3rd Party M&V is a Treasure Meant to Be Shared

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ABSTRACT

Third party measurement and verification (M&V) is imbedded within energy efficiency programs around the world. In many cases this M&V complies with protocols (such as IPMVP) requiring metering, representative sampling, and expert normalization and analysis. This high-quality M&V is often used for custom or unique projects within a program. It can be used to evaluate large complex system improvements, but also smaller repeatable projects that do not fall into a prescriptive bucket. These M&V projects range across emerging technologies, novel concepts, or questionable “efficiency” products. Third party M&V is difficult to find outside of efficiency programs, and often gets buried rather than shared. Without sharing this data, manufacturers are at the mercy of biased vendor data, misconceptions, or cherry-picked case studies. To accelerate decarbonization, this precious M&V data should be better shared throughout the efficiency community to help educate clients, and help programs optimize focus, or create new prescriptive measures.

This paper pulls from a utility program database of high-resolution M&V projects and shares the energy savings results of potentially repeatable projects. Examples of repeated projects range from motor balancing, EC motors, extruder barrel controls, leak repairs, and reactive power correction. The goal is to both share useful data and to discuss methods for better sharing within efficiency programs.

Introduction

The race to decarbonize requires fast and efficient dissemination of learned information across energy efficiency programs, customers, and government entities. One form of valuable information that is naturally generated within most efficiency programs is thousands of measured and verified (M&V) efficiency project case studies. There are a number of efforts, and organizations, like ACEEE, aimed at sharing knowledge and data across efficiency programs, but still much of this valuable M&V data is never put to good use. This paper focuses on experiences where we observed valuable research and data collection across hundreds of Midwest manufacturing case studies, but much of the useful information never got disseminated for the greater good.

Common projects requiring M&V range from large, complex system improvements to small repeatable projects that do not fall into a prescriptive bucket. These projects range across emerging technologies, process specific retrofits, novel concepts, or questionable “efficiency” products. Third party M&V outside of an efficiency program is expensive for end-users and rare. Therefore, energy efficiency programs are the primary drivers and stewards of generating M&V case studies. If this data is not shared, manufacturers can be at the mercy of biased vendor data, misconceptions, or cherry-picked case studies. It is critical that efficiency programs conduct their case studies in ways that can be, vetted, quality controlled, documented, and shared not just with other programs, but with the end-use customers. After all, most of the financial risk from an efficiency project is borne by the end user.

Where Efforts to Share are Already Succeeding

It is important to acknowledge that many important groups and initiatives already exist with the goal of helping accelerate the adoption of energy efficiency through knowledge transfer. This paper is merely contributing some small pieces to the effort. At the same time, our experiences with programs in Ohio suggests that the vast majority of case study data either does not get collected in a manner that is conducive to sharing, or just gets filed away as records. There are many novel manufacturing specific success and failure stories that never get shared.

A few significant examples of organizations focused on accelerating energy efficiency knowledge sharing include American Council for an Energy-Efficient Economy (ACEEE), or Consortiums for Energy Efficiency (CEE), American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), Department of Energy (DOE), Environmental Protection Agency (EPA), and the National Laboratories.

Furthermore, many of these organizations have initiatives specifically geared towards extracting knowledge from the many case studies created within efficiency programs. CEE has many relevant initiatives that help shape how programs are designed and how to incentivize different technologies, such as their 2018 Emerging Technologies Collaborative. California Public Utilities Commission maintains the Database for Energy Efficiency Resources (DEER) which strives to do much of what this paper talks about, but with California specific projects. However, these two initiatives focus on the commercial and residential sectors, not industrial.

California Measurement Advisory Council (CALMAC) does an excellent job of maintaining a searchable database of industrial specific studies on energy efficiency. However, digging out specific case study stories that manufacturers can relate to can still be challenging.

Lastly, the existence of Technical Reference Manuals across different states and the “cohort” mentality approach of efficiency programs are natural vehicles for knowledge sharing and infrastructure building.

Efficiency Program Case Studies Are Naturally High Quality

Most efficiency programs must conduct M&V that both meets certain protocols and accuracy standards and is then peer reviewed by a second team of experts, called program evaluators. There exist several guidelines and practices to help match appropriate M&V requirements to varying project types and program goals. Additionally, there are some requirements set by electric grid operators so that energy efficiency can be treated as a resource to the grid. Most of these guidelines reference each other and are similar because of the nature of M&V. One such document commonly referred to by multiple organizations internationally is the International Performance Measurement and Verification Protocol (IPMVP, 2012). As an example, the IPMVP is referenced by both utilities and the grid operator in the Midwest region of the United States. Other notable M&V guideline documents include ASHRAE Guideline 14-2014 (ASHRAE, 2014) and ISO 17741:2016 (ISO, 2016).

The accuracy and certainty of energy savings are important to three distinct entities, the end-user, the energy-efficiency program administrator, and the Independent System Operators (ISO) or Regional Transmission Organizations (RTO). In this paper’s case studies, the M&V must meet requirements of the Pennsylvania Jersey Maryland (PJM) RTO, as outlined in PJM Manual 18b. In many of the presented case studies the energy demand savings had to be evaluated such that it could be bid into the PJM capacity market.

The IPMVP categorizes M&V into four options; Option A and B pertains to metering the system being affected, Option C relates to facility level metering, and Option D relates to calibrated simulation. Most of the case studies in this paper apply Option A and B, which requires installation of accurate metering equipment to measure energy consumption of the systems, and any significant variables, before and after implementation of the efficiency project. The measured data is then used with appropriate engineering calculations and analysis techniques to determine the energy savings. These calculations and techniques can vary dependent on the data available and the complexity of the project. There are guidelines for such techniques but no set standards since each non-prescriptive project is unique and cannot be generalized. Hence it is up to the party performing the M&V to understand the efficiency project and determine which techniques are appropriate for the M&V. The impact an engineer's understanding and analysis of a project has on the accuracy of M&V was demonstrated by Kleinhenz, Seryak, Brown and Sever in 2013 (Kleinhenz, 2013).

Case Studies

In 2019 a controversial Ohio House Bill 6 was passed ending 12 years of state-mandated utility energy-efficiency programs. At the closure of these programs, it is important to reflect on the fruit of the labor, lessons learned, and share unique insights within the greater efficiency community. We worked closely within one of the programs to create and deliver M&V of efficiency projects across prescriptive, custom, and new construction rebates, and large customer "Self-Direct" programs. Additionally, we provided program design consulting, Strategic Energy Management (SEM), energy audits, and developed new prescriptive measures. This paper pulls from this work and attempts to bring to surface a small sampling of some of the case studies manufacturers would appreciate seeing. We aim to help illustrate the value of better sharing M&V case studies and facilitate conversation on where programs are doing a good job and where we can improve. The case studies are organized into four types: suspicious efficiency technologies, process specific technologies, "low hanging fruit" projects where real savings numbers are hard to find, and emerging technologies.

Type 1: Suspicious Efficiency Technologies

There are lots of products and technologies being pushed at manufacturers in the name of energy efficiency that can be intentionally or unintentionally misleading. In some of these instances the product itself does provide value to a customer, just not energy efficiency. However, when energy efficiency incentives are available, it is tempting for vendors to try to take advantage.

While working within Ohio energy efficiency programs, questionable energy efficiency projects would get presented on a daily basis, and most would get dismissed without M&V efforts or significant engineering analysis. However, some would warrant in depth analysis to officially rule them out due to lack of available credible case studies, lack of available technical data, growing interest among the program's customers, or persistence of a vendor.

Reactive Power Correction Units.

Reactive power correction (RPC) devices are sold under many different names by many different vendors, and typically are marketed more generically as power saving boxes you can add to almost any piece of equipment. In most cases, these types of devices (boxes installed at the power feeds) are capacitors that help correct power factor. We observed these products being pushed with lots of biased or unreliable case studies where as much as 10% to 30% of an energy bill is slashed simply by installing the devices. For a technology like this, end use customers greatly benefit from high-quality third-party M&V commissioned from a trusted efficiency program.

We were commissioned to conduct such as case study for a large manufacturer who had already invested $68,000 into this technology to install RPC devices across their 15 air compressors system, totaling 1,125-hp. To test the technology, we were able to install true-power meters to record power at one-minute intervals, current transducers to measure amperage at one-second intervals and use a spot power meter to accurately measure instant power factor, kVAr, kVA, kW, voltage, and amperage of each electric phase. We conducted our metering upstream from the RPC devices. With the RPC device enabled, we took measurement of the compressor at both 100% loaded and the fully unloaded states, since power factor varies with motor load. We then disabled, or bypassed, the RPC devices and repeated the same tests. Since this testing can be time intensive and detrimental to plant production needs, we only conducted the full testing on two of the 15 compressors.

The facility did not have significant power factor issues and we did not expect measurable energy savings to result from this technology. However, to our surprise we did observe an overall energy efficiency improvement on the two compressors. The savings were small (less than 1.5% overall) and potentially a byproduct of other system variables we could not identify or control. However, the overall story was that the product provided little to no energy savings. A sample of the data trends and summary tables are shown below.

Table 1. Energy and power reduction of reactive power correction devices.

	Loaded Power Draw (kW)				Unloaded Power Draw (kW)			
Air Compressor	RPC - Bypassed	RPC - Active	Difference	%	RPC - Bypassed	RPC - Active	Difference	%
ACP-011	50.8	51.9	1.1	2.2%	13.9	13.4	-0.5	-3.7%
ACP-016	101.5	100.4	-1.1	-1.1%	41.1	40.5	-0.6	-1.5%

Table 2. Savings quantified for entire project, assuming two case studies are representative of all 15 air compressors.

	Utility Peak Demand Savings (kW)	PJM capacity savings (kW)	Energy Savings (kWh/year)	Energy Cost Savings ($/year)	Cost to Implement ($)	Simple Payback (years)
Total Comp Air System	17.9	17.9	120,640	$8,957	$68,872	7.7

In conclusion, the RPC devices did not prove to be a technology the efficiency program wanted to pursue moving forward. Furthermore, much of the available product literature is complicated and confusing, discussing topics like electrical harmonics, phase angles, reactive power, and making simple claims to "reduce energy in the lines." It is easy to see how accessible, high quality case can provide much value to both manufacturers and efficiency program managers, when deciding on technologies to pursue or help quickly refute a technology they are skeptical.

New Large Dishwashers.

This case study features an example of a project that may have been a useful product to the customer for reasons not associated with efficiency. However, the project was misleadingly spotlighted by the vendor as an efficiency project. A large commercial dishwasher vendor sold their product on the assumption that their new dishwasher system would be more energy efficient. The vendor was unable to provide information on why the new dishwashers would achieve energy savings but did provide significant savings number estimates they had calculated. We were asked to conduct M&V of the vendor's projects to determine if there was validity to the savings claims. In two case studies we found little to negative savings, as shown in the summary table, below. In this situation there was no significant energy-saving technology advantage to the new dishwashers, and the electric resistance booster heater was basically the same technology in both the pre- and post-scenarios.

Table 3. Savings and economic analysis of dishwasher projects.

	Utility Peak Demand Savings (kW)	Energy Savings (kWh/year)	Energy Cost Savings ($/year)	Cost to Implement ($)	Simple Payback (years)
Case Study 1	2.1	1,152	$271	$35,058	129.5
Case Study 2	-6.8	-2,173	-$783	$28,451	NA

In conclusion, this is an example where the vendor's provided case study data and energy savings claims are unreliable. However, an end-use customer does not have easy access to reliable case studies. The M&V on these two projects are potentially the only credible case studies that exist for this type of dishwasher retrofit.

Type 2: Process Specific Technologies

This section highlights energy efficiency projects applied to specific manufacturing processes. This type of case study can be difficult to efficiently disseminate because there are so many different manufacturing processes and efficiency options. Additionally, manufacturers are competitive, and often hesitant to share new processes or equipment information they develop in-house. Therefore, high quality sharable case studies rarely exist. For example, if a unique silicon wafer manufacturer upgrades their crystal grower incubator, it's likely that M&V only gets performed if an energy efficiency program requires it. Additionally, the lessons learned from this case study will only get shared with another silicon wafer plant with efforts from the efficiency program managers.

Wastewater Treatment Plant Aeration Technology Upgrades

We evaluated upgrades of converting "jet aeration" systems into "fine air bubble diffuser aeration" systems for 16 aeration tanks across two different wastewater treatment plants. The treatment of wastewater consists of collecting and aerating the waste in large open-air, in-ground tanks. The aeration promotes microbial digestion of organic matter in the water. Older aeration processes rely on jet aeration systems, which require both mixing pumps and air blowers to push mixed water and air through nozzles into the tanks. However, fine air bubble diffuser systems more evenly distribute air throughout a tank via porous diffusers across the tank floor. This aeration system is a more effective method of providing oxygen to the tanks, places less demand on the central blower system, and requires no mixing pumps. For example, in Case Study 1 of Table 4, 28 20-hp mixing pumps were removed across 14 tanks, plus almost 700-hp of a 2,100-hp blower system was taken offline after the conversion to fine bubble diffuser aeration. Images of the pre- and post-project setups in an empty tank are shown below.

Figure 1. Schematic of high velocity jet aeration pushed through one pipe (left) vs. low pressure fine air bubble diffuser aeration through many discharge points (right)

Table 4. Savings and economic analysis of aeration projects.

	Utility Peak Demand Savings (kW)	PJM Capacity Savings (kW)	Energy Savings (kWh/year)	Energy Cost Savings ($/year)	Cost to Implement ($)	Simple Payback (years)
Case Study 1	534.0	372.3	4,639,022	$329,605	$3,242,245	9.8
Case Study 2	32.9	31.4	321,588	$22,454	$138,000	6.1

In conclusion, this specific technology upgrade concept is fairly well understood within the wastewater treatment industry. However, seeing the actual cost benefits of real implemented projects is rare. Case studies like these can significantly help manufacturers properly prioritize these upgrade investments against other competing investments. For example, a manufacturer may be able to conclude from these case studies that similar projects may fall into the five to ten year simple payback range. This is very helpful.

Plastic Extruder Barrell Heat Controls Upgrades

We evaluated PLC controls upgrades to 11 different plastic extruder lines, each containing multiple extruder barrels, for a total of 30 barrels. Each barrel has a cooling water circuit and electric heater bands. Heat is produced within the extruder from friction between the plastic pellets and the extruder screw. The melted plastic must be kept within a certain temperature range dictated by the process. Thus, a cooling circuit provides chilled water to the extruder barrel to lower the temperature when necessary. Additionally, electric resistance heater bands cycle on if the temperature drops too low. This constant over-heating and over-cooling cycling wastes energy.

The PLC controller upgrades better control the cooling process. This includes utilizing a warmer cooling water temperature and better logic to control when cooling is activated, resulting in lower cooling water loads and less re-heating energy from the heat band. The case study savings and cost benefit analysis are shown in the table below.

Table 5. Savings and economic analysis of extruder controls projects.

	Number of Barrels	Utility Peak Demand Savings (kW)	PJM Capacity Savings (kW)	Energy Savings (kWh/year)	Energy Cost Savings ($/year)	Cost to Implement ($)	Simple Payback (years)
Case Study 1	3	0.0	-	39,809	$2,389	$21,191	8.9
Case Study 2	2	0.0	8.7	76,796	$4,608	$26,836	5.8
Case Study 3	3	0.0	-	67,311	$4,039	$27,083	6.7
Case Study 4	3	16.1	-	264,037	$17,388	$41,738	2.4
Case Study 5	2	29.7	-	297,213	$20,684	$41,842	2.0
Case Study 6	2	83.8	53.2	466,193	$36,016	$53,000	1.5
Case Study 7	3	11.0	-	403,584	$25,271	$49,901	2.0
Case Study 8	3	62.2	69.3	486,365	$35,153	$59,050	1.7
Case Study 9	3	0.0	-	109,208	$6,552	$40,744	6.2
Case Study 10	3	7.8	-	443,960	$27,386	$55,718	2.0
Case Study 11	3	0.0	83.6	731,986	$43,919	$78,459	1.8
Total	**30**	**210.6**	**214.8**	**3,386,462**	**$223,405**	**$495,562**	**2.2**

In conclusion, this is a fairly process specific upgrade for extruder lines, but extruder lines are highly common and prevalent across the country. It is likely that high volumes of this opportunity or similar opportunities exist. Without real life case studies, it is difficult to put projects like these on the radars of facility engineers.

Type 3: "Low Hanging Fruit" Projects with Hard-to-Find Real Numbers

This section highlights valuable studies that collected rarely seen high quality energy savings numbers on efficiency projects that are generally accepted as obvious "low hanging fruit" type projects. The problem with "low hanging fruit" projects is that they are often more complicated or time intensive than customers realize to implement and evaluating their true cost savings is tricky. These types of opportunities are so prevalent that it is necessary to often incentivize them prescriptively within efficiency programs, and cost-benefits are evaluated with rough engineering calculations or rules of thumb. For this reason, it can be rare to capture high quality M&V case studies. Throughout the development of one Ohio efficiency program, we were provided the luxury of conducting detailed M&V for several high-volume, low hanging fruit type projects in an effort to formulate prescriptive measure guidelines. The two efficiency measures presented in this paper are compressed air leak repairs, and fan motor assembly recommissioning.

Comp Air Leaks

As means to designing a more prescriptive compressed air leak repair program, we were commissioned to conduct detailed M&V of focused compressed air leak repair initiatives across five different manufacturers. The leaks were identified, tagged, and documented by a local vendor for the pre-repair scenario. For the post-repair scenario, the vendor and manufacturer provided a log of all the repaired leak repairs. The five sites were selected strategically such that we could conduct some of our testing and metering during non-production hours, to remove the variable of process loads. During the site visit we would tour the site to validate all production equipment was off and no notable air loads existed, other than leaks. The sites were also selected such that they had air systems sized such that a single variable frequency drive (VFD) compressor could primarily meet all air demands during our testing periods. Having a single VFD compressor to meter further minimized extra variables and made it easy to calculate the plant's leak load as a function of each VFD compressor's CAGI performance curve.

We conducted three different types of tests during pre- and post-scenarios at each site. One test was a simple power draw metering for several weeks pre- and post-repairs across multiple production and non-production periods. The second test was high resolution one second interval data collected during our non-production site visit. This high-resolution data increased our accuracy of leak load calculations from the CAGI performance curve. Third, we installed pressure transducers throughout the plant to ensure consistent pressure settings, and conducted a system bleed down test, and then a re-pressurization test to compare the timespan for each in pre-vs post-repair scenarios. All three tests were interesting and useful, but the simple non-production power draw reading proved to be the most reliable test, and the other two were primarily used to validate that the project did reduce air leak loads.

Of the five case studies, only three of the plants put serious effort into repairing identified compressed air leaks. The largest of the three plants put forth the most significant effort, claiming to have repaired 97 leaks. This largest site was an older facility with acres of compressed air distribution. Our testing calculated the pre-scenario leak load to be 66% of the plant's average overall air demand, and the post-scenario leak load to only be 27%. For reference, according to the U.S. Dept. of Energy's (DOE) Compressed Air Challenge, 30% of a facilities' compressed air is lost to leaks on average. So, with that baseline, Case Study 1 went from a worst performing plant to a high performer. The case study results are summarized in the following table.

Table 6. Savings and economic analysis of compressed air leak projects

	Utility Peak Demand Savings (kW)	PJM capacity savings (kW)	Energy Savings (kWh/year)	Energy Cost Savings ($/year)	Cost to Implement ($)	Average CFM Reduction	Pre- % Avg. Load to Leaks	Post- % Avg. Load to Leaks
Case Study 1	121.3	121.3	1,062,588	$75,400	internal	765	66%	27%
Case Study 2	17.2	17.2	150,688	$10,692	internal	97	53%	33%
Case Study 3	6.7	6.7	46,310	$3,422	internal	20		
Case Study 4	Customer failed to complete initiative to repair leaks & no significant savings observed in data							
Case Study 5	Customer failed to conduct initiative to repair leaks & negative savings observed in data							

In conclusion, even though repairing compressed air leaks is a widely known efficiency measure, it is less known how much savings can be verifiably achieved. Though this data does exist in other publications, if you know where to look, these case studies were performed at a rarely high quality standard, thanks to agreeable manufacturers willing to partake in the studies. Efficiency projects like this can always benefit from more case studies. Manufacturers will only pursue "low-hanging fruit" if they trust there is value in pursuing it.

Motor Fan Assembly Updates and Cleaning

This project consisted of replacing the sheaves, bushings, the v-belt (cogged), and the motor base to update a 15-hp return air fan motor assembly. The original sheaves accommodated three cogged v-belts. The new sheaves accommodate a single cogged v-belt. The original base was replaced with a self-adjusting base. In addition to the motor updates, during our metering period, the air handler unit and thus the return air fan was cleaned via pressure washing. To our surprise we were able to capture clear energy savings from the cleaning. The metered power reductions can be seen in the trend data below.

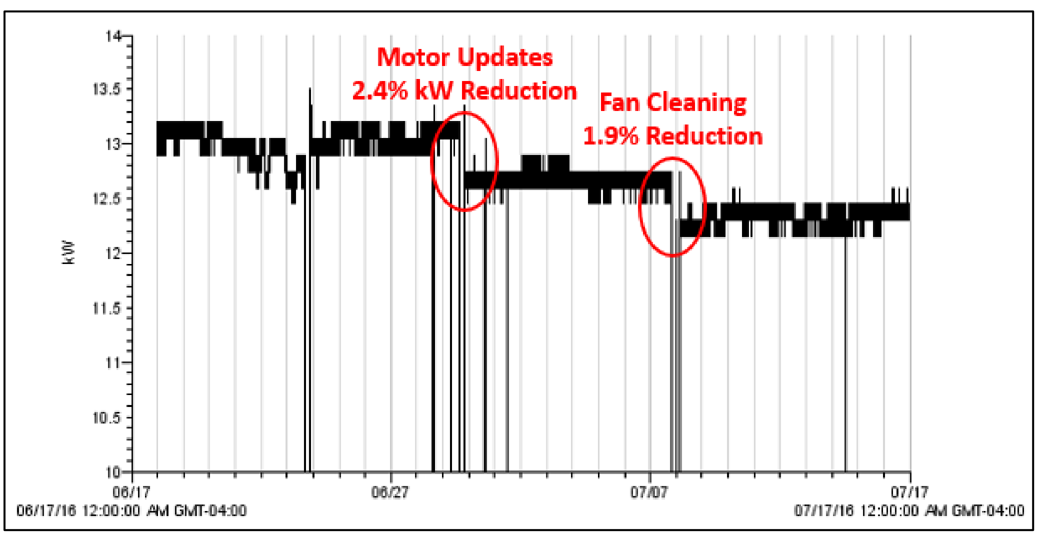

Figure 2. Fan motor power trend data for pre- and post-project implementation.

Table 7. Savings and economic analysis of motor updates and cleaning

	Peak Demand Savings (kW)	Reduction from Baseline (%)	Annual Energy Savings (kWh/year)	Annual Energy Cost Savings ($/year)	Cost to Implement ($)	Simple Payback (years)
Motor Updates	0.32	2.4%	2,727	$194	$3,749	19.3
Motor Cleaning	0.26	1.9%	2,651	$184	$1,812	9.8
Total Combined	**0.58**	**4.3%**	**5,378**	**$378**	**$5,561**	**14.7**

In conclusion, this energy efficiency project had a surprising amount of savings with surprisingly clear data obtained. Third party M&V on such a mundane improvement is rare. This one case study is helpful, but probably insufficient by itself to draw generalized conclusions about energy savings from motor upgrades and cleaning. Better case study sharing among efficiency programs would help fill this gap in information and determine if this should be more widely adopted as an incentivized efficiency measure.

Type 4: Emerging Technologies

New energy efficiency products are always emerging and being offered to manufacturers. Many of these products are valid innovations and accelerating their market adoption is important. Energy efficiency programs are great catalysts for this. The act of incentivizing these new technologies helps to validate their legitimacy in the eyes of an end-user, and the incentives can help mitigate the first cost risk until the technology gains in popularity. In many instances these emerging technologies come with case studies provided by vendors, but non-vendor case studies are hard to find. Additionally, the true economics of these technologies can be mysterious.

Convert PSC Motors to EC Motors

Back in 2010, replacing standard permanent split capacitor (PSC) motors with electrically commutating (EC) motors was a new concept within Ohio’s manufacturing and commercial sectors. In fact, still today knowing where to apply EC motors, and what their economic paybacks are can be very confusing to the average end-use customer.

Large industrial sites can have thousands of fractional horsepower motors throughout their facility and campuses. These fractional horsepower motors power condenser fans, evaporator fans, exhaust fans, small pumps, etc. Currently, most of these fraction horsepower motors are PSC. Unlike larger horsepower PSC motors, fractional horsepower PSC motors have very poor efficiencies, typically around 30%. EC motors have significantly higher efficiencies at fractional horsepower sizes.

In an effort to help develop accurate prescriptive savings numbers for an efficiency program, we were commissioned to provide true power, spot power and amperage metering M&V across 71 EC motor retrofits at six different locations. This analysis was then extrapolated to a larger portfolio of 471 motor replacements, which we only did visual inspections with no metering. The table below summarizes the determined savings, and simple payback where all the information was available. It can be seen that the EC motor technology does have a longer simple payback than other standard prescriptive measures, but in most cases would still pay back within the product lifespan. The longer simple payback for case study 4 is potentially due to higher first cost from the project being spread across 19 sites. It should be noted that the majority of EC motor applications in these case studies are for condenser and evaporator fans in refrigeration applications.

Table 8. Savings and economic analysis of EC motor replacements

	Number of Stores	Number Motors Metered	Number Motors Replaced	Utility Peak Demand Savings (kW)	Annual Energy Savings (kWh/year)	Annual Energy Cost Savings ($/year)	Cost to Implement ($)	Simple Payback (years)
Case Study 1	1	23	29	2.3	14,582	$301	$4,368	14.5
Case Study 2	1	17	17	1.5	11,710	$205	-	-
Case Study 3	1	13	13	0.4	3,279	$58	-	-
Case Study 4	19	18	104	7.9	67,034	$1,128	$31,396	27.8
Case Study 5	1	0	296	9.2	80,337	$1,324	$15,600	11.8
Case Study 6	1	0	12	0.8	6,722	$114	$1,495	13.1

In conclusion, ten years ago EC motors were an emerging technology. Now they are more commonplace, but their economic paybacks are still confusing or vague to many consumers or design engineers. Case studies like these can be compiled across efficiency programs to provide a clearer picture of where EC motors save the most energy, what their potential paybacks are. Furthermore, it would be interesting to see how the cost benefit of EC motors changes over time as the technology gets adopted. Energy efficiency programs might possess the fastest and highest quality mechanisms to collect and deliver this information.

Conclusions

Although there are many organizations and initiatives built around sharing energy efficiency data and knowledge, there is still a lot of data that gets missed, especially within the programs we worked. This paper is only one small contribution to a large field of knowledge sharing efforts. Additionally, the manufacturing sector is a challenging sector to conduct data sharing because there are so many niche processes and needs.

Upon reflection of our work within Ohio, one of the most impressive best practices one of the energy efficiency programs implemented was to have all M&V projects be fully transparent and documented within a technical memo that was issued to the client. Not all programs we worked with had this practice. Some programs kept all the engineering analysis and technical documentation behind the scenes and primarily only engaged with the customers for investigative questions and issuing the determined incentives. The act of requiring technical memos, with documented savings and analysis calculations and methodologies helps make all of the information conducive for sharing. Also, the act of providing the memos to the customers created transparency and useful investment validation to the organization's stakeholders who took on the investment risk. Although we did not take pleasure in telling clients they would receive no rebate, as engineers we found it equally rewarding to conduct analyses that detailed little to no energy savings as it was to issue memos with large savings. In all scenarios we appreciated the chance to educate the client on what went right, or what went wrong in their project, and set them up for future success. We recommend all efficiency programs consider this requirement of formal technical memos or reports at the conclusion of each M&V project.

Even if we cannot share all our knowledge with everyone we want, one of the greatest benefits of working within these energy efficiency programs and conducting such a significant number of case studies is the ability to build our own team's knowledge. We are fortunate to directly work with hundreds of end-use customers and manufacturing trade organizations where we can anonymize all of these success and failure stories and directly use them to help our clients make similar decisions. Manufacturers are highly sensitive to risk, and the comfort of trusted case studies is often one of most useful tools for overcoming anxiety around efficiency project investments.

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