Worst Practices: An Evaluator's Perspective

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ABSTRACT

Presentations on "best practices" abound at all major energy-efficiency conferences. As well they should, for these sessions share valuable expertise, establish high standards, and teach secrets to success. Unfortunately, in our experience performing ex-post evaluations of hundreds of industrial energy-efficiency projects, the authors contend that best practices are often unattainable in a practical industrial setting.

Ask any parent or teacher: some of the best lessons are learned through failure. And it doesn't take many clicks through the television channels to conclude that people are drawn to embarrassment, failure, and tragedy like moths to a flame.

Therefore, this paper takes a different approach by sharing some of the "*worst* practices" observed in industrial energy-efficiency. The authors present this material so that industrial energy managers and operations personnel may learn through the mistakes of others.

What is an Evaluator?

As facility managers are well aware, most utilities offer energy conservation or demand-side management (DSM) programs to their customers. Traditionally (and oversimplified), these programs exist because it is more cost-effective to invest in demand-side load reduction than supply-side capacity expansion. In business management, a "program" is an organized method to accomplish a mission or goal and "program evaluation" involves collecting information about said programs in order to make informed business decisions. In the energy utility industry, evaluation is a critical business function that supports programs that provide incentives, rebates, and technical assistance to customers for efficiency projects. Many utilities perform regular evaluations to quantify gross and net program impacts and research key aspects of the program process.

For large, complex programs, it is common for utilities to employ the services of independent firms that specialize in the evaluation of energy programs. Such third-party evaluations tend to be highly technical and multi-disciplinary. An "impact evaluation" typically involves an independent assessment of the savings attributed to a given program via detailed, research on a statistically representative sample of program participants. Evaluation firms usually estimate total program impact by modeling the statistical relationship between the program's *expected* tracking savings and the evaluator's *actual* verified savings. In other words, evaluators collect a *lot* of information about relatively *few* customers and leverage this data statistically to conclude how well the program is performing overall. Evaluators may perform data collection by a variety of methods, such as on-site inspection, telephone interview, Internet or mail survey, or billing analysis.

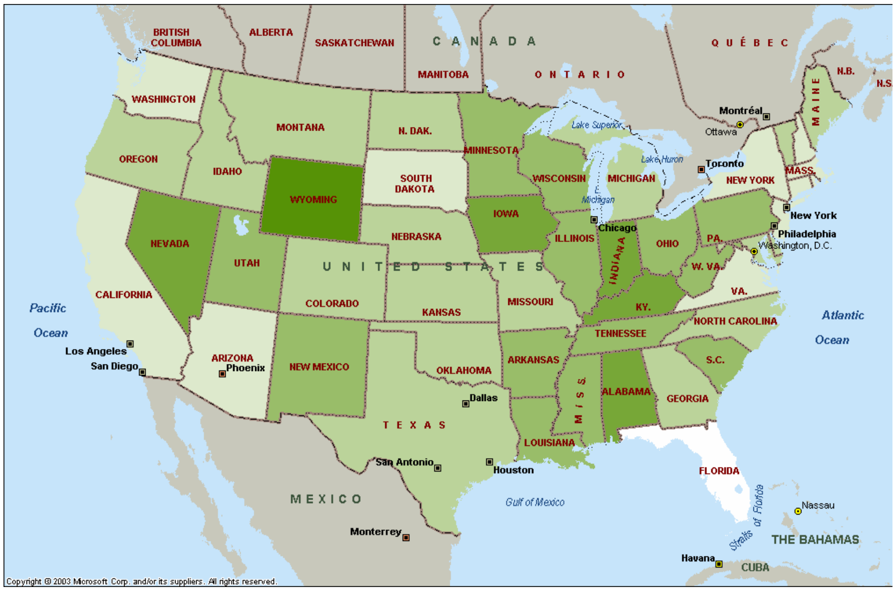
The authors have visited hundreds of industrial facilities to assess the savings of energy-efficiency measures in support of such program impact evaluations. These visits tend to occur about one year after measure installation, so commissioning usually is complete, the novelty has worn off, and regular usage patterns are established. Validating the energy impacts of a project independently and objectively can be very challenging. To the inevitable frustration of program sponsors, it is not uncommon for evaluation findings to be inconsistent with the original implementation of the energy-efficiency measure. Evaluators learn to expect the unexpected and that things are often not as they seem.

In short, an evaluator bears witness to a great many energy-efficiency projects, both good and bad. This role as an objective observer provides unique insight on how some projects come together nicely while others fall apart.

Industrial Overview

Industry represents 31% of overall U.S. electric sales, yet it has received a disproportionate amount of demand-side management savings compared to other market sectors. As seen in Figure 1, industrial electric load is not consistent across our country. Florida and much of the Northeast represent the lowest density of industrial usage, while Wyoming, Nevada, and the Ohio and Mississippi river valleys continue to lead the nation in the manufacturing sector.

Figure 1. Percentage of Annual Electric Sales to the Industrial Market by State



Rank	State	Industrial
1	Wyoming	54%
2	Kentucky	49%
3	Indiana	44%
4	Alabama	41%
5	Nevada	41%
6	Iowa	41%
7	West Virginia	40%
8	Arkansas	39%
9	South Carolina	38%
10	Louisiana	38%
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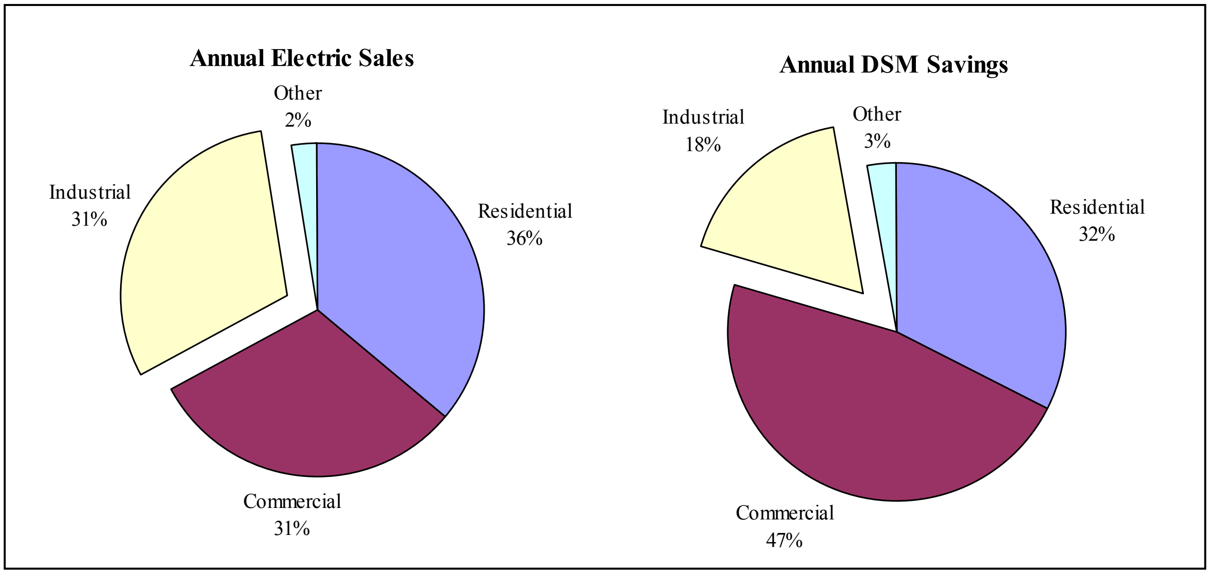
41	California	18%
42	New Hampshire	18%
43	Arizona	17%
44	Virginia	17%
45	Massachusetts	16%
46	Rhode Island	15%
47	Connecticut	15%
48	New York	14%
49	New Jersey	12%
50	Florida	9%

Source: Energy Information Administration, Form EIA-826

Based upon a review of 1994 through 2005 Energy Information Administration (EIA) reports, 31% of electric sales in the United States were consumed by the industrial sector, while yielding only 18% of all demand-side management (DSM) savings. For comparison, the commercial sector accounts for an equivalent 31% of sales and 47% of savings, and the residential sector accounts for 36% of sales and 32% of savings. Numerous factors have contributed to the imbalance depicted in Figure 2, such as the challenge of promoting efficiency in a waning industrial market, the high savings potential of lighting and cooling end-uses in commercial facilities, and the willingness of the residential market to reduce household energy costs.

Figure 2. Disproportional DSM for Industry



Source: Energy Information Administration, Form EIA-861, 1994-2005

Worst Practice #1: Technical Inexperience

Some energy-efficiency contractors approach an industrial customer no differently than any other facility. They change T12 fluorescents to low-power T8s, retrofit constant-speed motors with variable-speed drives, add direct digital control systems, install low-flow this and high-efficiency that… All of these "facility-blind" methods effectively presume that energy savings are universal, but industrial experts know better. Quite simply, a device that saves energy on a test bench cannot assure the same success in a manufacturing environment.

There are countless technical reasons why an energy-efficiency measure may be incompatible with a particular industrial setting. Some factories have extreme ambient temperature and humidity conditions. Others have environmental issues with chemicals, dust and fumes. Voltage fluctuations, poor power factor, harmonics, and other electrical disturbances are common in manufacturing facilities. Health and safety, limited physical access, quality control concerns, and uninterruptible processes further compound the challenge. A successful efficiency project must address all such technical issues.

Obviously, this helps explain the availability of contractors that specialize in industrial projects. An electrical contractor accustomed to lighting retrofits in strip-malls may submit the low bid, but do not expect him to be capable of upgrading lights throughout an iron foundry.

Worst Practice #2: Underestimating the Manufacturing Mindset

Technical issues are only part of the equation. True, in a successful project, smart design and careful planning help anticipate technical roadblocks that are capable of stalling or ruining the most well intended plan. However, sometimes the most formidable barriers are completely non-technical in nature. On average, industrial efficiency projects have a consistently lower realization rate than commercial projects. Program administrators generally attribute this to the technical complexity of industrial versus commercial projects. While sometimes that may be the case, we have seen many technically sound projects fail in manufacturing plants due to largely interpersonal, labor/management, and philosophical conflicts. The key to success in industrial energy efficiency is respect, sensitivity, and understanding of the manufacturing mindset.

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.

Take this case of a glass bottle manufacturer. The only thing that mattered about their massive compressed air system was keeping it running well above demand. Since a momentary pressure drop would produce hundreds of ill-formed bottles, maintenance personnel were highly unreceptive to the idea of changing the compressed air system in any way. Some people close to this project attributed this "if it works, don't fix it" mindset as stemming from management at this plant. Maintenance personnel knew that properly design compressed air storage could mitigate the issue completely, but management was unreceptive to change. In other cases, exactly the opposite is true: management is pushing efficiency hard, but labor resists, afraid of change, the unknown, and loss of job security.

Years ago, I postulated that industrial efficiency has been neglected for so long because "efficiency experts" have often failed to realize the vital importance of being an *industrial* expert when dealing with industrial customers. The real reason for "if it works, don't fix it" is because at some time, someone *did* mess with it, it cost the company a lot of money, and that someone doesn't work there anymore.

Facility Management

Most research indicates that industrial facility managers are interested primarily in manufacturing, production, and operations, with energy efficiency and other business issues secondary to those priorities. This hierarchy is by no means inappropriate, but in practice, few who bear these responsibilities can spare any time for energy efficiency. And this is just one of many constraints and harsh realities of running an industrial facility in the United States today. There simply are not enough hours in the day, qualified personnel, or dollars in the budget to continuously pursue energy efficiency.

Worst Practice #3: Overzealous Quantification

There is such a thing as too much information, so be wary of the "you can't manage what you don't measure" trap. Dr. W. Edwards Deming, often incorrectly cited for that quote, actually warns that many things which must be managed *cannot* be measured. By all means, continue to track and proactively review all available energy usage data, for that is a *best* practice. But do yourself a favor and perform additional sub-metering and quantification only when absolutely necessary. Too many data collection projects are initiated without a complete, compelling, and practical plan for *using* the data. Take it from an energy consultant who does this for a living: don't collect a morsel of data unless you know exactly how – and how often – you are going to use it.

Worst Practice #4: Asking the Wrong Questions

From an outside perspective, and with the utmost respect for their commitment and diligence, many industrial facility managers often are *too* focused on manufacturing operations. Particularly with regard to energy, they often are too close to the problem to see the solution. Ask a facility manager *how much* energy the plant consumes, its peak demand, and monthly expenditures, and you will hear precise answers spout immediately from short-term memory. Ask *where* the energy goes, *when* usage peaks, *what* the proportion by end-use is, *how* energy relates to production – and most importantly – *why* all of these things are so, and responses come more slowly, sometimes in silence or with speculation.

Worst Practice #5: Missing the Big Picture

The first concept taught in thermodynamics is that of a "control volume". A control volume is an imaginary surface that completely surrounds and encloses the device or system under consideration. Once defined, one should be able to account for all mass, heat, and work that flows in and out of a control volume. This concept is critical to the application of the first law of thermodynamics, a.k.a. the law of conservation of energy.

Figure 3. Energy Balance of an Industrial Facility

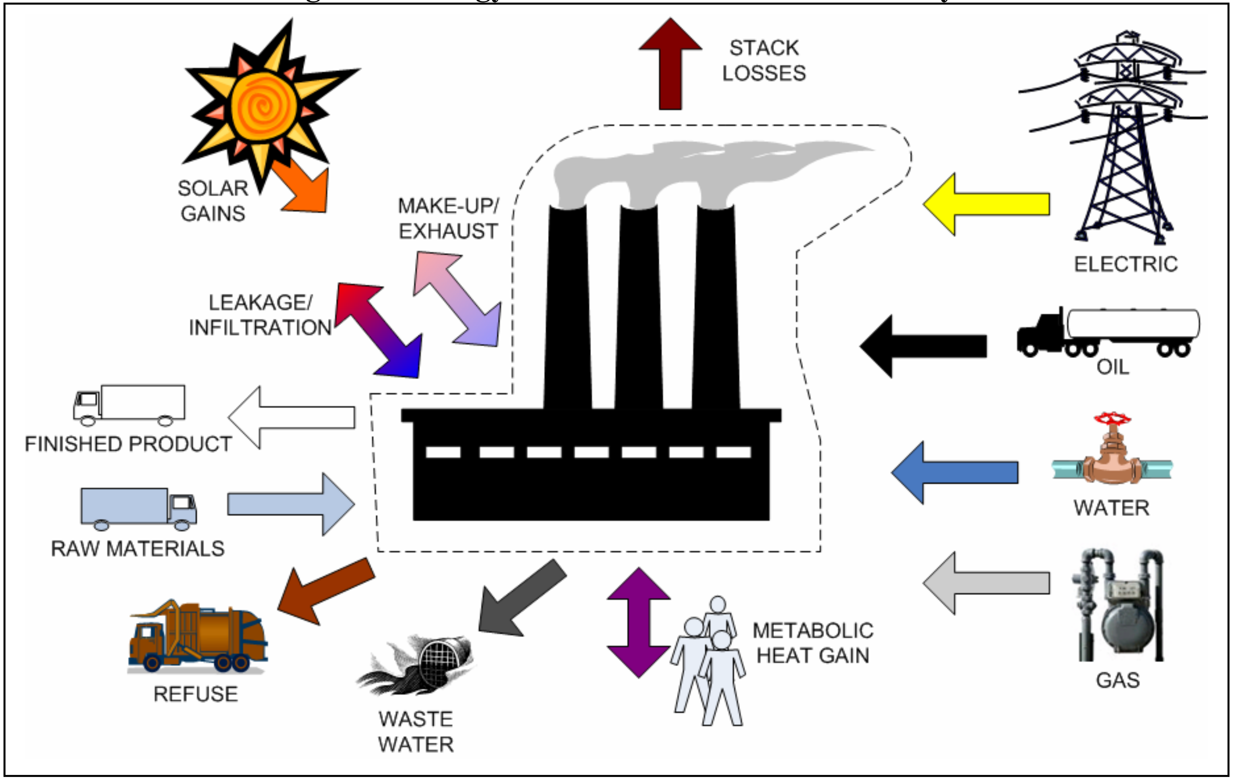


Figure 3 illustrates the complex energy balance of a system that consists of a hypothetical industrial facility. According to the first law of thermodynamics, the internal energy E of the factory changes according to Q, the net heat gained or lost, plus W, the net work done to or by the system. The drawing depicts commodity energy inputs from the right, material transfer of internal energy below and to the left, and typical ambient gains and losses above.

Quantifying all of the mass, heat, and work transfer for your factory is a massive undertaking that is not recommended under normal circumstances. One might consult a book like Energy Analysis of 108 Industrial Processes (Brown, Hamel & Hedman 1996) for insight into the detailed analytical accounting of energy per unit of production. The real important lesson is simply recognizing the incredible complexity of your facility as a system. Strive to identify all sources of energy gain and loss throughout your plant, recognize the dynamic interaction between them, and implement projects that improve net efficiency for the entire system.

Worst Practice #6: Neglecting O&M

In our experience, some facility managers do not fully appreciate the economic value of regular operations and maintenance (O&M) procedures. The following definition of O&M has appeared in several sources, but it most likely has its origins at Pacific Northwest National Laboratory (Parker et al. 1993). According to this definition, an item or activity can be considered O&M if it meets one or more of the following criteria:

- Any item or activity that will bring equipment back into its original design and specification,
- A repetitive activity,
- A low cost item that can be installed or performed by the O&M staff, although it may be contracted,
- An activity that is financed as an expense rather than capital,
- An item or activity that has a simple payback of less than one year, and
- An activity affecting the operation of equipment: set points, schedules, control settings, and procedures.

Despite its inherent cost-effectiveness, O&M procedures are widely under-utilized as savings opportunities. Drive belts, for example, develop increased wear and slippage with age; regular belt inspection, adjustment, and replacement help to maintain top mechanical and hence energy efficiency. The same logic applies to air filter replacement, condenser/evaporator coil cleaning, and motor bearing lubrication. Compressed air leak reduction (see Worst Practice #11) is one of the more compelling illustrations of how proactive maintenance saves energy.

Our research identifies manufacturers as having a particular interest in O&M due to their high cost of operation. Unfortunately, operational budgets are one of the most frequently mentioned barriers to O&M in industry, for those who develop budgets are apt to cut O&M costs, e.g., downsizing maintenance staff, in lieu of other needs.

Worst Practice #7: Reluctance to Change

Although electronic, variable-speed drive (VSD) systems were developed over 20 years ago, some major manufacturers still are hesitant to install VSDs on process machinery. But they have countless applications in industry, providing accurate speed control that can lead to lower process energy, improved product consistency, and less manufacturing waste. Unfortunately, most engineers are hesitant to pursue process improvements in industrial facilities, and the market remains untapped.

Estimating Energy Savings

Worst Practice #8: Using the Wrong Tool for the Job

In recent years, many energy-efficiency incentive programs have become highly reliant on spreadsheet "tools" to estimate the impact of the measure. Typically, these tools require a few inputs such as square footage and climate zone, and give the savings associated with improved air conditioner efficiency lighting upgrades. For the most part this is an efficient way of generating an estimate using generic "canned" analyses.

Problems arise when the operators of these tools do not understand that the tool has limits and will not be applicable in all situations. One municipal utility has as a tool that generates effective full load hours (EFLH) of cooling equipment based on operating schedule and occupancy. The tool seemed to produce reasonable estimates in most cases but 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.

Worst Practice #9: Bold Assumptions

The utilization of 8,760 annual hours (24 hours/day x 365 days/year) is extremely common in energy savings calculations. While some equipment such as emergency lighting, ventilation, or air compressors at a large industrial facility truly may operate non-stop throughout an entire year, in practice very few devices never stop during a 365-day period. For instance, factory shutdown or other maintenance practices are overlooked when assigning 8,760 operating hours. It is human nature to overstate operating hours, but unfortunately, this falsely inflates savings and erodes program cost-effectiveness.

On the flip side, we continue to see measures which claim to eliminate equipment altogether, like a new 200 hp air compressor that replaces two vintage 100 hp machines. Equipment is rarely removed from an industrial environment; instead, it is relegated to standby, even if it means having backup for the backups. Be wary of savings calculations that assign zero operating hours to post-retrofit equipment. Unless you see it loaded on a truck with your own two eyes, rest assured that if it can run again, it will, thus eroding measure savings.

Worst Practice #10: Neglecting Interaction

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.

Compressed Air

Compressed air is a significant electrical end-use at many manufacturing facilities. Unfortunately, it is nearly universally a major source of wasted energy. Energy experts refer to compressed air as industry's fourth utility (after electricity, natural gas, and water), but it is seldom scrutinized or factored into production costs as such. Since one does not purchase compressed air as a commodity, rather generating it on-site, energy managers typically blend compressed air costs into overhead. Beyond the compressor room, most plant personnel actually view compressed air as a “free” resource. Behind this misperception and ambiguity lie major savings opportunities that can positively affect the bottom-line.

Sometimes compressed air is truly irreplaceable and mission-critical to operations, as in some glass or plastic industries where the air actually creates the product. In the mining and petroleum industries, compressed air is sometimes a means of transporting power in hazardous locations more safely than electrical lines. Some printing, textile, and paper operations use compressed air as a mechanical force, driving pistons or air-gears to manipulate machine parts. Universally, compressed air is popular for driving hand-tools, blow-off and cleaning, and part ejection and transport.

Worst Practice #11: Compressed Air Leakage

Leakage totaling 10% of total compressed air capacity is not uncommon, and leakage rates upwards of 40% have been observed. Even though energy savings from repairing compressed air leaks can be substantial, regular maintenance procedures are often not in place for compressed air systems.

Table 1. Estimate of Annual Leakage Costs (Talbot 1993, 169)

Equivalent Hole Diameter	Leakage Rate scfm	10^3 scf per year (4,000 hrs)	Cost per year (40¢ / 1,000 cf)
1/64"	0.25	60	$24
1/32"	0.99	238	$95
1/16"	3.96	950	$380
1/8"	15.86	3,806	$1,522
1/4"	63.44	15,226	$6,090
3/8"	142.74	34,258	$13,703

Air at 100 psig. Orifice with sharp edges (Coefficient of flow = 0.61).

As seen in Table 1, several small leaks can have considerable financial impact. During the leak survey of one glass container facility, it was noticed that several workers had cut open the end of flexible compressed air hoses and permanently directed the output to cool them! These deliberately cut hoses – certainly not natural leaks – illustrate how compressed air is viewed by many as a “free” resource. Though seemingly insignificant at this large industrial plant, eliminating ten open 3/8” hoses had the potential to save this company $137,000 per year. A few strategically placed fans would have achieved the same level of comfort at a fraction of the cost.

Worst Practice #12: Compressed Air as Mechanical Force

As mentioned earlier, many manufacturing facilities employ compressed air as a mechanical force. A textile plant in Alabama is filled with 40-year-old pneumatic sewing machines for lack of capital to purchase more efficient, modern, electric models. The company was unaware of the net operating costs of the pneumatic machines because the air compressor is considered operating overhead. The compressed air associated with the pneumatic sewing machines costs the facility approximately $5,000 per year. Engineers estimate the annual cost of the compressed air It is common for custom process machinery to employ compressed air to slide, advance, or eject mechanical parts. Such machinery often possess retrofit potential for brushless DC servo motors, a.k.a. electrically commutated motors (ECM), that can perform the same tasks with a fraction of the energy input.

Worst Practice #13: Storage Receivers at Distribution Pressure

In recent years, evaluators have witnessed instances when compressed air storage tanks, a.k.a. receivers, have been installed through the program 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.

Worst Practice #14: Old Compressors as Trim Units

Particularly in the case of air compressors, customers often retain pre-retrofit equipment remaining as backup to the new equipment. Evaluators sometimes 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. Always consider the part-load efficiency of your compressors when designing a multiple compressor system.

Why Seemingly Good Projects Fail

Worst Practice #15: The Good Idea Gone Bad

Several years ago we performed an energy study at a large manufacturing facility. I feel I have to be intentionally vague on some of the details because the plant is fairly unique and there are a limited number of similar sites in the country. Let me simply say it consists of multiple buildings in a campus setting with a total footprint of several million square feet. Sixty percent of the complex is devoted to R&D and manufacturing. The campus is located in a cold climate but still requires multiple chillers and has a total cooling requirement well in excess of 2,000 tons [peak load – not base load]. This cooling load, and the corresponding chiller operation, was scrutinized at some point in the past and the waste heat from the chillers was identified as a potential "free" energy source.

A "preheat loop" [called the 90 degree loop by site personnel] was installed including a heat exchanger on the condenser side and two 75 horsepower circulating pumps. This loop feeds existing preheat coils in the air handlers serving the main manufacturing buildings on the campus. A review of the study recommending this system found sound foundations for the project. However, time marches on.

This dynamic facility is under seemingly constant remodeling and modernization. Significant changes were made to the manufacturing sections including new process equipment and modifications in clean room requirements. What was noticeable during our engineering study was a disconnect between the operation of the chiller plant and the required cooling loads during swing and winter months. The site had evolved and the preheat loop operation was never revisited. Plant personnel were now running chillers with false loads and no loads to provide "free" cooling. Our recommendation was to scrap the loop. It had served its purpose. The preheat coils could easily be met by other sources, including a significant existing steam foot print in each building. [When I revisited the plant 5 years later the loop was still in operation. I was told the cost to change the system was prohibitive. I had the feeling that the loop was championed internally and that cost was political – not capital. Other more costly changes were implemented at the site from our recommendations.]

Successful energy engineering projects identify – and satisfy – both the financial and underlying hurdles to implementation. You have to break the barriers set in place. You have to find that path of least resistance that finally convinces decision makers to change the way they do business.

Worst Practice #16: Operational Atrophy

The manufacturing process and the end product drive the decisions in any production facility. That is the reason why they are there. The surrounding electrical and mechanical systems are important, but the average operation has limited time, personnel, and expertise to compare their importance with the process lines. For example, consider what was uncovered at a metal fabricating facility. This shop in Southwestern Connecticut successfully reinvented itself over its 60 year plus history more than once. It successfully made the transition from a foundry and machine tooling company to a manufacturer of precision machined components for the aerospace industry. The shop floor was changed, new digital machining equipment installed, the old foundry section converted to R&D, and processes were modified to accommodate the new technologies. And the 60+ year old heating system with its 250 BHP boiler still fed low pressure steam to the facility.

That boiler fed the foundry in its heyday, a foundry that no longer existed. We followed the steam piping to fan coil units throughout the plant – fan coil units that were valved off and no longer used. Heating was now provided by gas fired rooftop units that provided required ventilation and DX cooling in selected areas. Yet that steam boiler chugged merrily along producing steam 365 days a year. Domestic hot water was never part of its task. The last steam line led to the remaining vestige of the good old days – a series quenching and hardening baths still in use. The remainder of the plant was retooled to space age specifications but this part of the process still relied upon live steam perking into 40+ year old baths. Now, they did think about this system and actually did make some modifications – they converted from #6 to #2 oil "several years ago" and installed proper draw ventilation systems over the baths. No one ever took the time to look at the steam system in its totality. The other side of the problem coin was I couldn't tell the site about this.

This study was done through a utility company auditing program and "fuel switching" was strictly prohibited. Clearly, obstacles to changes are not always on the customer's side. I thought deeply about that problem during lunch as I thumbed through the Watlow catalogue of immersion heaters I found on the facility directors bookcase. You know, to this day I can't remember if I ever put that catalogue back in the bookcase or left it open on his desk.

Conclusions

It is hoped that this paper will help industrial customers and those who serve them to capture more of their savings potential, while avoiding some common traps and mistakes. If the reader takes away just one lesson here, let it be the tremendous value of stepping back to view energy from a broader perspective. No plant manager has time to "stop and smell the roses" but one must first learn to "see the forest for the trees" to succeed in energy efficiency.

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