The Silver Bullet List: Impactful Investments in Energy Efficiency

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ABSTRACT

This paper seeks to find out where to focus funds in order to achieve maximum energy savings. A comparison of energy efficiency projects after an energy audit to projects not associated with an energy audit reveals that projects that are initiated after an energy audit are 27% cheaper for electrical projects and 15% cheaper for natural gas projects on a per unit energy basis. Additionally, an evaluation of different technologies based on the magnitude of energy savings, popularity, and cost effectiveness resulted in a ranked list of technology categories that are considered the best for implementing impactful energy efficiency projects for electricity savings and natural gas savings.

Furthermore, the evaluation revealed that popularity of nearly all energy efficiency technologies is increasing. Overall, the analyzed trends indicate that large opportunities for implementing energy efficiency projects are available and can be cost effectively implemented with the aide of energy efficiency professionals.

Introduction

The business of energy efficiency is focused on the future because we can only save on future energy use. As a result, the best energy efficiency technology will be the one with the greatest future potential. This analysis seeks to predict which technology categories are the best for energy efficiency and what value energy efficiency experts provide by evaluating records of past energy efficiency projects. Yogi Berra succinctly described the inherent limitations and difficulty of this analysis when he stated, "It's tough to make predictions, especially about the future."

Undaunted, this analysis will progress with the objective of seeking to determine the value of energy efficiency experts in the field by evaluating projects that were initiated after an energy audit and those not associated with an energy audit. Additionally, this analysis seeks to identify the best energy efficiency technologies based on three versions of the term best.

1. Technologies that have the greatest energy saving potential.
2. Technologies that are the most popular.
3. Technologies that are the most cost-effective.

Data Source

The dataset used in this analysis is a composite of two privately held datasets that contain details related to energy audits and custom rebate projects (projects) for a Midwest utility.[1] The trends that can be extracted from this data are being made available because of its potential benefit to the industry and society. The dataset does not entirely encompass the utility's program offerings, but it is considered representative. The sample size is large (2,858 projects), represents

[1] Alliant Energy Corporation

a diverse customer base, and covers an acceptable timeframe (over 10 years of completed projects and 5 years for energy audits).

A limitation of the dataset is that technology categories like lighting are recorded in the database; not the specific equipment installed before and after the project. This means that results can not explicitly state which technologies, like LED lighting, are the best. However, experienced energy efficiency professionals can overcome this limitation with an understanding of what specific equipment is available in the market. Technologies related to industrial processes are also recorded under a single category (processes) so specific process configurations or equipment cannot be investigated. The data does reveal the overall opportunity trend for industrial processes; which is informative to utilities, customers, and others.

Additionally, the energy savings reported for each technology is dependent on what type of energy the customer is being supplied. This means that, for many technologies, only the electrical energy savings or the natural gas energy savings is calculated; not both. The limited fidelity of the dataset is a restriction on the depth of the analysis, but the breadth of coverage remains intact. The first use of the data will be to ascertain if the value of energy audits extends beyond customer satisfaction and into quantifiable financial value to the utility.

Value-added Energy Audits

The energy efficiency funnel, diagrammed in Figure 1, represents the stages that a customer passes through in order to progress towards the completion of an energy efficiency project. The majority of energy efficiency projects bypass a formal evaluation of the energy saving potential of a customer's facility via an energy audit and skip directly to the commitment stage[2].

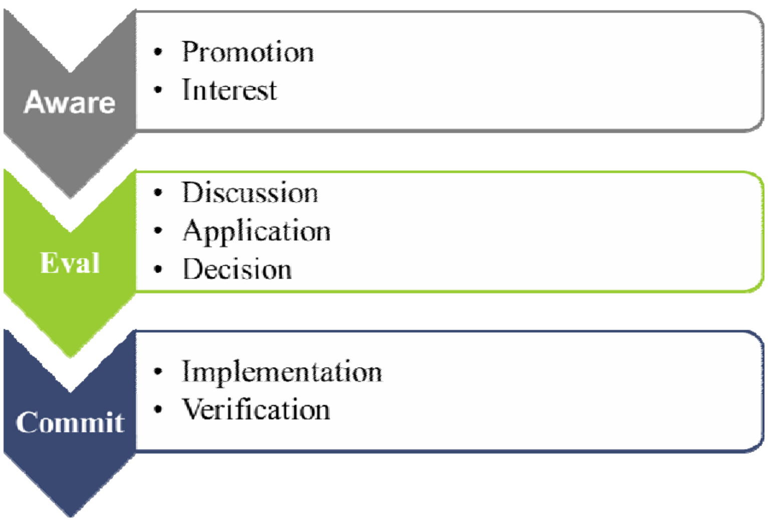

Figure 1: Energy efficiency funnel

As a result, an analyst must rewind the progression of the project so that the details can be discussed with the customer and the customer can make a more informed decision based on an estimate of energy and cost savings. It is suspected that the cost to the utility company for energy efficiency projects is lower when an energy audit is conducted before the projects are initiated.

[2] Only 17% of evaluated projects were preceded by an energy audit.

The cost per unit of saved energy is used to evaluate the impact energy audits have on projects. The earliest energy audit in the 763-audit database was completed in July, 2010. Therefore, only projects submitted after July, 2010 were used in this portion of the analysis, which resulted in a sample size of 1,562 projects. These projects were divided into those that occurred after an energy audit (After Energy Audit) and those that occurred prior to an energy audit or no energy audit for the facility was completed in the specified timeframe (No Energy Audit). Energy audits are provided by the utility so the cost of the audit should be incorporated into the project cost for the utility's perspective. This was done by determining the unit cost of identified savings from the energy audit ($/kWh and $/therm) and then multiplying these unit costs by the project's savings (kWh and therm). As a result, the utility cost for a project is the aggregate of the rebate analysis fee, rebate amount, and a portion of the energy audit. The average unit cost of all 1,562 projects initiated after July, 2010 was used as a baseline for comparison so that the difference between the two project types, No Energy Audit and After Energy Audit, could be compared as shown in Figure 2.

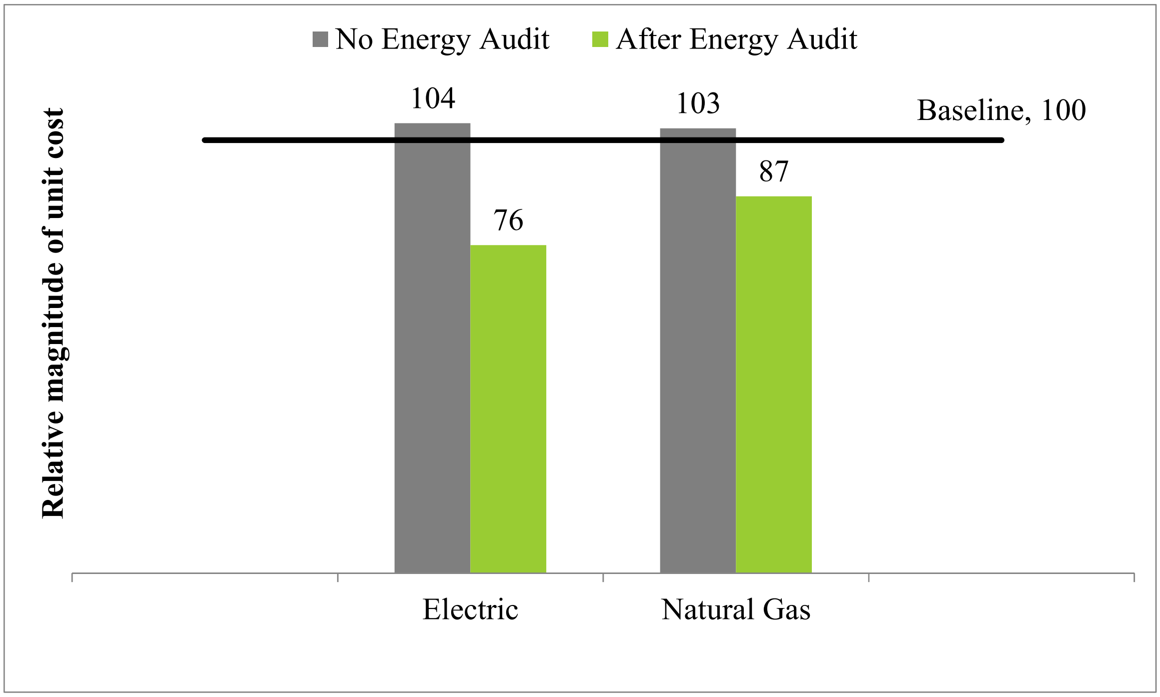

Figure 2: Comparison of unit cost of energy efficiency projects from utility perspective

It is easy to observe that energy efficiency projects that follow an energy audit are cheaper for the utility company than those that are not associated with an energy audit. Electrical energy savings are approximately 27% cheaper on a per unit energy ($/kWh) basis and natural gas energy savings are 15% less than energy-saving projects that are not preceded by an energy audit, on a per unit energy basis ($/therm). These results clearly convey the quantifiable value of energy audits and the energy efficiency experts that conduct them; which echoes the conclusions of a past energy audit value assessment. (Maxwell, 2013)

Relying on the knowledge and experience of experts in the field is good, but it is impractical and unnecessary to conduct an energy audit for every one of a utility's customers. It is just as valuable to know what energy efficiency technologies are the best so that they can be promoted and supported independent of energy audits.

Defining the Best Energy Efficiency Technologies

Determining the best energy efficiency technology from a database of projects is like predicting what car will win a race by looking at what has already happened in the race. You need to know how fast the car is going (magnitude), the car's acceleration (rate of change), and the distance remaining in the race (market potential). The dataset can be used to determine the current magnitude and rate of change. However, the market limits cannot be determined from the data, even if the theoretical limitations of each technology are known, because the opportunity to implement the most efficient technology is unknown. Some may speculate that the rate of change of a technology correlates to market limits. That is, the more positive the change the more positive the market potential and the more negative the change the more negative the market potential. But this is like predicting the distance remaining in a race by how fast a car is accelerating. In drag racing this may be accurate, but market adoption of technology is best predicted with Student's t-distribution; which has more than 50% of the market potential remaining when the rate of change starts to decrease. (Weisstein, 2015)

Additionally, advancements in technology create new adoption curves that intersect and disrupt previously established trends. This means that the rate of adoption for a particular technology may experience points of undulation or inflection (pit stops or speed zones) that do not predict the market's remaining potential (distance left in the race). For example, T12 fluorescent lighting that is being operated today may be replaced with light emitting diode (LED) lighting instead of T8 fluorescent lighting.

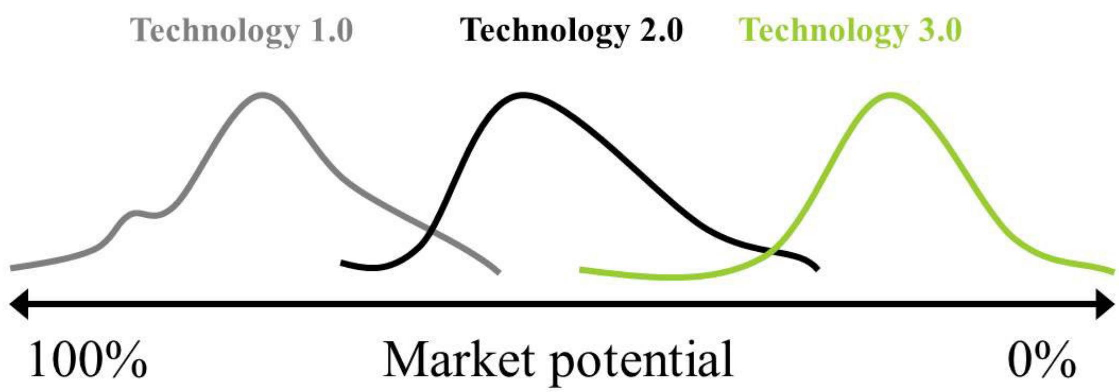

Figure 3: Cascading Technology Adoption Curves

As a result of these limitations, the ranked results presented in this document are derived from the magnitude and rate of change of each investigated variable and ranked using Pugh's method.[3]

The Best Energy Saving Technology

As Figure 4 shows, the technology with the best energy saving potential will primarily have the largest magnitude of energy savings (kWh, therms) because the magnitude of savings is

[3] Ranking based on a weighted sum of the ranked average magnitude and rate of change; referred to as primary or secondary criteria. When two technologies result in the same cumulative rank, the one with the higher ranked primary criteria will be the higher ranked technology.

an attribute of the technology itself and not dependent on the market. Secondarily, the greatest increase in energy savings over time indicates overall market acceptance and large opportunity. If two technologies have the same cumulative ranking the one with the largest magnitude energy savings will be attributed a higher rank (i.e. be considered better).

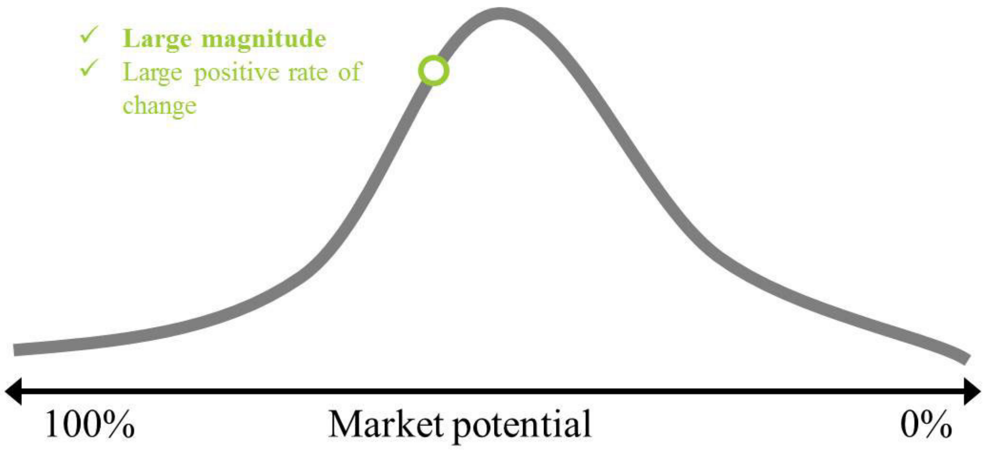

Figure 4: Graphical representation of criteria for the technology with the best energy saving potential

The Most Popular Technology

The most popular technology in the near future will primarily have the greatest positive rate of change in quantity of projects, which is assumed to correlate to increasing market demand. The second criterion is the magnitude of the quantity. The magnitude is indicative of the incumbent energy savings technology, which may still have significant market potential. This is graphically represented in Figure 5.

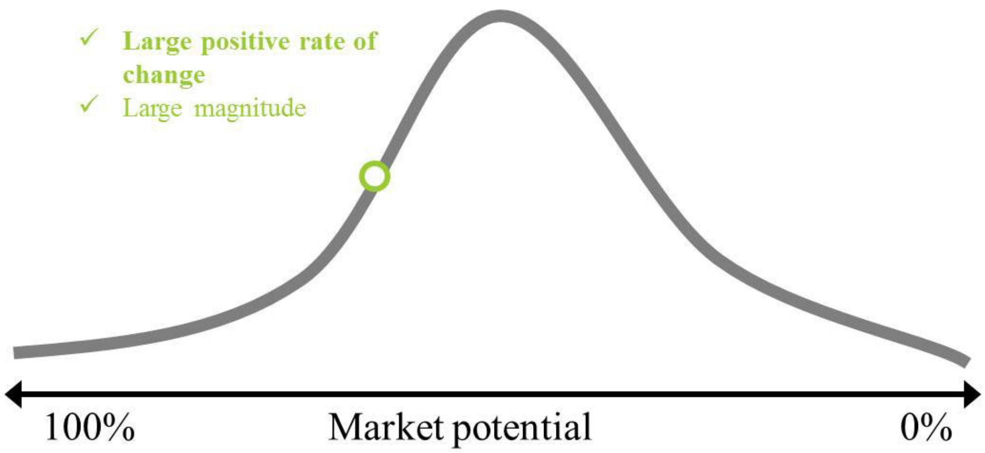

Figure 5: Graphical representation of criteria for most popular technology

The Most Cost Effective Technology

Figure 6 illustrates the most cost effective technology, which will primarily have the greatest negative rate of change in the unit cost of energy saved. This signals that the technology is quickly becoming cheaper. Secondarily, the technology with the smallest unit cost of energy saved is already the cheapest option.

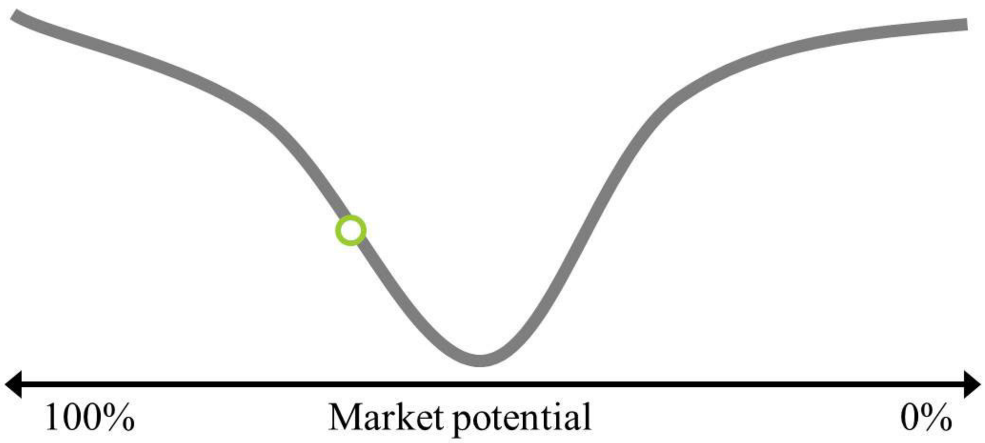

Figure 6: Graphical representation of criteria for the most cost effective technology

Best Energy Savings Technologies

Electrical energy saving potential for each technology is defined as the electrical energy savings (annual kWh) per project for each technology. Table 1 provides the ranked list of technology categories based on energy savings per project. The table also includes the relative average magnitude of the energy savings where the baseline energy savings magnitude is equal to the average of the datum and set to 1. Additionally, the magnitude and direction of the rate of change in the energy savings per project is listed.

Table 1: Technology categories ranked by electrical energy savings

Technology category	Rank	Relative average magnitude	Rate of change	
			Direction	Relative magnitude
Process	1	3.58	+	85.2
Lighting	2	1.88	+	117
Refrigeration	3	0.34	+	12.1
New Construction	4	1.44	-	59.4
Controls	5	0.15	+	11.3
Compressed Air	6	0.96	-	31.4
HVAC	7	0.47	-	3.50
VFDs	8	1.10	-	119
Motors	9	0.08	-	2.61
Envelope	10	0.02	-	0.33

This table reveals that energy efficiency technologies that improve processes can be expected to provide the largest energy savings in the future. Also, only four of the ten categories have positive rates of change (Process, Lighting, Refrigeration, and Controls). This indicates that energy savings from these technologies is increasing over time. In contrast, the other six technology categories are seeing a decline in the energy savings per project. This is likely because existing equipment in these technology categories is already highly energy-efficient or the marketplace is becoming saturated with the technology.

Natural gas saving potential for each technology is defined as the fuel energy savings (annual therms) per project for each technology. Table 1 provides the results of the analysis where the baseline energy savings is set to 1 so a relative comparison among technologies can be provided.

Table 2: Technology categories ranked by natural gas energy savings

Technology category	Rank	Relative average magnitude	Rate of change	
			Direction	Relative magnitude
HVAC	1	2.30	+	1.58
VFDs	2	0.23	+	1.36
Refrigeration	3	0.05	+	0.28
Process	4	4.42	-	7.08
New Construction	5	2.45	-	5.99
Envelope	6	0.42	-	0.17

It is important to note that only six of the ten technology categories were considered to have adequate natural gas savings.[4] As expected, energy efficiency projects related to heating, ventilating, and air-conditioning (HVAC) provide the greatest opportunity for future natural gas savings. Natural gas savings from process improvement projects are a significantly higher magnitude of energy savings, but they appear to be declining quickly (i.e. diminishing returns). It is worth pointing out that increases to refrigeration systems, which are typically in grocery stores, provide an opportunity for natural gas savings. The savings is small, but increasing.

Most Popular Technologies

The popularity of a technology is simply defined as the quantity of projects completed. Table 3 provides the ranked list of electrical energy saving technology categories base on their popularity.

[4] The technology categories excluded are those that principally save electrical energy, like lighting.

Table 3: Technology categories that save electricity ranked by popularity

Technology category	Rank	Relative average magnitude	Rate of change	
			Direction	Relative magnitude
Lighting	1	3.24	+	7.25
Process	2	1.49	+	1.88
HVAC	3	1.51	+	1.15
Refrigeration	4	0.53	+	0.73
Compressed Air	5	0.53	+	0.08
Controls	6	0.33	+	0.35
New Construction	7	1.44	-	0.95
Motors	8	0.23	+	0.13
VFDs	9	0.43	-	0.71
Envelope	10	0.25	+	0.08

As expected, lighting is the most popular energy efficiency project by a substantial margin. Eight of the ten categories show positive rates of change. This suggests that, overall, implementing energy efficiency projects is becoming more popular. The first technology category with a negative rate of change is new construction. This is not surprising given the timeframe that the analysis covers, 2010 to 2015. What is interesting is that the popularity of variable frequency drive (VFD) projects is low and decreasing. This is likely the result of a prescriptive rebate being made available to the technology so that custom calculations are performed on a less frequent basis. It may also signal that popularity is high and a gradual decrease in implementation is on the horizon.

Like electricity-saving technologies, the popularity of natural gas saving technologies is determined from the quantity of projects completed. Table 4 provides the results for natural gas saving technology popularity.

Table 4: Technology categories that save natural gas ranked by popularity

Technology category	Rank	Relative average magnitude	Rate of change	
			Direction	Relative magnitude
HVAC	1	1.56	+	31.5
Process	2	0.78	+	8.92
New Construction	3	1.13	-	40.5
Envelope	4	0.53	-	3.93

It is important to note that only four of the ten technology categories were considered to be applicable and have substantial enough natural gas savings to be included. The HVAC technology category is once again the best technology for saving future natural gas energy. Also, as previously observed, new construction projects have a large negative rate of change; which indicates a strong decrease in recent popularity because of national economic downturns in the late 2000s.

Most Cost Effective Technologies

The cost effectiveness of a technology is evaluate based on the unit cost of energy ($/kWh). Table 5 provides the ranked list of technologies base on their cost effectiveness.

Table 5: Technology categories that save electricity ranked by cost effectiveness

Technology category	Rank	Relative average magnitude	Rate of change	
			Direction	Relative magnitude
VFDs	1	0.41	+	0.84
Compressed Air	2	0.49	+	0.91
Refrigeration	3	0.69	+	0.61
Lighting	4	0.67	+	0.99
Motors	5	1.81	-	7.51
Controls	6	0.75	+	0.92
Process	7	0.69	+	1.37
Envelope	8	1.20	+	4.52
HVAC	9	1.79	+	1.88
New Construction	10	1.49	+	5.47

The table reveals that the unit cost of nearly all technologies is increasing as indicated by 9/10ths of the technologies having a positive rate of change. This is to be expected because of economic factors like inflation and increasingly stringent energy codes. The table also confirms an intuitive assumption that more complex projects like HVAC, building envelopes, and new construction are going to be more costly. Interestingly, the unit cost of motors is the highest of all technology categories, which makes sense because existing motors are already very energy efficient. It is worth noting that the unit cost of process and controls projects is lower than the average unit cost of all technologies.

Like electricity-saving technologies, the popularity of natural gas saving technologies is determined from the quantity of projects completed. Table 6 provides the results for natural gas saving technology popularity.

Table 6: Technology categories that save natural gas ranked by cost effectiveness

Technology category	Rank	Relative average magnitude	Rate of change	
			Direction	Relative magnitude
Process	1	0.56	-	0.11
HVAC	2	0.75	+	0.17
Envelope	3	0.85	+	0.08
Lighting	4	1.21	-	0.78
Refrigeration	5	1.85	-	9.59
Controls	6	0.92	+	2.12
New Construction	7	1.32	+	1.11

It was anticipated that process and HVAC technology projects would be the most cost effective projects and the table above confirms this. Interestingly, the unit cost of process projects is the lowest of the applicable technologies and the rate of change is negative, which indicates that the unit cost is decreasing over time. Lighting and refrigeration projects that save natural gas are typically associated with grocery stores or similar facilities were there is a large amount of simultaneous heating and cooling. Specifically for grocery stores, the display case lighting creates a load for the refrigeration system, the refrigeration system creates a load for the HVAC system, and the HVAC system creates a load for the refrigeration system. These complex interactions underscore the aforementioned advantage of energy audits.

Conclusions

Finally, the results of the three evaluations (best energy savings, most popular, and most cost effective) were combined and re-ranked so that the overall best energy efficiency technologies can be presented in Table 7 and Table 8. Figure 7 plots the magnitude of energy savings and the unit cost of each technology so that those technologies in the upper-left corner of the plot can clearly be seen as the best.

Table 7: Overall best technologies for electrical energy savings

Technology category	Rank
Lighting	1
Process	2
Refrigeration	3
Compressed Air	4
Controls	5
VFDs	6
HVAC	7
New Construction	8
Motors	9
Envelope	10

Table 8: Overall best technologies for natural gas savings

Technology category	Rank
HVAC	1
Process	2
Envelope	3
New Construction	4
Refrigeration	5

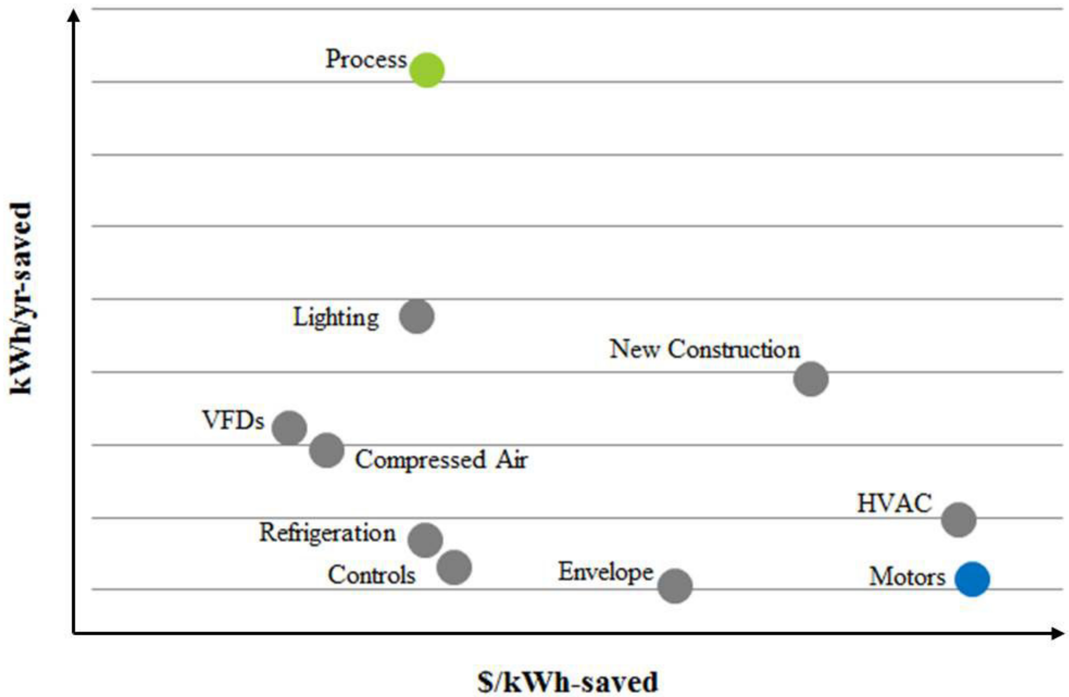

Figure 7: Plot of energy savings and unit cost for each technology

Energy efficiency projects related to processes are the best combination of electrical and natural gas savings. Lighting projects are the best for electrical energy savings. Technologies related to building envelops and electrical motors are the most expensive and least impactful. These results are no surprise to an energy efficiency expert. Importantly, many of the most cost-effective energy efficiency projects involve the interaction of multiple technology categories and require a holistic systems approach.

The most rewarding result of the analysis is that popularity of nearly all energy efficiency technologies is increasing and experienced energy auditors can add significant financial value to utility programs. Further, trends indicate that large opportunities for implementing energy efficiency projects are available.

References

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