Fan and Pump Systems: The Untapped Energy Savings

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ABSTRACT

This paper addresses two developments in energy-efficiency programs for the industrial sector: (1) the shift from component-focused programs to system-focused efforts, and (2) the increased realization that energy savings by themselves do not motivate implementation by industrial facilities. We examined a system-focused effort — a pilot program in Wisconsin that demonstrated optimization of fan, pump, and blower systems — to assess the energy-saving potential, as well as the non-energy factors that need to be present to realize this potential through implementation by industrial facilities.

Specifically, we found substantial potential for energy savings in a system-based approach to optimizing fan, pump, and blower systems. However, implementation rates for the pilot program were low. Chances for success were improved for those facilities that experienced non-energy benefits, such as enhancement of the production process, and those with a history of efficiency improvements (energy or otherwise). Similar energy-efficiency programs should direct their attention at industrial facilities that are likely to exhibit one of these characteristics.

Introduction

The Energy Center of Wisconsin (ECW) is concluding a six-year Performance Optimization Services (POS) program that was intended to demonstrate the savings potential inherent in the optimization of industrial fan, pump, and blower systems. Through the development of case studies, training for end-users and consulting engineers, and a program evaluation, ECW identified both the great potential for energy savings inherent in this approach and the challenges in realizing this potential.

Performance Optimization – An Emerging Approach to Energy Efficiency

Performance optimization is a systems approach, as opposed to the more frequently used component approach, to energy efficiency. An advantage of performance optimization is that both production improvements and increased amounts of energy savings can be identified. The system approach requires a higher level of sophistication than the component approach.

Industrial operational problems such as equipment vibration, insufficient capacity, and control difficulties are excellent indicators of performance optimization potential. These types of operational difficulties frequently indicate system components fighting each other. Equipment competition results in excessive energy use.

After identifying a candidate system, the next step is to quantify how the system is presently operating. This is done by taking measurements of such variables as flow, pressure, temperature, and electrical consumption. The measurements determine system needs, quantify inefficiencies, and provide a basis to design system modification.

The first mission of facility staff is to make the equipment work. Inefficiencies occur due to sizing for a future expected load, changes in production volumes, or mismatched equipment installed during a breakdown. Solutions typically include improving control techniques, adjusting machine output, and removing system bottlenecks. For example, an oversized fan might be controlled to meet current production needs by the use of an outlet damper, but slowing down the fan and opening the damper could increase system efficiency.

Trend toward Performance Optimization among Energy Efficiency Efforts

System optimization has become an increasingly common strategy for energy efficiency programs that target the industrial sector. Several recent initiatives sponsored by the U.S. Department of Energy and other organizations emphasize the systems-approach. Examples of these programs include the national "challenge" programs and the emergence of building commissioning.

Barriers to Energy Efficiency Projects in the Industrial Sector

One common obstacle facing these industrial-sector programs is the difficulty in moving from the identification of energy-saving opportunities to implementation by industrial facilities. The experiences of past demand-side management efforts by utilities throughout North America suggests that it takes more than just energy savings resulting in low payback periods to convince industrial facilities to implement energy-saving opportunities. Past research and analysis suggests that several other factors influence industrial decisions, including:

- the need for non-energy benefits, such as improved product quality, greater reliability, increased productivity, reduced maintenance, or facilitation of long-term environmental compliance (Seratt, Way & Peters, 1994; Kyricopoulos, Faruqui & Wikler, 1994);
- the minimization of risk, especially to the production process (Kyricopoulos, Faruqui & Wikler, 1994; Warfel, 1998);
- the availability of funds for improvements generally and for the specific energy-saving measure specifically (i.e., compared to alternative investments that may offer higher potential returns) (Kyricopoulos, Faruqui & Wikler, 1994; Warfel, 1998); and
- the existence of an internal "project champion" to see the energy-saving improvement through the internal decision-making process (Seratt, Way & Peters, 1994; Warfel, 1998).

The POS program attempted to address some of these factors by using a prescreening process to identify facilities with desired technical and financial characteristics. We considered the remaining factors in our analysis of the program.

A Performance Optimization Pilot in Wisconsin

Efforts to apply systems optimization in Wisconsin originated in 1994 with Wisconsin Demand-Side Demonstration's POS pilot program, which was modeled for Wisconsin based on a similar program offered by Ontario Hydro. The program was transferred to the Wisconsin Center for Demand-Side Research (WCDSR) at the close of 1994 and ultimately became a project within the Energy Center of Wisconsin when WCDSR merged with ECW (Kallock, Cooney & Sabo 1995).

This analysis of the program relies primarily on the efforts, results, and experiences since ECW took over the program on January 1, 1996. The POS pilot program consisted of three components: case studies, training, and evaluation. Together, these efforts have been an attempt to create awareness of system optimization in Wisconsin, to develop a statewide market for performance optimization services, and to learn from our efforts.

Case Study Development

The program's largest effort consisted of the development of case study sites to demonstrate the application of the performance optimization approach and to document costs and energy savings. Together with Wisconsin's major utilities and some smaller municipal utilities and cooperatives, ECW marketed its POS program to industrial facilities statewide. This part of the program consisted of the following steps:

- identification of potential case study sites by ECW and participating utilities (based on a set of qualifying criteria and pre-screening of each facility);
- contact with the facilities by ECW and/or local utility to gauge their level of interest and to offer a free performance optimization site evaluation;
- a free site evaluation by an expert POS consultant to identify opportunities;
- a detailed feasibility study conducted by the POS consultant at the facility's expense (often with co-funding by the local utility and/or ECW);
- implementation at the facility's initiative (often with conservation incentives from the local utility); and
- documentation of costs and benefits of the performance optimizing projects.

Training

While efforts to develop case study sites have been completed, ECW continues to hold workshops throughout the state for both consulting engineers and end-users. These workshops are designed to create an awareness of the systems-approach to analyzing or changing fan, pump, and blower systems, and to help develop a market for POS consulting services. As of January 31, 1999, ECW had held 10 workshops with a total attendance of over 400 engineers, end-users, and utility staff.

Program Evaluation

Two program evaluations provide insight to the potential viability of this kind of systems-based program to promote energy efficiency in the industrial sector in Wisconsin. Hagler Bailly Consulting, Inc., conducted a mid-project assessment in 1995 when the Wisconsin Center for Demand Side Research ran the program. The evaluation found that performance optimization potential existed at most sites visited by the program staff and consultants, but decision-making criteria at participating facilities proved to be a hurdle for implementation of recommended improvements. In particular, industrial customers were found to be more concerned about short-term production goals and downtime than the potential long-term benefits of performance optimization. Other barriers to the performance optimization approach included the costs of the feasibility study and project implementation; the team-approach to industrial decision-making, which requires several people to be convinced of the benefits of a performance optimizing project; and the reluctance of some consulting engineers to become involved in a feasibility study that might not result in any additional work, such as project implementation (Kallock, Cooney & Sabo 1995).

ECW initiated a second, end-of-project evaluation toward the end of 1998. The purpose of this evaluation was to:

- document the outcome of the POS demonstration program;
- determine the reasons for facilities' participation and implementation of improvements, or the lack thereof; and
- determine the effect of the demonstration on the development of a market for performance optimization consulting.

This evaluation is currently in progress. Results should be available in June 1999.

Moving from Savings Potential to Savings Realization

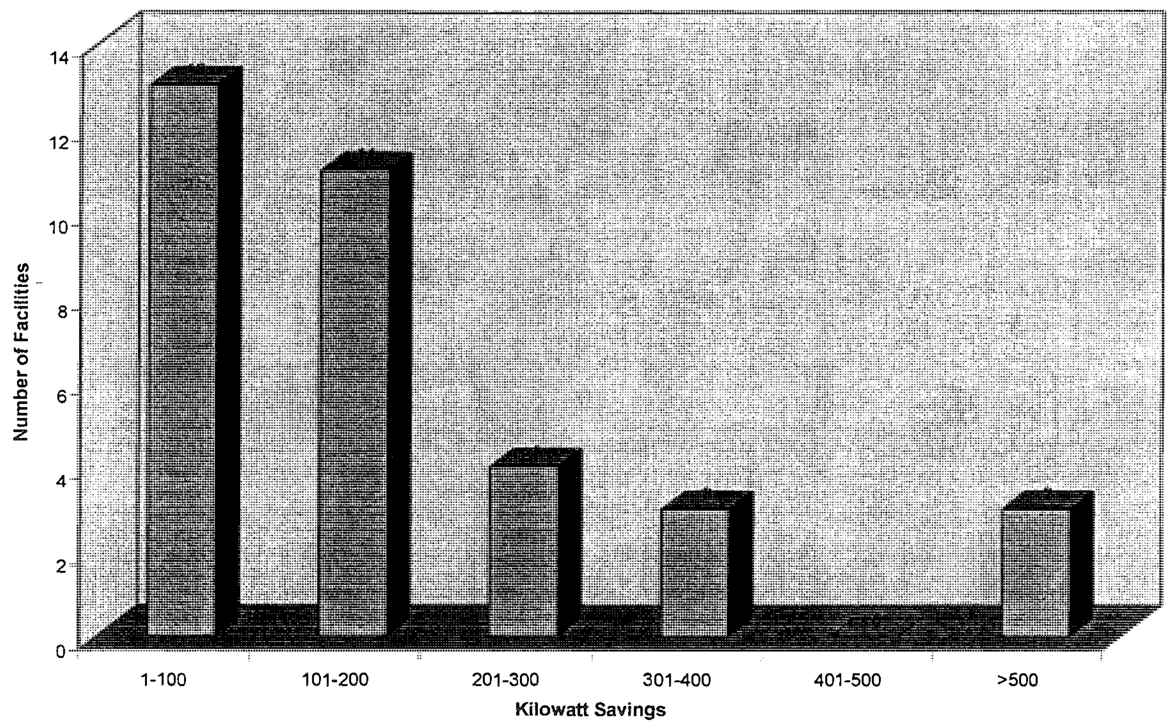
Identifying energy-saving opportunities through optimization of industrial systems was comparatively easy; realizing these opportunities proved to be much more difficult. As others have concluded previously, demonstrating energy savings and/or low payback periods is not enough. ECW's experience suggests some additional factors that are needed to realize the potential energy savings inherent in performance optimization.

Savings Potential Identified

Preliminary results of ECW's end-of-project evaluation suggest that 36 site evaluations identified energy saving opportunities exceeding a total of 10 megawatts, resulting in potential annual energy savings of $3 million at an implementation cost of approximately $5 million in out-of-pocket expenses. The costs per kilowatt of potential savings ranged from $63 to $840 with an average of $442. Participating industry types ranged from a brewery to a die casting facility; but paper mills, water treatment plants, and foundries were relatively common.

The median energy saving potentials was 132 kilowatts based typically on the replacement of, or adjustments to, one to three fans. Implementation costs were typically estimated to be $59,000 and would be offset in less than two years by annual energy savings of $38,000. However, the size, costs, and savings opportunities of projects varied greatly. The smallest project would have cost an estimated $2,500 (implementation cost) and produced savings of 40 kilowatts and $13,800 in annual energy costs. The largest project would have cost an estimated $1.9 million and produced savings of 3,840 kilowatts and $1.3 million in annual energy costs. Figure 1 shows the distribution of identified projects by power savings. [Note: Potential power savings were not quantified for 2 of the 36 facilities that received site evaluations; the figure below excludes these two facilities.]

Figure 1: Power Savings Identified



Because savings potentials are based only on a site evaluation, we compared savings estimates from the site evaluations to those identified in more detailed feasibility studies, where comparable data were available. We found that the initial estimates developed during the site evaluations were slightly conservative, underestimating the power savings identified in the feasibility studies by 6 percent and the financial savings by 16 percent, on average. However, this analysis is based on a limited number of cases. We did not compare the estimates derived from the site evaluations with actual savings because the number of implementers was low.

Barriers to Greater Implementation

Even with great technical potential, performance optimization projects may not be realized, however, due to the following implementation barriers.

Staff time available for "optimizing" a working system. Regardless of cost efficiency potential, facility staff must first address non-functioning equipment. Staff in many industries are busy just keeping the facility operating, thereby making is difficult to take on a project which seeks to modify equipment currently getting the job done.

Risk of changing anything related to production. The industrial facility's focus is on production. Plant staff have a great aversion to implementing any project which has a possibility to negatively impact production. Minimizing production risk is generally a priority over cost savings.

Lack of trust that estimates will result in reality. Industrial staff often discount estimates provided by an outside technical expert. This skepticism may be based on past experience of expert advice that did not work in reality or the impression that the expert has something to gain by justifying the sale of a study.

Investment to properly design solution and estimate savings. The performance optimization process requires an up-front investment in a feasibility study, but industrial businesses have difficulty investing in a study when there is strong internal competition for financial resources for tangible production-related hardware.

Savings Realized

Due to these and possibly other barriers, the actual savings realized as a result of the 36 site evaluations were substantially lower than the total amount of savings potential identified by these evaluations. An internal file review indicates that ECW's consultants conducted 36 site evaluations and completed 11 feasibility studies en route to developing implementations in four case studies. One additional case study is pending implementation scheduled for 1999, and one other facility traded potential energy cost savings associated with its performance optimizing improvements for other production benefits. Preliminary results from the end-of-project program evaluation suggest that up to five additional facilities may have implemented some of the improvements identified during the site evaluations, but implementation and energy savings have not been verified for these facilities. (Approximately 15 additional facilities had received site evaluations and had their files closed before ECW took over the program.)

The four projects that have been implemented to date resulted in estimated savings of 436 kilowatts and $162,000 in annual energy costs. The implementation costs of these projects were $192,000, resulting in an average overall payback of 1.2 years. Together, these projects realized five percent of the total potential energy savings identified by the 36 site evaluations. If the remaining project is implemented in 1999, as planned, the total savings realized would increase to 852 kilowatts and $253,000 annually.

Four projects have been documented in published case studies:

- Louisiana-Pacific Corporation's mill in Tomahawk downsized motors and slowed three fans used in drying and separating wood flakes. These changes were made possible by the opening of partially closed dampers, the replacement of some dampers with variable inlet vanes, and the replacement of belt drives. In addition to energy savings, Louisiana-Pacific experienced better-controlled airflow leading to more consistent moisture content in the facility's product, and reduced emissions of volatile organic compounds from the drying system. A facility representative appeared to be even more enthusiastic over the reduced emissions than the energy savings.
- G. Heileman Brewery in La Crosse trimmed the impeller on a cooling pump, thereby allowing the brewery to open the gate valve on discharge. This adjustment allowed the efficiency-minded brewery to increase cooling system capacity, which they had wanted to do for years.
- Ellsworth Cooperative Creamery in Ellsworth, which also has a history of efficiency improvements, changed the size of fan pulleys and opened a damper in a large exhaust fan system to achieve constant airflow with less energy.

- The North Shore Water Commission in Milwaukee lowered the pumping pressure used to distribute drinking water to three Milwaukee-area communities and installed a computer-controlled variable frequency drive to take advantage of off-peak energy rates. The lower water pressure was expected to reduce pump and system maintenance and decrease water loss and occurrences of broken water mains without compromising customer service. The Commission proceeded with the project despite the two-year payback (the highest of the four case study sites) because of its interest in the continuous improvement of its operations.

<table>
<tr><th colspan="2">Case Study Results</th></tr>
<tr><td>Ellsworth Cooperative Creamery
• removed fan damper control and slowed fan speed (pulley size change)
• 42 kW reduction in demand
• savings of $12,000 annually
• project cost of $8,000
• payback of 8 months</td><td>G. Heileman (now Stroh Brewery Company)
• opened throttling valve and trimmed cooling system pump impeller, improving cooling system capacity and allowing increased production capacity
• 58 kW reduction in demand
• savings of $19,000 annually
• project cost of $7,600
• payback of 5 months</td></tr>
<tr><td>Louisiana-Pacific Corporation
• opened fan outlet damper and slowed fan speed (fan pulley size change) on system
• removed outlet damper, added variable inlet vanes, and slowed fan speed (fan pulley size change) on another system
• installed smaller motors
• 290 kW reduction in demand
• savings of $85,260 annually
• project cost of $85,000
• payback of 1 year</td><td>North Shore Water Commission
• reduced system water pressure to cut pumping energy and reduce both leak rates and piping ruptures;
• maximized amount of off-peak water pumping through the use of elevated storage
• 46 kW reduction in demand
• savings of $46,000 annually
• project cost of $91,000
• payback of 2 years</td></tr>
</table>

These case studies suggest a pattern among facilities that implemented system-optimizing recommendations. Each case study facility exhibited an interest in efficiency improvements and/or experienced operational problems that were alleviated by the recommended improvements.

Conclusions

The technical potential for energy savings from system optimization of industrial fan, pump, and blower systems appears to be substantial. Realization of this potential is more difficult, however, because implementation depends on competing priorities within industrial facilities. The ECW performance optimization projects demonstrated that chances for successful implementation are enhanced in industrial facilities that have an efficiency ethic or a current production problem that can be addressed by a performance optimizing solution. These factors can overcome existing barriers to energy-efficiency projects in the industrial sector and lead to the realization of energy savings.

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