

Energy Savings Guide for Industrial Facilities

**This guide has been prepared by the Technical Staff at Sensor Synergy, Inc.
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Edited by James Wiczer, PhD

i. Content Summaries

Electricity Use Monitoring in Manufacturing and Industrial Facilities

Although it may seem straight-forward, the consumption of electricity by manufacturing machines may not always track with production activities. Physical measurements of power-use during the work day can help you understand the relationship between electricity consumption at your facility and your production activities. Since manufacturing facilities are so diverse, the same machine in two different manufacturing facilities can have very different energy operating costs. Learning the details of this relationship can go a long way toward reducing electricity costs. Detailed examples are described in this section.

Are You Paying Too Much Trying to Save Money on Your Electricity Bill?

It is well known that you can't fix a problem until you know what the problem is. But, in some cases it just costs too much to determine where the power is being used at a facility. Smart-meters, smart-buildings, smart-grid, and smart building automation systems are just a few of the "buzz-words" swirling around these days -- and all represent technology options to help you get a better handle on the important question "where are my electricity dollars going?" But, a key question is - "How much will it cost to find-out how we are spending money on electricity to run our machines?" Not all power monitoring solutions are the same. Some monitor power-use and power-quality, others just one or the other. If you want to focus on reducing your electricity bill, it may be adequate to focus on tracking your power-usage and leave the power quality issues for another day.

Should I Monitor the Whole Plant or Individual Equipment Power Use?

A question often asked by our customers relates to the recommended strategy to save the most money on their electric bill. Specifically, the question most often asked is " ... to save the most money, would it be better to continuously monitor all the power coming into our plant or to monitor individual pieces of equipment connected to power distribution panels scattered throughout our facility.

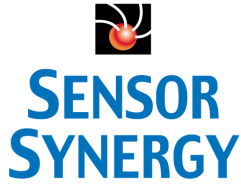
In many cases, monitoring individual equipment gives you better insights into saving money. As is usually the case with these types of decisions, there are lots of engineering trade-offs and no simple, always correct answer, but here are some guidelines that we used to reach our answer. Many of these issues may apply to your situation. Although these guidelines are not perfect, they may help you select the best approach for your needs.

Monitoring Electricity Use in Compressed Air Equipment

A "power-use" monitoring system can help you identify costs associated with various pieces of production and support equipment - such as extrusion machines, air compressors, pumps, mixers, heat treatment ovens, and HVAC equipment. The total power consumed by any single machine in a "typical" week will depend greatly on the details of your week. Physical measurements are needed due to the duty cycle variations associated with production loads, environment changes, operator issues, shift issues, and many, many other factors.

Table of Contents

i. Content Summaries	2
Electricity Use Monitoring in Manufacturing and Industrial Facilities.....	2
Are You Paying Too Much Trying to Save Money on Your Electricity Bill?	2
Should I Monitor the Whole Plant or Individual Equipment Power Use?.....	2
Monitoring Electricity Use in Compressed Air Equipment.....	3
1. Electricity-Use Monitoring in Manufacturing and Industrial Facilities	6
Identify equipment power usage patterns and correlate with plant activities	6
Low-cost actions can save many dollars	6
Power-use monitoring is necessary to understand the size of the problem.	6
Simple, no capital expenditure power saving solutions	8
More advanced solutions.....	8
2. Are You Paying Too Much Trying to Save Money on Your Electricity Bill?.....	9
What Can I Do?	9
Permanent or Portable Installation.	9
Determine your goal and stick to it.....	9
Select the accuracy you need for your goal.....	9
Stay focused on the goal - saving money on your electric bill.....	10
3. Should I Monitor Power Use for the Whole-Plant or Individual Equipment?	11
Make measurements that provide actionable information to reduce power consumption.....	11
Make measurements with enough resolution in the power data so that individual pieces of equipment or processes can be identified.....	11
Make measurements with enough time resolution to allow for meaningful feedback to the users.	12
Select a remote monitoring measurement system that allows you to view changes in power consumption near the work location where changes are being made.	12
Select a monitoring system without too much "installation and setup" effort.....	13
Make and record measurements that will help you analyze prior events and possibly prior electric bills.....	13
4. Monitoring Electricity Use in Compressed Air Equipment	15
Why Monitor Electricity Use in Equipment.....	15
Limits on Boiler-Plate Information	15



Energy Savings Guide for Industrial Facilities

SSI-TN-WA110 October 2010

Technology Note

Nothing Like Direct Measurements	15
Financially Sound Decisions Need Energy Operating Cost Data	15
Air Compressors in Manufacturing Facilities	15
The Cost of Operating Through an Idle Period vs. the Cost of Turning the System On and Off	16
Too Much Air Compressor Capacity Wastes Dollars on Electricity.	16
Too Little Air Compressor Capacity is also Bad for Productivity	17
Is it Too Little Capacity or Is it Really Too Many Leaks?.....	17
Other Types of Production Equipment	17
Appendix A - Useful Facts and Figures	18
Appendix B -- Useful Links for Additional Information.....	19
Compressed Air Challenge - Initiative launched by the U.S. Department of Energy in 2001.	19
U.S. Department of Energy - Overview on Saving Energy.....	19
Sensor Synergy Inc.	19

1. Electricity-Use Monitoring in Manufacturing and Industrial Facilities

Although it may seem straight-forward, the consumption of electricity by manufacturing machine may not always track with production activities. Sometimes power consumed may change only a disappointingly small amount whether you are in a full production mode during an "off-shift" period, or "on break" during a work shift. Worse than this, sometimes significant amounts of electrical power are being consumed by large machines which are thought to be "off-load, "idle" or in "stand-by" mode.

Identify equipment power usage patterns and correlate with plant activities

In the simplest case, monitoring power-usage can identify equipment that is using significant amount of electricity (burning money) at a time when your plant is not in a production mode.

In more advanced applications, power-use monitoring can compare alternate approaches to identify inappropriately large amounts of electricity consumption (kW-hr) by a particular piece of equipment. This can help include the cost of energy in production planning activities and validate the use of alternate approaches that do not use as many power-hungry tools.

Low-cost actions can save many dollars

For example, consider the case of two power-hungry machines may perform similar operations in a production environment, but they may have significantly different power usage profiles. This type of situation can occur with essential machines such as air-compressors, extrusion machines, required HVAC equipment, or process heaters. Often machines will consume different amounts of electricity with different work-load profiles.

Essential industrial machines will frequently have a back-up, older version, or a second machine to share the work load. Often these two machines may perform similar operations and even similar throughput, but one machine may have been designed with different technology making it more efficient than the other machine. And our experience has shown that the older machine is not always the power-hungry offender.

Many machines do not work efficiently when they are not operated at their target production rate.

This optimum power efficiency rate is often a goal during machine design and typically cannot be adjusted during its operational lifetime. Monitoring machine's power consumption in your manufacturing environment with production loads commonly found at your facility may help you discover that one of these machines is more efficient than the other.

With knowledge about which machine is more efficient, operations may be scheduled to take advantage of this difference in order to save significant dollars during the course of a typical year. This type of change requires no expenditure of capital equipment (\$'s) resources.

Power-use monitoring is necessary to understand the size of the problem.

Industrial and manufacturing facilities frequently use target time periods for recovering an investment through payback from process improvements resulting

from the investment. In many manufacturing environments, this "Return on Investment (ROI) period can range from 6 months to 3 years or longer.

To assess what type of electricity-use reduction program you can consider, you first must know the number of dollars used to supply a machine with electricity during the ROI period. For example, if your company typically uses a 12-month ROI period for production improvement projects you must assess your target machine's electricity consumption during a typical 12-month period with a power-use monitoring tool.

This type of monitoring system may need to gather information during a 2 week period for 24 hours a day, seven days a week. Sometimes measurements of power-use need to be extended to fully capture changes during weekends, month-end production bumps, or seasonal activities.

Let's say that you have determined that you can use a 2 week measurement period. If your power-use monitoring system is like Sensor Synergy's Watts Aware 118, it will provide power use measurement results in both kW-hr per user selected time period and dollars per user selected time period.

Now let's say that your power-use monitoring system has determined that your target machine has consumed about \$620 of electricity during this 2-week monitoring period. A simple calculation will determine that your target machine's average weekly consumption of electricity is about ($\$620/2$) \$310/week. For your company's ROI period of 12 months (52 weeks), your target machine uses:

$$\begin{aligned} & \mathbf{\$310/week \times 52 \text{ weeks}/(1\text{-year ROI} \\ & \quad \mathbf{\text{period})} \\ & \mathbf{= \$ 16,120} \end{aligned}$$

You now have discovered through measurements that in your manufacturing environment with your typical production loads, your target machine consumes about \$16,000 during the time period that your company's expects a return on its manufacturing process improvement projects.

If you are considering an improvement to this machine that costs \$30,000 you have a problem. No matter how efficient your machine becomes after this project, you cannot recover enough dollars during the 12-month ROI period by reducing electricity use. Even if you reduce this machine's electricity use to virtually \$0, you still have only saved about \$16,000 during the 12 month ROI period, and your company wants to recover all of the money from the project within 12 months. And realistically, these types of efficiency improvement projects may reduce consumption by 10% to 40% - not eliminate electricity consumption completely.

However, if you are considering a project that costs \$1,500 to upgrade your machine, and you are reasonably confident you will experience a 20% to 25% reduction in electricity consumption, you may be a hero. For this case, consider the worst case of a 20% reduction in electricity consumption. To make this an extra worst case, also assume that your power-monitoring measurements were flawed for some reason and were 10% too high. You actually only spent \$14,500/year on electricity for this piece of equipment. Either you had an extra heavy production session or some other problem distorted your measurements. Even in the worst case scenario, this change will save your company \$2,900 the first year during the 12-month ROI period.

$$\mathbf{\text{First year savings} = \$2,900 = 0.20 \times \$14,500}$$

Your improvement will recover the costs of the enhancement in the first 6 months and your company will experience the benefits of your efforts for the entire 12-month ROI period --- plus as a bonus these savings will continue for many years

afterwards as long as the equipment is still in service.

Knowing the size of the problem, you can consider a range of electricity-use reduction projects - some requiring no capital expenditures.

Simple, no capital expenditure power saving solutions

Consider the straightforward problem of equipment using electricity and burning dollars during off-shift time periods, so that the equipment will be "instantly" ready (warmed-up) when the main production shift arrives at your plant.

For this problem, one of the simplest solutions with the least expensive up-front costs is to arrange for a production worker to arrive at your plant earlier than normal and turn equipment "on" in preparation for the start of the main production shift. Depending on the equipment and the length of time necessary to "warm-up" your equipment prior to the production shift, your early start worker could arrive at work from 10 minutes to 1 hour before the arrival of the main shift.

The power-use monitoring system will help identify costs associated with not turning off the equipment at the end of the prior shift and that can be compared with the cost of bringing in a production worker prior to the normal start time. With this "manual" approach, it is important to arrange for another production worker to stay at the end of the shift and shut down the equipment.

More advanced solutions

A slightly more advanced solution with greater up-front costs and lower on-going costs, is to purchase automated equipment to start and stop your equipment based on a time-of-day / day-of-week clock. This automated approach may require contacting the manufacturer of your equipment to find automated "on-off" devices or the use of a small PLC unit to perform a more complex start and stop set of procedures on your equipment.

Still more advanced solutions may utilize sophisticated "smart" automation equipment that turns equipment "on" and "off" based on other factors in addition to a time-of-day clock. A power-use monitor will help you determine how many dollars are wasted on running equipment during off-shift hours so you can better decide how many dollars can be spent on automation equipment.

In some cases a \$20 "occupancy sensor switch" turning lights on and off in a seldom used room might be easy to justify. In other cases a \$20,000 to \$30,000 "staging" air compressor controller networked to multiple pieces of air compressor equipment may not be justified by the expected savings in an acceptable ROI time period.

2. Are You Paying Too Much Trying to Save Money on Your Electricity Bill?

It is well known that you can't fix a problem until you know what the problem is. But, in some cases it just costs too much to determine where the power is being used at a facility. Advanced metering initiative (AMI), smart meters, sub-metering, smart-buildings, building automation systems, and smart-grid are just a few of the "buzz-words" swirling around the technology options you might consider to help you get a better handle on the important question "where are my electricity dollars going?"

What Can I Do?

Make intelligent choices about the type of power monitoring that is most appropriate for your needs.
One size does not fit all!

Should you be monitoring all of the power used in your plant or measure the power used by some key power-hungry pieces of equipment with a portable tool?

Permanent or Portable Installation.

Should you use a permanently installed solution or a mobile solution that can be easily moved around to various power distribution panels or pieces of equipment. Permanent installations frequently require a more involved (and expensive) installation that requires power interruption, new wiring in conduit and often a more expensive set of hardware to complete the solution. Permanent solutions can be more accurate than portable solutions. Portable

solutions can provide a "quick view" of power consumption status, may require much less expensive installation and less expensive hardware and may be 95% accurate compared to permanent solutions that may be "revenue grade" 99.8% accurate.

Determine your goal and stick to it.

Are you trying to verify the accuracy of your electric bill from your utility or are you trying to reduce electricity consumption in your facility by understanding where the power is going and then developing a plan to reduce your usage?

This issue will help you determine what level of accuracy you need for your situation.

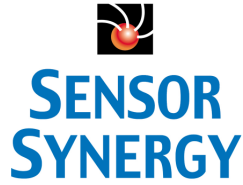
Concerns about the accuracy of your utility provided electric meter (which is used to determine your monthly "electric bill") can be handled by a call directly to your utility. Either they will replace your meter or explain their quality control processes about when your meter was last calibrated.

Select the accuracy you need for your goal.

The world is full of trade-offs that we make all of the time. Measuring power use is subject to similar engineering trade-offs that you apply to other parts of your job. No magic here - just common sense.

Trade-off monitoring system cost for accuracy of the results.

Do you really need "revenue grade" measurements that are accurate to 0.2 % of the "actual value" or can you settle for a +/- 3% accuracy for 1/10 the cost?



Are You Paying Too Much Trying to Save Money on Your Electric Bill

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Technology Note

For example, when making a measurement of a recently manufactured part, you do not put every part under an electron microscope to verify that the finish is sufficiently smooth and within product specifications. No, you use an appropriate monitoring tool that is just accurate enough to tell you that your product is within the required specifications -- Typically, you just use the tool needed to get the job done -- and nothing more sophisticated or expensive.

Stay focused on the goal - saving money on your electric bill.

Don't get distracted by other issues that can hugely inflate the price of a power-use monitoring solution!

Building automation systems can provide much information about electricity use at your facility in addition to controlling lights, heating, ventilation, and air conditioning. But at a price! It is a rare situation in which a building automation system can return enough dollars from electricity savings within the first 5 years to pay for the acquisition and maintenance costs of the system (ROI). Under many situations, a monitoring system that only tracks electric power use, can pay for itself in less than 3 months!

3. Should I Monitor Power Use for the Whole-Plant or Individual Equipment?

A question often asked by our customers relates to the recommended strategy to save the most money on their electric bill. Specifically, the question most often asked is " ... to save the most money, would it be better to continuously monitor all the power coming into our plant to monitor individual pieces of equipment and smaller power distribution panels.

In many cases, monitoring individual equipment gives you better insights into saving money. As is usually the case with these types of decisions, there are lots of engineering trade-offs and no simple, always correct answer, but here are some guidelines that we used to reach our answer. Many of these issues may apply to your situation. Although these guidelines are not perfect, they may help you select the best approach for your needs.

Make measurements that provide actionable information to reduce power consumption.

Measurements of "whole-plant" power usage may mask the power use information of individual pieces of equipment or processes.

Whole-plant power measurements may not provide actionable data because the information is all-encompassing, individual processes may not be resolvable.

If your goal is to save money on your plant's electric bill, focus on electricity consumption or peak demand measurements. Power quality is a different issue that can be explored on a different project.

It is useful to measure the current used by a piece of equipment connected to your factory's power grid. But, from the perspective of "what do I need to do to save dollars on the electric bill", it may not be useful to measure the number of spikes coming into your facility from your electricity service provider or the exact frequency of your 60 Hz signal (Is it really 59.9985 Hz?).

If your boss wants to cut electricity expenses, focus on the cost goal of identifying big users of electricity and then exploring alternatives such as eliminating wasteful operations of equipment, acquisition of more modern energy efficient equipment, alternate production approaches, and other energy savings actions. There are reasons to make power quality measurements and that should be part of another project involved with power quality. Worry about summer-time "brown-outs" and equipment damage from voltage spikes with a different project. Don't confuse people (boss, co-workers, staff) with a mix of recommendations and conclusions about actions to both reduce electricity consumption and improve the quality of the power coming from your service provider. Typically, these are separate issues.

Make measurements with enough resolution in the power data so that individual pieces of equipment or processes can be identified.

Whole-plant power measurements force your scale factors to mask tiny changes in power consumption.

There may be so many, small and frequent changes to power measurements for an entire plant, the particular power change you are trying to measure in correlation with powering down a piece of equipment on the plant floor may be unidentifiable.

If you are focused on studying the power consumption of a single piece of equipment that consumes between 100 watts (0.1 kW) and 2,000

watts (2kW), make sure your monitoring equipment can measure and display changes below 50 watts and above 2 kW while measuring the total connected power. This is a reasonable requirement. Saving money on the electric bill is all about the aggregate of many smaller power drains.

For example, a 2 kW power drain during a 24-hr, 365 usage cycle will cost about \$5/day or \$1800/year. Make an impact on 10 or more of these size power drains and on-the-whole your impact can be significant. A 10% reduction in this modest power usage add up to significant dollars (\$1,800/yr). A few modest sized projects like this can make an impact in the aggregate.

Your monitoring system should give you the ability to see small changes in power consumption (on the order of 50 watts) and larger changes in power consumption (on the order of 2 kW), while measuring a larger steady power consumption of 200 kW. If you connect your power monitoring sensors to a power distribution panel supplying 200 kW to various pieces of equipment but you want to initially study a single piece of equipment that consumes 0 watts when disconnected, 100 watts when set to an idle condition or 2 kW when operating at peak load. The same piece of equipment should be able to monitor a 200 hp air compressor consuming 150 kW.

Make measurements with enough time resolution to allow for meaningful feedback to the users.

Real-time or near real-time feedback from your monitoring system is important in order to understand your power-use data and derive actionable information from power-on/power-off/power-level tests. To be useful, the monitoring system that records changes in your power-use must deliver meaningful information to you within 15 seconds of the action that causes a change in power

consumption. Specifically, when a piece of equipment is turned on or off, you must be able to see the impact of that change on your power consumption profile within a few seconds -- in order to make actionable conclusions from your test. If your power-use monitoring system collects and sends data to you only once every 15 minutes, you will not be able to resolve actions that test the power consumption of individual machines.

For example, in power-on/power-off tests, 15-minute measurement intervals will not allow you to determine if the power measurements that you are viewing were affected only by the target machine in your tests. It is possible that some other piece of equipment - elsewhere in your facility but supplied by the same power distribution panel - happens to turn on or off during the 15-minute data acquisition interval.

In addition, if you need to wait 15 minutes between each test, efforts to associate power consumption with different pieces of equipment become impractical. The long delay between even the simplest tests make these types of tests too inefficient and too time consuming. In addition, as described above, long time intervals increase the uncertainty in the data.

In summary, if too much time elapses between measurements or there is too much time delay before you can view the data, then the information is simply not useful.

Select a remote monitoring measurement system that allows you to view changes in power consumption near the work location where changes are being made.

Whole-plant power-use monitoring systems do not typically make it easy to view real-time power-consumption data on the plant floor -- where the

action is. Making a change to the electricity consumption profile on a piece of equipment and then walking 350 feet to the main electrical service entrance panel to read an LCD display on the main breaker panel -- and then walk back to the equipment you are working with -- is impractical. Aside from the poor use of your valuable time, during your walk other pieces of equipment may turn on or off. Finally, real world limitations demand that if it is too time-intensive to check for changes in power consumption, you probably won't do it as often as is needed - if at all.

You should be able to see the effect of your changes instantly in close proximity to the physical location where the changes are being made. You should not have to walk 100 feet to a view a meter hanging on a power distribution panel. You also should not have to first download data from a memory device into a computer in order to see the results of your equipment power changes. You need to have measurement data that is easy to view, instantly available, and close to the action.

Select a monitoring system without too much "installation and setup" effort.

Monitoring systems for individual pieces of equipment can be easy to setup and install and easy to move from one piece of equipment to another.

For "whole-plant" monitoring, the installation and setup is frequently an involved process with conduit installation, power outages, and wiring modifications.

Beware of dangerous voltages that may be present during installation and setup as well as dangerous voltages that may be present at the monitoring instrumentation. There are some approaches, like Sensor Synergy's Watts Aware that minimizes exposure to dangerous voltages during installation and does not involve any exposure to high voltages after installation and setup.

Make and record measurements that will help you analyze prior events and possibly prior electric bills.

Electricity use monitoring solutions that monitor all of the electricity used by your facility often do not provide the time-resolution or the power-level resolution to identify specific actions that can be used to reduce your electric bill.

Although measurements on individual pieces of equipment may only be responsible for a fraction of your on-going electric bill, in the aggregate you will be able to make a significant impact on your bill during a few months of focused, energy- cost reduction activities.

As in many situations, you may discover that 20% of your equipment is responsible for 80% of your electric bill. Making changes to electricity consumption profiles for the most power hungry equipment in your facility will have a noticeable impact on energy savings and help you get the most "bang for your buck" - or the most electric bill cost reduction per dollar invested in efficiency improvement projects.

There may be many ways to reduce electricity consumption in your facility. However, from a cost perspective, it may be best to focus on actions that are cost-justified by the expected returns.

To know the expected returns on an efficiency improvement project, you first need to know how much is being spent prior to the project. Sensor Synergy's Watts Aware 118 can help you make these cost of operation measurements. Information on the cost of electricity to operate a machine running under the conditions at your plant (throughput, mechanical load, etc.) will help you determine how much you can spend on an energy-efficiency/electricity-use-reduction project.

For example, to reduce the use of electricity in your plant, you may be able to add variable speed drive modules, replace old inefficient motors with more modern higher efficiency motors, replace improperly sized motors, and/or replace inefficient lighting fixtures with more efficient lights. All of these changes can reduce electricity consumptions. But, the question you must answer is - "which steps are most cost effective"? To answer this question, you must estimate the expected cost savings as a result of your energy efficiency project. This estimate must be based on your pre-project electricity cost usage study and the expected electricity-use reduction percentage.

Electricity-use monitoring solutions focused on equipment can identify which pieces of equipment are the most power-hungry and which equipment uses relatively little power. Projects to reduce electricity consumption should focus on the power-hungry users. If a smaller electricity consumers cannot cost justify an energy efficiency project, then it may be appropriate to leave those machines alone.

4. Monitoring Electricity Use in Compressed Air Equipment

Why Monitor Electricity Use in Equipment

A "power-use" monitoring system can help you identify costs associated with various pieces of production and support equipment - such as extrusion machines, air compressors, pumps, mixers, heat treatment ovens, and HVAC equipment. The total power consumed by any single machine in a "typical" week will depend greatly on the details of your week. Physical measurements are needed due to the duty cycle variations associated with production loads, environment changes, operator issues, shift issues, and many, many other factors.

Limits on Boiler-Plate Information

The boiler-plate label on a piece of equipment may indicate the peak amount of power consumed by a piece of equipment, but this information cannot provide a useful indicator about power usage in your operations. In general, this information is designed to help the electrical installer provide the correct size power cable and the appropriate circuit breaker when operating at maximum load. But, in most production environments, equipment rarely operates at maximum load all of the time. So, the boiler plate information will allow you to determine the maximum power your piece of production or support equipment can use under the most extreme conditions. But, you may not be able to determine how much electrical power your equipment uses in your facility's environment working at mechanical loads your production processes create.

Nothing Like Direct Measurements

Direct power-use measurements during a significant period of time (9 days, 2 weeks, or 1 month) will provide you with valuable operational cost information specific to your operations. Many times, the 2nd shift, 3rd shift and weekend electrical costs can dominate the overall cost of operations. And, often provide the greatest opportunities for savings!

Measurements that gather data 24 hours a day, 7 days a week including weekends can be essential for understanding the actual costs of providing electricity to your machines. Weekend effects and end of month production changes can have an important effect on the energy costs of certain operations.

Financially Sound Decisions Need Energy Operating Cost Data

For example, once the cost of not turning off a piece of equipment during an idle period is determined, financially sound decisions can be made regarding the amount of effort and dollars that should be expended to turn off each piece of equipment during an idle period. Also, the one can determine how long a piece of equipment can be allowed to be idle before the financial incentive justifies taken corrective action to turn the machine off - possibly with an automatic controller. Of course all of these decisions depend on the costs to operate the machine and the cost of the automatic controls.

Air Compressors in Manufacturing Facilities

Another good example relates to air compressors. When a facility based compressed-air system is turned off, the entire system - header pipes, receiver tanks, dryers etc - must be brought back to a pressurized state before operations that use compressed air can begin. If it takes 15 minutes to re-pressurize your system, and the system will be idle for only 30 minutes, it may not be economically feasible to turn off your compressors during this short of an idle period. However, if the system will be idle for an entire 8 hour shift, it may be economically sound to turn off the compressors and the end of the last shift of the day and turn them on again 15 minutes prior to the start of the next shift.

The Cost of Operating Through an Idle Period vs. the Cost of Turning the System On and Off

The cost of operating the compressors during the 8-hour idle shift compared with the costs of bringing in a production worker 15-minutes prior to the normal start time must be considered. With this "manual" approach, it is important to arrange for another production worker to stay at the end of the shift and shut down the equipment.

A slightly more advanced solution with greater up-front costs and lower on-going costs, is to purchase automated equipment to start and stop your equipment based on a time-of-day / day-of-week clock. This automated approach may require contacting the manufacturer of your equipment to find automated "on-off" devices compatible with your equipment or the use of a small PLC unit to perform a more complex start and stop set of procedures on your equipment.

Still more advanced solutions may utilize sophisticated "smart" automation equipment that turn equipment "on" and "off" based on other factors in addition to a time-of-day clock. Information measured by power-use monitors will help you determine how many dollars are wasted on running equipment during off-shift hours so you can better decide how many dollars can be spent on automation equipment to turn compressors - or other pieces of equipment - on and off.

In some cases a \$20 "occupancy sensor switch" turning lights on and off in a seldom used room might be easy to justify. But, in other cases an advanced "staging" air compressor controller networked to multiple pieces of air compressor equipment for \$20,000 to \$30,000 may not be justified by the expected savings in an acceptable ROI time period.

Too Much Air Compressor Capacity Wastes Dollars on Electricity.

For the case of air compressors, other factors can be measured and interpreted by smart air compressor controller systems that can control multiple air compressor units. These types of systems turn on and off different air compressor units based on the size of the air compressor unit, the plant's current demand for compressed air, pressure in the compressed air header pipes, air flow rates and other factors.

Many have observed that normal production shift variations change the compressed air "base-load". At facilities with several air compressors on-line at the same time, it may be necessary to re-configure which air compressors are base-line operational and which compressors are on stand-by to provide "trim-load" capacity. Adjusting these air compressors to keep them operating near their peak capacity can provide significant opportunities to save money. Air

compressors operate most efficiently when they are loaded to operate near their (maximum) design pressure and cubic feet per minute output. Substantial dollar savings can be achieved by eliminating the expense of running large (power-hungry) air compressor units that spend too much time operating in an off-load mode because they have too much capacity for the demand.

Too Little Air Compressor Capacity is also Bad for Productivity

Power-use monitoring can also identify the other side of this issue -- too little compressed air capacity. If your air compressors cannot keep up with the demand your facility makes for compressed air, the pressure in your compressed air system will sag. If the pressure gets too low, some of your manufacturing machines may make more defective materials, operate incorrectly in some other way, or even turn off.

One indication of an undersized air compressor can be found when the power-use monitor indicates that the compressor is consuming the maximum rated electrical power for extended periods of time during peak production periods.

Is it Too Little Capacity or Is it Really Too Many Leaks?

This may be an indicator that your compressor does not have enough capacity for the number of machines demanding compressed air or it may mean that the leaks in the compressed air system within your facility have become out of control and need to be serviced to reduce the demand for compressed air. To the air compressor system, the leaks appear as another machine demanding compressed air 24/7. The number of leaks and the size of the leaks determine how much this demand is in cubic feet

per minute. The demand from leaks never "turns-off".

Other Types of Production Equipment

For other types of production equipment, these other factors may include production "load" requirements dynamically measured during the workday. For example, in some situations presence detectors like opto-interrupters can identify when new parts are delivered to your equipment. Smart controllers can "turn-on" equipment at the appropriate time instead of letting the equipment run in an idle, power-wasting mode. In fact, sometimes power consumption during "off" hours can dominate the overall electricity use by a particular piece of equipment.

Once these types of unproductive power drains are identified and the costs of running these machines is determined, users have many options to reduce this wasted electricity consumption. Some of these options are described above in this note but there are other options including: replacing older style motors with newer energy efficient electric motors, inserting variable speed drive modules in the control electronics for appropriate motors, replacing older equipment with newer more energy efficient equipment.

But you can't solve a problem unless you can identify what the problem is and how much the problem costs. And power-use monitors, such as Sensor Synergy's Watts Aware 118, can help you identify these problems, determine the cost of operations, and point you in the right direction to reduce these unproductive wastes of electricity, resources, and dollars.

Appendix A - Useful Facts and Figures

Electric Motors

- 746 Watts of power = 1 Horsepower
- Motors are usually rated with their output mechanical power.
- Electric Motors can be 60% to 95% efficient in converting input electrical power to mechanical power
- Lower horsepower (less than 1 horsepower) motors are generally not as efficient as larger 10 to 500 hp motors at full load.
- Brake Horsepower (bhp) refers to the electric motors horsepower without losses caused by gears or auxiliary equipment.
- A 100 bhp electric motor used in an air compressor may be 90% efficient. Latest technology may be 95% efficient.

Compressed Air Systems

- Many industrial air compressors operate in a cyclic manner shifting between fully loaded to unloaded. The cycles typically can have a period between 60 seconds and 5 minutes.
- In the full mechanical load operation, the air compressor may use close to the maximum amount of electricity the motor will tolerate. In the unloaded part of the duty cycle, the motor may use from 40% to 80% of the energy used by the same motor in the full load case.
- The higher the compressed air pressure set point, the more expensive it is to operate the compressed air system. As a rule of thumb, for every 2 psig of air pressure decrease in the set point, the electricity cost of operation decreases by 1%.
- The power factor for a typical 3-phase motor driving a compressed air system is 0.85

Electric Power-Use Calculations

- Electrical Power is the RATE at which energy is delivered from the supply cables to a user of electricity.
- Electrical Power is usually expressed in Watts or kiloWatts. 1 Watt corresponds to an energy delivery rate of 1 Joule/second. 1 kiloWatt is 1,000 Joules of energy/second.
- A Joule is the amount of energy needed to apply 0.74 pounds of force for a distance of 1 foot.
- Electrical Power delivered to a system is equal to the sum of the instantaneous Voltage x Current for the entire time the electricity is connected.
- 1 kiloWatt of electricity drawn from the electricity grid for a period of 1-hour is referred to as a kiloWatt-hour (kWH). In the U.S., 1 kWH costs between \$0.05 and \$0.15 - depending on your location and your negotiated pricing agreements with the local electric utility company.
- 3-Phase, Delta configured, power systems require a correction factor on the measured current of 1/1.732. So, a balanced 3-phase, 480 Volt AC motor drawing an rms current of 100 amps on each of its 3-legs will use power as
$$3 \text{ phases} \times [480 \text{ volts} \times (100 \text{ amps} / 1.732 \text{ current correction factor})] \times 0.85 \text{ power factor}$$

Appendix B -- Useful Links for Additional Information

Compressed Air Challenge - Initiative launched by the U.S. Department of Energy in 2001.

www.compressedairchallenge.org
www.compressedairchallenge.org/library/index.html

U.S. Department of Energy - Overview on Saving Energy

www.energy.gov/energyefficiency/index.htm
www.energysavers.gov/tips/

Sensor Synergy Inc.

www.sensorsynergy.com/WattsAware.htm