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Energy Management Mistakes in Industrial and Commercial Facilities

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Energy Management Mistakes in Industrial and Commercial Facilities
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Introduction

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This course is a broad overview of facility energy management. It is intended to identify areas that may be overlooked such as the interrelationship of projects or the importance of understanding the details. It is not intended to teach the details of various energy calculations though some general calculations are covered. It does, however, give a big picture to allow important areas not to be forgotten. Successful energy management is more about avoiding simple mistakes and recognizing the obvious. This course identifies some common mistakes and lays a foundation of points to consider whether implementing a comprehensive energy management program or completing a single project. The information may not be new for some but the goal is to gain some new knowledge or perspective that can be applied. Take time reading the material and consider its application.

The Big Picture

Energy management begins with taking a large systems view of the entire facility being managed. Almost everything crossing the facility boundary can impact energy whether it flows through a meter, arrives by truck, or walks through the door. When an energy saving measure is implemented, it is imperative to consider any ripple effect it may have in other areas. For example, a reduction in lighting energy will also affect space conditioning energy or a disgruntled employee can contribute to energy waste.

After understanding that the facility operates as a system, identify the item that makes the largest impact on energy consumption and what drives it. For example, in most retail facilities space conditioning is the greatest component of energy consumption. In industrial facilities, the manufacturing process is usually the largest consumer. In distribution centers, lighting can be the major component. Identifying the largest energy user pinpoints a likely starting point for conservation efforts.

Next, to become successful in energy management, a realistic system of quantifying consumption must be developed for a facility. The typical method is dollars spent on energy. This method falls far short of accurately measuring program success. However it is the method most preferred by the finance staff. Granted, the main objective is to drive down the cost, but the dollar amount of the energy bill often tells us very little about energy efficiency. Therefore, it is necessary to somehow normalize consumption patterns to account for the various variables. For example, in an industrial facility it may be units energy per unit produced, in a hospital it may be units energy per patient-hours, or in a retail space it may be units energy per square foot per degree day. This approach is important because it allows an answer to the question “Did our energy costs change because of some internal activity or an external impact?”

Here's an example: Jill is responsible for energy management in an injection molding facility. She tracks electric energy consumption as kWh per completed widget. She has invested in insulation jackets for the old injection molders and installed variable frequency drives on the pump motors to improve efficiency. Two months after the improvements had been installed, her plant manager comes to her to discuss the recent electric bill. He shows her that usage is up 10% over the same period last year and says the improvements must not be working. Jill pulls out her latest graph that shows kWh per completed widget is 25% less than the same period last year but production is up 46% per cent. Through Jill's energy management effort the plant is producing 46% more product with only a 10% increase in electrical energy. Yes, usage is up but so is production efficiency.

Notice that the preceding example looks at usage not dollars. If usage is the same and dollars have changed then one of two things have happened, prices charged by the supplier have changed or the way the energy is used has impacted cost. More about this will be discussed later.

Production of waste also wastes energy. It takes energy to manufacturer a bad product. As waste accumulates, begin thinking of it as energy dollars. In the example preceding with Jill, the energy manager, the completed widget unit was a good widget. The kWh per completed good widget will decrease as waste is reduced. Waste comes in many forms other than bad product. It can be compressed air pressure that is too high, water that is overheated, exhausted heat than can be recovered or simply poor thermostat management.

Key points to remember are:

1. Energy usages interact within a facility - rarely standing alone
2. Energy must be tracked in such a way that allows for variables yet captures efficiency
3. Waste takes many forms.

What Can and Can't Be Controlled

It is important in the world of energy management to understand those things that can be controlled and those that cannot. Any attempt to control the uncontrollable only results in frustration and wasted effort.

Regulated Prices

Regulated tariff prices for utilities are mostly out of the energy manager's control. Other than some input during the rate making process, the prices are set by the regulatory agencies. The control you do have is in understanding how to use energy most cost effectively within the tariff. For example, most electric tariffs for larger users have an electrical demand component (kWd) in addition to the energy usage charge (kWh). Depending on the utility, this demand charge may be higher during different seasons or time of day. The goal is to flatten the demand profile or move the higher demands to off peak times. By doing this, the average cost per unit of electrical energy will decrease. Your utility representative is usually the best source for explaining how to best optimize your usage under your pricing tariff. There are also energy consultants available but utilities often provide the same service at no cost.

Employees

Employees also have an impact on energy management. Although employees can't be fully controlled, they can be educated and trained on how their actions impact efficiency. An employee needs to be aware of how their daily tasks fit into the overall picture. One plant, as a part of their energy management program, had a goal to improve plant energy efficiency by 10% through employee education. The plant held a one hour weekly employee training session. During these sessions the employees were taught the big picture of the plant's process, how utility rates work, how their individual tasks fit in, and were encouraged to offer suggestions for efficiency improvements. They were also given instruction on how to lower their utility expenses at home. The program was a great success. Never underestimate the impact a concerted effort by employees can have on facility energy efficiency.

Weather

Some facilities are greatly impacted by weather variations. Weather is simply uncontrollable. The most that can be done is to be sure the building is as thermally cost efficient as possible. Also, some utilities are beginning to offer fixed bills for weather sensitive loads. These programs are different than equalized billing programs which have a true up month. The fixed bill programs are contracted usually for a year and that is what you pay regardless of weather impacted usage. This is a new concept that has limited availability throughout the country and has a level of risk that some regulators dislike.

The Economy

The general economy of the facilities' business sector is uncontrollable by the energy manager. For example, if demand slumps for the product being produced then the energy per unit will increase due to the consumption of energy overheads such as lighting and space conditioning. Another example could be a grocery store where sales decrease but energy is still demanded to keep product cooled.

Design Deficiencies

Another factor that is uncontrollable may be certain inherent design deficiencies. An example would be north facing doors in a northern climate or extremely low ceilings that prohibit the use of more efficient lighting fixtures.

As you can see, it is important to recognize controllable and uncontrollable items so individual focus can be placed where it will produce the most results.

The Big Three

Next, let's consider the usual big three energy consuming sectors within industrial and commercial facilities. They are process equipment, lighting, and space conditioning.

Process Equipment

Process equipment are those pieces of equipment used to manufacture a product. Large energy consumption occurs when materials are melted, frozen, formed, separated, joined, or chemically altered. Often just one piece of equipment dominates usage such as one large motor or kiln. This makes it more difficult to make continuous energy improvements. However, reduction of waste and better quality control always result in energy savings per unit manufactured. In processes that require heat or removal of heat, only heat or cool to the minimum extent required. Where varying centrifugal loads occur on pumps and fans, use variable frequency drives to match input to load. Continuously look for ways to reduce friction, drag, head, and other items that impede product flow or require work. Reducing these items produces a reduction in energy consumption.

Two pieces of process equipment that merit a little more discussion are industrial refrigeration systems and motors. Industrial refrigeration systems can be prime candidates for efficiency improvements. The following are areas to consider that lead to more efficiency:

- Floating head pressure
- Variable frequency drives on evaporative condensers
- Heat recovery
- Central ammonia plant instead of packaged "Freon" systems
- Multi-staging for systems serving different temperature zones

Most industrial processes require the use of motors. Motor efficiency has improved over the years and premium efficient motors should be considered when their extra cost can be recovered through energy savings. The following table indicates the efficiency level needed for a motor to be classified as premium efficient.

	Totally enclosed fan-cooled and explosion-proof motors premium efficiencies (percent)				Open drip-proof motors premium efficiencies (percent)			
RPM	3600	1800	1200	900	3600	1800	1200	900
HP								
1	78.5	85.5	82.5	77.0	84.0	85.5	82.5	77.0
1.5	85.5	86.5	87.5	80.0	85.5	86.5	86.5	78.5
2	86.5	86.5	88.5	85.5	86.5	86.5	87.5	87.5
3	87.5	89.5	89.5	85.5	86.5	88.5	88.5	88.5
5	89.5	89.5	89.5	87.5	87.5	89.5	89.5	89.5

7.5	91.0	91.7	91.7	88.5	90.2	91.0	91.7	91.0
10	91.7	91.7	91.7	91.0	91.0	91.7	92.4	91.7
15	92.4	93.0	92.4	91.0	91.7	93.0	92.4	91.7
20	92.4	93.0	92.4	91.7	92.4	93.0	93.0	92.4
25	93.0	94.1	93.6	91.7	93.0	93.6	93.6	92.4
30	93.0	94.1	93.6	93.0	93.0	94.1	94.1	93.0
40	93.6	94.5	94.5	93.0	93.6	94.5	94.5	93.0
50	94.1	94.5	94.5	93.6	94.1	94.5	94.5	93.6
60	94.5	95.0	95.0	93.6	94.5	95.0	95.0	94.1
75	94.5	95.4	95.0	94.5	94.5	95.4	95.0	95.0
100	95.0	95.8	95.4	94.5	94.5	95.4	95.4	95.0
125	95.8	95.8	95.4	95.0	95.0	95.8	95.4	95.0
150	95.8	96.2	96.2	95.0	95.0	96.2	95.8	95.0
200	96.2	96.2	96.2	95.4	95.8	96.2	95.8	95.0

Refer to the preceding table for the following example. A plant utilizes a 1800 rpm totally enclosed 150 hp motor to convey raw materials The motor is operated almost constantly (7200 hours per year). The motor is over 25 years old and is budgeted for replacement. The efficiency is estimated at 90% (table not shown). The minimum efficiency of a new motor is 95% (table not shown) but a premium efficiency motor is 96.2% (see preceding table). Assuming the cost for electric energy is \$8.00 per kilowatt demand (kWd) and \$0.04 per kilowatt hour energy (kWh) then the annual energy cost calculation is as follows:

kWd existing = 150 hp X 0.746 kW/hp ÷ 0.90 eff = 124.3 kWd
kWd existing annual cost = 124.3 kWd X \$8.00/kWd X 12 months/year = \$11932.80
kWh existing = 124.3 kWd X 7200 hours = 894960 kWh
kWh existing annual cost = 894960 kWh X \$0.04/kWh = \$35798.40
Total annual energy cost for existing motor = \$47731.20

kWd minimum eff. = 150 hp X 0.746 kW/hp ÷ 0.95 eff = 117.7 kWd
kWd minimum eff. annual cost = 117.7 kWd X \$8.00/kWd X 12 months/year = \$11299.20
kWh minimum eff. = 124.3 kWd X 7200 hours = 847440 kWh
kWh minimum eff. annual cost = 847440 kWh X \$0.04/kWh = \$33897.60
Total annual energy cost for new minimum efficiency motor = \$45196.80

kWd premium eff. = 150 hp X 0.746 kW/hp ÷ 0.962 eff = 116.3 kWd
kWd premium eff annual cost = 116.3 kWd X \$8.00/kWd X 12 months/year = \$11164.80
kWh premium eff. = 116.3 kWd X 7200 hours = 837360 kWh
kWh premium eff annual cost = 837360 kWh X \$0.04/kWh = \$33494.40
Total annual energy cost for new premium efficiency motor = \$44659.20

Note that the above is a simple example and assumes constant 100% loading and a simple electric tariff. The energy manager must know the nuances of the actual situation and also how to apply the applicable electric tariff. In addition, many factors will need to be considered as to whether to select the minimum efficient motor or the premium efficient motor. Some of those factors will be discussed later in this course.

Lighting Equipment

Lighting is often the largest energy consumer in large office areas, retail stores, and distribution centers. The most common lighting source in commercial buildings is fluorescent lighting fixtures with occasionally some high intensity discharge (HID) lamps in high ceiling warehouse type spaces. Current practice is T-8 (8/8 of an inch in diameter) fluorescent lamps driven by electronic ballasts. Most facilities have upgraded from T-12 fluorescent lamps with magnetic ballasts to these more efficient T-8s. Newer T-5 fluorescent lamp technology is on the market and is becoming more accepted but higher initial cost at this time is still a barrier. In high ceiling areas high pressure sodium or metal halide HID sources are more common, however there are now available six and eight lamp high output industrial fluorescent fixtures that save energy while maintaining light level.

Many non-energy qualities need to be considered also. These are such things as light color and level. Sometimes color is critical in such operations as retail and printing. Light level needs to be appropriate for the tasks being performed. A great source of information is the Illuminating Engineering Society (IES) which covers lighting design issues in detail. Also, remember that reduction in lighting loads also reduces cooling load.

The table below displays some general lighting information.

Lamp type, number, & ballast	Initial lumens per fixture	Mean lumens per fixture	Initial lumens per watt (efficacy)	Mean lumens per watt (efficacy)
1-60W incandescent	890	890	15	15
1-13W Compact Fluorescent	900	774	53	46
2-F40T12ES Fluorescent w/ Eff Mag Ballast	5800	5220	81	73
2-F32T8 Fluorescent w/ electronic ballast	5600	5040	97	87
2-F32T8 Fluorescent HO T8 w/ elec. Ballast	NA	5183	NA	96
2-FP54T5HO Fluorescent w/ elec. Ballast	8800	8272	75	71
1-400W Metal Halide w/ magnetic ballast	36000	23500	80	52
1-400W Pulse Start Metal Halide w/ mag. ballast	42000	32800	94	73
1-400W High Pressure Sodium w/ mag. ballast	50000	45000	106	96
1-400W Mercury Vapor w/ magnetic ballast	19500	16500	43	37

The numbers in the preceding table are averages and will vary by manufacturer. Note that some sources lose significant light output as they age. Therefore, the mean numbers can be more important than the initial ones. This is one reason high output fluorescent lighting is sometimes a better choice than metal halide or high pressure sodium for industrial lighting applications.

Space Conditioning Equipment

The third primary area for energy consumption is space conditioning equipment. In a highly weather responsive facility, space conditioning usage can vary widely from season to season and year to year. Most mistakes occur when the facility is constructed. First cost considerations usually lead to the installation of lower cost inefficient equipment or poor HVAC design. In today’s market, utilities often offer energy efficiency incentives that in some cases cover the entire incremental cost of installing more efficient equipment. Become aware of current utility programs and use them where applicable. Here's a short list of points to consider with space conditioning equipment.

- Temperature set points
- Variable frequency drive applications
- Equipment efficiency
- Heat recovery
- Set back of temperature
- Thermal system improvements

Each structure is unique and responds differently as a function of its thermal characteristics. Space conditioning energy savings can be complex at times and may even require simulation software to accurately model.

Energy Economic Considerations

There are many forms of energy sources in facilities but usually include at least electricity and natural gas. If not natural gas, then propane, fuel oil, wood, or coal. In addition, biomass is becoming an energy source. Regardless of source, energy can be considered to have both an instantaneous and usage component.

Instantaneous is sometimes referred to as demand because the equipment "demands" that inrush of energy to operate. For example, a 100 watt lamp demands 100 watts of energy to produce light. The next component, usage, is demand over a period of time. If the 100 watt lamp demands energy for ten hours, then it consumes 1000 watt-hours or 1 kilowatt-hour of energy. This is important because the cost of energy is often divided into both demand charges and energy usage charges. It is also important because if a facility can manage to lower the demand component, that decreases the size of the infrastructure needed to deliver the energy whether it is wires, pipes, or trucks.

Suppose the energy source for the facility is "blocks". At the peak time of day twenty blocks of energy are needed. Blocks have no storage properties and must be delivered exactly when demanded. The rest of the day the peak block need is five. Trucks must be purchased to deliver the blocks and each truck has a capacity of one block. To meet the facility demand twenty trucks must be purchased. However, the majority of the time only five trucks are being used and fifteen are idle. The point is that energy infrastructure must be in place all the way back to the source whether it is a well head, coal mine, or generating station to meet the peak demand. The cost of the infrastructure must be recovered in revenue and it is usually collected from those that create the peak demand.

The facility energy manager needs to develop a demand and usage profile for each energy type. This profile will show where the peaks occur. With this information, various strategies may be developed to shift, eliminate, or lower the peaks.

Another consideration is when to replace inefficient equipment. Several factors enter into this decision. First, is the equipment a significant contributor to energy consumption? If it is a major consumer, move it to near the top of the project list. Second, are there maintenance issues with the equipment, either current or impending? Third, is it near the end of its useful life? Fourth, is it economically feasible? Let's look at economics which actually encompasses all of these questions.

Almost anything can show a payback with broad enough assumptions and projections. First, decide if the equipment is at the end of its life and will be replaced anyway. If that is the case then from an energy efficiency cost effectiveness only consider the incremental cost of the higher efficient unit to the standard one. In this simple case, the incremental cost should be recovered through energy savings only in the required time to meet the company ROI. Now for something more complicated. In this case, the equipment considered for replacement is a part of the manufacturing process. The plant operates two shifts. The existing equipment has a motor load and a compressed air load both of which cycle. The new equipment requires lower air pressure, allows better quality control, and has more efficient motors. It is also projected that the manufacturing output will increase with the new equipment. The existing equipment is only five years old. Here's a list of factors to consider in deciding whether or not to replace the equipment.

- Motor efficiency savings
- Compressed air savings
- Compressed air system maintenance savings
- Energy savings per unit produced versus the old equipment (this include value of better quality control and elimination of waste)
- Cost of taking down the process during equipment upgrade
- Cost of equipment and installation
- Any production labor savings

As can be seen, energy economics can become as complicated as desired. As with all energy upgrades, as the hours of use increase the payback period decreases. This is one reason that very few energy enhancements in single shift operations payback in a reasonable period of time without extremely high utility rates, huge jumps in equipment efficiency, and or incentive programs.

When considering an equipment upgrade, the equipment vendor can be a great source of information but also a source of poor economic projections. Question all aspects of vendor payback analysis. Frequently vendors venture into areas outside their expertise. They are, however, the best source of technical data on their product. Because of their general lack of knowledge on energy tariff applications and equipment load factors, savings are often overstated. This is not to discredit those astute vendors but to make sure the buyer is diligent. Some equipment will be operating as long as thirty years.

Another tool to consider when considering an energy efficiency improvement project is the use of performance contracting. Performance contracting companies install the energy saving measures and are repaid for the project over time from savings. The end user does not need to invest any cash, only make the payments from savings. Overall net cash flow would be positive for a viable project. The “performance” part of the title means the contractor often guarantees the equipment to save or “perform” as stated. In most cases though, the contracts are written with many exceptions that need to be thoroughly understood.

Understanding of Terms

An overview of energy management would not be complete without mentioning the importance of understanding the details. In practice the energy manager must have a complete understanding of the terminology being used. If a word, term, or unit used by a vendor or consultant is unfamiliar or inconsistent to you, ask for clarification. Even people who have been in the energy industry for years can misuse terms.

For example, one common unit often misunderstood is the conversion unit of horsepower to kilowatt demand for savings calculations. The conversion factor is 0.746 kW (kilowatt) per 1 hp (horsepower). It is important to recognize this is an output unit conversion but for energy consumption savings the input kW demand is needed. In other words, know at what point in the system the calculation is occurring. For the preceding example, the efficiency of the system would need to be applied to calculate input energy. In other words, the input of a fully loaded 150 horsepower 90% efficient motor would be 124.3 kW demand (150 hp X 0.746 kW/hp ÷ 0.90 eff.). As this motor operates over time it may only be partially loaded and may not run continuously. All these parameters need to be considered for an accurate energy calculation.

Once again, know your terms such as kilowatt demand, kilowatt hour, facility charge, therm, decatherm, MMBTUH, CCF, BTU, BTUH, boiler horsepower, brake horsepower, load diversity, load factor, power factor, KVAR, KVA, energy efficient vs. premium efficient, and the list goes on.

Whenever presented a project proposal, be sure to review the details including all calculations and assumptions. Once satisfied with the review then have someone else review it. Then review it yourself once more. This is not to suggest overanalyzing; but, small calculation errors and poor assumptions are often overlooked. If an uneasy feeling develops about a project where something doesn’t “feel right” or something just doesn’t make sense, there is usually a reason.

Who’s Responsible for Energy Management?

The short answer is one person must be responsible and everyone is responsible. Now to elaborate a little. One person needs to be charged for responsibility of the facilities energy management program. The higher up in the company this responsibility falls usually the more successful the program will be. This also depends on the size of the company and the complexity of the facility. This person does not have to be the “doing” person but needs to be the person ultimately responsible for energy management. The tasks and projects could be delegated. For the highest success rate, everyone in the facility must have an awareness and be committed to doing their part. As mentioned earlier, time invested in employee training will pay off for all involved.

Future Trends

Economic growth requires energy consumption. As countries seek to expand their economies, the demand for energy grows. This course is not about the development of energy supplies, an in-depth subject itself, but about end use management. With increases in demand for end uses of energy, the price of energy increases and facilities are forced to hold costs inline through better energy management practices.

One area that continues to be refined is control technology. The better the control device or system becomes, the less energy is wasted. The controls can be for anything from building temperature to process flow. Most improvements in energy efficiency involve technology improvements. This has been demonstrated especially with lighting as it moved from incandescent to fluorescent to high intensity discharge and possibly on to the transporting of sunlight using fiber optics. A technology that would allow facilities to economically fully capture all the wasted energy and utilize it would revolutionize energy management. An enormous amount of low grade heat bellows from facilities daily.

Resources and Standards

In order to stay up to date on energy standards and technologies, the energy manager needs to develop a list of resources. Here are some of the primary sources for energy managers.

Utilities

Utilities can be one of the best resources. Most utilities have energy efficiency programs for customers. Utility representatives can often provide audits and assistance with calculations. They also often offer incentives for efficiency improvements. In addition, they usually have access to research information on emerging technologies through trade associations such as EPRI (Electric Power Research Institute) and GRI (Gas Research Institute). They also have access to industry specific information such as plastics, healthcare, and food processing to name a few. Use them to do some of your legwork.

ASHRAE (American Society of Heating, Refrigerating, and Air-conditioning Engineers)

ASHRAE is a great source for HVAC and refrigeration information. ASHRAE also produces energy efficiency standards for facility energy usage (mostly non-process related).

IES (Illuminating Energy Society)

This is the “go-to” place for information on lighting. Especially design and applications.

DOE (Department of Energy)

The DOE has a plethora of information on everything from commercial swimming pool covers to premium efficiency motors. DOE also has software for such things as comparing motors to simulating building energy consumption.

Vendors

Vendors can be the best source for equipment specific information and technology advancement in manufacturing industries in particular. Just exert caution with savings quotes as mentioned earlier.

Other

There are numerous other sources also. These include state agencies, trader associations, professional societies, university research centers, etc. Since no one can know it all, develop a network of persons for specific knowledge areas.

Conclusion

The effective energy manager needs a broad understanding of the facility, its characteristics, and all factors affecting efficiency. Below is a brief review of the items discussed in this course:

- Understand the big picture and interaction of all items affecting energy consumption
- Know the items that can actually be controlled
- Determine the major energy consumers in the facility
- Learn the key points of energy economics
- Never underestimate the importance of the details
- Assign responsibility for overall energy management
- Identify resources and standards to implement programs and projects

With a thorough understanding of the above points, the energy manger can avoid many energy management mistakes that often occur in industrial and commercial facilities.