Examples and Best Practices of High-Yield Energy Efficiency Projects

Regina Montalbano, P.E., Spencer Lipp, P.E., and David Bruder, P.E.,
Lockheed Martin Corporation

ABSTRACT

As savings increase, energy efficiency projects have more potential to deliver cost-effectiveness to utility programs, rate payers, and end use customers. High energy savings projects help program administrators achieve savings goals for lower unit administration cost. This allows rate payers to realize higher measureable benefits from the program and a reduced need for electricity generation. Higher energy savings certainly assist end use customers by reducing their electricity bill while incentives often significantly lower a hefty first cost. A challenge for all program implementers is to identify these large scale projects and influence the customer to move forward with installation. This paper highlights some best practices of a customized program implementer that targets projects with annual savings greater than one million kilowatt-hours (kWh) and consistently delivers projects with savings over four million kWh. Several best practices are described and illustrated by way of an actual project example.

Introduction

Energy efficiency program administrators have been creating and managing programs that target large commercial and industrial (C/I) energy users for decades. There are several good reasons for this:

The larger the user, the larger the savings potential. It stands to reason that the more energy consumed at a customer facility, the greater the absolute savings potential is, if one assumes that most facilities could reduce their consumption by a nominal percentage, say 10 to 20 percent.

- Large project size means lower cost per unit of savings. There are fixed costs and variable costs involved in implementing an energy savings project, both for the end user and the program administrator. Spreading those fixed costs over a larger savings quantity means lower cost per unit of savings (kW, kWh or Therms). It is arguable that this is especially true for program administrators where technical assistance, savings estimate review and approval, and measurement and verification costs are borne by the program.

- The largest users are among the most important customers for the serving utility (and non-utility program administrators, where applicable). Large customers demand a high level of customer service. Utilities and program administrators will always benefit from serving their largest customers well and will ensure a high level of customer satisfaction in the process.

- There are some downsides to large projects as well, such as historically low net-to-gross ratios, but these are generally outweighed by lower gross unit cost of savings, long measure lives, and high customer satisfaction and good will.

While these large projects are beneficial for all the reasons cited, challenges exist in identification and implementation. The following examples suggest best practices for implementers (and program administrators) looking to improve their success rate on large energy savings projects. These best practices include early collaboration between the implementation team and design engineers in the development of the project, approaching the analysis from a system basis rather than by individual component, and illustrating and evaluating all potential customer benefits of the project. Each best practice is illustrated using a real-world experience of an implementer applying these practices.

Best Practice #1: Collaborate with Design Engineers

Typical Scenario

Many implementers work with facility personnel to identify energy projects. To do this, the implementer targets systems that the customer is willing to modify and defines a project scope that maximizes efficiency. Once energy savings are calculated and presented to the customer, the cost savings and utility incentive are used to help sell the project to management. If the project is attractive to the organization, it is funded and moves into its implementation phase.

At this time, the customer typically hires a design firm or other contractors to further develop the solution into a defined design that can be implemented. The designers and contractors are then one step removed from the engineer that conceived the energy efficiency project. As trade-offs are made by the designers and contractors, the project elements affecting energy efficiency measures often bear no more (and often less) importance than aspects pertaining to first cost, usability, maintenance, and ease of installation. The customer may or may not fully understand the implications of the trade-offs on the energy efficiency measures, yet those decisions are often made without consulting the implementer. The end result is that the proposed energy efficiency measures may not be installed as proposed and estimated energy savings may not be realized.

These occurrences could cause the relationships between energy efficiency program implementers, customers, and contractors to be strained. The customer secured funding for the project based on savings projected by the implementer; the contractor may have bid the job as a fixed price contract without understanding the commissioning required to reach energy-efficient operating targets. Both the implementer and the contractors have contributed to a disappointed customer. In addition, the implementer delivers less value than expected in terms of installed savings to utility programs.

Solution

This scenario has been successfully mitigated by fostering early involvement, maintained throughout the life of the project, of design engineers or contractors and the entire implementation team for the energy efficiency project. Early collaboration among the entire project team also helps utilities document influence as the implementers assist designers in justifying premium efficiency equipment, controls upgrades or optimization algorithms, and other design tweaks that greatly affect the system's energy consumption. Continual support from the program implementer through the design and construction process ensures that the energy efficiency techniques will not be stripped out by design engineers or contractors that may be focusing on other aspects of the project such as cost, process flow or product quality. Additionally, this collaboration may even produce alternatives that could increase the savings for the projects.

By having all parties work together rather than as separate entities, a synergy is developed amongst the team and better results are achieved all around. The customer realizes more energy and cost savings, the designers are confident that the customer will be satisfied with the design and the implementer and utility can document more project savings per unit administration cost. This success then propels the team to continue developing future projects and the cycle continues.

Project Example: Comprehensive HVAC Optimization

Initial Conditions

A large campus consisting of seven commercial and light industrial buildings expressed interest in an energy audit offered to them through utility incentive programs. All seven buildings were served by a central chilled water plant which supplied chilled water to air handling units (AHUs) that provided conditioned air to industrial process and office spaces.

The initial audit revealed several energy savings opportunities within the HVAC system. While the existing system met the facility's cooling loads, its operation had not been optimized through control strategies. The system supplied a constant chilled water temperature and reheated air before discharge. In addition, the chilled water loop, condensing water loop, and AHU coils were all operating with a temperature differential that was less than design. Finally, none of the primary or condenser water pumps, tower fans, nor AHU supply or return fans utilized VFD control.

As a result of the initial energy audit, several energy efficiency measures were identified. Having little experience with energy projects or incentive programs, the customer only considered implementing a small portion of the recommended reset strategies. We worked with this customer to develop an incentive application to quantify associated savings. The original annual energy savings estimate for the control strategy was 0.817 million kWh and 330 kW.

Best Practice Implementation

After the application was approved by the utility, the customer initiated a capital request for implementation. We continued working with the customer but the project moved to an idle state after funding was initially approved. With continued follow-up, we learned that a designer/contractor became involved in the project and the initial scope was brought into question.

Our engineers then began working with the customer and the designer/contractor to assess implementation options. With the goal of expanding the initial incentive application scope to maximize energy savings and utility incentives, the customer, designer/contractor, and our engineers pooled resources and re-evaluated all of the energy-saving strategies originally recommended in the audit report, including: chilled water reset, chiller sequencing, VFD control on chillers, pumps and fans, differential pressure resets, and supply air temperature resets. While we assessed the associated energy savings, the designer/contractor provided cost information and assessed installation feasibility, and the customer contributed financial metrics or hurdle rates to direct efforts to projects that could secure capital for implementation.

Collectively, these strategies facilitated the development of an energy efficiency package that would warrant capital approval and reinvigorated the facility's excitement to implement. This package of energy efficiency measures targeted a minimum of 15 degree F temperature differential on the condenser water loop, chilled water loop, and across the AHU cooling coils. It also included mechanical upgrades such as replacement of existing cooling coils with new, oversized coils to reduce chilled water flow as well as a whole facility upgrade from pneumatic to DDC controls.

While the customer had initially been hesitant to move forward with energy efficiency measures, our close collaboration with the designer/contractor inspired a level of confidence that motivated them to move forward with the proposed, comprehensive energy efficiency package.

Project Results

As was depicted in the updated incentive application, the project pursued a more aggressive setback schedule, temperature resets, and differential pressure resets than would have otherwise been considered without the support of the entire implementation team. The project scope from which the facility implemented the project estimated annual savings of 5.47 million kWh per year and 988 kW. While the project scope increased significantly, the additional capital expenditure was easily justified through annual energy cost savings and utility incentives. A summary of the project metrics is shown in the table below:

Metric	Initial	Best Practice
Energy Savings (million kWh)	0.817	5.47
Demand Savings (kW)	330	988
Incentive Estimate ($)	$156,000	$919,000

The project not only delivered significant energy savings, but it resulted in a highly satisfied customer who appreciated the support provided by the utility and the incentive process. The implementer's involvement drove the customer's decision to implement the enhanced control strategies which delivered significant savings to the utility. While the measures could have been implemented in a phased approach to achieve the same level of savings, since the utility was able to capture the savings from multiple implemented measures within one application, the administration and review costs were reduced.

The customer now views the designer/contractor, the utility, and the implementer as integral assets for developing future energy savings projects. Without our collaboration with the design team, the customer may not have implemented any of the proposed energy efficiency measures. Yet, because of the outcome of this project, the customer is looking to initiate additional projects with the team.

Best Practice #2: Perform System Load Balances

Best Practice Detail

Oftentimes, during facility walk-throughs implementers tend to focus on the "low hanging fruit" - one-for-one retrofit type projects that are relatively easy to identify and can provide an acceptable payback with a modest level of savings. With increasingly efficient baseline requirements and years of energy efficiency incentive program availability, these one-for-one retrofit opportunities are picked over or their qualifying savings are severely discounted by incentive program rules. In facilities where the low hanging fruit no longer exists, another approach is necessary to identify viable, high energy savings projects.

Best practice #2 is a technique that addresses this challenge. When auditing a facility, it is important to review the system using a holistic approach with the first step being to perform a brief load balance or system capacity versus system demand check. This technique quickly identifies potential operational deficiencies and opportunities within the system.

To do this, the engineer must first identify all of the end uses or demands of the system. Then the approximate load factor of operating equipment needs to be determined along with any other relevant operating parameters. This could involve short term monitoring (1-2 days) or instantaneous readings from the building automation system, local displays or gauges. Finally, a simple comparison of the calculated supply to the demand loads/capacities reveals a potential opportunity.

This best practice often points to energy efficiency measures that are commonly overlooked because they involve an additional level of expertise, knowledge of design options, and/or direct impact on the industrial process. An example of this would involve optimizing a water distribution system by alleviating piping constraints and over-pumping, which would be identified from load balances that point to an inherent issue in the system's mechanical design.

Once an imbalance or design issue is identified, implementers should work with designers as indicated in Best Practice #1 above, to further develop the project for implementation. The end result is that implementers identify novel energy efficiency measures with considerably higher savings than one-for-one retrofits and deliver high value to utility programs and their customers.

Project Example: Process Refrigeration System Upgrade

Initial Conditions

A manufacturing plant utilized an ammonia refrigeration system to provide cooling for its manufacturing processes and cold storage rooms. The facility operated four to five days per week, depending on product demand, but the refrigeration system ran continuously to provide cooling to the product storage areas.

Refrigeration loads were met using a two stage ammonia refrigeration system. The low stage was originally a liquid overfeed or pumped liquid system that served the low stage evaporators and provided intercooling to the high stage system (HSS). HSS was a flooded direct-expansion refrigeration system that served other process evaporators. The systems rejected heat to a series of evaporative condensers located on the facility's roof.

At the time our energy efficiency audit was conducted, the facility was having difficulty meeting temperatures required by its process. Initially, the facility staff believed that a lack of condensing capacity was to blame for the issue citing that without adequate condensing capacity, the refrigerant would not fully condense to its liquid state and would not be able to absorb as much heat while traveling through the evaporators. Because of this initial notion, they had just installed another evaporative condenser a few months prior to our audit and were anticipating saving 0.673 million kWh/yr. To their surprise, the new condenser neither alleviated the issue of meeting the required process temperatures nor delivered the expected energy savings.

Best Practice Implementation

During the audit, we immediately noted that a one-for-one replacement was not necessary for the refrigeration system; the recent installation of the new evaporative condenser proved that there was another issue responsible for the struggle to maintain process temperatures. To identify the energy efficiency opportunity, we first put together an equipment list of all of the system evaporators and their designed capacities. From this exercise, we determined that the demand side of the system was designed to absorb 325 tons of refrigeration (TR) from the low stage system and 870 TR from the high stage system.

After learning that a total of 1,195 TR was required by the facility we then assessed the supply side of the refrigeration system. The facility had typically been running all three of the low stage compressors at approximately 85% load, while running two of the high stage compressors at approximately 100% load. The supply side of the refrigeration system load balance was then considered to be:

$$Low\ Stage\ Supply = (0.85)\left({}^{3}/_{3}\right)(900\ hp) = 765\ hp \approx 765\ TR$$

$$High\ Stage\ Supply = (1)\left({}^{2}/_{4}\right)(2{,}500\ hp) = 1{,}250\ hp \approx 1{,}250\ TR$$

$$Total\ System\ Supply = 765\ TR + 1{,}250\ TR = 2{,}015\ TR$$

where the first three terms in each of the low and high stage calculations refer to load factor, operating compressors as a fraction of total, and total subsystem horsepower, respectively.

We then subtracted the supplied load from the required load to determine the system imbalance or the savings opportunity:

$$Load\ Imbalance = 2{,}015\ TR - 1{,}195\ TR = 820\ TR \approx 820\ hp$$

By assuming that the system operates 8,000 hours per year to account for maintenance, the savings potential was estimated at:

$$Savings\ Potential = 820\ hp * 0.746 \frac{kW}{hp} * 8{,}000 \frac{hours}{year} = 4.89\ million\ {}^{kWh}/_{yr}$$

The facility managers were obviously eager to move forward with the project to improve the operation of the system and achieve the substantial level of savings we estimated. They immediately engaged us to continue developing the project. To do so and to confirm the load balance, we installed data loggers to monitor true power of all seven compressors plus ancillary pumps. The monitored data were fed into a bin simulation spreadsheet to more accurately estimate savings. Taking into account the three weeks of monitored compressor data as well as production data, the savings calculations yielded an estimate of 4.275 million kWh/year. This was only 13% less than what was estimated via the simple load balance.

Project Results

Upon further investigation of the system, engineers were able to identify the source of the condensing capacity restraint - the evaporative condensers were not piped properly and were operating in a flooded fashion. This prevented full condensation of the refrigerant and limited the refrigeration capacity of the system. Our team also identified a series of inefficiencies inherent in the mechanical design such as piping constraints throughout, poor control of evaporator flow, and operation of the high stage system as flooded DX rather than pumped liquid. Corrections were immediately implemented. A summary of the project metrics is shown in the table below:

Metric	Initial	Best Practice
Energy Savings (million kWh)	0.673	4.27
Demand Savings (kW)	60.7	473
Incentive Estimate ($)	$107,000	$688,000

By addressing these issues, the projected savings for the project was increased to over four million kWh per year. Even with a significant project cost increase, the overall benefits of the project delivers much greater value to the customer, implementer, and program administrator.

Best Practice #3: Frame the Business Proposition

Best Practice Detail

Projects requiring significant capital will need support and approval from upper management. However, these projects are often initially developed at the facility level and need to be presented “up the chain”. Because of the high level of funding required to implement them, management is often hesitant to allocate dollars to large scale energy projects, especially when capital budgets are limited and other investments, such as R&D, all target the same capital dollars.

One way of avoiding this issue is to propose phases for implementation. Ideally, the project could be structured such that the budget for each portion could be absorbed by the facility and not be above the threshold that requires Corporate involvement. By installing the project in phases, the implementer may even be able to deliver the utility incentives from the current phase during the time at which a future phase is being funded. In this case the incentive dollars can be directly rolled into the next phase’s funding and can lessen the capital burden on the facility.

If phasing is not an option for the project, the implementer should focus efforts on framing its business proposition. Presenting non-energy benefits such as improvements in product quality, higher levels of facility productivity, capacity growth or the creation of equipment redundancy, environmental benefits, increased reliability, and lower costs can pique management’s interest in the project. Since decision makers of large corporations are often concerned about not just energy but other important facets of company growth, quantifying and documenting these benefits will aid in the approval of projects that were conceived as energy efficiency projects but also resonate with the organization’s key objectives.

Project Example: Printing Process System Upgrade

This example involves a printing press at a plastic bag manufacturing plant. The facility makes plastic bags for produce such as carrots and lettuce and prints custom ink patterns on them. The facility initially had several printing presses of varying vintages through which large rolls of plastic film were fed for printing. Other areas of the facility use bag machines to cut, trim, and mend the printed plastic film into bags.

Initial Conditions

One of the limitations of the older vintage presses involved the number of colors that could be employed on a given design pattern for the bags. The facility had seven presses and all were either 4-color or 6-color presses. This aspect limited the creativity and complexity of the bag design. The packaging facility's clients desire a robust and attractive package design to stand out on the supermarket shelves. Another limitation for the existing presses at the facility was their speed. Heat is used to dry the ink with ovens and if the product is run too quickly through the process, the ink will not dry properly and smear.

We were tasked with performing an energy analysis on the prospect of installing a new 10-color printing press. The main energy efficiency components involved the recirculation of the hot air in the oven component and the increased speed capabilities of the state of the art press.

The existing older vintage presses used once-through air as a means of drying the ink on the plastic film. Since the ink on this product is oil based, volatile organic compounds (VOCs) are present and this VOC laden exhaust air must be treated in an oxidizer to temperatures above 1,500°F before being released to the atmosphere. Thus, each cubic foot per minute (CFM) that is recirculated saves gas use at the heated oven and also at the oxidizer.

The proposed retrofit press was able to run product two to four times faster than the existing press depending on the product line being produced at the time. Additionally, the printing process was a batch process running a product for a number of hours. The new press had a significantly shorter set-up time for product changes which increased the overall output.

We reviewed the design parameters of the existing and proposed presses to analyze the potential energy savings. Since the project involved an increase in production rate, the overall production efficiency needed to be used to normalize the energy used for the comparison. While the estimated cost savings due to the energy improvements were substantial, the overall cost of $3M for the new press produced a simple payback of 20 years which was well beyond the company's criteria for investment.

Best Practice Implementation

At this point in the development of the project, we worked with the plant manager to frame the project in a manner that would entice the CEO to make the financial investment. While each customer situation is unique depending on their business practices, significant secondary benefits were identified for this project, including:

- <u>Product complexity</u> – The addition of the 10-color press allows for more complex designs to be printed on the bag. This benefit allowed the facility to work with some existing customers to enhance their design with additional colors. With the more complex design, the facility could charge more money per bag and increase revenue on their existing contracts. Furthermore, for new business, the 10-color press would allow them to be more creative with optional designs for new business that competitors without a 10 color press could not match.

- <u>Incremental cost</u> – With aging existing presses, at some point in the future these presses will need to be replaced. While the actual cost of the 10-color press is $3M, the difference between the 10-color and a like for like replacement of a 6 color was $1.3M.

- Labor savings – Each press in operation is manned at all times to ensure proper and safe operation. The increase in speed was able to take two presses out of service. Thus, reducing the labor required.

- Environmental component – As commercial markets such as Whole Foods[1] and Walmart[2] enact environmental standards to their produce suppliers, those are passed down to the bag manufacturers and other secondary suppliers. According to the CEO of the bag manufacturer, every contract bidding process has an environmental component in the scoring. Energy savings projects and quantifiable greenhouse gas emissions savings projects that are implemented by suppliers are often used as differentiators in the bidding process. Although this is a difficult benefit to quantify with dollars generated per year, the value of this is evident.

Project Results

Our efforts to quantify all benefits in terms of cost savings and additional revenue made the project a viable financial investment to the customer. The project's energy savings verified through measurements were over 203,000 Therms and the utility incentive was over $200,000. While evaluating all primary and secondary benefits was a time consuming endeavor, the project would not have been implemented without the extended analysis and the resulting savings would have been zero. A summary of the project metrics is shown in the table below:

Metric	Initial	Best Practice
Energy Savings (Therms)	0.00	203,000
Incentive Estimate ($)	$0.00	$203,000

With this scenario, documenting the influence of the program implementer is important to maintain the true net to gross (NTG) associated with the project. Even though this project had many secondary benefits that were part of the decision making process, the project would not have been implemented without the program and the evaluation that the implementer performed quantifying the overall project benefits. As a result of this process, the customer was fortunate enough to receive a significant utility incentive, the implementer was able to deliver a high-yield energy savings project to the utility, and the utility was able to claim the savings against their incurred program administration costs.

Conclusion

As energy efficiency programs across the U.S and other countries evolve and mature, deeper penetration into the facilities are required to develop and implement large energy savings projects. Best practices presented in the paper address the relationships, engineering, and sales tactics that help an implementer improve upon the standard retrofit projects and deliver high savings projects to their utility and end-use customers. While Industrial customers possess unique facilities, systems and processes, the general strategies of these best practices can be applied to many facilities. Successful high savings projects further support the confidence that the customer has in the implementer and strengthen the relationship even further, which can be leveraged into future projects.

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[1] http://www.bevnet.com/news/2013/whole-foods-demands-supply-chain-audits-from-coconut-water-companies

[2] http://corporate.walmart.com/global-responsibility/environment-sustainability/greenhouse-gas-emissions