Determining the Full Value of Industrial Efficiency Programs

Patrick Lilly, Regional Economic Research, Inc.
Dennis Pearson, Seattle City Light

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Each industrial setting, the efficiency measures installed, and the processes affected are described in this paper. The projects chosen for evaluation cover a wide range of industrial processes and end uses. Findings include energy (kWh) and peak demand (kW) savings indexed to changes in production volume, an assessment of non-energy benefits to the participating customer, and cost-effectiveness analyses from four stakeholder perspectives, including levelized cost (expressed in cents per kWh) and benefit-cost ratios, both including and excluding quantifiable non-energy benefits. A summary of conclusions and lessons learned is also provided.

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Introduction

The (ESP) program was initially a BPA-sponsored industrial retrofit program. Between 1988 and 1996 the BPA paid incentives for energy efficiency improvements in manufacturing, processing, and refining industries. For projects contracted since January 1997, ESP has been funded solely by SCL. Between 1988 and 1998, a total of 75 industrial ESP incentive projects have been contracted in SCL's service area, accounting for nearly 55 million kWh of annual energy savings. Through 1997, the average total resource cost of these energy savings was 1.8 cents/kWh, based on verified (pre-evaluation) energy savings and total actual project cost (Pearson 1998).

After the measures are installed, short-term metering is done to verify energy savings. The final incentive amount is dependent on these verified energy savings. These verified (pre-evaluation) savings may or may not include changes in pre/post-retrofit production levels and do not include an assessment of demand (kW) and non-energy benefits.

Scope

The overall purpose of the current series of case study impact evaluations is to provide a more comprehensive assessment of the value of a sample of industrial incentive efficiency projects by:

- Determining the net production-indexed annual and lifecycle kWh and kW savings resulting from the installation of energy efficiency measures and comparing these savings with pre-evaluation project-verified savings.

- Measuring any secondary, attributable energy, and demand savings on electrical process equipment downstream of the retrofitted equipment.
- Identifying and valuing the non-energy benefits to the customer. Non-energy benefits can include such factors as reductions in the cost of operations and maintenance, labor, air and water emissions, and increases in production, or production capacity.[1]
- Calculating the cost-effectiveness of the project from all stakeholder perspectives, both including and excluding non-energy benefits.
- Providing recommendations to the customer and to the utility.

Projects Selected for Case Study Evaluation

The five projects selected for case study evaluations were chosen to represent:

1. A wide variety of industrial processes and end-use equipment,
2. Both large and small projects, in terms of kWh savings and project costs, and
3. A mix of new and established retrofit projects.

The following list contains descriptions of each of the five ESP projects evaluated.

1. Lafarge Cement Mill Conversion project was by far the largest and most expensive of the five ESP projects evaluated. This project involved the installation of sectionalized grinding chambers in the raw mill and finish mill #1 (of two finish mills) to increase product-throughput speed and energy efficiency, and the installation of an ASD on the 250 horsepower (HP) cement slurry discharge pump. Under baseline conditions, the raw and finish mills were large, single-section cylindrical mills where solid steel grinding balls of all sizes were mixed together to crush the cement ingredients. This caused inefficiency in the grinding process by expending energy and time tumbling large grinding balls to impact cement material already pulverized and, conversely, tumbling light-weight grinding balls to impact raw, course material, to little avail. By matching the size of the grinding media with the coarseness of the cement ingredients in each of the new grinding chambers, grinding efficiency was expected to increase. Consequently, the energy consumption of the 2,000 and 2,500 HP electric motors powering the raw mill and finish mill #1 was expected to decrease. (Lilly, Parekh & Swanson, 1997c)
2. ARCO Products Company's ESP project involved the installation of ASDs on each of two 175 HP electric pumps used to move gasoline from storage tanks into tanker trucks. The ASDs allowed for the regulation and lowering of pumping pressure and reduced wear on the pumping system's flow-rate meters, due to the elimination of the "hammer effect" caused by sudden increases in pumping pressure. (Lilly, Parekh & Swanson, 1997b)
3. Viox Corporation's project entailed the design of a custom-made product drying system in a specialty glass manufacturing plant. This new drying system decreased the time it took to dry batches of glass "frit."[2] The new system utilizes screens and gravity to drain

[1] One preliminary study of an industrial sector incentive program in SCL's service area found that the inclusion of non-energy impacts decreased the average service area (customer and utility) levelized cost of the program from 2.8 cents/kWh to 1.4 cents/kWh—a 50% reduction in program costs (Das et al., 1992).

[2] Glass frit is a mixture of tiny glass shards and water, formed in the early stages of Viox's glass fabrication process.

excess water, and small electric resistance heaters and airflow supplied by tapping into the plant's existing ventilation system to evaporate the remaining water surrounding the glass particles. (Lilly & Parekh, 1997a)

4. The Lafarge Cement Plant Air Compressor project included the replacement of two 200 HP rotary-*vane* with two high-efficiency 150 HP rotary-*screw* air compressors serving the company's instrument and plant air systems. The project was designed to decrease energy consumption and decrease air compressor downtime due to the expected reduction in the frequency of compressor overhauls. (Lilly & Parekh, 1998)
5. The Rainier Cold Storage project installed computerized controls on the plant's refrigeration system. The control system was designed to adjust the compressor's discharge and suction pressures and to optimize the cycling of the plant's seven compressors to meet the changing cooling requirements of this seafood storage facility. (Lilly & Pearson, 1998)

Methodology

Energy and Demand Savings Assessment

Energy consumption in manufacturing plants is often a complex function of a variety of factors that should be considered when assessing energy savings. Some of these variables include:

- <u>Pre-post change in production volume,</u> product type, batch size, or changes in ambient or process temperature.
- <u>Change in air or liquid pumping pressure</u>. This applied to the ARCO Products and Lafarge Cement air compressor projects.
- <u>Staged or phased-in, post-retrofit period</u>. This occurs when difficulties are experienced in achieving and stabilizing optimal production efficiency during the post-retrofit period. This necessitates longer term metering, indexed to coincident changes in production level in order to record the energy use until production and energy use stabilizes.
- <u>Secondary and attributable energy impacts on electrical process equipment downstream of the ESP incentivized measures</u>. For example, at the Lafarge Cement Plant, significant energy savings were also found in the non-incentivized finish mill #2 as a direct result of the efficiency and product quality improvements in Lafarge's raw mill.

In all five case studies, the energy and demand savings assessment methodology consisted of the following:

1. Conducting meetings with involved SCL Energy Management Analysts, plant management, and plant production and maintenance staff to explain the purpose and value of the evaluation, identify key contact staff, understand the production process, discuss production data and process confidentiality issues, identify coincident production data, and begin the identification of potential non-energy impacts and the availability of supportive data.
2. Developing a final evaluation plan to outline the electrical metering plan, production and non-energy impacts data acquisition, non-energy benefits assessment, and the required cost-effectiveness tests. In all but one case study, *end-use* kW metering was gathered and aggregated upward to hourly, daily, or monthly kWh data in order to match the available coincident production data. In the sole case of the Rainier Cold

Storage project, *whole facility*, 15-minute interval kW and monthly energy billing data were used.

3. Constructing and testing various energy savings regression models that were compatible with the end-use metered energy, production, and process data. These models were designed to provide an estimate of post-retrofit electric energy and peak demand savings per unit of product. These models relate monthly kW and kWh usage per unit of production to a series of coincident, pre-/post retrofit production variables.

Examples of some of the coincident explanatory variables included:

- A pre-/post retrofit binary variable. This variable served as a composite of all change in kWh or kW use after the measures were installed. The coefficient of this variable is a point estimate of energy or demand savings per unit of production. These coefficients were used to calculate annual and life cycle kWh and kW savings.
- Changes in production volume and product type or grade manufactured over time. The smallest time interval for which coincident production data were available became the unit of time used in the energy savings regression analyses.
- Changes in pumping pressure.
- Ambient temperature change.
- If applicable, binary variables to account for the "shakedown" period sometimes needed to reach optimal post-retrofit efficiency.

Similarly, separate kW regression equations were completed to determine peak demand (kW) savings for each of the affected end uses.

Non-Energy Benefits Assessment

Generally, the non-energy impacts assessment was a process of identifying, with the aid of plant management and operations staff, the likely non-energy effects of each project, determining what pre/- and post-retrofit data were needed to support the analysis, gathering the relevant data, and calculating pre/post change in each non-energy impact. If the necessary data were not available, that particular non-energy benefit was dropped from the analysis. An important lesson here is to screen potential case study sites before the installation of the new equipment to ensure that the needed non-energy benefit data are available over the pre- and post-retrofit periods.

Most of the non-energy benefits involved reductions in operations and maintenance costs, with the remainder resulting from lower air emissions of sulfur dioxide (SO_2). By far, the most complex non-energy benefit assessed in the Lafarge project was the economic benefit of reduced air emissions from the cement plant's kiln stack due to the increased fineness and uniformity in the wet cement coming from the renovated raw mill. This, in turn, caused the kiln to function more efficiently at lower and more stable operating temperatures and reduced emissions of sulfur and nitrous oxides. Separate regression models were constructed to assess pre/post changes in sulfur dioxide (SO_2 in PPM), nitrous oxides (NO_x in PPM), and particulate matter (% opacity). These models were designed to explain daily emissions in each type of pollutant as a function of the raw mill conversion itself, pre-/post-retrofit change in production volume, the type of fuel being burned in the kiln and the change in the chemical composition of the cement ingredients.

Findings

Energy Savings

Table 1 lists the evaluation-based energy savings and compares these kWh savings with the estimated savings in the project proposal. For all five case studies combined, annual evaluated energy savings were 5,453 MWh, or 128% of the original estimated savings at the time each project was proposed.

The Lafarge mill conversion project involved the most energy-intensive manufacturing process of the five projects evaluated, including three large electric motors, ranging from 250 to 2,500 HP—accounting for 4,256 MWh or 78% of total evaluated energy savings across all five case studies. The ASD installed on the 250 HP raw mill slurry discharge pump at Lafarge proved to have only 60% of the proposed savings and the evaluation of finish mill #1 revealed 86% of expected kWh savings. Because of the greater than expected savings in the raw mill itself and the secondary savings it caused in finish mill #2, the mill conversion project's combined savings were nearly 1,100 MWh greater than those estimated at the time of the project proposal, or 134% of proposal estimated energy savings.

Table 1: Comparison of Proposal and Evaluation-Based Energy Savings

ESP Case Study Evaluation	Proposal Savings (kWh/yr.)	Evaluation Savings (kWh/yr.)	Realization Rate
Lafarge Cement Mill Conversion			
▪ Raw Mill Conversion	866,445	1,601,868	185%
▪ Secondary Effect on Finish Mill #2	NA	778,707	NA
▪ Raw Mill Slry. Pump	411,744	247,128	60%
▪ Finish Mill #1 Retro.	1,900,000	1,628,838	86%
Mill Conversion Subtotal:	3,178,189	4,256,541	134%
Lafarge Air Compressors	285,847	494,001	173%
Lafarge Projects Subtotal:	3,464,036	4,750,542	137%
ARCO	168,610	156,100	93%
Viox	95,634	179,200[a]	187%
Rainier Cold Storage	542,078	366,993	68%
Remaining Projects Subtotal:	806,322	702,293	87%
Total:	4,270,358	5,452,835	128%

(a) Viox energy savings are based on expected production increases.

Likewise, the Lafarge Air Compressor evaluation savings were greater than expected at 494 MWh of annual energy savings, 173% of the savings expected at the time of the project was proposed. Together, the Lafarge mill conversion and air compressor project savings of 4,750 MWh represent 137% of total savings across all five evaluated projects.

At ARCO, the ASDs installed on the two 175 HP pumps resulted in 156,100 kWh of annual savings—93% of proposal-based estimates.

The new drying system at Viox Corporation yielded much greater than expected energy savings at 187% of proposed savings. Viox's evaluation savings are based on greater forecasted production over the life of the new dryers.

The computerized refrigeration control system at Rainier Cold Storage revealed 367 MWh of annual energy savings—68% of expected savings. It should be noted that the original savings estimate of 542 MWh of yearly savings was thought by both plant and SCL staff to be an overestimate on the part of the vendor selling the control system. The current evaluation savings are, however, 119% of the routine short-term verification done shortly after the control system was installed. This provides strong evidence that these energy savings were persisting at this site, five years after the measures were installed in 1992.

Secondary Energy Savings in Non-Incentivized Equipment. In addition to the 3,476 MWh of savings measured on Lafarge's raw and finish mill #1, secondary and attributable energy savings totaling 779 MWh were found on the non-incentivized finish mill #2. This secondary effect on the efficiency of finish mill #2 resulted from the finer quality of the cement material coming from the ESP-funded raw mill conversion. This decreased the amount of time needed to complete the finish milling and consequently decreased the kWh use-per-ton of cement produced in both of Lafarge's finish mills.

Additional secondary and attributable savings of 2,500 MWh were found in the efficiency of the cement kiln's drying process. The increased fineness and consistency of the raw mill cement outflow into the kiln reduced the time it takes to dry each ton of raw cement. This, in turn, lessened the electrical load on the motor drive system used to rotate the kiln. However, these kiln savings were not included in this evaluation because the evaluation team was not able to separate the ESP-funded energy savings effects from the routine annual maintenance that was performed on the kiln at the same time the ESP-funded measures were installed.

The air compressor project at Lafarge also saw collateral and attributable savings on the non-incentivized standby plant air compressor after the ESP-funded, primary plant air compressor was installed. The effect of these additional kWh savings was the primary cause of the resulting 173% realization rate for this project.

Demand Savings

Table 2 lists the demand savings found in each case study. Reductions in peak demand, although measurable, were small in comparison to energy (kWh) savings (see Table 1). The 540 kW reduction across all five projects amounts to only $4,512 in annual savings, or about 2% of total customer kWh, kW, and non-energy benefit dollar savings (see Table 3).

Table 2: Evaluation-Based Peak Demand Savings (a)

ESP Project	Evaluation-Based Demand Savings (kW)
Lafarge Mill Conversion	
• Raw Mill Retrofit	367
• Finish Mill #1	79
Lafarge Air Compressor	88
Lafarge Subtotal:	534
ARCO	11
Viox	-5
Rainier Cold Storage	not significant
Remaining Projects Subtotal:	6
Total	540

(a) Estimated demand savings are not an ESP project requirement.

Non-Energy Benefits

Eighty-one percent of customer's *non-energy* savings were the result of reduced operations and maintenance expenses. The remaining 19% included reductions in air emissions. The non-energy impacts included:

Lafarge Mill Conversion (present value of total lifetime non-energy savings: $246,246):

- Reduced cost of replacing the steel balls used as grinding media as a consequence of the increased throughput speed of cement product caused by the new mill segmentation.
- Motor life extension of slurry pump motor caused by the ASD.
- The increased consistency of the raw cement mill slurry improved cement kiln stability, lowering emissions of SO_2 by 78%, and reduced monetary fines imposed by the local air quality control agency for emission exceedances.

The Puget Sound Air Pollution Control Agency (PSAPCA) regulates industrial air emissions in the Puget Sound area and imposes fines for air pollution exceedances. The increased uniformity of cement product emerging from the new, sectionalized raw mill lowered the average kiln operating temperatures and increased kiln operating stability. This desirable condition reduced the kiln stack's SO_2 by 78%, from 249 PPM to only 54 PPM. Also, kiln stack emissions of nitrous oxides (NO_X) were reduced by 40% as a result of the raw mill conversion. However, since PSAPCA does not currently regulate NO_X emissions, this finding does not as yet have an economic benefit to Lafarge. The pre-/post-retrofit change in particulate air emissions was not significantly different.

Lafarge Air Compressors (present value of lifetime non-energy savings $156,788):

- Reduced frequency and cost of overhauling the replaced rotary-vane compressors.
- Decreased cost of lubrication oil and reduced load on cooling system used to cool the replaced compressors.

ARCO Petroleum Terminal (present value of lifetime non-energy savings $37,825):

- Reduced cost of recalibrating fuel flow rate meters, due to decreased "hammer effect" caused by the consistent pressure regulation of the ASD.
- Small savings in reduced wear on the motor bearings.

Viox Corporation (present value of lifetime non-energy savings $17,039):

- Decreased cost of replacing heating elements and controls in the replaced annealing ovens.

Rainier Cold Storage (present value of lifetime non-energy savings $3,330):

- Lower cost of refrigeration control sensor replacement.

Table 3 presents the estimated annual value of the non-energy benefits and compares these to the annual customer kWh and kW electric bill savings. Across all five of the evaluated ESP projects, customers are realizing a total of $55,361 in non-energy benefits each year. This is in addition to their annual $179,052 in energy and demand bill savings. Non-energy savings were 24% of total dollar savings, while demand savings were only 2% of total savings. Clearly, kWh savings dominate all project benefits at 74% of total annual customer savings.

Table 3: Annual Dollar Value of Energy, Demand, and Non-Energy Benefits to the Customer

Project	Annual Customer $ Savings (1995 $)			
	kWh $ Savings	kW $ Savings	Non-Energy Benefit $ Savings	Total Annual $ Savings
Lafarge Mill Conversion	$136,137	$3,627	$27,490	$167,254
Lafarge Air Compressors	15,413	769	21,091	37,273
Lafarge Subtotal:	$151,550	$4,396	$48,581	$204,527
ARCO	$5,246	$217	$4,305	$9,768
Viox	7,179	(101)	2,003	9,081
Rainier Cold Storage	10,565	0	472	11,037
Remaining Project Subtotal:	$22,990	$116	$6,780	$29,886
Total $ Savings:	$174,540	$4,512	$55,361	$234,413
Percent of Total:	74%	2%	24%	100%

Potential Production Capacity Increases

At two of the project sites, the Lafarge mill retrofit and Viox, the ESP incentivized measures resulted in potential production capacity increases. The Lafarge mill retrofit increased the throughput speed of the cement grinding process, and at Viox the new dryers doubled the potential glass frit drying capacity of the plant—an increase of 480,000 lbs./yr.

However, before these production capacity increases can be realized, existing constraints would have to be reduced or eliminated, including:

1. At Lafarge, the capacity of the cement kiln would have to be increased to match the potential increased throughput from the raw mill conversion.
2. At Viox, the capacity of the plant's glass melting furnace would have to be increased.
3. The market demand for cement products from Lafarge and specialty glass products from Viox would have to increase to meet the production capacity increases at both plants.

Because the realization of these capacity increases at Lafarge and Viox are a function of conditions that have not yet occurred, neither of these potential production increases were included in the energy and non-energy benefits and cost-effectiveness analyses.

Cost-Effectiveness

The cost-effectiveness of each evaluated project included the calculation of:

- <u>Customer payback periods</u>, or the number of years to recover the customers investment, based on 1) the project proposal-estimated energy savings and customer costs and 2) the evaluation-derived energy, demand, and non-energy benefits and actual customer costs.
- <u>Net present value and cost-benefit ratios</u> from the customer, utility, service area (customer and utility), and total cost perspectives (customer, utility, and the BPA)—both with and without the value of non-energy benefits.
- <u>The levelized costs in cents/kWh</u> from each of the four stakeholder perspectives listed above—both with and without the value of non-energy benefits.

The following presents a summary of some of the cost-effectiveness findings.[3]

Figure 1 illustrates the customer's simple payback periods based on the customer's total project costs for each the five case studies, in terms of each project's *proposed kWh bill savings,* and compares these with the *evaluation-based payback* periods, which include the energy and non-energy savings measured in the evaluation. Overall, Figure 1 illustrates that the customer's average payback period was cut in half—dropping from an average of 2.6 years based on the project proposal to 1.3 years as a result of including the additional kW, kWh, and non-energy savings measured in these five case studies. The payback time to the customer would have been seven years if no incentive was paid and the customer absorbed all project costs—considerably greater than the typical one to two year payback threshold desired by most industrial customers. However, due to cost overruns or less than projected energy savings, not all projects resulted in lower payback periods, including Viox and Rainier Cold Storage.

Figure 2 compares the customer's evaluation-based benefit-cost ratios, including and excluding the value of non-energy benefits. The benefit-cost ratio is a standard index of the economic advantage of a particular business decision, calculated by dividing the net present value of the project costs into the discounted value of all project benefits over the life of the project (discount rate = 10%, measure life = 15 years). Overall, the inclusion of the value of the non-energy benefits increased the average customer benefit-cost ratio from 6.6 to 8.4—a 27% increase.

Figure 3 depicts the benefit-cost ratios for each project from the total cost perspective (BPA, SCL, and customer costs and benefits), and the service area perspective (SCL and customer costs and benefits). From a total cost perspective the benefit-cost ratios averaged 3.6, with none below 2.1. The service area benefit-cost ratios are all larger than those of the total cost perspective, since the BPA absorbed the cost of the incentive payments to customers, leaving only the customer share of the project cost and SCL's administrative costs.

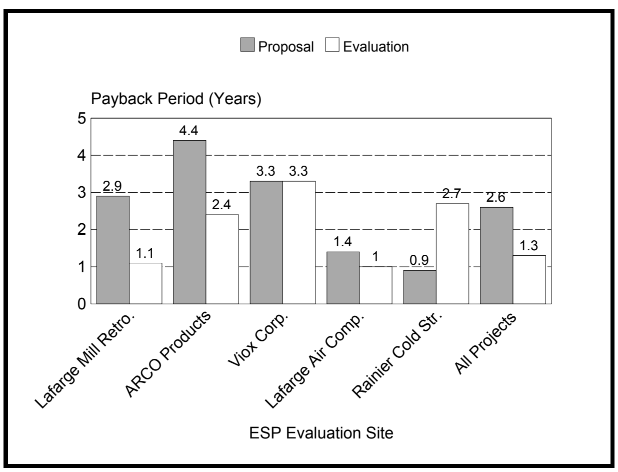

Figure 1. Customer Payback Period in Years: Proposal-Based vs. Evaluation-Based

[3] See the reports and contact information listed in the reference section of this paper for detailed cost-effectiveness results.

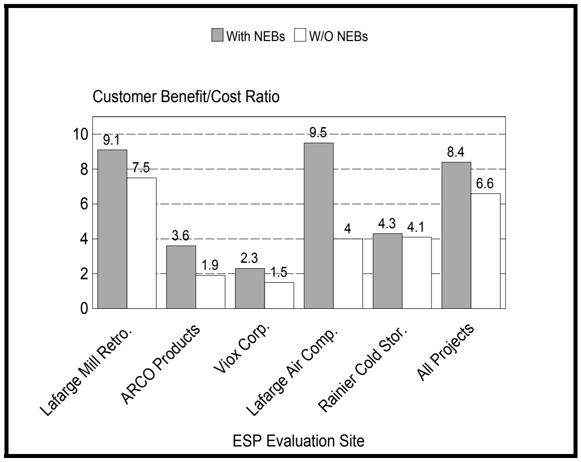

Figure 2. Customer Benefit-Cost Ratio with and without the Value of Non-Energy Benefits

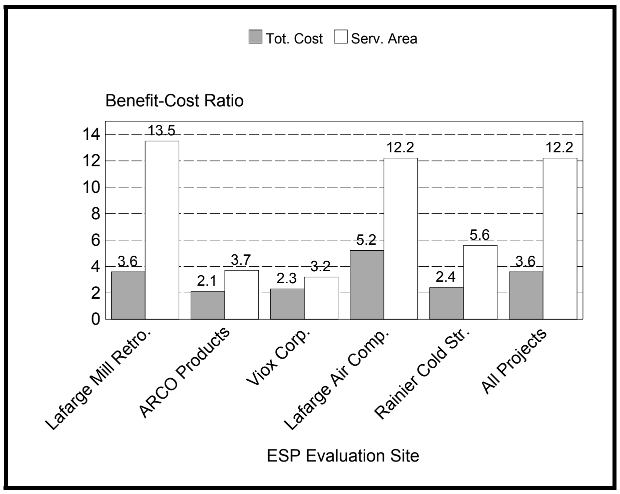

Figure 3. Benefit-Cost Ratios: Total Cost (BPA + Utility + Customer) and Service Area (Customer + Utility) Perspectives

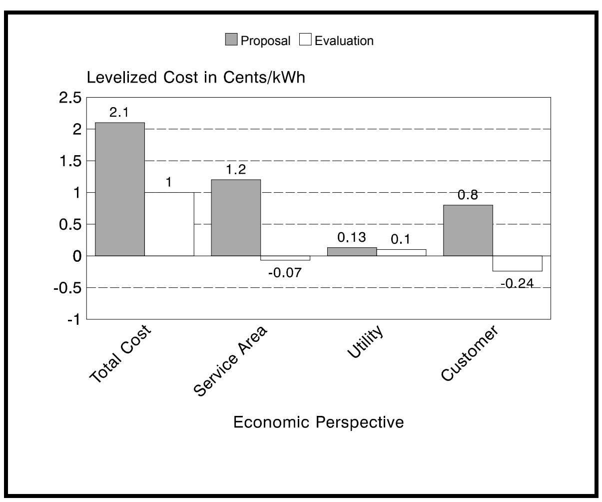

Figure 4. Average Levelized Cost Based on Project Proposal and Evaluation

Figure 4 compares the *proposal-based* and *evaluation-based* levelized cost in cents per kWh for all projects combined, from all economic perspectives: 1) total resource cost, 2) service area (utility and customer costs combined), 3) utility, and 4) customer perspectives. The levelized costs shown in Figure 4 are an important indicator of the overall value of the ESP program itself and the additional value revealed in the evaluations. In general, the goal is to keep the costs of delivering energy efficiency programs at or below the utility's cost of generating, or buying, and distributing electricity. And, if the customer's levelized cost for a particular efficiency project is below their electricity cost in cents/kWh, they are realizing a net reduction in the electrical portion of their operating costs.

Figure 4 illustrates that the total resource levelized cost across all five case studies was 2.1 cents/kWh based on the project proposals. This cost decreased by 52%, to only 1 cent/kWh after factoring in the additional kWh, kW, and non-energy benefit evaluation impacts. The combined evaluation-based energy and non-energy impacts over the life of the measures were most evident in the service area and customer perspectives, where *negative* levelized costs resulted. From the customer's perspective, the overall levelized cost was *minus* 0.24 cents/kWh. If the ESP-funded incentives weren't available and these five customers paid the entire cost of these projects, the levelized cost would have increased significantly to 3.0 cents/kWh.

Recommendations to Participating Customers

Each evaluation case study resulted in a set of recommendations to plant management and operations staff, that if implemented, could result in additional efficiency gains. Generally, these included follow-up recommendations to investigate and adjust the operation of the affected process equipment to increase existing energy or non-energy savings. For example, at ARCO an additional 45,000 kWh of annual savings could be achieved if pumping pressure were reduced from 65 psig to 60 psig. And at the Lafarge mill conversion, a recommendation was included to monitor the operation of the ASD on the raw mill slurry pump motor to determine if the lower than expected energy savings are due to unnecessary pump cavitation while the sump is being filled.

The individual evaluation reports listed in the References section at the end of this paper contain detailed descriptions of all recommendations (Lilly & Parekh, 1998a; Lilly, Parekh & Swanson, 1997b; Lilly, Parekh & Swanson, 1997c; Lilly & Parekh, 1998; Lilly & Pearson, 1998).

Conclusions

This series of case studies has revealed a more complete picture of the value of the ESP program to the customer and to SCL—additional value that would not have been as fully measured without these evaluations. This work has also provided a method that can be used by others to complete comprehensive evaluations of industrial efficiency projects.

Outcomes

- Total evaluation-measured energy savings for these five case studies were 28% greater than the estimated kWh savings in the project proposals.
- The interdependency of each industrial process stage can, under certain circumstances, lead to additional indirect energy savings. These savings are often times not captured

during routine project verification. For example, at the Lafarge mill conversion project, substantial secondary and attributable energy savings (778 MWh/yr.) were measured in finish mill #2, the only mill *not* converted as part of this ESP project.

- Demand savings, while measurable, were small in comparison to total energy and non-energy impacts, accounting for 2% of total annual customer bill savings.
- Non-energy impacts added substantial value to the customer, accounting for 24% of the total customer economic benefit across all five sites. Most of these savings included reduced operations and maintenance costs. The remaining non-energy savings were decreased fines for violating regional pollution ordinances as a consequence of a 78% reduction in the SO_2 emissions at Lafarge Cement.
- Customer's evaluation-based payback periods averaged 1.3 years and their benefit-cost ratios ranged between 2.3 and 9.5, including the net-present value of all customer costs and energy and non-energy benefits.
- In most cases, the additional savings identified in the evaluations significantly reduced levelized cost and greatly improved the benefit-cost ratios from all stakeholder perspectives. The additional value of energy, demand, and non-energy benefits measured in these case studies lowered the proposal-based average levelized cost from 2.1 cents/kWh to 1.0 cent/kWh from a total cost perspective—a 52% reduction.
- The combined energy and non-energy savings and positive cost-effectiveness results revealed in these evaluations can be used as examples in the marketing of similar incentives-based industrial efficiency programs. The more the owners and managers of industries know about the wide spectrum of efficiency possibilities, the more likely they are to justify efficient process equipment changes and to benefit from them.

Methodological Lessons Learned

The additional energy, demand, and non-energy savings exhibited in this sample of industrial incentive projects support the conclusion that, when feasible, industrial impact evaluations should be performed to reveal these otherwise hidden benefits. If this additional value is not assessed, the customer and the sponsoring energy services provider or utility will know less about the true value of their industrial efficiency programs. These case studies have provided a method for a more comprehensive assessment of industrial electrical efficiency programs, including:

- The development of production-indexed regression models to determine energy savings using site-specific variables that are predictive of energy and demand savings.
- A procedure for the investigation and measurement of non-energy benefits.
- A technique to calculate levelized costs incorporating a wide range of both energy and non-energy economic benefits.

These evaluations are also time consuming and expensive. The following lessons learned are offered to others who want to conduct similar industrial case studies:

- Prescreen the sites being considered for evaluation to determine the availability and form of the necessary production, process, and non-energy-related data needed for the evaluation. Often these data are proprietary and its use maybe subject to restriction.
- Interview key plant operations staff to get their expert insight regarding all likely direct and indirect energy use impacts and non-energy benefits of a project. This will provide a better understanding of their entire manufacturing process and ensure that all affected end-use equipment is metered. It's important to make the assessment of non-energy

impacts an integral part of the planning and implementation of the project itself, so that potential non-energy benefits are identified early on, sufficient supportive data are captured, and attribution can be established between measured change in non-energy costs and the process equipment changes.

- To the extent possible, select sites where pre-retrofit end-use metering and concurrent production data gathering can easily be performed, rather than have to depend on the data gathered as part of the routine project proposal. This will ensure that the kW, kWh, and coincident production data gathered will accurately represent baseline energy use and nominal production conditions.
- If conducting several impact evaluations simultaneously, make certain that enough key evaluation staff are assigned so that once the data are gathered, the analyses and reporting phases can proceed on two or more projects concurrently. This will greatly reduce the timeline for finishing all of the evaluation projects.

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