Lessons Learned: Financing & Measuring Manufacturing Process Energy Efficiency Gain as a Utility Incentive Program

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ABSTRACT

This paper discusses the lessons learned from two recent innovative utility-sponsored programs that paid incentives for energy savings achieved from non-hardware manufacturing process improvements. The authors provide examples of plant process improvement energy savings, outline the program approach used, review program successes and difficulties, and offer ideas for potentially more effective manufacturing plant energy efficiency incentive programs that would obtain more plant energy savings by encouraging more non-hardware plant process and energy management improvements.

Introduction

The paper is organized into six sections, A through F, to better understand the concepts and the utility energy efficiency incentive programs tested for improving non-hardware manufacturing process improvements. Section A reviews three categories of plant energy-using equipment and three types of energy savings to better understand how manufacturing process improvements energy savings are generated. Section B describes two completed utility incentive programs for plant energy savings based on implementing manufacturing process improvements with several brief plant case examples. Section C reviews the advantages of these two completed utility-sponsored programs, and Section D reviews lessons learned about the program limitations. Section E recommends improvements to the original program design if similar programs were offered again. Section F recommends two follow-up research and development program approaches to help find the most effective energy efficiency incentive programs that strongly encourage improving non-hardware manufacturing processes, plant energy management and employee energy conservation practices, all of which could potentially significantly expand plant energy savings and are a big opportunity to complement current utility and government agency programs which have historically focused primarily on higher energy efficiency equipment incentives.

Understanding Manufacturing Process Energy Savings

Three Production Equipment Classifications of Plant Energy Use

1. **Direct energy use production equipment.** The best examples of this category are factory machines that use a fixed average amount of energy per part made, or production operation performed. Direct equipment energy use is roughly proportional to the amount of parts produced or amount of production achieved, and after factoring in equipment downtime, energy use is roughly proportional to equipment running hours producing the

part or part operation. If zero parts are produced, then no energy is used by this equipment. Most of the machines on the factory floor which are operated primarily by electric motors and controls to perform operations to produce parts fit the direct energy use equipment classification very well.

2. **Indirect or "overhead" energy use equipment.** This classification of plant equipment tends to use a fixed amount of energy per hour whether production occurs or not and whether or not direct energy use equipment is operated. Typical indirect equipment examples are lights, many air compressor systems, HVAC equipment, water chillers, and all of which consume considerable energy if this equipment is "on" or running at operating conditions.
3. **Direct/utilization energy use equipment.** This classification of equipment is a combination of both direct and indirect energy use equipment. Good examples are found in many kinds of process heating equipment including gas and electric furnaces and ovens, steam boilers, hot water process equipment and the like. If this equipment is operating at its full operating temperature then a significant amount of energy is being used whether or not any production is being done, but significant production may also significantly increase the total energy use of the equipment. Thus average plant or product line production volume and patterns of equipment scheduled use determine both an average utilization percent of the equipment's maximum production capacity and average equipment energy-used per production unit. Ideally the average energy use per part for this equipment needs to be checked for different levels of equipment and plant volume so that reasonably accurate total annual energy use estimates for the equipment and average energy used per part can be made for given plant production volumes.

Three Energy Savings Types of Manufacturing Non-equipment Process Improvements

Type A energy savings result from reducing the operation of direct energy-use equipment. A good example is a scrap or rework reduction project that reduces direct energy-using equipment operation hours by reducing the need to produce excess parts to achieve the required number of good parts or by reducing direct energy using equipment hours to rework parts. The range of quality tools and techniques can range from basic data gathering and analysis techniques to using very sophisticated statistical software tools to identify root causes and/or develop experiments to test best solutions. Decreasing production scrap and rework normally results in decreasing direct equipment running hours and energy to lower direct energy intensity (average direct equipment energy used per production unit produced). The production operation step where product defects are created and the operation step where defects are identified and removed from operations will determine the amount of direct equipment energy saved.

Type B energy savings result from increased production units per work shift (increased production velocity) that will use less average plant indirect ("overhead") equipment energy per production output unit. To save plant energy by increasing the number of parts produced per hour or work shift requires either producing more parts for the same plant operating hours of indirect equipment or producing the same number of parts with reduced plant indirect equipment operating hours. Type B energy savings are associated with most manufacturing process improvements. Some examples are listed as follows:

1. **Speeding up assembly line operations to a lower average cycle time for the entire line by better line balancing the cycle times o**f production operations at each work station, and/or reducing the average cycle time for all pacing or highest utilization work stations. Techniques for reducing this average cycle time might include re-assigning tasks between work stations, changing work station layouts and changing part supply storage locations to reduce walking and other wasteful worker motions, or eliminate various kinds of production delays, etc.
2. **Similar to 2.1 is identifying and solving hidden production bottleneck problems** that have been preventing a faster line rate or plant production rate.
3. **Increasing equipment run time percent of total shift hours worked by reducing all the causes and time wasted for equipment down time.** Examples for reducing planned downtime include reducing equipment changeover times from Part A to Part B or planned maintenance procedure times. Examples of reducing unplanned downtime include streamlining maintenance procedures, using startup checklists to prevent unplanned downtime, and achieving quicker turnaround time for unplanned and planned downtime adjustments and repairs, and the like.

If the plant can utilize existing or newly created capacity by producing more production per work shift, the total energy use of the plant could potentially increase in total but the energy intensity, average energy used per part, has decreased and is the basis for claiming energy savings. If the production velocity has been increased but the plant cannot sell or produce more parts, typically some energy savings are naturally achieved because of reduced need for indirect equipment energy use. Examples would include needing fewer overtime hours on weekends or reducing overtime hours on a 2nd or 3rd shift that result in shortening total plant operating hours.

If on the other hand, it is not possible to decrease the total plant operating hours despite obtaining higher plant production velocity, for example reducing hours on only one of several production lines, there are typically still good opportunities to reduce operating hours of specific units of associated indirect equipment used such as unneeded lights, ventilation, compressed air, and the like. However, it is important to pro-actively look for and implement these energy savings opportunities to turn off or reduce unneeded indirect equipment energy use to fully realize the energy savings potential created via increasing greater production velocity.

Analyzing energy intensity by day of the week and by shift hours (if metered data is available) typically reveals big jumps in energy intensity for 2nd and 3rd shifts and for week-ends. This higher energy intensity results when fewer machines or a small fraction of all the direct energy using equipment that normally operates during the normal 5-day 1st shift, is being operated on the only partly-manned 2nd or 3rd shifts or weekends. Unfortunately most or all of the plant indirect energy use equipment is too often being wastefully operated on these overtime shifts because no action has been made to make it possible to turn off and/or to encourage reducing the use of unneeded indirect energy-using equipment. Seemingly, most plant managers, supervisors and operators alike seem to be completely unaware of the energy and dollars that they are wasting on the plant indirect energy-using equipment. (An awareness campaign on just this one issue would likely save a lot of wasted indirect energy use in many, many factories that we have observed.)

Type C energy savings are those that reduce energy use per production unit produced for individual machines. This type of improvement results in an individual processing machine using less average equipment energy per part processed. For example, loading in more parts into a batch oven or furnace (direct-utilization type of energy use equipment) increases the physical capacity utilization of the oven for that batch process and nearly always results in less oven or furnace equipment energy being used per part in that batch process. Another case example occurred in a process improvement project case in which we reduced the time an electric resistance-heated mold was open for unloading the finished molded compound-rubber part, cleaning the mold, reloading raw material into the mold, and closing the mold to cure the next part. In this real-world example less heat was lost in unloading, cleaning and reloading the mold, and thus less energy and time were needed to bring the mold back to temperature and shortened the total molding and curing time per part. The Kaizen or process improvement team working on this project also devised an insulating outside blanket for the machine which also reduced heat lost on the external surfaces of the machine. All of these improvements resulted in a Type C energy savings enabling the mold press to use less electric heat energy (direct equipment energy used) per molded part.

Two Southern California Utility Energy Savings Incentive Programs Based on Manufacturing Process Improvements

The two similar utility incentive programs discussed in this paper were called "VeSM " programs, whose letter abbreviation was derived from the term, "Value and Energy Stream Mapping" and was based on the idea of adding energy usage parameters to a Value Stream Mapping (VSM) manufacturing process assessment technique, a classic "Lean Manufacturing" process assessment technique. (Church 2005) In practice the "VeSM" phase one assessments actually utilized multiple analytical techniques in the diagnostic first phase of the client study to help identify process improvement opportunities that would potentially save significant amounts of energy. The 2nd phase of a company project engagement was the team training, analysis, and implementation of up to two process improvement projects that achieved minimum qualifying energy savings for incentive payments.

Common manufacturing process improvements included improving employee and equipment productivity, decreasing production scrap & rework, and/or increasing equipment run time percent of work shift hours. These process improvements increase average factory plant production per operating hour (production velocity) and decrease manufacturing energy intensity (energy used per production output unit produced). These process improvements result in either decreasing plant operating hours for the same level of production, or quite often increasing plant production (and plant capacity) for the same plant operating hours and frequently using nearly the same plant resources. Increased plant capacity not only potentially supports more production being assigned to a plant in multi-plant situations, but also encourages increasing sales to utilize the new-found plant capacity. In many cases, the plant will use more total energy but use it more efficiently.

The first program completed plant improvement projects in 24 companies from 2004-2005 funding period as part of Southern California Edison's (SCE) Innovative Design Energy Efficiency Application (IDEEA) program. Based on the energy savings success of the 1st VeSM program a second program followed in 2006-2008 as a 3rd party industrial sector energy efficiency program funded by Southern California Edison and both subsidiaries of Sempra Utilities. The 1st program permitted averaging the energy savings of completed improvement projects on the condition that the completed projects produced energy savings that comfortably exceeded the total program target average energy savings per project. This averaging feature encouraged more risk taking on improvement projects whose estimated energy savings were close to the target, resulting in more projects attempted. The second program had a late start and a slow learning curve for how to effectively market to and perform suitable improvement projects in large gas-using plants, many of which were also continuous process plants. The 2nd program provided approximately 20 additional engagements that had much tougher approval criteria standards for proceeding with a phase 2 improvement project implementation.

The contracts between the utilities and CMTC, the 3rd party contractor selected by the utilities, were based on the same expected cost effectiveness results as other utility hardware programs with similar administrative and marketing costs. For the first phase of the VeSM program engagement, the industrial plant end user would pay $7,500 out-of-pocket to CMTC to conduct the phase one assessment study to identify manufacturing process improvement project opportunities with likely estimated qualifying minimum energy savings. Also estimates were made of expected energy savings of candidate improvement projects to check if energy savings exceeded the qualifying minimum energy savings for a fixed $10,000 payment from the utility for each successfully implemented project. If energy savings estimates were sufficient in amount and approved, a limit of two Phase 2 process improvement projects per plant were implemented, and near the end of the second program in one plant more than two projects were approved.

California Manufacturing Technology Consulting (CMTC) was the 3rd party contractor selected by the utilities for the VeSM contracts, and is a non-profit consulting organization that is one of 60 U.S. Manufacturing Extension Partnership (MEP) organizations under the National Institutes of Standards and Technology (NIST) in the Department of Commerce. The primary mission of the MEP organizations located in each state is to assist U.S. manufacturing companies, and especially small manufacturing companies survive and grow. (For more information see web site: www.nist.gov/mep/ *)*

A Description of VeSM Phase 1 Diagnostic Assessment Studies

As explained earlier the Phase 1 assessment engagement started with creating a Value Stream Map (VSM) that included energy usage information (VeSM). To a reader unfamiliar with Lean Manufacturing concepts, techniques or jargon, imagine VSM as a flow chart of each process step at each machine or workstation with a table of manufacturing performance statistics gathered about each process step as well as summarizing performance tables about selected groups of process steps working together.

When analyzing factory processes which had significant quality 1st time yield and rework issues, statistical analysis tools or root cause di**sc**overy and investigation techniques were used to help identify causes of scrap and rework and projects that would eliminate or reduce the causes of scrap. The 2nd VeSM contract included large natural gas usage plants many of which utilized continuous process equipment where either statistical process analysis tools or heat loss mapping analysis were more suitable techniques for discovering process improvement opportunities in addition to any value stream mapping analysis of all the facility discrete processes.

VeSM Phase 2 Manufacturing Process Improvement Implementation Examples

After process improvement projects have been identified in Phase 1 that appear to meet minimum energy savings levels, it is necessary to review the findings with the client and review what the client must contribute to implement the process improvement as well as the expected benefits before proceeding to the Phase 2 project implementation. Also in the 2nd Edison contract it was necessary to have an Edison engineer review the estimated Phase 2 electrical energy savings calculations. After the client committed to support the proposed improvement project and the Edison engineer approved the electrical energy savings estimates, then one or more "Kaizen" (quick improvement) teams were formed to implement the VeSM Phase 2 improvement projects. The teams were provided an expert trainer, project manager and facilitator to help the teams investigate, problem solve and implement the selected process improvement.

Five VeSM Case Study Results that illustrate the diversity of tools and techniques used in implementing manufacturing process improvements that qualified for the utility energy savings incentive payments and saved much larger dollars in material and labor are listed as follows:

1. **Food products manufacturer.** Conducted two Kaizen team improvement projects a) one for equipment changeover time reduction and b) the second Kaizen team focused on increasing equipment run time via better equipment maintenance, faster equipment repair/recovery, better start-up procedure checks to reduce the risk of an unexpected line shutdown, etc. The combined project results increased actual equipment run time percent of shift hours worked (actual line capacity) from an average of just under 50% to about 80% for a 60% increase of available plant capacity per work shift. These projects saved about 240,000 kWh/yr. The 60% gain in plant capacity enabled the company to significantly increase plant production and sales for a very large financial company benefit.
2. **Manufacturer of custom designed aircraft window frames.** Manufacturing processes started with forging the rough frame followed by various machining, finishing and coating operations. A knowledgeable engineer trained and led a plant Kaizen team to change from traditional batch manufacturing with 1000-piece lots to 20 piece lots using Just-in-Time Lean techniques that maintained a constant hourly production rate at all machining operations and at all the newly created flexible work cells. Plant production (and capacity) per hour, and per shift increased by nearly 80% for the same labor force and equipment, and avoided the planned addition of a 3rd shift to reduce the amount of past-due sales orders.
3. **Automated roof tile manufacturing plant.** An expert consultant on quality techniques led a Kaizen team and provided team training and coaching to help team members apply fundamental quality analysis tools to identify root causes of scrap and then devise & test solutions for eliminating or reducing these causes of plant scrap. The results were to reduce scrap rates by 5% which permitted a 5% increase in production and sales. Labor and material dollar savings also significantly exceeded energy savings dollars.
4. **Continuous Process Chemical Plant.** The diagnostic tool employed in this VeSM Phase one assessment study was mapping the heat loss through the various stages of the entire continuous process chemical plant. A Kaizen plant team, investigated the largest heat loss areas where the improvement opportunities seemed greatest and found potential savings of 270,000 thermos (over 10 times greater than necessary for incentive payments) from three potential equipment modification improvement projects which met the company's capital expenditure ROI (return on investment) hurdle.
5. **Large aluminum smelter and producer of custom cast aluminum alloy logs and slabs with recent historically high slab scrap rates from internal cracks.** The Kaizen

team project leader used computer stepwise regression and other factor comparison analysis software tools to find that previously-suspected chemical and metallurgical factors didn't explain recent historically high scrap occurrence, and found that scrap rates for the same products varied by work crews on all shifts. Moreover, the analysis found that standardizing and implementing the plant's known best-practice work procedures for all workers should lower plant scrap rates to conservatively save 113,000 Therms and 59,500 kWh/year in addition to much larger labor and material dollar savings. Further investigation of industry practices found that competitors had invested in selective automated controls and equipment to add more repeatability and precision to the casting process and if implemented in this plant it would likely double the expected savings described previously from manually standardizing the work procedures.

6. **Typical High Value Benefit of Improved Plant Capacity from Process Improvements.** Besides the material and labor dollar savings typically being several times higher than the energy savings that paid for the process improvement project training and coaching, we should point out that significantly increased plant capacity is frequently equal to hundreds of thousands of dollars in additional purchased equipment which is an extremely valuable benefit of most process improvement projects. It is not unusual that even a 5% capacity gain could easily be worth over a hundred thousand dollars of new purchased equivalent equipment capacity value in many medium-sized plants.

Favorable Lessons Learned from the Two VeSM Utility Programs

1. **Both VeSM utility energy efficiency programs demonstrated that energy savings can be achieved for comparable program costs to equipment energy efficiency upgrade programs.** There were a substantial number of plants in the two programs that demonstrated significant energy savings well beyond the minimum required to meet the needed energy savings incentive payment to pay CMTC (the contractor select by the utility) to facilitate the process improvement. Further most of these plant process improvements have been sustained since they were originally implemented.
2. **Qualified manufacturing process improvements typically yield labor, and/or materials savings plus equivalent plant capacity dollar value several times annual energy dollar savings** which financed the consulting expertise to train plant personnel and facilitate the process improvement**.** Some of the cash savings generated from manufacturing process improvements can potentially help provide scarce capital for purchasing high ROI, more energy efficient equipment upgrades, and further increasing energy savings.
3. **Significant energy, material and labor savings can frequently be achieved from manufacturing process improvements without capital expenditures.** Many process improvement projects will require low cost expenditures for supplies, tools, costs for moving equipment and the like. But avoiding the requirement of large capital expenditures removes a significant barrier to getting started in many plants with an energy savings initiatives.
4. **A VeSM program can be an extremely advantageous program for economic development programs offered by utilities and local or state governments to economicall**y troubled manufacturing plants because of the previously cited advantages.

Lessons Learned –Important Limitations of the VeSM Program Concept

1. **The program does not apply to smaller or lower energy using manufacturing plants**. The ideal target industrial plants need to use a sufficient amount of total energy so that expected energy savings for two kaizen projects would typically save more than the required minimum amount of energy savings for the incentive payment that pays for the expertise to implement the improvements. Also the plants need to have some good process improvement opportunities available that will yield sufficient energy savings.
2. **The program concept of saving energy via non-equipment process improvements is typically not understood by either company managers or utility personnel without providing training and a variety of detailed case examples.** Thus the program requires vigorous sales and marketing with some training for not only prospective company clients but internally to key utility program personnel and auditors. Both utility internal industrial customer account representatives and many utility field engineers are often familiar with many of their customer plants and operations and thus potentially could be a very valuable resource in their ability to identify good manufacturing plant process improvement customer prospects. We learned that key utility personnel will not support the program if they don't completely understand it to be able to help and be willing to identify company prospects.

   Also busy utility customer account executives may need some sort of motivation to overcome their reluctance to spend time on any activity that gives them less time to spend on their familiar equipment energy efficiency programs that they may believe more directly support their performance goals.
3. **The amount of process improvement and energy savings is sometimes hard to forecast; plant process improvements often take months to implement; and several projects need to be ongoing at one time to efficiently meet program goals.** Process improvements typically take several months to achieve because very few plants are willing or can afford to assign a team of key employees to an improvement team full time for one or two weeks. Often four hours or less per week is the maximum number of hours that plants were willing to schedule for team members to work on team projects. Thus projects frequently require several months to implement**.**
4. **Sustaining process improvements is likely a bigger issue than with new equipment energy efficiency upgrades and thus requires "up-front" plant management commitment to perform follow-up sustaining practices.** Both equipment and process energy savings gains are subject to plant production volume fluctuations that can easily degrade savings. Moreover, **w**ithout performance metric**s** and a pro-active management, many people-dependent process improvements like changeover reduction or tighter quality inspection procedures ar**e** subject to reversal because of employee or supervision turnover. Fortunately, once high employee performance has been demonstrated, relapsing to previous inefficient more costly performance tends to be a small minority of cases. If the third party contractor, the utility and a manufacturing client plant top manager sign a MOU (memorandum of understanding) clearly stating how the planned process improvement gains will be sustained by the client---for example maintaining metrics, pro-active monitoring and retraining, conducting follow-up audits, etc.---then the probability that the client company will sustain the process improvement energy, labor and material savings will be greatly improved.

Recommendations for Improvements to Original VeSM Program Design

Require a written agreement for phase two project implementation approval regarding a) the methods of energy savings calculations and b) the required client maintenance of supporting data & performance metrics and c) required annual follow-up energy savings audit calculation reports. This importance of this recommended VeSM program improvement was underestimated at first in the VeSM program. This requirement would have made it easier and quicker to conduct follow-up audits on project performance and energy savings, months after initial project completion. Plant energy intensity often fluctuates daily and the average plant energy intensity for a given time period is dependent on many items such as production volume, product mix (if applicable), plant and equipment operating hours, important equipment changes including energy efficiency upgrades, process improvement project(s) implemented, number of expedited customer orders and the like. This recommendation requires, based on the energy saving calculation approach, a) to define the relevant data and metrics that need to be collected as they occur and stored and maintained in ideally one ongoing spreadsheet file, b) to document significant plant equipment changes and other operation changes that likely significantly affected energy use when they occurred and c) to calculate achieved annual energy savings estimates each year or when major changes occur for an agreed-upon number of years following the project implementation.

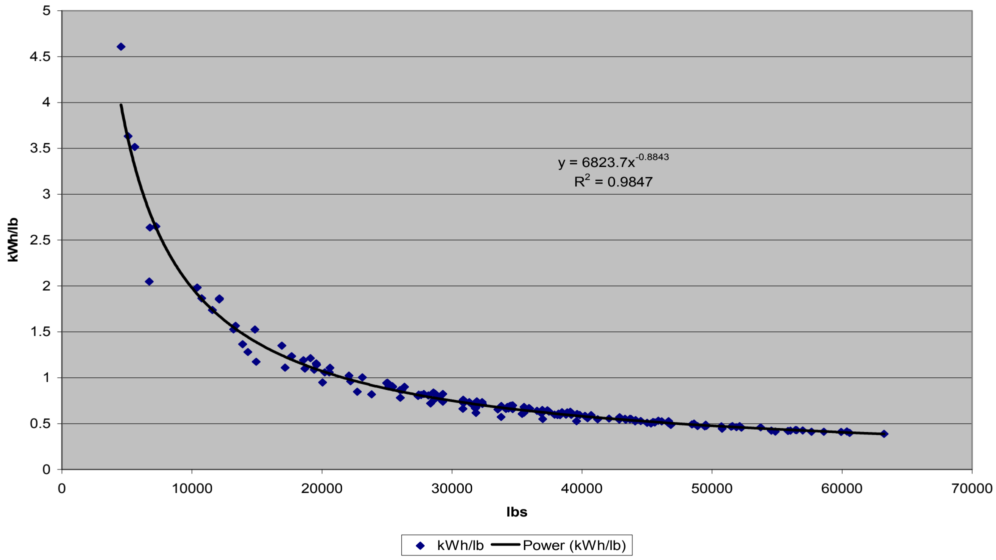
Obviously collecting and maintaining the performance data that tracks the sustainment of the specific process improvement implemented is necessary, otherwise one would not know whether the specific improvement project initial performance results have been maintained. Once the key data collection, data retention and energy savings re-calculating procedure is set up, then the follow-up audits and calculations on energy savings become relatively quick and easy.

To learn more about the VeSM program energy calculation approaches and tools, we suggest reading our ACEEE 2007 Summer Conference paper. (LaPalme, et al 2007)

In the VeSM programs we used two primary calculation tools: The first tool was a spreadsheet template tool to capture and calculate annual energy use of the plant equipment classified into direct, direct/utilization and indirect energy use equipment categories. (Review earlier explanations of these energy-use equipment categories.) We used this spreadsheet tool to map the annual plant equipment energy use and to double check that the annual sum of individual direct and indirect equipment units matched the last 12 months of metered actual total plant energy use within 5%.

As shown in Figure1 below, the other energy savings calculation tool used was to perform a regression curve fitting analysis on samples (ideally 30 or more data points) of daily intervals or weekly intervals of plant energy intensity (energy used per production unit) to develop plant energy intensity operating curves as a function of production volume for periods just before and right after the improvement project implementation. We found the best regression equation (or curve-fitting) type formula to be the non-linear exponential decreasing type formula (versus a linear formula) for calculating plant energy intensity as a function of plant production volume. By comparing the differences of energy intensity before and after improvement changes at the same average production volume on the two regression curves (before and after), we calculate the difference in estimated energy intensity (and thus energy savings) before and after the improvement projects without mixing in possible plant volume effects.

Figure 1: Regression Energy Intensity Curve as Function of Production Volume,



Further we recommend that annually and whenever significant plant operation changes occur that likely significantly affect plant energy use, to document the changes and re-calculate total plant energy use and re-calculate average energy intensity regression curves to observe and document how these significant plant operations changes affected average plant energy intensity levels.

If energy savings incentive payments are made on forecasted energy usage and energy savings after improvement projects are completed, it might be a good practice to withhold for a year, part of the full incentive payment for forecasted annual energy savings and adjust the final incentive installment payment based on actual (versus forecasted) energy saved as a result of the improvement projects. Such a practice would also tend to further encourage maintaining an accurate data base to re-calculate actual energy savings achieved for process improvement projects.

Use incentive payments for implemented projects proportional to the total energy savings achieved above a required site minimum instead of the fixed payment system per improvement project completed. This change would provide an incentive to keep working on some projects like a scrap reduction project to keep generating performance improvements and energy savings until further work is no longer cost effective. The fixed payment scheme actually provided a negative incentive to keep working on an improvement project beyond the minimum qualifying savings. Also this proposed change would encourage the contractor and company to pursue more than two improvement projects and also likely encourage more risk taking by both companies and contractors to achieve more energy savings and incentives for improved energy efficiency.

Recommend performing a combined initial plant assessment of energy saving opportunities from a) plant equipment energy efficiency upgrades that would qualify for rebates, b) no-cost/low-cost energy savings measures and c) VeSM-type manufacturing process improvement projects. We believe the combined plant assessment of the all these types of opportunities to save energy would identify more total energy savings opportunities to the plant management and would cost less than separate audits. Even if no incentives were provided for the energy savings, there is a greater chance the plant would implement many of the identified no-cost/low cost energy saving measures if plant management were aware of the energy cost savings. In the VeSM program company plants, we observed that plant personnel were typically not aware of the numerous no-cost and low-cost energy savings opportunities in their plants and frequently were not aware of the good ROI (return on investment) available for equipment energy efficiency upgrade opportunities in their facility.

Both utility engineers and contractors looking for equipment energy efficiency upgrade opportunities tend to be rewarded for identifying the highest total equipment upgrade energy savings and total rebate dollars granted and thus have a natural incentive to focus on finding large equipment units that use lots of energy and thus have large average potential energy savings per site surveyed for equipment energy efficiency upgrades. There is little energy contractor incentive to look for opportunities to reduce total plant energy use from cost effective no-cost/low cost energy saving changes to equipment, to equipment maintenance, or equipment use application, or of low cost/effective purchases of additional small equipment such as motion sensor switches or a sonic leak detector for compressed air leaks and the like.

To mention some lighting examples we have visited many plants which had recently installed new, more energy efficient factory floor lighting and received a generous rebate, but the plant manager or controller when asked, said no motion sensors for offices or the new floor light fixtures had ever been mentioned or proposed as an option by their contractor when our factory tour revealed perhaps 20 to 25% lights could have been turned off in frequently unoccupied floor areas in their plant. Nor had perhaps any investigation been made of some relatively low cost rewiring and switch changes for the floor lighting that would have made it possible to turn off more unneeded lights in their facility such as unneeded floor lighting for partially-manned 2nd or 3rd work shifts or week-end work shifts. (We could provide similar examples for new and existing compressed air systems, HVAC equipment, water chiller circulation systems, etc.)

Conclusion –Two Follow-on Recommended Program Research Candidates

A 2004 DOE report estimated that perhaps 70% of the opportunity to improve U.S. manufacturing plant energy efficiency was in improving plant equipment energy efficiency applications and about 30% was in improving plant energy management practices. (DOE 2004) Regardless of the percentage, the point is that in addition to potentially improving equipment energy efficiency, there is a significant opportunity to improve U.S. manufacturing plant energy management practices. The energy management practices would include implementing the most efficient manufacturing processes, practicing better maintenance procedures, improving employee behavior to be more energy aware and demonstrate more motivated behavior to conserve energy use, etc. The authors believe there is a great opportunity and need to conduct more field research trials for devising and testing practical, cost-effective utility energy efficiency incentive programs that include incentives for improving energy management practices. Thus we recommend two promising field research programs as follows:

Recommended Research Candidate 1: Develop & test an energy savings incentive program for manufacturing process improvement projects with the three suggested refinements above to the VeSM type programs. Based on the knowledge gained and lessons learned, the authors believe that the two completed utility programs yielded sufficiently promising results from non-equipment manufacturing process improvement projects to merit additional field testing of the VeSM program concepts with the changes and refinements outlined above in this paper.

Recommended Research Candidate 2: The authors recommend research and development of incentive programs for energy savings achieved from energy efficiency improvement of the entire manufacturing plant. The concept is based on providing an incentive for achieving plant energy savings by improving total plant energy intensity (energy used per production unit) over defined time periods that recognizes all the deliberate actions taken to save energy and improve plant energy efficiency. Presumably more total energy savings opportunities per plant could be identified, justified and implemented than with just equipment energy efficiency upgrade programs alone. If incentives have already been paid for energy savings achieved by upgrading major plant equipment energy efficiency projects, then these equipment rebate or incentive payments for new equipment energy savings can easily be deducted from the total plant energy savings incentive earned based on improvements to total plant energy intensity, and thus reward all the additional actions made in addition to any equipment-energy-efficiency upgrade projects to save plant energy.

To make a total plant energy savings incentive program feasible, the program needs clear rules for documentation, data collection and preservation, energy savings calculation methods and for auditing energy savings. Developing and providing an easy-to-use but reliable standard energy savings calculation tool would also be helpful to this proposed research trial program. Note that the DOE (Department of Energy) has developed a standard energy savings calculation tool based on a regression model template that is being field tested for measuring total plant energy savings achieved over a 3 year period by testing data from significant plant data for the newly developed Department of Energy SEP (Superior Energy Performance) Certification program. It could be that this newly developed DOE SEP energy savings measurement tool might be adapted for use in utility or government sponsored manufacturing energy savings incentive programs based on improvements of total plant energy intensity.

The state-of-the-art best practice standards for both equipment energy efficiency technology and more efficient, faster plant production techniques have both advanced significantly in the last 10 years creating even more opportunities for efficiency improvement. However, there seem to be no or at least very few utility energy efficiency programs that are paying incentives for energy savings achieved as a result of non-equipment manufacturing process improvement. Unfortunately wasteful human production and energy management practices are pretty common in the average manufacturing plants that we have visited. If these plants are typical then there is both a great need and opportunity for energy efficiency incentive programs in many U.S. manufacturing plants.

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