Myth-Busting Savings Calculations

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Abstract

Myths abound in the calculation of energy program impacts. As a consulting firm with a broad clientele of energy companies, it is discouraging, almost shameful, how often we encounter the same errors, misconceptions, and pitfalls in the course of program evaluation.

In practice, energy and engineering companies make continuous adjustments to their computational methods in an effort to refine and improve the validity of energy and savings estimates. This reactive fine-tuning tends to occur at the program, utility, or regional level. The International Energy Program Evaluation Conference (IEPEC) is a biennial opportunity for leading evaluation engineers not to differentiate themselves, or showcase their wares, but to share their intellect and experiences. With the energy industry as uncertain as ever, we should embrace any chance to benefit from our collective experience and intellect. Mistakes should not be repeated, and myths must be debunked.

The authors, experienced professional engineers, have performed and/or managed ex-post evaluation of program impacts on well over a thousand energy-efficiency projects worldwide. This paper will share some of these experiences and feature case studies that involve popular energy myths, mistakes, and misnomers.

Introduction

Energy program evaluation is more than an objective assessment of program performance and effectiveness. Evaluation is more than the numerical basis for commission filings. Evaluation is an opportunity to close the feedback loop -- to take a retrospective assessment and apply findings, lessons, and insight towards program redesign and future implementation. Great opportunities are lost when one does not learn from the mistakes of oneself and others.

Fortunately, the "discrepancies" identified most often in evaluation are easily fixed. Developing detailed implementation procedures and comprehensive participation guidelines is a worthy but neglected upfront investment. One can streamline the program process by eliminating the array of assumptions, procedures, methods, and interpretations available to vendors, contractors, and customers. Such procedural improvements can help minimize anomalies, reduce variability, and improve program results.

Out of Sight, Out of Mind

The idiom "out of sight, out of mind" seems to best summarize these first few energy misconceptions. These examples also share a bit of false optimism in that they presume energy usage is lower or more tightly controlled than actuality.

"Equipment is Off Nights and Weekends"

Our research suggests a nearly universal tendency to underestimate off-shift equipment operation. When asked to characterize the operation of building energy systems, most facility personnel instinctively link equipment operation with business schedules. But building systems do not adhere to majority rules, e.g. lighting schedules better reflect the extremes (the first person in and the last to leave) than core business/production hours. As a result, many facility managers share a common, false perception that energy usage drops dramatically after hours.

This is particularly noteworthy because it has been shown that customers typically overestimate hours of operation. Some theorize that it is simply human nature to round numbers up; even that modern culture itself encourages expressions of excess. And, of course, efficiency programs inherently introduce performance bias whereby hours drive savings which drive incentives for consumers, as well as rewards for meeting targets at every level.

Partial occupancy situations rank amongst the least efficient, for few buildings can target lighting, heating, and cooling to precise, occupied areas. Consequently, shoulder and off-peak periods often harbor substantial opportunity for energy savings. With more utilities offering interval metered data as an online service for a modest fee, few excuses remain for off-peak energy ignorance.

In short, do not assume that your automated controls, operational procedures, cleaning crew, or security group are performing as expected. Controls in particular often inspire false confidence. Few things are more enlightening than an impromptu after-hours visit to see just how dark, quiet, and hot/cold it really is.

"…Except for Security Lighting"

On that note, a word of warning from engineers who actually have performed midnight site visits: you might be surprised by the number of lights that burn all night.

The term "security lighting" is usually a misnomer in this context, for interior after-hours lighting falls under building *safety* codes. Of course, one must adhere responsibly to regulations such as the NFPA Life Safety Code 101 which provide for a safe, lit egress path. But recognize that most lighting designers will err (appropriately) on the side of caution and configure more 24/7 lights than necessary. If your interior night lighting seems excessive, or if floor plans or space functions have changed over time, a review by a lighting designer and/or code official may be in your best energy interests.

On the other hand, most exterior lighting beyond an exit door does not fall under the jurisdiction of safety codes. These lights typically are either ornamental or truly security-related. In fact, some municipalities have codes which limit outdoor night lighting, and some organizations hope to impose stricter regulations on such "light pollution."

Ample opportunities exist at most facilities to reduce nighttime lighting usage both inside and out, either by controls or retrofitting existing fixtures. But be sure to preserve compliance with all applicable codes and regulations before making any changes, including corporate security, safety, and insurance policies.

Default Assumptions

Like it or not, all savings estimates are built upon assumptions, and those assumptions can make or break the project. Regrettably, many of these examples illustrate a tendency towards extreme values, which helps typecast evaluators as "savings critical" instead of "reality rooters!" Here are some of the most prevalent, and risky assumptions.

Annual Hours of Use = 8,760

"It is on all the time" rarely equals 8,760 hours, yet casual reports of "always on" are pandemic in energy calculations. Evaluators can practically guarantee that self-reported usage is overestimated if the hours-of-use are listed as 8,760 hours per year. Start at the ceiling, and there is only one direction to go, right? Seriously, very few measures truly operate continuously, 24 hours per day, 365 days per year unless actually required by code (egress lighting, exhaust fans, etc.) Yes, those air compressors, fans, and lights are always running, but do they really ride through all holidays and shutdowns without a single hour of maintenance downtime all year?

Annual Hours of Use = 8,736

Unfortunately, this is not the result of heeding that last point and granting one day of maintenance downtime per year. The estimate of 8,736 annual hours is derived from 24 hours/day x 7 days/week x 52 weeks/year ... except there are not 52 full, seven-day weeks in a year, so 8,736 hours represents only 364 days. To be really precise, one could argue that an annual estimate should represent 365¼ days per year – or 8,766 hours – to account for leap years.

Annual Hours of Use = 0

At the other end of the spectrum, beware energy-efficiency measures which eliminate equipment or usage altogether. This is most prevalent in central systems where multiple pieces of equipment operate in parallel, sequence, or serve as backup. Savings for an air compressor retrofit often presume the original unit is replaced by a new compressor. But more often than not, the original unit is not discarded but retained to 1) serve as emergency backup and 2) supplement load if needs increase. The same phenomenon is seen commonly with chillers, pumps, and even process machinery. Inevitably, this equipment runs again, so never say never.

Night Setback = 55 °F

This is just one of the "universal default" parameters seen repeatedly in HVAC engineering, the typical setback temperature in a heating climate. In of itself, it is not necessarily "bad", but this seemingly innocent creature is an accomplice in countless overstatements of savings. Without delving into thermodynamics, suffice it to say that most HVAC calculations grossly oversimplify the "energy versus temperature over time" relationship. To an energy engineer, night setback should be a red flag for bold, underlying assumptions regarding thermal mass and lag effects, equipment sizing, control bands, heating/cooling efficiency, and duty cycling. Setback is a great measure with tremendous savings potential, but unfortunately its savings are often notoriously optimistic.

Load Factor = 80%

This is another universal default: de-rating motor horsepower by 20% to provide a conservative estimate of actual load. But it is usually wrong… an adjustment in the correct direction, indeed, but still optimistic. Remember, energy efficiency is not a priority those who specify equipment; their primary interest is making sure that the equipment that fulfills the mechanical requirements. People would rather not believe that their costly motors are grossly oversized, but in general they are, and for many applications they remain a prudent technical choice for the operator despite negative energy implications.

"Your mileage may vary," of course; some motors regularly operate into their service factor (above 100% rated load). The authors by no means suggest a replacement for the 80% default. We merely emphasize that 50% loading is considerably more commonplace than one might think.

Popular "Mythconceptions"

Things are not always as they seem. These next myths are rooted in truth, but they become problematic when pushed just a little too far.

Cleaning Refrigerator Coils Saves Energy

No discussion of energy myths would be complete without this one. While thermodynamically it stands to reason that cleaning refrigerator coils improves heat transfer efficiency, actual studies have concluded no measurable evidence of efficiency gain by cleaning them (Litt, Megowan & Meier 1993). Studies have shown that the same largely is true for air conditioners. Coil fouling indeed reduces system capacity, but system efficiency is not significantly affected until air flow is obstructed 50% (Proctor Engineering Group 1999).

The Magic, Infinitesimal VSD

Variable speed drives provide excellent savings potential, especially at low loads, and metering and bin calculations prove it. The problem is that some of these calculations, while robust enough to express energy in usage, speed, or temperature bins, neglect other constraints such as minimum head pressure. Engineers must consider such constraints and set a "floor" in the calculations to fix VSD power at the minimum allowable state. In general, VSD power as low as 20% of constant speed is within reason. VSD savings remain substantial without out claiming that a 200 HP chilled water pump equals a hair dryer.

Less Lighting Requires More Heating

This is a common concept: more efficient lighting reduces internal gains and that translates into higher heating costs. The answer to this is yes…and no. Responsible engineers strive to incorporate thermodynamic effects in all energy calculations with appropriate rigor, accounting for interaction with metabolic heat, solar gains, and other factors. But consider this typical elementary school: a classroom with 25 occupants, large expanses of south facing glass, and a vintage heating system with hot water blowing by a faulty valve despite no call for heat from the local thermostat. The space temperature is 7 °F higher than the set point, and the teacher has cracked open the window. What is the heating impact of the super-T8 fixtures?

Fan Affinity Laws

Engineers often use "affinity laws" in design and energy calculations for pumps and fans. In one common form, fan laws state that the change in power (P_1/P_2) varies directly with (=) the change in speed (n_1/n_2) cubed, i.e. to the power three. One can see where this equation would be useful for estimating the energy savings of a variable-speed drive… and it is. But it is widely misapplied and misused. The apparent simplicity of the equation inspires its use by persons not aware of the underlying assumptions and restrictions governing its use.

Finally, even when applied correctly, it has been shown that the "law" reflects theory not reality. In practice, engineers have found that empirical data support an exponent on the speed ratio closer to 2.6 or 2.8. So once again, we find an equation in common use where the default parameter $(n_1/n_2)^3$ inherently overstates savings.

Interactive Effects Are Minor

Extremely few energy-utilization devices operate in pure isolation. Yes, that new motor on production line #2 really did increase total throughput! But it also raised plant temperature 2 degrees, which increased ventilation requirements, and now the AC units in the cafeteria aren't cycling as often. CFM usage is up on the air compressors in proportion to line speed, but they are also running hotter and a little less efficient with the ambient plant air intake. George in shipping is running two electric fans he brought in from home. And quality control is backing up because Betty is too hot now that the compressor room doors have to stay open. Sounds absurd? Not completely. Don't underestimate the butterfly effect.

Controls Have No Demand Impact

Not so long ago, in a land not so far away, efficiency programs dismissed kW impacts for VSD and control measures. But deregulation, reliability issues, capacity constraints, rising fuel costs, and real-time pricing have moved kW demand into the limelight like never before. While an efficiency measure can theoretically save energy but no peak demand, more often than not, diversified demand impacts are quantifiable and actually not zero.

Certainly, energy-efficiency cooling measures impart fewer savings on the hottest day of the year, but this does not mean there will be no demand savings. For this to be the case, all cooling equipment would have to be is sized perfectly such that it will precisely reach peak utilization on the hottest day of the year. The economic and litigious climate dictates otherwise.

Since the probability of a contractor getting a call back on an expensive installation is much less on an oversized system than an undersized system, conservative safety factors are employed to avoid complaints. Likewise, the overhanging threat of a lawsuit can give even the most confident and experienced designer pause when considering a "perfectly sized system". As a result, VSD controls on HVAC systems, when measured, show savings during coincident peak demand periods.

Somehow, the concept that VSDs do not realize coincident peak demand savings has migrated to non-weather dependent loads. We have seen 0 kW savings claimed for well pumping operations, food processing equipment and even milking machine vacuum pumps. The milking machine vacuum pump VSD controls are big savers because the pump are grossly oversized to maintain suction in the event that a milk machine slips off a cow's teat, resulting in a massive suction leak. An interruption in suction can disturbs the cow's milk production so the vacuum pump is sized for the production requirement plus a massive suction leak. Typically, before VSD controls were implemented for this application, the excess vacuum was throttled off, so the savings are substantial when moving to VSD controls. Since the event of the milk machine falling off a teat is infrequent, the demand savings are substantial, even during critical system peak periods, as the likelihood of a milking machine slipping a teat is not a temperature dependent function.

Peak Demand = Maximum kW

The term itself "peak demand" is a source of much confusion and continues to warrant explanation. The problem is rooted in the fact that kW itself is time-independent; it has yet to join up with an "h" for hours. But with power modulating 60 times per second, carrying random waveform transients, and subject to inrush surges and spikes, instantaneous "peak demand" in its most literal sense is meaningless. Accordingly, "demand" in our vernacular is – brace yourself – always an *average*… the average demand across a specific interval. A handheld power meters display a root-mean squared (RMS) value, an integrated average across the sampled waveform. Energy companies that generate and distribute electricity typically base demand charges on average[1] 15, 30 or 60 minute intervals. "Peak demand" suggests interest in the highest of these average demands, and with no qualifiers it implies the maximum over a full calendar year. Nowadays, peak demand usually is defined to characterize more specific time-periods in consideration of month, day of week, and time of day.

[1] The authors respectfully acknowledge all metering experts but contend that the discussion is complicated enough without explaining "sliding windows" and "buckets".

The Best Tool for the Job

The use of estimation tools has become prevalent among energy efficiency programs. For most cases, they give a reasonably accurate estimate of the energy impacts for typical efficiency measures. As with any tool, one should understand how it works before using it, for a powerful tool in experienced hands is dangerous.

One program we know spent a great deal of time developing a tool that estimated "effective full load hours" for a building's air conditioning system based upon limited input parameters. It was a reasonably accurate tool when applied to typical commercial buildings, but it failed miserably in three cases. One was medical facility running 100% outside air, the second had greatly oversized cooling capacity relative to the actual load, and the third facility was dominated by internal, non-weather dependent loads. It turns out that the tool was built upon data from buildings with return air, reasonable HVAC sizing, and minimal internal loads.

Efficient Equipment Reduces Energy Usage

Installing an energy-efficient thingamajig does not necessarily mean the thingamajig saves energy. Surely, there are "snake-oil" devices out there that purport false savings, but the real shame is when good equipment is misapplied, improperly installed, or not used as intended. Who hasn't seen an occupancy sensor that has been taped over? Or a programmable thermostat in override mode? Or compact fluorescent office lighting supplemented with halogen torchieres? Of course, these things happen all the time, and a certain amount of money spent on efficiency inevitably goes to waste.

Not so obvious, however, are wasted investments in the more big ticket items. It is so regrettable because they harness such tremendous savings potential, but until energy management systems come in a box along with a full-time, trained operator, EMS will continue to be one of the most underperforming efficiency measures. Without a doubt, automated controls are vital to the current and future state of energy in this country. But, like a tool in inexperienced hands, an EMS can wield destructive power. Consider this high-efficiency, variable-speed centrifugal chiller: a well-designed project, fully commissioned, and saving energy as intended for eight months straight… until the operator quits, his manager unwittingly disturbs the condenser and chiller water setpoints, and it goes unnoticed for two years.

We would be remiss if we did not mention "snapback" here, that not-so-distant relative of free-ridership and spillover. Snapback theorizes that the savings achieved via energy-efficiency may – behaviorally – justify users thereafter to consume more energy than they otherwise would have. Some have studied its effect and concluded that it is not particularly prevalent. They should meet my mother who sees "50% Off" so buys double or my sister who "saves room for dessert"…

Manufacturers Prioritize Energy Efficiency

Why do industrial efficiency projects consistently have a lower realization rate than commercial projects? Some program administrators attribute this to the technical complexity of industrial versus commercial projects. That may have something to do with it, but we have seen many technically sound projects fail in manufacturing plants due to largely interpersonal, labor/management, and philosophical conflicts.

In our market research projects, manufacturers almost universally describe themselves as being primarily interested in manufacturing product, with energy conservation or any other business considerations secondary to core production goals. This causes manufacturers to be overly cautious about introducing any potential improvements that may inadvertently affect production.

Understand that this does not mean that industry does not value energy-efficiency, only that there are other serious considerations which often take a higher priority. To successfully implement industrial energy efficiency project, it is important not only to realize this, but to respect it and communicate that respect.

Facility Managers Know Everything

At the risk of insulting the dedicated people who in many ways make doing business possible, this point simply emphasizes that building energy usage is incredibly complex and defies perfect understanding. Figure 1 illustrates the complex energy balance of a system that consists of a hypothetical industrial facility.

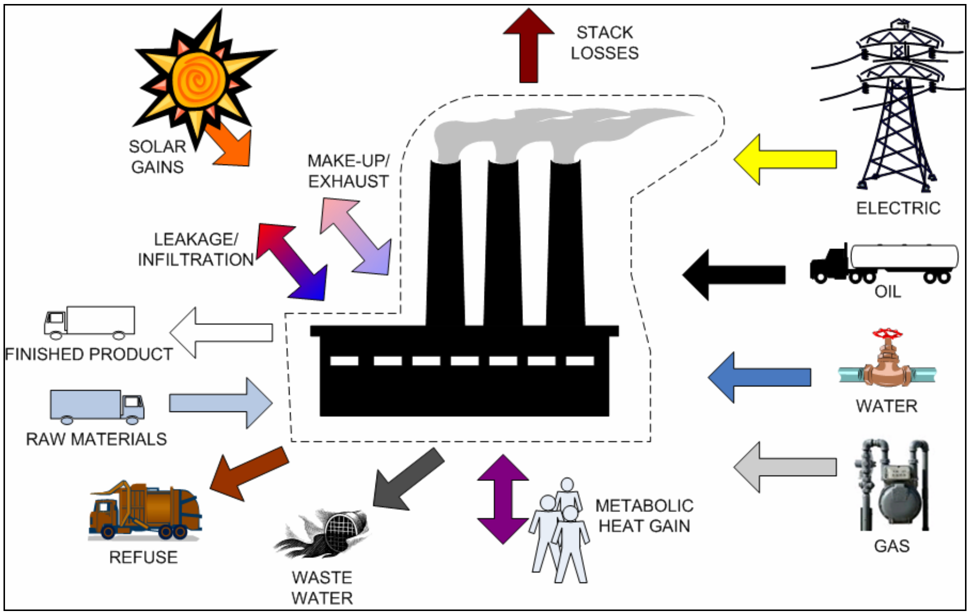

Figure 1. Energy Balance of an Industrial Facility

The drawing depicts commodity energy inputs from the right, material transfer of internal energy below and to the left, and typical ambient gains and losses above. According to the first law of thermodynamics, the internal energy E of the factory changes according to Q, the net heat gained or lost, plus W, the net work done to or by the system. Quantifying all of the mass, heat, and work transfer is a massive undertaking that is not recommended under normal circumstances. Once one recognizes the incredible complexity of a building as a system, it becomes more acceptable that some of the energy input, consumption, and losses are unknown.

Compressed Air Receivers Save Energy/Demand

Evaluators have seen instances when compressed air storage receivers have been installed without an appropriate pressure/flow controller. Similarly, evaluators sometimes find controllers installed but disabled or improperly configured. Without a positive pressure differential of 5-10 psi between a compressed air receiver and downstream distribution piping, there is no meaningful energy or demand savings benefit to installing a receiver. Storage receivers are increasingly popular compressed air system improvements, but we are astounded by how many are installed with no pressure differential to the distribution header.

Operate Most-Efficient Units First

In situations where multiple pieces of central equipment combine to meet load – chillers, boilers, exhaust fans, air compressors, refrigeration, etc. – most believe that the most-efficient units should run first or the most number of hours. Not always. When one considers the part-load efficiency, load and operating profile of the system as a whole, the opposite can actually be true. Particularly in the case of air compressors, customers often retain pre-retrofit equipment remaining as backup to the new equipment, and evaluators find the original low-efficiency equipment operating as "lag" or "trim" to the new high-efficiency "lead" unit(s). Upon further investigation of some of these systems, we have observed numerous instances where it would actually be more efficient to base load the old compressor and run the new units as trim machines.

Conclusions

In recent years, several landmark documents have been published that garnered national and international attention in their attempts to – amongst other things – establish definitive protocols for quantifying energy impacts. While such publications may not encompass all custom applications, and engineers may disagree on specific points, program managers and evaluators should embrace efforts such as the International Performance Measurement and Verification Protocol (IPMVP) and encourage their widespread adoption.

With the energy industry as uncertain as ever, we should embrace every chance to benefit from our collective experience and intellect. Mistakes should not be repeated, and myths must be debunked. Great opportunities are lost when one does not learn from the mistakes of others.

References

Litt, Barbara, Megowan, Andrew and Meier, Alan, 1993. "[Refrigerator] maintenance doesn't necessarily lower energy use," *Home Energy Magazine*, January/February 1993.

Proctor Engineering Group, 1999. "An Assessment of Technical Degradation Factor: Commercial Air Conditioners and Energy Management Systems, Final Report," CADMAC Report #2028P.