Savings Estimates for Dust Collection System Controls: Strategies Used and Lessons Learned

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ABSTRACT

Dust collection systems as a single endpoint account for a significant portion of electricity consumption in wood product manufacturing. A range of energy efficiency options – fan speed reduction, static pressure reduction, system balancing, system isolation, and system replacement – are available to reduce electricity consumption (as well as energy used for space heating). Identifying the appropriate energy efficiency strategy at a given facility balances the effort required to develop a technical understanding of the system, the optimum strategies for that system, and the economic and management factors that drive project completion. This balance is not always struck successfully.

Because wood product manufacturing is the second-largest manufacturing revenue-generator in Vermont, working with customers in this sector has been a priority for Efficiency Vermont. Efficiency Vermont is the state's Energy Efficiency Utility, providing financial incentives, technical assistance, and third-party verification to leverage energy efficiency opportunities in Vermont's industrial market. In 2003, Efficiency Vermont was approached by a dust collection system controls vendor to propose the vendor's systems in three different wood products manufacturing facilities. The vendor's system installs motorized blast gates at each duct intake and controls those gates by the ON/OFF state of each machine, and also uses pressure sensors located at various points in the ductwork to communicate with a variable frequency drive (VFD) that controls the system's fan speed. Efficiency Vermont offered financial incentives on each of the three proposals, and two of the facilities ultimately installed the system.

Efficiency Vermont encountered a number of challenges on one of the system installations. Efficiency Vermont provided a design incentive to the vendor to perform the field measurements on the largest dust collection system of the three manufacturers and used that data to refine the vendor's energy savings estimate and determine a financial incentive. The vendor developed a ductwork and blast gate inventory, interviewed facility personnel on hours of operation, collected air velocity measurements in each duct, and metered the electric demand of each of three, 200-hp fan motors. The vendor used that data to estimate air flow requirements, and Efficiency Vermont estimated the annual energy savings to be 1,265 megawatt-hours (MWh) per year. Six months after installation and an initial "breaking-in" period, the annualized savings were calculated from metered data to be 1,073 MWh, 15 percent less than the initial estimate. In reviewing its evaluation process on this project, Efficiency Vermont realized that specific improvements would have included metering of machine operation and review of production data to ensure that measurements would be taken at a time that represented "typical" production levels. Other errors could have been eliminated – and opportunities identified – by a more thorough, third-party evaluation of the facility, and the enhancement of in-house industrial expertise has resulted in more careful management of vendor-generated projects.

Introduction

Wood product and furniture manufacturing are critical industrial sectors in Vermont. Recently, these two sectors combined were the second-largest manufacturing revenue-generator in the state, bringing in nearly $600 million in revenues (U.S. Census Bureau, 1997), and the second-largest manufacturing employer in the state (U.S. Census Bureau, 2001). The 207 Vermont firms in these sectors employ over 6,200 people, or about 12.5 percent of the manufacturing work force. Maintaining the competitiveness and profitability of these industrial sectors is a priority for the State of Vermont, and working with these firms has been a priority for Efficiency Vermont, the state's Energy Efficiency Utility.

Efficiency Vermont, the state's "energy efficiency utility", provides statewide technical and financial assistance for commercial new construction projects and builds working relationships with strategic partners (e.g., trade associations, state agencies), design professionals (e.g., architects, engineers), and trade allies (e.g., general contractors, electrical contractors, mechanical contractors). All Efficiency Vermont services are delivered by an independent non-utility contractor under a multi-year, performance-based contract with the state's Public Service Board. Funding for services provided to all residential and business markets is provided by an energy efficiency charge that has phased in over five years. Efficiency Vermont's annual budget started at $5.6 million in 2000 and has risen to a now-constant level of $14 million, slightly under 2 percent of total electricity revenues.

Efficiency Vermont's work in the wood products manufacturing sector has encompassed a broad range of energy efficiency opportunities. Reductions in energy use at these facilities can be accomplished by (Emplaincourt, et al., 2003):

1. Improvements in dust collection system efficiency;
2. Improvements in compressed air system efficiency (notably leak detection and repair, large-use component isolation, storage receivers, cycling dryers, low-pressure drop filters, and variable frequency drive control of motors);
3. Improvements in lighting efficiency (use of T-5 fluorescent or pulse-start metal halide fixtures in highbay ambient lighting applications and "Super T-8" fluorescent systems in task or office lighting applications);
4. Improvements in space conditioning efficiency (equipment efficiency and improvements in ventilation controls); and
5. Waste heat capture from compressed air systems and/or other processes.

To leverage energy efficiency investments in these areas, Efficiency Vermont offers a range of technical and financial assistance services, including:

1. Walk-through of a facility to qualitatively identify energy efficiency opportunities worth pursuing;
2. Third-party review of vendor or contractor proposals for non-process or process equipment to identify available energy efficiency opportunities;
3. Energy savings and cash flow estimates for potential energy efficiency improvements, whether for facility expansion, planned equipment purchase or replacement, or discretionary retrofit projects;
4. Metering power draw and energy consumption of existing equipment;

5. Hiring a technical subcontractor to conduct a more thorough facility evaluation to quantify energy efficiency opportunities;
6. Verifying installation of equipment according to energy efficient specifications and, if specified in advance, checking equipment performance against sequence of operations; and
7. Financial incentives toward evaluation, design, and equipment purchase.

In 2003, Efficiency Vermont was approached by a manufacturer's representative of a dust collection control system that had researched potential customers for its product and identified three facilities. The vendor's system would match air flow through the dust collection system to actual load (i.e., dust produced by equipment). The vendor requested determination of eligible financial incentives to incorporate into its proposals. As a prerequisite for a financial incentive determination in the largest and most complicated system of the three customers, Efficiency Vermont required a field study to ground the energy savings and cash flow impact estimates. The study conducted an air flow inventory throughout the ductwork and measured the power draw of the baghouse fan motor at full speed. The vendor and Efficiency Vermont presented to the customer an energy savings estimate to encourage implementation. The energy savings estimate proved to be an overestimate by 15 percent.

Efficiency Vermont has three potential responses to this experience. The first is to require additional field measurements – such as motor logging to determine actual equipment operation schedules – to further refine energy savings estimates. The second is to undertake a more comprehensive, independent third-party system evaluation to identify the full range of energy efficiency opportunities and propose an optimum solution. The primary risks of the second option are either (1) that the more comprehensive, and more expensive, study would result in the same management decision as the proposed vendor solution, or (2) that the more comprehensive study expands a project scope beyond the customer's capacity to accommodate (due to scheduling, budget, or staff limitations). The third is to continue to work with vendors while exercising greater caution and scaling down savings estimates. This paper assesses the lessons learned on this case study and how Efficiency Vermont has responded to those lessons.

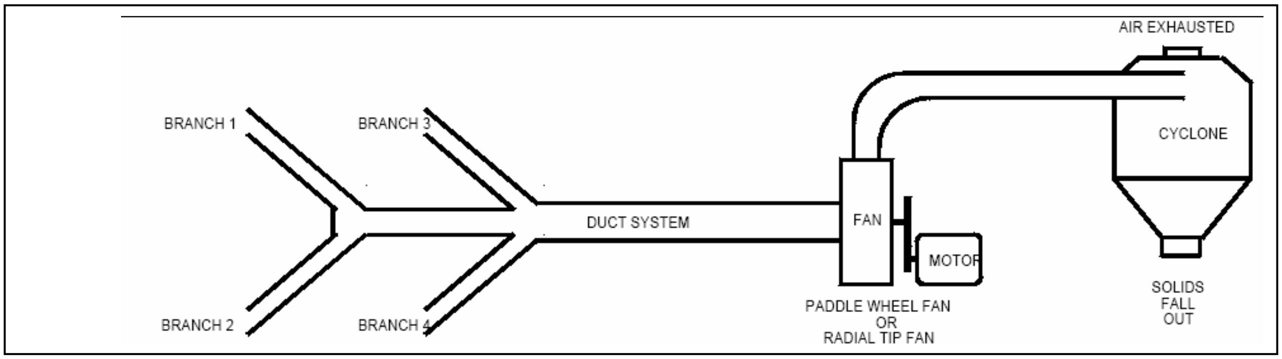
Dust Collection Systems and Traditional Efficiency Approaches

The design intent of a dust collection system is to move equipment-generated sawdust away from equipment and collect the dust for disposal or other use in a central location. Furniture manufacturers can use two different kinds of systems, positive pressure or negative pressure, which depend primarily upon the location of the fan (up or downstream). Dust collection systems consist of the following:

1. Intake vents at the equipment. Depending upon its size and function, a given piece of equipment can have multiple intake vents. Occasionally, these intake vents may be manually operable, and closing the vents can reduce airflow and motor load. Generally, equipment operators do not close the intake vents when shutting off the equipment.
2. Ductwork to convey the dust from the equipment to the cyclone.
3. Cyclone and/or baghouse to collect and capture the dust and separate it from the airstream.
4. Fan and motor to develop the negative or positive pressure and airflow to convey the dust from the equipment to the cyclone and baghouse.

The selection and placement of a cyclone or baghouse for separation of the collected material from the airstream has a significant impact on energy efficiency. “Clean-air” fans such as a backward-inclined or airfoil fans are more energy efficient, but need to be placed downstream from either a baghouse or combination of cyclone and baghouse (otherwise the collected dust would destructively erode blade surfaces) (NEEA 2002). “Material-handling” fans such as flat-bladed or radial-tip fans are less efficient and need more frequent replacement, but do not require the separation of material from the air stream. Figure 1 provides a schematic diagram of a typical material-handling fan with a dust collection system.

Figure 1. Schematic Diagram of Customer’s Dust Collection System



Source: NEEA, 2003.

Dust collection systems need to provide a sufficient air velocity to move and prevent the settling of the largest particle size (and to meet fire safety standards). However, while dust collection systems are “in balance” when designed, production changes add equipment and ductwork branches, generally without corresponding changes to the system design. As a consequence, most older dust collection systems are significantly out of balance, resulting in inefficient energy use (see below).

Dust Collection Systems and Energy Use

Dust collection systems represent a significant portion of a furniture manufacturer’s total electricity use. The system fan works against the static pressure of the entire system – the blast gates, the ductwork, and the upstream or downstream cyclone and/or baghouse. If a poor system design (e.g., sharp elbows or undersized ductwork) increases the total amount of static pressure in the system, the operating point on the fan’s performance curve shifts, increasing the total brake horsepower required by the fan (up to the maximum point on the curve). Additionally, system designers may create overcapacity in a dust collection system to ensure adequate dust capture and movement, either to accommodate system expansion or to be conservative. Since theoretical fan energy use increases with its speed cubed (ASHRAE, 2001), this can be an expensive safety net. In the case of the three Vermont field studies, the power demand of the dust collection system accounted for 20 to 40 percent of each facility’s total demand.

Energy Efficiency Options

The primary retrofit energy efficiency options for existing dust collection systems include (NEEA 2002):

1. Fan speed reduction (using variable frequency drive);
2. Excess velocity reduction (by replacing undersized with properly-sized ductwork);
3. System balancing (with balancing gates, preferably in conjunction with a variable frequency drive); and
4. System isolation or sectionalization (as a function of plant operation, with variable frequency drive to ensure proper velocity in "active" ductwork).

In the "Just Enough … Air" program run by the Northwest Energy Efficiency Alliance, fan speed reduction projects yielded dust collection system energy reductions of 23 to 39 percent (NEEA 2002). While the above opportunities are appropriate for system retrofits, system replacement projects (where options such as new ductwork, fan placement, and enhanced controls are more easily integrated) can yield system savings as high as 50 percent. (NEEA 2002).

Case Study

This case study focuses on the largest and most complicated dust collection system of the three customers approached in 2003.

Project Information

The facility in question manufactures a wide range of hardwood furniture products and uses sanders, planers, routers, saws. Three negative-pressure dust collection systems, each powered by a 200-hp motor, serve a total of 85 different machines. The machine inventory is presented in Table 1.

Table 1. Machine Inventory for Dust Collection Systems

System	Machine Type	Machine Count	Blast Gate Diameter (in.)
System 1	Auto Stroke, Curtis Table Stroke, Handsaw, Sanders, Spindle Abrasive Wheel, Tannenwitz, Yates Hand Stroke	33	4 to 10
System 2	Dove Tail, Sanders	13	6, 8, or 10
System 3	BMR, Backnives, Drill, Lathes, Sanders, Routers, Saws, Shapers, Tennoner	39	4, 5, 6, 8, 10 or 12

Source: EnergyEcon. 2003

Prior to the onset of the project, the facility operated each 200-hp motor at full speed during two shifts. The vendor used a fluke meter to measure phase voltage and current on each of the three legs on each 200-hp motor to determine the power draw for each motor. From a discussion with the customer, it was assumed that each motor operated at that load and continuously for each of the facility's two shifts. The baseline energy use estimate is presented in Table 2.

Table 2. Baseline Energy Consumption

	System 1	System 2	System 3
Measured kW	128	131	132
Measured HP	171	175	176
Measured kVA	147	147	147
Measured kVAr	72	71.1	68.2
Estimated Energy Use	561,000 kWh/yr	574,000 kWh/yr	578,000 kWh/yr

Source: EnergyEcon. 2003

Vendor's Proposal and Field Study

The vendor proposed the installation of a control system and motorized blast gates on the dust collection duct intakes on each woodworking machine. Each blast gate would close when a machine operator would turn off a machine. The variable frequency drive (VFD) proposed by the vendor to control the baghouse fan would respond to pressure sensors installed in the dust collection system ductwork, using pressure measurements as a proxy for the duct velocity threshold. The control system could both open and close duct intakes (even when machines are shut off) to ensure adequate airflow and use the VFD to control the speed of the baghouse fan to meet or exceed needed velocity and avoid excess pressure drops (which can damage ductwork).

In response to Efficiency Vermont's request, the vendor undertook a field measurement study to obtain needed key assumptions in the energy savings analysis. The steps of the field measurement study were to:

1. Calculate the airflow (in cubic feet per minute, cfm) required at each duct at each machine to meet needed velocity (see Table 3).
2. Measure actual airflows at each machine, either at each intake duct or at the closest major trunk where the machine's individual intake ducts converge. The distributor took one measurement per machine and did not measure over a period of time (see Table 3).
3. Compare the actual air flows with the rated flow of the system
4. Estimate the operating frequencies of each machine through conversations with the facility manager (for example, System 1's Auto Stroke only operates 60 percent of the time)

Table 3. Airflow Measurements in Each Main Duct

System	Measured Main Duct Airflow (cfm)	Minimum Required Main Duct Airflow (cfm)*
System 1	43,600	25,300
System 2	43,600	25,300
System 3	79,500	46,100

Source: EnergyEcon. 2003. * Determined by vendor software package, based on system design

Energy Savings Methodology

The vendor's original energy savings analysis simply took the ratio of the required to measured airflows for each system's main duct and applied the fan laws to determine the average fan power requirement (raising the ratio to an exponent of 3) and multiplied this average power requirement by the 4,380 operating hours. Efficiency Vermont requested the application of a lower exponent (2.5) that Efficiency Vermont uses for centrifugal fans, and the vendor estimated the energy savings at 1.26 million kWh annually, or 74 percent (see Table 4). The vendor's and Efficiency Vermont's energy savings analysis were reviewed and approved by a third-party, independent technical expert (under contract to the Vermont Department of Public Service, which verifies all savings claims), particularly because the performance of the vendor's system at the other Vermont location closely matched the estimated energy savings.

Table 4. Estimated Electric Energy and Peak Savings per System

System	Vendor/Efficiency Vermont Savings Estimate
System 1	404,000 kWh/yr 92 kW
System 2	452,000 kWh/yr 103 kW
System 3	408,000 kWh/yr 93 kW
TOTAL	1,264,000 kWh/yr 288 kW

Source: EnergyEcon. 2003; Efficiency Vermont analysis

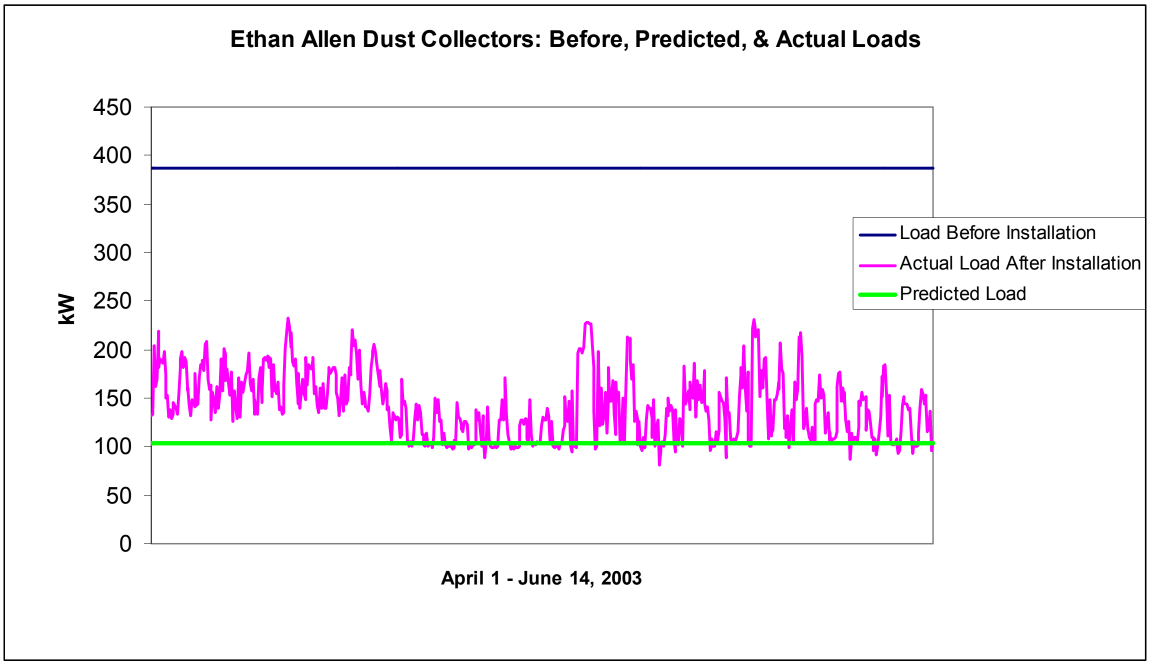
Based upon the customer's electric demand and energy charges, Efficiency Vermont estimated that $400,000 project would yield annual cost savings of $110,000. Efficiency Vermont offered a financial incentive of $117,000, creating a simple payback period of 2.6 years.

Field Results

The control system has a data tracking module that allowed Efficiency Vermont to evaluate the system operation six months after installation. The vendor supplied Efficiency Vermont with 5-minute interval data covering a period of five months, yielding production data for a total of 643 hours (see Figure 2). Efficiency Vermont multiplied the power associated with each 5-minute interval to estimate kWh consumption in that interval, added the kWh consumption during the 643 hours, then extrapolated that amount across 4,380 hours of total use.

The annual energy savings determined by this methodology is 1.1 MWh, or 85 percent of the predicted outcome. The minimum observable reduction in coincident demand during the measured time period is 154 kW.

Figure 2. Measured Power Consumption of Fan Motors (Systems 1, 2, and 3)



Source: Ecogate and Efficiency Vermont, 2003.

Using the same electricity energy and power charges, and assuming that only the minimum demand reduction was realized, the cost savings associated with the metered data was $98,000 annually. However, during the test period, the five monthly peak demand reductions were 169, 154, 216, 160, and 203 kW. Using the average of these – 180 kW – across an entire year yields an annual cost savings of $101,075. The difference between the original estimate and the estimate from the measured data is presented in Table 5.

Table 5. Estimated versus Measured Savings

	Savings Estimate	Estimate from Metered Data
Project Cost	$400,000	$400,000
Energy Savings	1,264,000 kWh/yr	1,073,000 kWh/yr
Demand Savings	288 kW	154 kW
Annual Cost Savings	$110,000	$100,000
Incentive	$117,000	$117,000
Simple Payback	2.57 years	2.83 years

Source: Efficiency Vermont

In an effort to determine the discrepancy between estimated and metered energy consumption, Efficiency Vermont re-reviewed the facility interviews to generate a bin-hour analysis on each dust collection system. Efficiency Vermont also questioned the software's "minimum required main duct airflow," because the vendor's analysis appeared to assume that airflow through a 23-inch secondary main duct flowed into, rather in addition to, a larger 40-inch duct for Systems 1 and 2. Using the bin-hour analysis and adding the airflow from the secondary duct, Efficiency Vermont's revised savings estimate was 130 kW and 1,182,000 kWh per year, still an overestimate by 10 percent.

Efficiency Vermont then contacted the customer and found that the following changes to the system operation had occurred:

1. The equipment distributor had needed to increase the minimum speed setpoint because of the control system's configuration and performance.
2. The customer had closed a neighboring plant and moved some of the production into this facility, increasing the number of machines operating at any one time as well as the load on the dust collection system.

Either change could have potentially caused the 15 percent difference between estimated and actual energy savings. Additionally, the field measurement methodology did not track the actual operating profile of the equipment. The energy savings analysis inherently assumed a smooth distribution of equipment operation. If, in actuality, there is a greater degree of coincident equipment operation than assumed, actual energy savings would be lower than those estimated. With the available data, Efficiency Vermont could not determine to what degree each of the two system changes or the operating profile assumptions contributed to the energy savings overestimate.

Efficiency Vermont lowered its savings claim for the project to the 154 kW and 1,073 MWh per year estimated from the metered data.

Impacts on Efficiency Vermont's Technical Approach

There are three possible responses to the challenges experienced on this project: future refinements for field studies conducted to evaluated energy savings for this vendor's particular product; a commitment to comprehensive system evaluations prior to vendor involvement, and subsequent requests for proposals for identified and approved projects; or more careful management of vendor-generated projects and more conservative savings estimates without additional assessment.

Recommendations for Future Dust Collection System Evaluations

In retrospect, Efficiency Vermont would approach this project a little bit differently. Specifically, the field measurement effort would use motor loggers to test the accuracy of reported operating profiles. Motor loggers would definitely be used on the set of equipment that posed the greatest demand on the dust collection system. If the reported operating profiles differed substantially from measurements on those machines, Efficiency Vermont would use motor loggers on an additional set of equipment to refine the remaining operating profile assumptions. While this recommendation would increase the cost of the field measurement effort, Efficiency Vermont would highlight to the customer the other potential benefits to this data. Furniture manufacturers in the United States need to operate efficiently to remain competitive. By assessing usage patterns of different pieces of equipment, the facility could evaluate its own efficiency in making each furniture part and assembled product.

Switch to Comprehensive, Non-Vendor-Generated Evaluations

One of this paper's reviewers suggested that the primary reason for the high level of savings for this vendor's product was the system's poor design. The disadvantage of relying upon a vendor to initiate a project and conduct a field evaluation is the unlikelihood of a recommendation that would not involve that vendor's product. Efficiency Vermont is aware that other demand-side management programs, notably Northeast Utilities' PRIME and NYSERDA's Flex-Tech programs, offer objective facility evaluations to identify a range of energy efficiency opportunities to leverage projects. Such an evaluation could have evaluated the full range of energy efficiency options identified in this paper and recommended the most effective options, based upon cost, savings, production schedules, design and system track record, and customer's level of comfort with the options.

While this case study cannot be re-initiated, there is the possibility that, given the range of factors to consider, this vendor's product might have ultimately proven to be the best fit for the situation. Successful vendors have business models that leverage investments in energy efficient technologies. One role for demand-side management programs is to guard ratepayers against fraudulent vendor claims and to guarantee appropriate use of system benefit charge funds. Another role is to support vendors whose business models and technologies prove effective and perform well, while clearly communicating risks and uncertainties to customers.

More Careful Management of Projects and Conservative Savings Estimates

The last response is to exercise greater caution on vendor-generated projects. The case study project still proved successful, reducing dust collection energy consumption by an estimated 62 percent. And, as mentioned above, Efficiency Vermont seeks to support effective vendor business models and technologies. But the experience on this and other projects has resulted in the exercise of greater care when vendors initiate projects with Efficiency Vermont customers.

Since the completion of this project, Efficiency Vermont has built its in-house expertise in process systems by adding technical staff with industrial backgrounds. This staff is able to provide independent recommendations that may or may not refer customers to particular vendors. In some cases, staff recommend against the use of any new equipment, instead providing financial incentives toward labor and parts (e.g., retro-commissioning, compressed air system isolation) that yield significant savings. The case study presented in this paper represented a portion of Efficiency Vermont's learning process, a process that is certainly ongoing.

Conclusion

The energy use of dust collection systems represents an opportunity for furniture and other secondary wood product manufacturers to reduce energy costs and improve their bottom line. Most facilities have added equipment to and made sufficient changes in the original dust collection system design that the system is no longer appropriately balanced and is likely using a higher fan speed and larger airflow than necessary. A range of options are available to maintain system performance while lowering energy consumption.

Efficiency Vermont supported a vendor-initiated field study to evaluate the potential savings for a particular solution – a control system consisting of motorized blast gates at equipment intake ducts, pressure sensors, and a VFD. Energy savings estimates from the field study by the vendor, Efficiency Vermont, and a third-party reviewer overestimated the energy savings, in comparison to about five months of metered data. The overestimate likely originated from inadequate data on equipment operation, an underestimate of needed fan speed to maintain adequate air velocity, and subsequent production changes.

In response to these changes, Efficiency Vermont has augmented its in-house expertise to support and more carefully manage vendor-initiated projects. Comprehensive, third-party evaluations assess system behavior and design and identify, evaluate, and recommend a full range of energy efficiency options. While these studies provide excellent information, Efficiency Vermont has had challenges in encouraging customers to implement recommendations due to production scheduling issues, availability of vendors to bid on proposed work, financing availability, and the capability of customer staff to oversee or manage such a project. Vendors often provide "turnkey" services, addressing multiple market barriers to energy efficiency investments. While experiences such as the case study presented here signal a need for caution, Efficiency Vermont continues to be open to collaboration with vendors in promotion of energy efficiency solutions for customers' business needs.

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