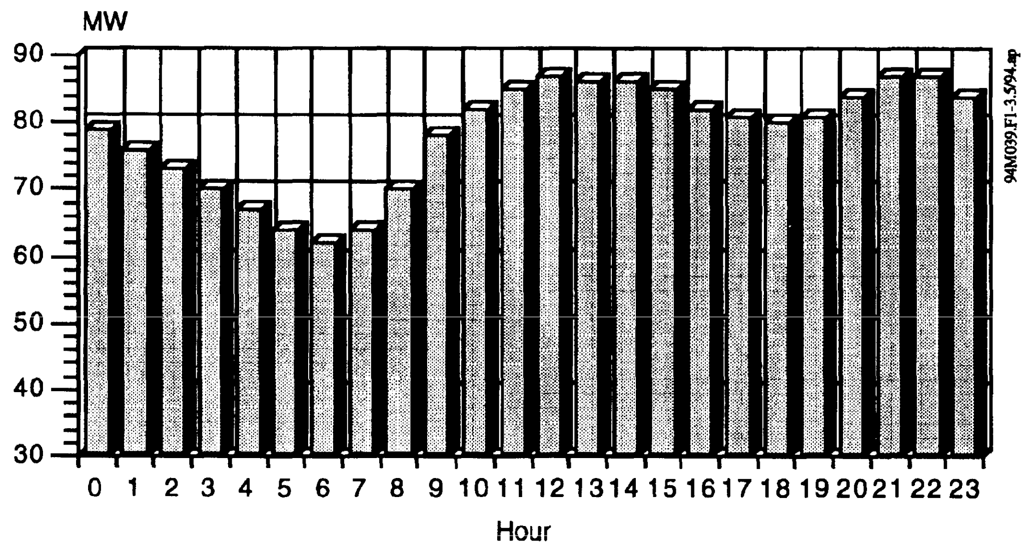

Figure 3. Area Load Profile for a Typical Day

the area load profile. The load shape for the 27 irrigation systems on a typical day show that the peak occurs at 1 p.m. A second slightly larger peak occurs at 10 p.m. On the peak day, the load profile is the same except that one of the two peaks occurs at 2 p.m. rather than 1 p.m.

Impact Analysis

The impact analysis examined two changes-the reductions in demand and the reduction in energy consumption.

Demand Savings. Participants in the Blackfoot Irrigation Conservation Program experienced significant kilowatt savings, particularly during the summer peak months. As shown in Table 3, participants reduced their average June kilowatt reading from 172 kW in 1991 to 134 kW in 1992, an average reduction of 23.8 percent. Since weighted nonparticipants had slight increases in their June readings, the net kilowatt savings were over 24.5 percent. The net savings were statistically significant at the 95 percent confidence level.

Table 3. Changes in Demand, By Month

Month of Read Date	Group	Average 1991 kW	Average 1992 kW	Average Percent Change	Net Percent Change
June	Participants	172	134	−23.8%	–
	Weighted nonparticipants	153	154	1.0%	-24.5%
July	Participants	175	135	-25.1%	-
	Weighted nonparticipants	155	152	-1.4%	-23.7%
August	Participants	180	126	-30.4%	-
	Weighted nonparticipants	158	156	-2.0%	-28.4%

The months of July and August had similar results. In July participants reduced their average monthly kilowatt readings by 25.1 percent. When compared with the weighted nonparticipants, participants showed a net reduction of 23.7 percent. In August participants experienced a decline of nearly one-third in their kilowatt readings, and when compared to the weighted nonparticipants they had net savings of 28.4 percent. In both July and August, the participant kilowatt reduction was significantly greater than the kilowatt changes of the nonparticipants.

Similar reductions in demand also occurred when only bills covering the peak days of 1991 and 1992 were examined. For example, for bills covering the 1992 peak day (June 10), the average participant decreased kilowatt use by 25 percent, from 170 kW in 1991 to 131 kW during this same period in 1992 (Table 4). However, the weighted nonparticipants exhibited a decrease of less than 1 percent over the year. Thus, the net kilowatt savings was 24.7 percent, or 39.0 kW.

A conditional demand analysis was also conducted to examine the influence of other variables, such as crop rotation, horsepower, and pumping lift, on the percent demand reduction:

Table 4. Change in Demand for Coincident Peak Days

Billing Period	Group	Average 1991 kW	Average 1992 kW	Average Total Change	Percent of Total	Average Percent Change	Net Percent Change
Billing period covering July 11 (1991 Peak)	Participants (n=17)	181	141	−41.5	−23%	−25.2%	–
	Weighted nonparticipants (n=86)	166	163	-3.6	-2%	-1.8%	-24.4%
Billing period covering June 10 (1992 Peak)	Participants (n=19)	170	131	-39.3	-23%	-24.9%	–
	Weighted nonparticipants (n=79)	157	157	−0.3	−0.2%	-0.2%	-24.7%

$$Perchgkw = b0 + b1*grntopot + b2*pottogrn + b3*tacres + b4*namephp + b5*eneffic + b6*tothead + b7*partic + b8*lift$$

where,

perchgkw	=	Percentage reduction in kW
grntopot	=	A binary variable (0, 1) indicating customers that grew grain in 1991 and potatoes in 1992
pottogrn	=	A binary variable (0, 1) indicating customers that grew potatoes in 1991 and grain in 1992
tacres	=	Total acres
namephp	=	Name plate horsepower
eneffic	=	Energy efficiency rating
tothead	=	Total head
partic	=	A binary variable (0, 1) indicating participation in the program
lift	=	Pumping lift

Participation in the program was the most important variable for explaining changes in peak demand. The parameter estimate of -22.9 confirmed the earlier finding that participation in the program will reduce demand by about 23 percent. Most of the other variables had only minor influences on the dependent variable, and none were statistically significant at a 95 percent confidence level.

Energy Savings. Participants experienced a substantial reduction in energy consumption, particularly during the peak summer months. For example, Table 4 shows that for the period June 15 to August 15, the average participant reduced energy consumption from 138,3388 kWh in 1991 to 73,280 kWh in 1992.

Table 5 also indicates that weighted nonparticipants reduced their average energy consumption during the peak growing season by 33.4 percent. The net impact of the program during the peak season, therefore, is the savings experienced by the participants (44 percent) less the savings experienced by the control group (33.4 percent), or 10.6 percent.

When the time frame is extended beyond the peak summer season to include the entire period for which billing data was available, the gross energy savings for participants actually decreased to 11.3 percent (Table 6). This occurred because a cold, wet spring of 1991 required less crop irrigation than the more typical weather in the spring of 1992. The net energy savings, however, was 25.5 percent, because the weighted nonparticipants increased energy consumption by 14.2 percent.

A conditional demand analysis revealed that the most important variable for predicting changes in kilowatt-hours, besides participation, is crop rotation. Switching crops from grain to potatoes *increased* energy consumption by about 57 percent, while switching from potatoes to grain *reduced* consumption by nearly 20 percent. These results are to be expected since potatoes typically require more water than grain (and thus more use of the pumps).

Another finding was that energy consumption increased slightly for customers with larger farms (total acres) and greater pumping lift. This is to be expected since larger farms and systems with higher pumping lift require more energy to irrigate.

Conclusions

The analysis of Idaho Power's load research data confirmed that the billing demand is a very good proxy of demand coincident with the area peak. As a result, the comparison of billing demands between 1991 and 1992 provides a reliable estimate of coincident peak demand savings.

Table 5. Changes in Kilowatt-Hours (kWh): June 15 to August 15

Group	1991 Average	1992 Average	Mean Difference	Percent of Total	Average Percent Change	Net Percent
Participants (N = 19)	138,338	73,280	−65,057	−47%	−44.0%	–
Weighted nonparticipants (N = 78)	113,384	68,937	−44,447	−39%	−33.4%	−10.6%

Table 6. Changes in Kilowatt-Hours (kWh): March to October Bills

Group	1991 Average	1992 Average	Mean Difference	Percent of Total	Average Percent Change	Net Percent
Participants (N = 19)	213,777	191,705	–22,071	–10%	–11.3%	–
Weighted nonparticipants (N = 78)	185,590	211,008	25,419	13%	14.2%	–25.5%

The impact evaluation found that the Blackfoot Conservation Program realized significant reductions in peak demand and energy consumption for the area in 1992. The impact evaluation estimate of 39 kW in average net coincident demand reduction for the rebate recipients is greater than the engineering estimates that were made at the time of the inspections, which projected an average savings of 32 kW–34 kW. However, the total program impact in 1992 was only 78 percent of Idaho Power's target of 1 megawatt under its original program plan. This is clearly due to the low rate at which audit recipients took advantage of the rebates for recommended measures. Only one-sixth of the audited irrigation systems applied for rebates before the 1992 growing season.

The program also realized significant energy savings during 1992. Rebate recipients reduced their consumption by more than 11 percent in spite of changes in weather that required more intensive pumping in 1992. A comparison sample of nonparticipants, weighted to be similar to participants with respect to crop rotation and 1991 consumption, increased its consumption by 25 MWh. Assuming that participants would have required comparable increases had they not upgraded their systems, the average net savings was 47 MWh. This is very close to the engineering estimates of average savings, which projected an average net savings of 49 MWh. In addition, the program was less costly than the $3 million that would have been required to upgrade the transmission facilities.

Endnotes

1. The Blackfoot-Pingree area is fed from two sources, a 161 kV line from Goshen and a 138 kV source at Don. The limiting factor is the 161/138 kV 135 Mva stepup transformer at Don. During an outage of the Goshen-Blackfoot 161 kV line, the potential exists for minor overloading of this tie bank during absolute summer peak conditions. This overloading condition occurs for about 20 hours during a 4 week period. Historically, permanent outages (greater than 4 hours) of the Goshen-Blackfoot 161 kV line have been very rare.

2. This method was partially based on an earlier study conducted by the Energy Services Department of Idaho Power Company entitled "Idaho Power Irrigation Pilot Impact Evaluation."