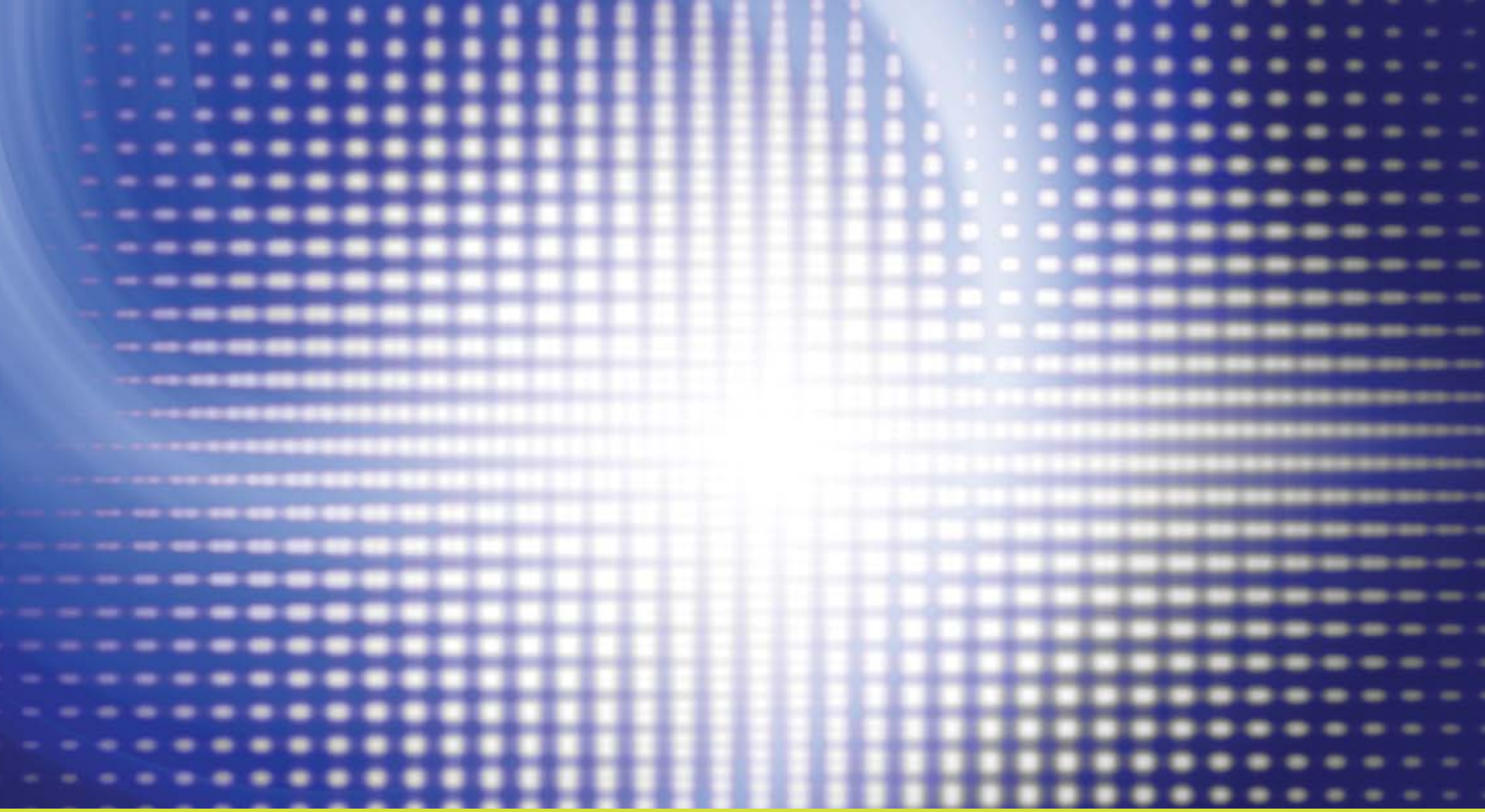

UTC Energy Management Guidebook

United Technologies

A systematic approach to formulating and implementing an effective energy management plan

United Technologies

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UTC FIRE & SECURITY
UTC POWER

Introduction

Rising energy costs and global environmental concerns affect our business every day. Our response is to develop ever cleaner and more efficient solutions both for ourselves and for our customers. Conserving resources and minimizing adverse impacts create competitive advantage in an environmentally conscious marketplace.

Every United Technologies (UTC) facility worldwide must take an active leadership role in reducing energy consumption, thereby reducing greenhouse gas emissions. Worldwide climate change is an environmental concern facing all of us. How society tackles this challenge will determine the quality of life for future generations.

UTC is pleased to provide you with this Supplier Energy Management Guidebook. The Guidebook will provide you with a systematic approach to formulating and implementing an effective energy management plan. The Guidebook offers standard work processes developed by UTC facilities managers, along with standard practices adopted from the ANSI MSE 2005 Standard for Energy Management.

After you have implemented these practices, your site will have taken significant steps in reducing your energy use, cost and impact on the environment.

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Energy & Greenhouse Gas (GHG) Data Management

The first and most important step in an energy and GHG management program is Data Management

Collect 24 months of all utility consumption data

Information from sources such as utility bills, utility meters, energy sub-meters, published utility tariffs, energy supply contracts and external market updates will be used for four main purposes:

1. To establish a baseline by answering the questions:

"How much energy do I currently use?"

"When do I use that energy?"

"How much is that energy costing me?"

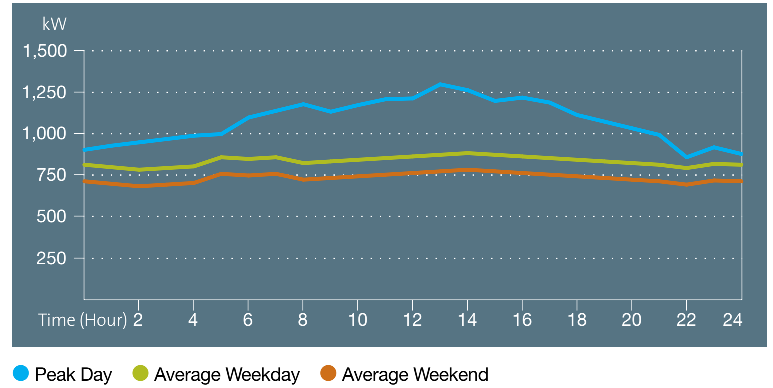
2. Establish a benchmark of optimal "Energy Intensity" in kWh/sq. ft. or mmbtu/unit of production.

3. To establish the site's GHG inventory (see Appendix F), the summation of all GHG emissions generated by operating the business including energy consumption and direct process emissions converted into carbon dioxide emissions equivalent (CO_2e).

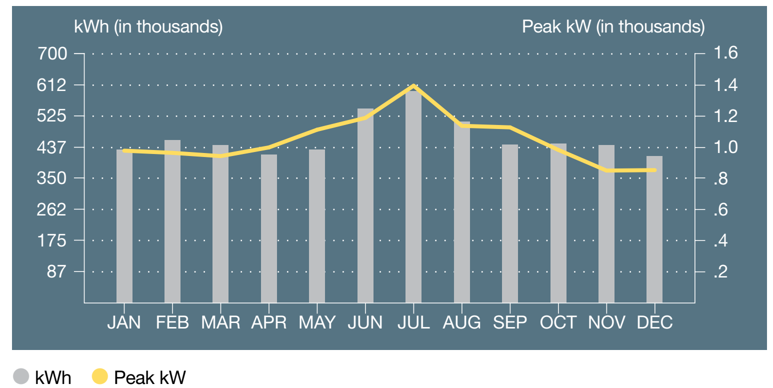
4. To evaluate the ongoing effectiveness of the energy management program to enable quick diagnosis of the root cause of any problem and timely implementation of effective corrective measures.

Consumption history should be recorded and displayed

Average Daily Electric Profile



Annual Electrical Profile



Essential Elements of Energy & GHG Data Management:

- Collect and record a 24-month history of all utility cost and consumption, including but not limited to electricity, natural gas and fuel oil
- Collect and report direct process emissions for all six greenhouse gases in conformance with The Greenhouse Gas Protocol, a corporate accounting and reporting standard by the World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). (see Appendix F)
- Keep a record of current energy supply contracts and utility tariffs for each account
- Keep a detailed record of consumption profiles (hourly for electric consumption, daily for natural gas use)
- Establish a budget and monthly consumption projection and compare the projection with actual data
- Conduct a review of utility invoices, checking for mistakes or misapplications of tariffs that add cost
- Allocate energy cost by business unit or department

Electrical and Natural Gas Consumption, Cost and GHG Emissions

	Electric					Natural Gas			
	Peak kW	kWh	Cost	Unit Cost $/kWh	Electric GHG Emissions metric tons	MCF	Cost	Unit Cost $/MCF	Natural Gas GHG Emissions metric tons
January	980	431,520	$50,584	$0.12	186	3,690	$39,007	$10.57	201
February	966	458,640	$52,666	$0.11	197	3,175	$37,460	$11.80	173
March	945	445,200	$51,183	$0.11	191	3,107	$33,579	$10.81	169
April	1,001	417,120	$50,755	$0.12	179	1,654	$21,264	$12.86	90
May	1,115	430,800	$55,930	$0.13	185	1,030	$10,831	$10.52	56
June	1,191	546,240	$78,364	$0.14	235	502	$5,404	$10.76	27
July	1,398	596,880	$88,069	$0.15	257	345	$3,588	$10.40	19
August	1,140	509,760	$70,944	$0.14	219	603	$5,567	$9.23	33
September	1,130	440,500	$55,000	$0.12	189	752	$6,855	$9.12	41
October	985	450,240	$48,254	$0.11	194	1,620	$18,385	$11.35	88
November	852	442,080	$45,987	$0.10	190	2,878	$36,646	$12.73	156
December	855	411,840	$45,160	$0.11	177	4,012	$52,184	$13.01	218
Total		5,580,820	$692,896	$0.12	2,400	23,368	$270,770	$11.59	1,270

While reducing energy consumption and cost is important for maintaining financial and competitive strength, it is also important to make a company commitment to improving the environment by reducing greenhouse gases. Energy conservation is the best way to accomplish that goal.

Utility Rate Review

Natural gas and electric utility companies offer rate structures (or tariffs) that vary according to customer size and load profiles.

For example, many electric utilities offer tariffs with one set of rates for on-peak hours and another for off-peak hours. These rate structures should be reviewed annually for suitability with your site's specific consumption profile. Utility companies can usually compare the cost of service for different tariffs by running a computer program.

It should be noted that rates change over time due to government regulation and market conditions. Site-specific requirements also change over time. So it makes sense to review rate structures periodically, and particularly whenever the site requirements change.

Best Practices

Request an annual rate from the utility company

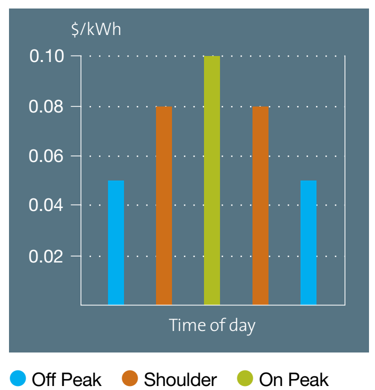
Review terms and conditions of each rate structure to make sure they apply

Check accuracy of:
- tax credits
- billed kW vs. actual kW
- power factor correction penalties
- credits for interruption riders

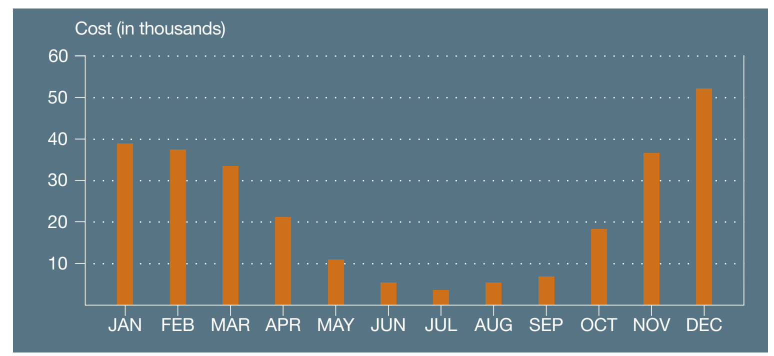
Check the status of all utility accounts. Large sites with multiple meters may be paying service charges for inactive meters

Review the status of utility company and/or government-sponsored conservation programs. Programs may offer incentives for investments in energy conservation projects

Utility Rate Review



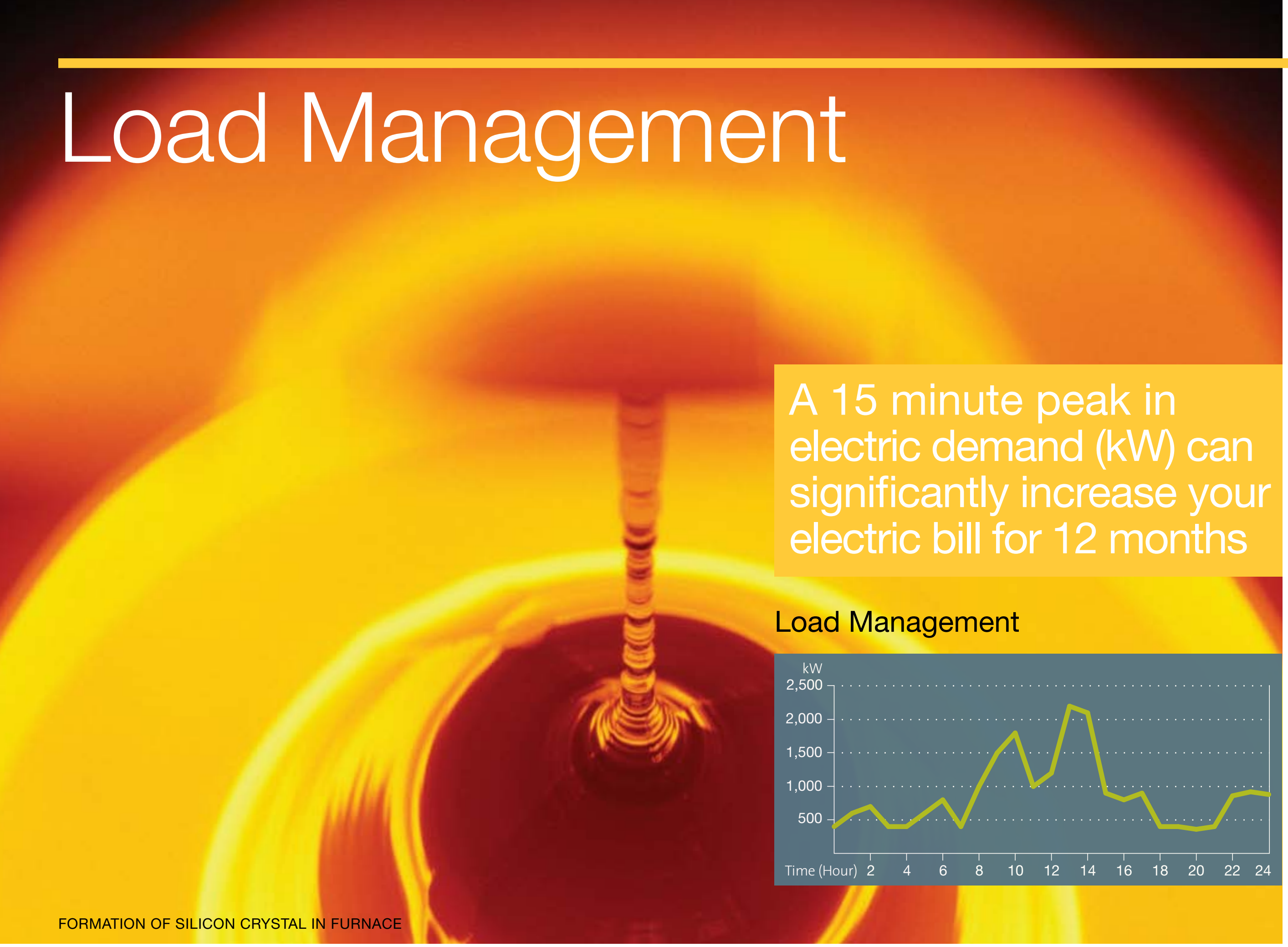
Annual Gas Consumption Profile



Utility rates should be checked annually

Review energy conservation rebate and incentive programs offered by your local utility company

Load Management



A 15 minute peak in electric demand (kW) can significantly increase your electric bill for 12 months

Load Management

FORMATION OF SILICON CRYSTAL IN FURNACE

Electric Load Management is a process of controlling electrical loads (manually or automatically) to minimize peaks. Load Management is called many different things: Load Shedding, Peak Shaving, Load Limiting, Demand Response and Demand Management just to name a few.

Whatever you call it, this process is an effective approach to reducing costs in two ways:

By reducing demand at peak times, your site can earn credits, discounts, or rebates from your electric utility company

Electric bills typically include a demand charge in addition to an energy charge (see "Sample Electric Bill," next page). So by limiting peak demand (kW) on an ongoing basis, you can reduce those monthly demand charges ($/kW). Since demand charges can amount to 40 – 50 percent of the electric bill, savings can be substantial

Effective Load Management requires a strategic approach that includes analyzing load profiles, understanding equipment and then installing control strategies. One additional and very important activity is monitoring. As with any continuous improvement process, ongoing monitoring or sub-metering must be employed to track progress.

Analyze Consumption Profiles

Energy consumption profiles should be reviewed and analyzed for cost drivers. A review of monthly energy data (natural gas and electric) will show seasonal trends. A review of consumption data in shorter increments will illustrate key cost drivers.

Large natural gas accounts should obtain daily consumption records

Large electrical accounts should obtain hourly consumption records

This detailed energy data is usually available from utility companies and is invaluable in understanding consumption patterns and cost drivers

Identification of Major Loads

The next step in an effective Load Management program is the identification of major energy consumers. A site survey should be completed and the operating characteristics of the top 10 energy consumers recorded. The cost of operation for each piece of equipment should be calculated or measured and then reconciled with the total energy bill.

Typically, large energy consumers include: chillers, boilers, air compressors, packaged AC units, ovens, lights and process heating.

Sample Electric Bill

Demand Charge ($7.10 per kW)	
$7.10 X 2100kW	= $14,910
+	
Energy Charge ($.065 per kWh)	
$0.065 X 350,000kWh	= $22,750
Total Electric Bill	$37,660

Analyze each cost component of your electric bill before you take action

Sample of Top 10 Electric Loads

	Equipment	Load	Operation
1.	Furnace	75kW	40hr/wk
2.	Air Conditioner	60kW	60hr/wk
3.	Air Compressor	50kW	168hr/wk
4.	Lighting	48kW	70hr/wk
5.	Parts Washer	20kW	10hr/wk
6.	Welding	20kW	10hr/wk
7.	Forklift	10kW	08hr/wk
8.	Hydraulic Testing	15kW	05hr/wk
9.	Oven	15kW	20hr/wk
10.	Overhead Crane	10kW	20hr/wk

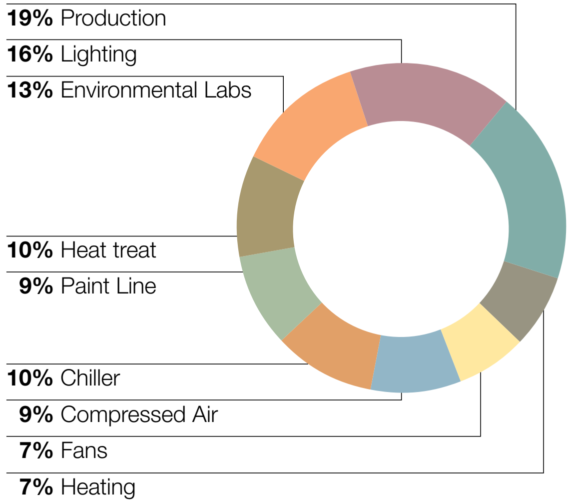
Some utilities have "Demand Response Programs" that offer incentive $ to customers that can reduce electrical loads during peak conditions

Control

Once you have a thorough understanding of the consumption profiles and have identified the equipment loads, you should develop a control strategy to limit peaks and manage cost.

Control strategies can be as simple as turning off equipment when a new peak is about to be set. Many sites employ a more complex control strategy utilizing an Energy Management System (EMS) to monitor and automatically shed equipment when the demand (kW) hits a programmed limit.

Typical Electric Consumption Breakdown



Sub-metering

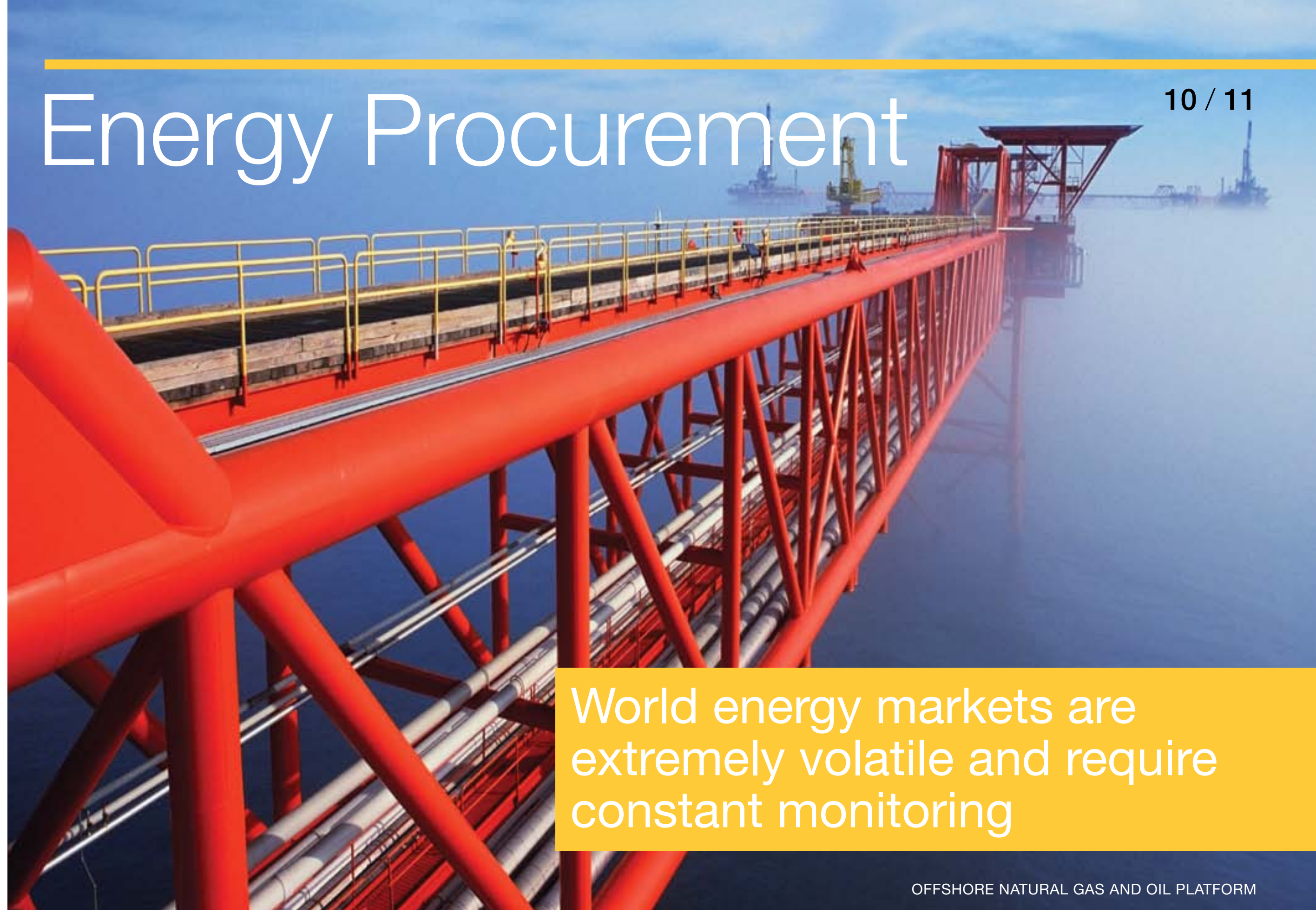
You can't control what you don't measure. Sub metering will give you the ability to better measure and, therefore, better manage energy use. A well designed sub metering system will show exactly where and when energy is being used. The data will support and improve budgeting and cost allocation. It will also validate savings from energy conservation efforts.

Inexpensive portable equipment metering and monitoring devices can be used in lieu of fixed submetering.

What Sub-Metering Will Enable You to Do

- Assign energy costs to specific departments
- Identify opportunities for potential energy efficiency improvements
- Determine equipment and system efficiency
- Quickly recognize performance problems in processes and equipment
- Uncover the causes of energy waste that may otherwise go undiscovered under a traditional metering and billing system
- Provide information necessary to develop effective RFPs (Requests for Proposal) or the competitive energy market
- Validate the accuracy of utility bills

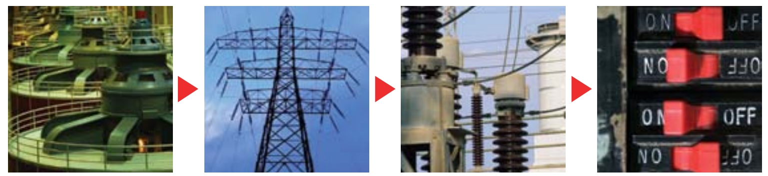
Energy Procurement



World energy markets are extremely volatile and require constant monitoring

OFFSHORE NATURAL GAS AND OIL PLATFORM

Electric Supply Chain



GENERATION TRANSMISSION LOCAL DISTRIBUTION CONSUMPTION

To develop and implement an effective energy procurement strategy, you first have to understand how the market works.

Deregulated markets allow the end user to choose competitive suppliers of electric power and natural gas.

In order to execute a successful procurement project we need to address two main areas of importance:

- Market rules
- Price volatility

Market Rules

Energy markets around the world are in various stages of deregulation. In some regions natural gas markets are deregulated (open competitive markets) while electric markets remain regulated monopolies. In other regions the reverse is true.

The rules for participating in the deregulated competitive market vary by location. For example, in some locations, only large customers can participate in the open market. In others everyone can participate (large industrials, small commercial and residential customers). In some markets, once you leave the local utility and take service from a competitive supplier, you cannot switch back to the utility company for service. Therefore, you must strive to clearly understand the market rules.

In all cases, only a portion of the total cost is deregulated or competitive. In electric markets, the generation component is competitive, while the transmission and distribution charges remain regulated and are billed by the local distribution company. In natural gas markets, the natural gas and interstate pipeline charges are competitive, while the local distribution remains regulated.

Market rules vary by location and frequently change

Natural Gas Supply Chain

Price Volatility

Market volatility is the norm. Consequently, you could pay significantly higher prices if procurement projects are not managed. Energy suppliers in competitive markets offer a variety of products. For example, in electric power markets suppliers offer:

Real-time pricing supply contract
With this option energy prices float or vary with real-time markets. This is sometimes referred to as index pricing

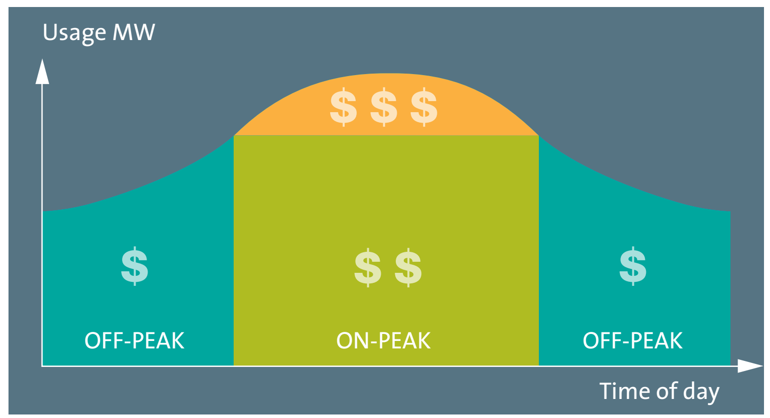
Fixed Price supply contract
A flat fixed price contract, this option provides budget certainty

Block and index supply contract
A combination of fixed and floating pricing, this option provides some budget certainty while allowing the end user to make adjustments to real-time price signals

Layered supply contract
- Customized layered supply contracts to match facility needs

Supplier selection is critical. End users should work with suppliers that offer pricing options that fit their consumption profile and will provide market price transparency. A site-specific consumption profile and local market conditions will dictate which product is best for your site.

Time-of-Day Electric Rates



“Shut-it-Off”

An effective “Shut-it-Off” program is a great way to engage employees in conservation efforts and save money

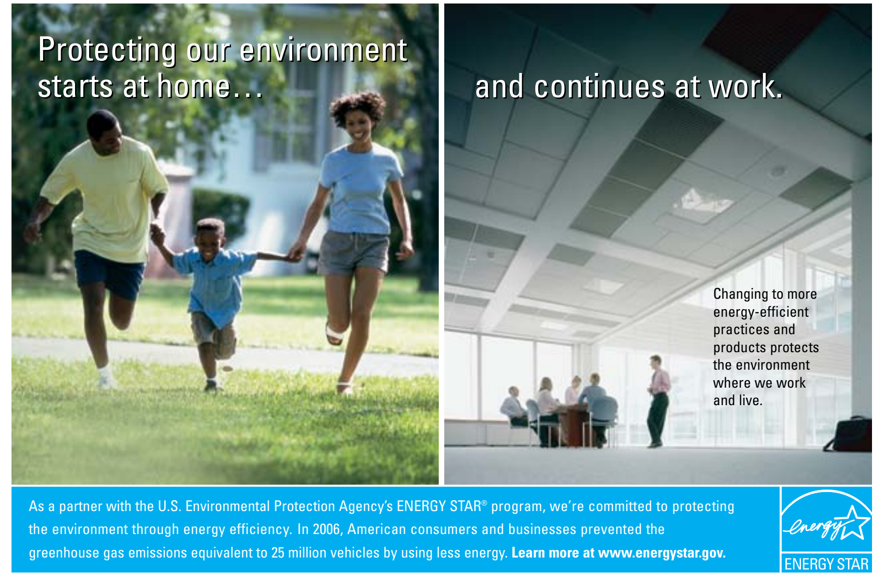
The simplest and most effective way to save energy is to Shut Off equipment that is not needed. Manufacturing equipment, office equipment and building services equipment should all be shut off or put in idle mode when not needed.

Site managers should initiate an effort to evaluate the operating requirements for all equipment and assign responsibility for ensuring that equipment is turned off at the end of the work day. Electric utility meters and building energy management systems can easily monitor daytime and night time consumption to track the effectiveness of “Shut-it-Off” efforts.

Electric consumption profiles should be reviewed and efforts made to eliminate waste

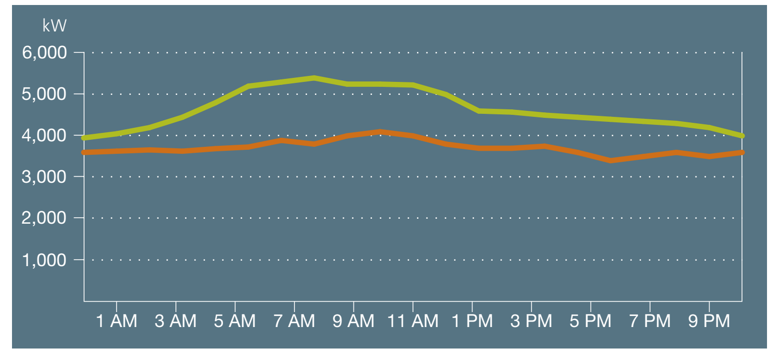
Best Practices

- Design and display posters that encourage participation from all employees
- Review manufacturing equipment operating requirements and investigate E-Stop features
- Display “Shut-it-Off” instructions with pictures
- Establish a factory energy team and schedule department “energy treasure hunts” afterhours to look for opportunities to shut down or set back systems
- Consider a competition among workgroups or departments to decrease energy usage
- Install motion sensors to turn off lights when rooms are unoccupied
- Install time clocks on exhaust fans to turn them off during unoccupied hours
- Install electrical interlocks between manufacturing equipment and support equipment (fans and pumps)
- Analyze detailed electrical profiles and identify all loads operating during non-manufacturing hours



EPA Energy Star has energy awareness posters for your use.

Electrical Demand Comparison



Normal Profile Holiday Profile

This chart illustrates the savings potential that a “Shut-it-Off” program can realize. The green (●) line depicts the electrical consumption profile for this site during a typical weekend. The orange (●) line depicts the consumption profile after the site facilities managers promoted “Shut-it-Off” in advance of a holiday weekend. “Shut-it-Off” is a program that everyone can contribute to and the savings are significant.

An effective “Shut-it-Off” program engages all employees

Lighting

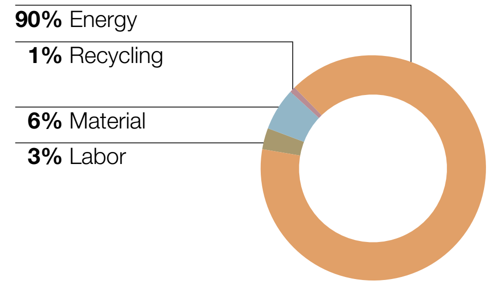
Modern lighting systems use 40 to 50 percent less energy than conventional lighting systems

Reducing the energy consumed by lighting is crucial to a successful energy management program. Lighting is a major energy drain, consuming 25 to 30 percent of the energy used to run a typical commercial building. Lighting also adds to air conditioning costs.

Fortunately, with the continual emergence of technologies that improve lighting efficiency, we have the opportunity to reduce the costs and consumption with reasonable payback.

As the chart indicates, energy is by far the largest cost component of a lighting system—comprising 90 percent of that cost. Consequently, effectively managing lighting energy usage can help bring overall costs down considerably.

Lighting Cost of Ownership



Source: http://www.energystar.gov/ia/business/Lighting.pdf

Lighting Management Program

Maximize Lighting System Efficiency

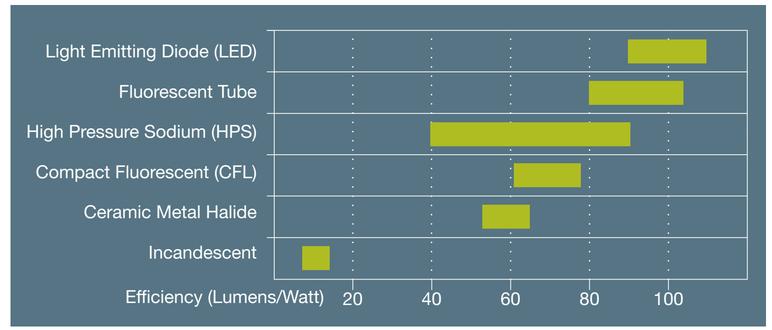
- Utilize the most efficient lighting system components available: ballasts, bulbs and fixtures

Meet standard light levels for various working environments

Control Lighting

- Institute manual shutoff programs to turn the lights off at the end of workday. Whenever possible deploy sensors and other controls to automatically turn off lights in unoccupied areas

Lighting Efficiency Comparison



Lighting System Efficiency Standards

Efficiency varies by light source. The following chart compares the efficiency of various light sources. Common lamp types are organized into families based on the technology used to produce light. Each lamp offers a tradeoff between efficiency, lamp life and quality of light. Lighting systems should be selected to meet the needs of the specific activity (office, shop floor or warehouse).

Recommended Light Levels

Area	Foot Candles	Lux
Open Office Plan	20–50	200–500
Conference Rooms	50–70	500–700
Hallway	10–20	100–200
Cafeteria	20-50	200–500
Warehouse/Storage	5–10	50–100
Manufacturing	30–50	300–500
Parking Lots	2	20

Best Practices

The following are proven cost and energy savings best practices that can provide significant savings. Each item should be reviewed and evaluated for implementation.

Install automated controls such as time clocks, motion sensors, occupancy sensors and building automation systems

Review all new lighting designs for maximum efficiency

Appoint "cell leaders" responsible for turning off shop floor lights after each shift

Use task lights to minimize the need for overhead lighting while still providing adequate light levels for specific tasks and activities

Install bi-level lighting in a warehouse

- Warehouse lighting can often be lowered during hours of low traffic. Motion sensors can be used to return lights to full brightness whenever someone enters the space

Use bi-level lighting controls to accommodate areas with natural light

- In areas with natural light, use electric lighting only where necessary. Install independent lighting control systems for these areas

Re-circuit shop floor lights to turn off lights in areas that do not work 2nd or 3rd shifts

Replace all incandescent lights with compact fluorescent lamps

Instruct housekeeping staff to shut off lights immediately after cleaning an area

Consider LED fixtures for various applications including exit signs and exterior lighting

Use photo cell and time clock controls on exterior lighting

Metrics

The following is a checklist of action-items you can implement to document and measure your progress in reducing energy costs and consumption associated with lighting. These procedures should be followed on a regular basis, not just when an energy audit is scheduled.

- Document connected lighting load (watts per square foot) and foot candle levels for each area (office, shop floor and warehouse)
- Review the Best Practice list for applicable energy efficiency improvements and develop a plan for implementation
- Control the operating hours of the lighting system manually or automatically

Sample Factory Floor Lighting System:

- 250 fixtures
- 2 x 4 fixture 4 lamps/fixture standard bulb, standard ballast
- 6 a.m. to 10 p.m. Mon – Fri (16 hrs/day, 80 hrs/wk)
- 7 a.m. to 2 p.m. Sat (7 hrs/wk)
- 0.085 $/kWh average cost per kWh

Operating Cost Calculator:

Operating cost = (Number of fixtures) x (kW/fixture) x (hrs/year) x (cost/kWh)

Example

250 fixtures x [188 watts/fix./1000watts/kW] x 87hrs/wk x 52wk/yr x $0.085/kWh = $ 18,073 per year

Compressed Air

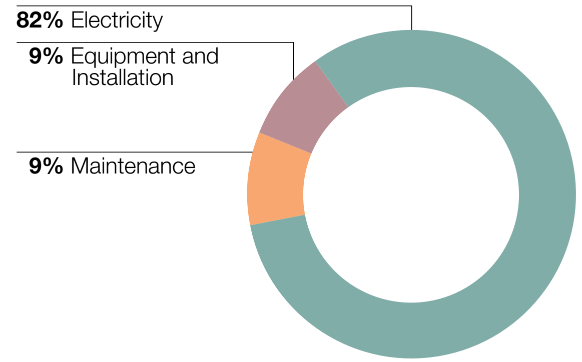
A 100 HP air compressor costs up to $60,000 per year to operate. Up to 50 percent is wasted (DOE)

Compressed air systems are integral to the operations of most industrial facilities—providing power for tools, equipment, and a broad range of processes—so much so that compressed air is considered industry's fourth utility after electricity, gas and water.

Compressed air systems also consume a lot of electricity—as much as 25 percent of what an entire facility consumes. The cost of the electricity to run a compressed air system is the largest portion of total system cost—82 percent.

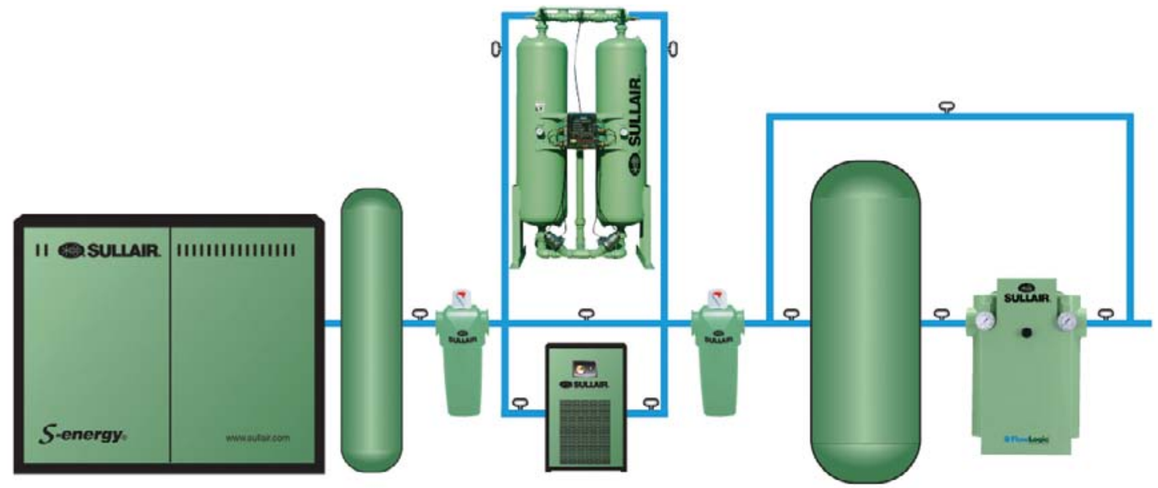
Fortunately, there are numerous opportunities for reducing waste and increasing the efficiency of the compressed air systems at your site. The diagram below highlights some of the components of a typical compressed air system where these opportunities exist. Fixing system leaks, avoiding inappropriate uses of compressed air, eliminating excessive pressure settings, using state of the art controls and maintaining the systems for peak performance can collectively save 20 to 50 percent.

Total Cost of Ownership



Source: U.S. Department of Energy

Compressed Air System



Add Real-Time monitoring capabilities to manage and control your compressed air system.

Compressed Air Management Program

The following activities should be part of any strategy to reduce compressed air system energy consumption and costs:

Document your compressed air system, including the supply side capacity and demand side requirements

- It's essential to know exactly what your compressed air system consists of and what the system is expected to do. On the supply side (compressors and air treatment), determine what equipment you have and the generating capacity of that equipment. On the demand side (distribution and storage systems and end-use equipment), determine how much compressed air you need, and at what level of quality, as well as load and pressure requirements. For analysis purposes, it is helpful to create a block diagram of your system. It is also important to measure your baseline and calculate your energy use and costs so you can establish current performance and cost levels and compare them to future levels

Monitor and record compressed air system pressure and air flow over time

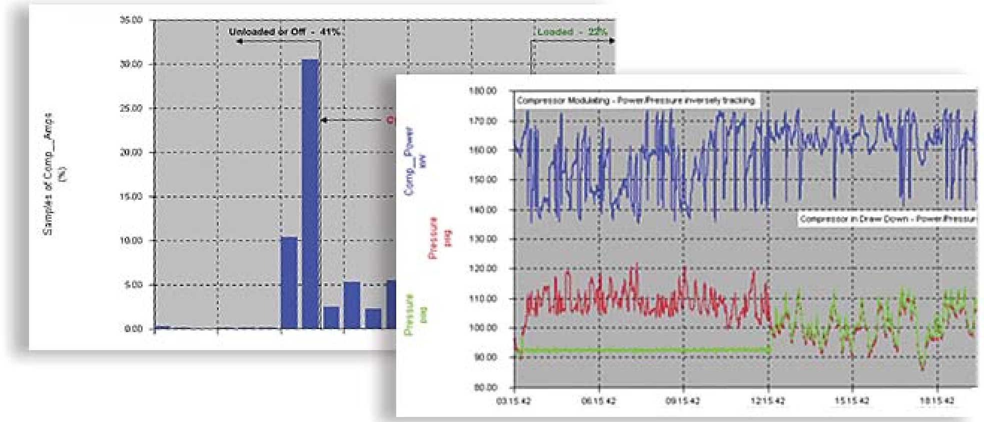
- Keep track of system performance to identify inefficiencies. Track any improved performance attributable to system enhancements

Develop and implement a control strategy to maximize system efficiency

- Compressed air system controls are intended to optimize the supply (volume and pressure) of compressed air with the system demand. A well conceived and implemented control strategy can help accomplish this goal by shutting off unneeded compressors and delaying the activation of additional compressors until they are needed

Develop and implement a well-defined leak management system

- 20 to 50 percent of the compressed air production in a facility can be lost to leakage. Leaks cause pressure drops that adversely affect tool performance and production processes. Leaks force you to run compressed air systems longer to make up the difference, thereby shortening the life of the system. An effective leak management program can reduce leaks to less than 10 percent of compressor output[1]



Compressed Air Efficiency Standards

Compressed air efficiency is the ratio of energy input to energy output.[2] The industry norm for comparing compressor efficiency is expressed in terms of bhp/100 acfm (brake horse power per actual cubic feet per minute) at a compressor discharge pressure of 100 psig (pounds per square inch gauge).[2] Whatever standards or measurements you use, put a monitoring system in place to record the performance of your compressed air system.

Excess air pressure wastes energy

Compressed Air Operating Standards

Ideally, compressed air system capacity should match the load. Put another way, supply should match demand. One way to accomplish this match is to deploy controls, such as flow pressure controls, to maintain system pressure and ensure that compressor output does indeed match system demand. Typically, compressed air is generated and stored at one pressure and then released at a lower pressure. The result is the ability to satisfy peak demands while preventing other compressors from coming on line when not needed, thereby saving energy. The goal is to maintain a consistent overall system pressure as close as possible to 5 PSI above the low pressure alarm set point. As noted earlier, leaks can cause pressure drops that affect system efficiency and performance. Therefore, compressed air systems should be checked for leaks at least once a year.

[1] U.S. Department of Energy: "Improving Compressed Air System Performance."
[2] U.S. Department of Energy: "Packaged Compressor Efficiency Ratings."

Compressed Air Cost Calculator quick rule of thumb: $1.25/day/hp

Compressed Air Operating Cost

The operating cost of a compressed air system is much more than the cost of the equipment. It can take 7 to 8 hp of electricity to produce 1 hp of air force. The annual energy cost of running a compressed air system is affected by several variables, including the horsepower (hp) of the compressor, motor efficiency, electric utility rates ($/kWh) and the hours of operation. See formula below to calculate operating cost.

$$\text{Operating cost (\$)} = \frac{\text{(hp) x (0.746) x (electric rate) x (hours)}}{\text{Motor efficiency}}$$

Another variable is the percentage of time that the system runs at a given operating level and the percentage of time it runs fully loaded.[1] Accordingly, the following formula can be used:

$$\text{Operating cost (\$)} = \frac{\text{(hp) x (0.746) x (electric rate) x (hours) x (\% time) x (\% full load)}}{\text{Motor efficiency}}$$

Here's an example: Let's say you have a 200 hp compressor that requires 215 bhp. The system operates 6,800 hours a year, running fully loaded 85 percent of the time with a motor efficiency of 95 percent, and the rest of the time at 25 percent of full load with a motor efficiency of 90 percent. For the purpose of this example, let's say that the electrical rate is $0.08/ kWh.[1] Here's how to calculate the costs:

Operating cost when fully loaded (85% of the time)

$$\frac{\text{(215 bhp) x (0.746) x (\$0.08/kWh) x (6,800 hrs) x (0.85) x (1.0)}}{0.95} = \$78,067$$

PLUS

Operating cost when partially loaded (15% of the time)

$$\frac{\text{(215 bhp) x (0.746HP/KW) x (\$0.08/kWh) x (6,800 hrs) x (0.15) x (0.25)}}{0.90} = \$3,635$$

Annual energy cost: $78,067 + $3,635 = $81,702.

Leak Management

Compressed air leaks are a significant waste of energy. For example, a compressor operating at 100 psi 24 hrs/day with a single 1/8″ air leak costs you over $3,600/year at .08 $kWh.[2]

Annual Cost of Air Leaks

	Orifice Diameter (Inches)							
Upstream Psig	1/16	1/8	1/4	3/8	1/2	5/8	3/4	7/8
70	$677	$2,707	$10,829	$24,366	$43,317	$67,683	$97,464	$132,659
80	$757	$3,028	$12,111	$27,249	$48,443	$75,693	$106,998	$148,358
90	$837	$3,348	$13,392	$30,133	$53,570	$83,703	$120,532	$164,057
100	$917	$3,669	$14,674	$33,017	$58,696	$91,713	$132,066	$179,767
110	$997	$3,969	$15,956	$35,900	$63,822	$99,722	$143,600	$195,456
120	$1,077	$4,309	$17,237	$38,784	$68,949	$107,732	$166,134	$211,166

Cost of energy = $0.0800 per kWh

Compressor efficiency = 4CFM per Bhp

Motor efficiency = 0.925

Increasing system efficiency and eliminating leaks will lower the cost of running a compressed air system

[1] U.S. Department of Energy: "Determine the Cost of Compressed Air for Your Plant."
[2] U.S. Department of Energy: "Improving Compressed Air System Performance."

Best Practices

The following proven best practices can help maximize compressed air system efficiency, minimize energy losses, and reduce energy consumption and the costs associated with system operation.

Create a block diagram of your compressed air system

- If you periodically add on to your system, it is possible that you are building additional inefficiencies into the system every time you add a component or sub-system

Measure the baseline use of air and calculate your current energy consumption and cost

- Measure and track energy consumption, pressure, flow and temperature

Work with a compressed air specialist to establish an effective compressor control strategy

- Since 1965, Sullair (a UTC company) has been recognized around the world as an innovator and leader in rotary screw compression technology. Sullair offers air system solutions to help compressed air users reduce energy cost and improve productivity by analyzing, managing and controlling compressed air systems

Identify and eliminate choke points

- A choke point is a blockage in the piping. Such blockages cause drops in pressure
- Reduce the operating pressure to the lowest level possible. "Shop air" at 100 psi is rarely required and higher pressure results in both higher energy use/cost and higher leakage rates

Eliminate unnecessary hose runs

- The shortest and most efficient distance between two points is a straight line. Unnecessary hose runs, particularly hoses that wind and curl impede the efficient flow of compressed air and cause pressure drops

Identify and eliminate leaks as part of a leak management program

- Conduct a leak audit at least once a year

Design closed loops and eliminate dead-head piping systems

- In a piping system with a dead end, users at the end of the line receive reduced pressure. By contrast, creating a piping loop enables the system to deliver equal pressure to everyone along the line. Be careful when adding on to your system not to create a dead end

Eliminate inappropriate uses of compressed air

- Compressed air is one of the most expensive sources of energy in an industrial facility. Compressed air is appropriate for some applications and processes, but is not a cost efficient source of power for others. Inappropriate uses for compressed air include such processes as cooling, vacuuming, drying, mixing and atomizing. *NOTE: For processes requiring a delivery pressure of 25 PSI or less, you are better off using a blower, rather than compressed air*

Use filters with the lowest pressure drop available that is able to deliver the required quality of air

- Filters are necessary throughout a system to ensure that clean air reaches the end-use application. Inefficient or dirty filters clog the system and cause pressure drops, while forcing the system to consume more energy to compensate for those pressure drops. Using the right psi filter and inspecting regularly can help reduce this form of inefficiency

High-demand devices should include a local storage tank to absorb peak air demands

Use cooler intake air

- Compressors operate more efficiently when the source of intake air is clean and cool. Put another way, it takes less energy to compress cool air than warmer air. An effective approach is to use outside air for compressor intake

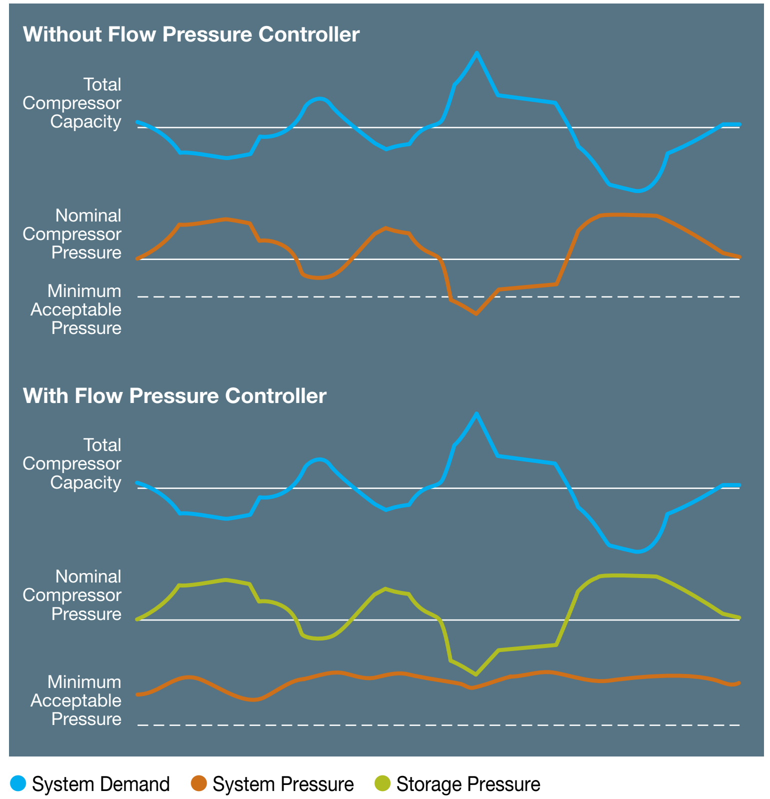
Consider deploying multiple smaller compressors rather than one large compressor

- With multiple compressors available, you can control the system to activate or shut down compressors only as they are needed, thereby reducing unnecessary energy consumption

Install interlocks and solenoid valves that shut off air when equipment is not running

- This, too, avoids consuming energy when it is not necessary to do so

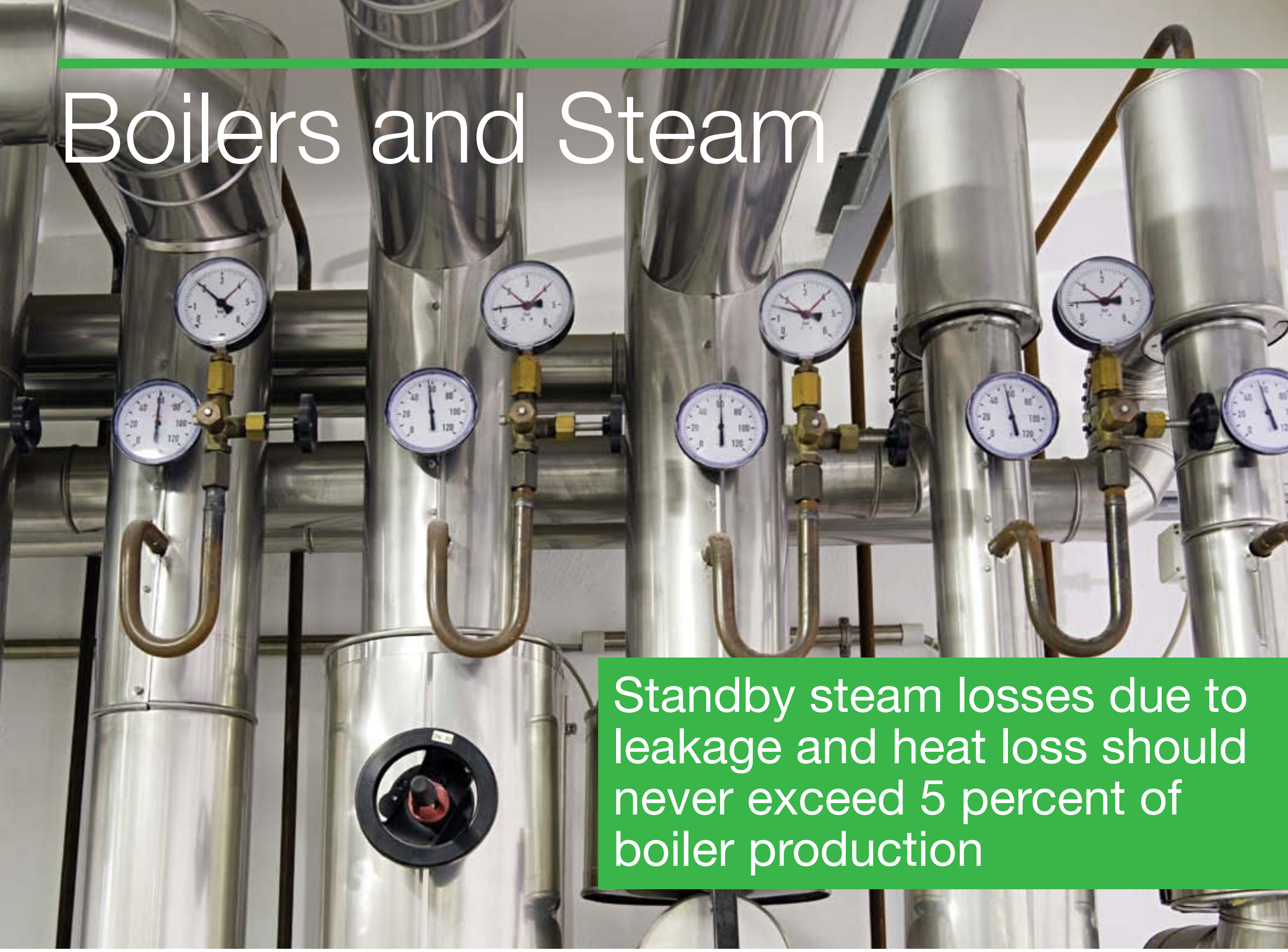
Fluctuating Compressed Air Problem



One 1/4˝ open nozzle used for employee cooling is roughly equivalent to 15 hp of compressed air

[1] North Carolina Division of Pollution Prevention and Environmental Assistance: "Energy Efficiency in Air Compressors."

Boilers and Steam

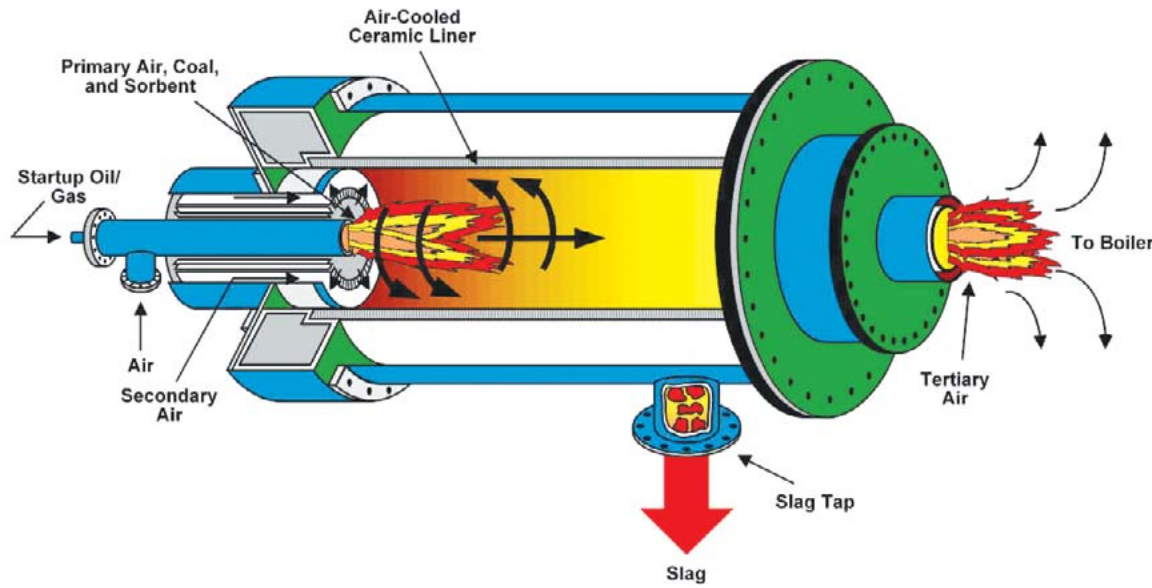


Standby steam losses due to leakage and heat loss should never exceed 5 percent of boiler production

Maximizing boiler efficiency is an essential component of any energy management program.

Ideally, a facility should deploy the most fuel efficient boilers available. While most boilers are designed for one specific kind of fuel, boilers can be configured for dual fuel operation. This is an important consideration, as fuel costs vary. Efforts must also be taken to maintain and operate boiler systems and components as efficiently as possible. A broad range of sophisticated control systems exist to improve the efficiency of boiler operation and deploy heat energy only when needed and at the capacity required. See “Best Practices” for tips on minimizing loss and maximizing boiler performance. Numerous opportunities exist to save energy, reduce consumption and maximize boiler efficiency. The following diagram illustrates areas (highlighted in green) in a typical steam-generating facility where savings opportunities exist.

Burner Controls



Burner controls help maintain boiler efficiency

Boiler/Steam Management Program

The following activities should be part of any strategy to reduce boiler/steam energy costs and usage:

Obtain Boiler Certification from local state authorities

- Boilers must be certified as being in proper working condition according to local state guidelines and regulations. Certification is also required by insurance providers. Typically, each state government has a department responsible for processing certification request applications, conducting inspections, and issuing certifications

Measure and document system efficiency, performance and maintenance on a regular basis

- This activity should be a part of every facility's standard operating procedures

Define current and future heating needs that are affected by your facility's boilers

- Heating needs are a combination of space heating and industrial process requirements. It is unlikely the space requirements in your facility will change much over the years. However, as technology evolves and processes change, so too will the heat energy requirements for those processes. Well thought-out estimates can help you determine the number, kind, and capacity of boilers you will need in the future. Matching boilers to need minimizes cost and energy waste

Employ state-of-the-art controls

- Control systems help ensure that boilers work efficiently and reliably and only generate the amount of steam or hot water needed for any given time period and any given process

Boiler Efficiency Standards

The overall efficiency of a boiler is measured by dividing the gross output energy by the input energy. One of the key indicators of boiler efficiency is "combustion efficiency," or how well a boiler burns fuel and transfers the heat. Combustion efficiency is stated as a percentage equal to 100 percent minus system losses measured at full load. Boilers are rated and compared by their input fuel consumption or horsepower (hp) as measured by Btu/hr. One boiler hp = 33,250 Btu/hr.

Boiler Efficiency Standards

Equipment	Size of Input Rating	Energy Efficiency
Gas-fired	300,000 Btu/h or more	80% minimum combustion efficiency
Oil-fired	300,000 Btu/h or more	83% minimum combustion efficiency

Hot water reset controls can save 14 percent of heating cost

Boiler efficiency is also affected by such factors as:

Standby losses—for example, energy losses that occur when a pilot flame is burning, consuming energy, at times when no heat is needed from the boiler

Short cycling losses—for example, when a boiler is first cycled on, the surfaces of the boiler are cooler, and therefore, additional energy is consumed in order to bring the boiler up to combustion conditions. The result is lower combustion efficiency

Condensate return—condensate is a by-product of heat transfer in a steam system; steam that has condensed still has value as hot water and should be returned to the boiler[2]

Boiler Operating Standards

A key to minimizing energy costs and consumption associated with boilers is to match the boiler capacity to the load required. The following are some ways to match boiler output to the load:

Install multiple smaller boilers

Only operate boilers that are needed for a given load at a given time and shut them down when they are not needed

Install controls to ensure complete, clean combustion at varying loads

Parallel positioning boiler controls can save 5 percent to 7 percent of fuel consumption

[1] Source: SoCalGas: "Gas Boilers Guideline."
[2] Armstrong Steam and Condensate Group: "Steam…Basic Concepts."

Best Practices

The following proven best practices can help maximize boiler efficiency, minimize heat/energy losses, and reduce energy consumption and the costs associated with boilers.

Burn alternate fuels to take advantage of fluctuating fuel costs

- Fuel markets are volatile, and costs change all the time. Be aware of which fuels are most cost effective at any point in time and be prepared to take advantage of potential fuel cost savings by being able to burn alternate fuels

Shut off boilers when not needed

- It is a costly proposition to generate steam, heat, and hot water when they are not needed

Optimize boiler staging to maximize efficiency and avoid part-load inefficiencies

- Operate boilers with capacity that matches the required load

Replace larger boilers with multiple boilers

- Use multiple boilers to supply a common load and sequence them to match load requirements

Seasonally adjust hot water temperature setpoints

- In parts of the country where weather and temperatures change significantly from season to season, there are savings opportunities resulting from adjusting temperature setpoints according to outdoor temperatures

Use control systems to automatically control and/or interlock boilers and pumping systems to provide the proper amount of steam for each process

- Control systems help ensure a reliable, safe, efficient supply of steam. And, for processes requiring a continuous supply of steam, controls help ensure that the steam supply is uninterrupted

Steam traps require maintenance for efficient operation

Boilers must be monitored regularly

Inspect and check all automatic control systems and valves to ensure proper operation

- When operating correctly, control systems greatly improve the efficiency of boiler operation. Therefore it is imperative to make sure these controls, such as temperature controls and valves, are working properly

Establish and implement a steam trap program

Put excess steam to use generating power with Carrier micro-turbines

Control the flow rate of the induced draft and forced draft fans by installing variable-speed drives

- Fans enable the flow of steam through the system. Deploying variable fans helps adjust the flow rate to meet changing load requirements

Maximize the return of all condensate to boiler

- An effective method of improving power boiler plant energy efficiency is to increase the condensate return to the boiler[1]

Periodically inspect condensate station vents for excessive plumes

- Excessive condensate can reduce heat transfer. It's important that the traps and vents be designed to open in order to drain the condensate and close to retain the steam

Consider heat recovery to preheat boiler make-up water

- To maximize efficiency and save energy, use heat recovered from the boiler to preheat make-up water

Measure, document, and record boiler efficiency and performance on a regular basis and utilize that information to improve system efficiency

- Only by taking frequent, regular measurements and documenting the results can you accurately gauge boiler performance over time and spot potential inefficiencies. One helpful monitoring tactic is to install steam meters to track heating needs

As part of regular inspection and maintenance procedures, check, test and calibrate the devices that measure pressure, temperature and flow

- Be sure to keep logs of all data from these devices and instruments and regularly review it to identify inefficiency trends

Monitor and minimize boiler blow-down through proper water management. Install an automatic blow-down central system

- Solids can accumulate in a boiler and form sludge, which impedes heat transfer. Such solids can also damage pipes, steam traps and process equipment. These impurities must be blown down by discharging some water from the boiler to a drain. This must be done in a precisely controlled manner to avoid wasting water and heat—hence the need for a properly working automatic blow-down system[1]

Inspect the entire system for leaks, defective valves and flanges, and corroded piping and components, pump seal or packing

- Leaks, corrosion, and other defects in a boiler/heating system waste heat and energy. A program of regular inspection is necessary to identify these deficiencies and correct them in order to prevent further losses and inefficiencies

Insulate all bare steam pipes and valves. Inspect system insulation on a regular basis and repair as needed

- Proper insulation prevents loss of heat, steam, and energy

Metrics

The following is a checklist of action-items you can implement to document and measure your progress in reducing energy costs and consumption associated with boilers. These procedures should be followed on a regular basis, not just when energy audits are scheduled.

- Track monthly energy consumption and cost data
- Provide maintenance history
- Measure and monitor winter peak load and summer base load BTUs per square foot
- Monitor combustion efficiency

System maintenance impacts system efficiency. Poorly maintained boilers are far less efficient than well maintained boilers

[1] U.S. Department of Energy: "Energy Tips – Steam."

HVAC Systems & Controls

THERMOGRAM OF HEATING DUCTS

Preventive maintenance practices can improve system efficiency and save costs without sacrificing comfort

Heating, Ventilating and Air-Conditioning (HVAC) systems account for 20 to 30 percent of the total energy consumed in industrial buildings.

Every building has one or more chillers, boilers, cooling towers, or pumps, or packaged equipment and air handling equipment. These systems are essential for providing adequate comfort levels for building occupants and proper temperature/humidity conditions for sensitive processes. Preventive maintenance best practices can maintain system efficiency and save costs without sacrificing comfort.

HVAC Management Program

Document system components (size and location)

Perform preventive maintenance to ensure operating efficiency

Use the full capabilities of you building automation system to control HVAC systems, lighting systems and other facility equipment

Time of Day Scheduling – a simple application to set back heating and cooling setpoints, and control lighting during unoccupied time periods (nights, weekends, holidays)

Demand Controlled Ventilation – a strategy to modulate ventilation air volume based on occupancy and/or indoor environmental conditions. Reducing ventilation air when not required to support occupancy will significantly reduce costs to condition hot or cold outside air to meet indoor air conditions

Daylighting Control – using photocells and occupancy sensors, it's easy to reduce artificial lighting significantly when sufficient daylight exists, or when spaces are unoccupied

Static Pressure Optimization – in VAV air systems, this application will monitor VAV damper position and dynamically reset duct static pressure setpoint to the minimum required to meet actual airflow requirements based on current building load and ambient conditions. The same can be done for chilled water and hot water distribution systems

Variable Frequency Motor Drives (VFD's) – pump and fan motors above 5 HP are often great candidates for a VFD that will modulate the motor speed when conditions allow

Once you have selected the most energy efficient equipment for your application and can program/monitor its operation from a Building Automation System the best thing to do is review OEM (original equipment manufacturer) operations and maintenance documents for a full schedule of recommended service and preventive maintenance procedures.

Preventive maintenance enhances system reliability and efficiency and extends the life of the equipment

Chillers

Well maintained chillers can use up to 20-25 percent less energy to produce the same amount of cooling

What's important

- Keep a good operation log & maintenance record
- Regularly scheduled operating inspections
- Annual inspections and clean up

What to focus on

- Keep tubes (water cooled chillers) and coils (air cooled chillers) clean
- Ensure refrigerant charges are optimized (not too much, not too little)
- Regular inspections & calibration of chiller controls

Cooling Towers

What's important

- Keep a good operation log & maintenance record
- Regularly scheduled operating inspections
- Water treatment

What to focus on

- Keep the tower clean to maximize heat transfer capability
- Ensure motor drive belts are adjusted properly
- Keep the fan blades clean for proper operation
- Proper operation of tower fan and water-level controls
- Good water treatment to reduce biological growth and to keep the concentration of suspended solids within acceptable limits
- Ensure spray nozzles aren't clogged

Retro-commissioning restores HVAC system efficiency

Packaged Equipment

What's important

- Regularly scheduled inspections at each seasonal start-up (cooling and heating)

What to focus on

- Keep condenser and evaporater coils clean for maximum heat transfer
- Ensure proper refrigeration charge
- Replace filters a minimum of four times per year to maintain proper air flow
- Keep drive belts maintained and properly aligned
- Clean, lubricate and adjust dampers for proper operation
- Repair air leaks in ductwork to prevent air from escaping to non-conditioned areas

Use Variable Frequency Drives (VFDs) on all large pumps, fans and towers (5 hp and above)

Air Handling Equipment

What's important

- Regularly scheduled inspections and maintenance

What to focus on

- Keep heating and cooling coils clean for maximum heat transfer
- Check coils for leaks
- Replace filters often to reduce static pressure and to maintain proper air flow
- Keep drive belts maintained and properly aligned
- Clean intake plenum of dirt and debris
- Inspect fan; lubricate and clean as needed

Best Practices

Establish a preventive maintenance program for all HVAC equipment

Whenever possible use cooling tower water to provide free cooling for process and air conditioning needs

Establish a cooling tower water quality program to eliminate algae and rust

Use Free Cooling whenever possible!

The efficient, proper operation and longevity of a water cooling system depend on ensuring the quality of the water to prevent corrosion and other damage that can adversely affect system performance.[1]

Control cooling tower fans with variable speed controls or a two-speed motor

Replace constant-volume air-handling systems with VAV-variable air volume systems

Establish an occupancy schedule and shut off all equipment during unoccupied hours

Install a heat exchanger to recover heat from exhaust air

Install back-draft dampers on fans discharging to the outdoors to eliminate infiltration when fans are off

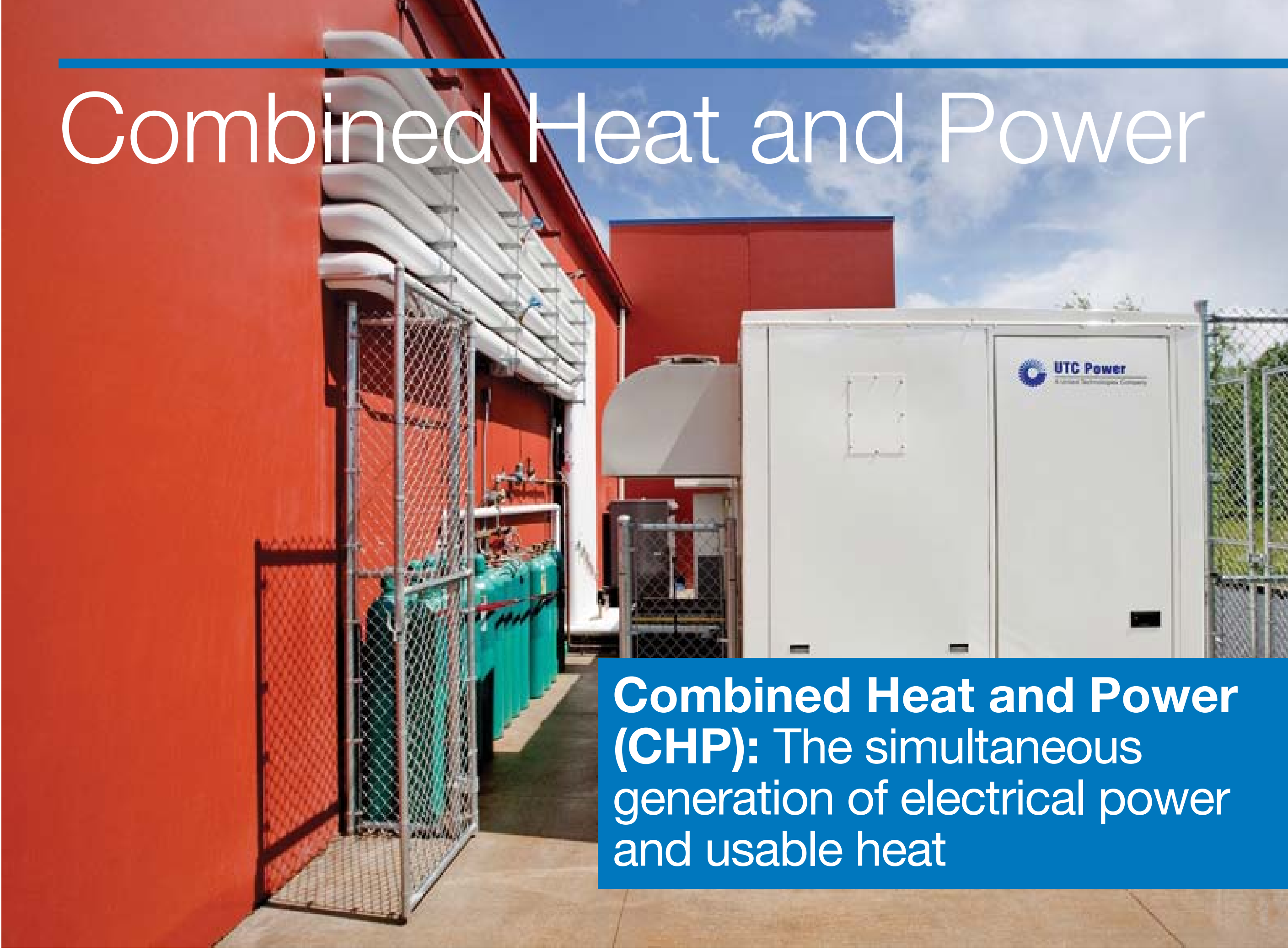
Shut off pumps when not required

Metrics

- Maintain an equipment inventory list
- Install programmable controls to maintain time and temperature set-points
- Maintain an HVAC maintenance log including a refrigerant maintenance log and details of annual inspection
- Complete an HVAC audit every three years

[1] U.S. Department of Energy: "Water Efficiency: Cooling Tower Management."

Combined Heat and Power



Combined Heat and Power (CHP): The simultaneous generation of electrical power and usable heat

Cogeneration or Combined Heat and Power (CHP) are broadly defined as the simultaneous generation of electrical power and heat. Compared to conventional systems, CHP significantly increases efficiency (up to 85 percent) by utilizing heat produced by electric generators.

A typical CHP application includes one of the following technologies to drive an electrical generator:

- Combustion turbine
- Reciprocating engine
- Micro turbine
- Fuel cell

Size in kW output is usually the determining factor in technology selection.

Packaged or "modular" CHP systems are available for commercial and light industrial applications. These small systems, ranging in size from 20 kW to 650 kW produce electricity and hot water from waste heat. Typically, cogeneration systems are designed to match the sites' hot water or steam requirements and not the electrical requirements. The best applications for cogeneration systems are facilities that always have a need for hot water or steam.

Clean Emissions:
Compared with traditional combustion power plants, a single UTC PureCell 400:

- Produces 400kW of electricity and approximately 1,700,000 Btu's of heat per hour

What to focus on

- Base electrical load, current and long term forecast
- Base thermal load, current and long term forecast
- Future electrical rates (at least 5 year projection)
- Future natural gas rates (at least 5 year projection)
- Environmental benefits
- Local utility or state incentives
- Electric utility company interconnect requirements
- Cogeneration system maintenance cost

Various technical factors such as utility rates, site thermal and electrical requirements, and electrical load profile all contribute to the viability of a cogeneration system. A feasibility study should be conducted by an expert who will evaluate site requirements and appropriate CHP options. UTC Power, Carrier and Pratt & Whitney Power Systems have extensive experience in CHP system development and operation featuring Fuel Cells, Micro-Turbines and Gas Turbine technologies.

Heat Rate: Denotes the amount of heat required to generate power (BTU/kWh)

Spark Spread: Difference between Natural Gas cost and Power Cost

Building Envelope

Much of a building's heat losses and gains occur through the roof, so there are often significant energy-savings opportunities related to roof efficiency.

The integrity of the building envelope has a dramatic impact on the energy required to heat and cool the building.

Therefore, the insulating properties of the roof, doors, and windows should all be maintained to minimize energy use. The three major contributors to energy inefficiency in the building envelope are:

- Infiltration of hot and cold air
- Solar radiation
- Heat loss through windows, walls, floors and roofs

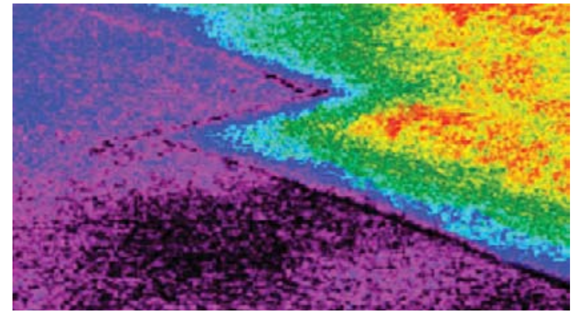
What to Focus On

Building envelope improvements are most cost-effective when they are conducted as part of new construction or retrofit initiatives.

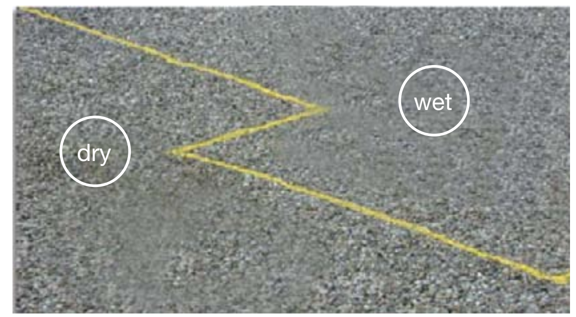
- Upgrade insulation levels as part of other projects (e.g., new construction, re-roofing)
- Check insulation for condensation and water penetration, replace as needed. Insulation is ineffective once it becomes wet
- Insulate roof voids. The integrity of the roof should be maintained each time the roof is penetrated
- Maintain window and door seals to eliminate drafts
- Install double- or triple-glazed windows with low-emissive (low-E) glass
- Install double-spaced automatic doors in areas where external doors are frequently left open
- Install plastic secondary door curtains inside delivery doors
- Use thermal scans to test the integrity of building insulation
- Establish a roof management plan
- Minimize solar heat gain through the use of window film or window shades

Best Practice:
Perform a thermal scan of the roof to check for damaged insulation

Building envelope thermographic study



Infrared thermographic Image



Control image, wet sections marked for removal

UTC Supplier Self-Assessment

Suppliers will be asked to complete a self-assessment questionnaire that includes the following UTC EH&S minimum expectations:

I. Does the facility provide safe working conditions for all employees, customers and contractors?

II. Does the facility adhere to all applicable national, regional, state and local laws and regulations governing Environment, Health, and Safety?

III. Does the facility operate in a manner that minimizes the impact to the environment?

IV. Does the facility limit the use of natural resources and promote sustainable natural resource practices?

V. Are EH&S values and expectations as in UTC Supplier Expectations I through IV, or similar, communicated to employees and suppliers?

Rules of Thumb

Fan Energy	100-1500 CFM per HP
Fan Energy	400 CFM per ton of air conditioning
Typical Lighting Design	1–2 watts per square feet
Chiller Size	300–400 square feet per ton
Chiller Water	2.4 GPM per ton (10°F Rise)
Condenser Water	3 GPM per ton (10°F Rise)
Chiller Electric Input	0.5–0.8 kW per ton
Chillers & Pumps & Towers	0.7–1.0 kW per ton
Domestic Hot Water Temperature Setpoint	105°F
Steam Absorbers	18 lbs. steam per ton
Boiler Hot Water Reset Controls	Saves 14% of annual heating cost
Compressed Air Operating Costs	$1.25 to $1.60 per HP per day

Common Energy Equations

Sensible Air Conditioning	BTU/hr.	= CFM X 60 min/hr. X .075 lb./cubic feet X.24 BTU/lb. X ΔT
	BTU/hr.	= 1.08 X CFM X ΔT
Latent Air Conditioning	BTU/hr.	= 60 min/hr. X .075 lb./cubic feet X CFM X ΔH
	BTU/hr.	= 4.5 X CFM X ΔH
Water Heating/Cooling	BTU/hr.	= GPM X 60 min/hr. X 8.33 lb./gal. X 1 BTU./lb./°F X ΔT
	BTU/hr.	= 500 X CFM X ΔT
Electric Power	kW	= 0.746 X HP/Motor Efficiency
	kW (3 phase)	$= \frac{\text{amps X volts X 1.73 X Power Factor X Motor Efficiency}}{1000}$
	Brake HP (3 phase)	$= \frac{\text{amps X volts X 1.73 X Power Factor X Motor Efficiency}}{746}$

Natural Gas Conversions

1 CF (cubic foot)	= Approximately 1,000 BTU's
1 CCF	= 100 CF = 1 Therm
1 Therm	= 100,000 BTU's = 100 CF = 0.1 MCF
1 MCF	= 1,000 CF = 10 therms = 1 decatherm
1 MCF	= 1 million BTU's = 1MMBTU
1 MMCF	= 1,000,000 CF = 1 billion BTU's

Conversion Factors

These units multiplied by...	...this factor will...	...convert to these units
Gal #6 Fuel Oil	0.1463	MCF Natural Gas
$/Gal #6 Fuel Oil	6.833	$/MCF Natural Gas
$/MCF Natural Gas	0.1463	$/Gal #6 Fuel Oil
Horsepower (electric)	0.746	Kilowatts
Lumen	0.001496	Watt
Lumen/sq ft	1	Foot-candles
Lux	0.0929	Foot-candles
Bar	14.5038	PSI
Barrels (oil, US)	42.0	Gallons (US)
Horsepower	2545	Btu/hr
Kilowatt-hrs	3414	Btu (Site)
Boiler Horse Power (BHP)	33,475	Btu/hr
Degrees Centigrade	F = (C x 1.8) + 32	Degrees Fahrenheit
Degrees Fahrenheit	C = (F - 32) x 0.555	Degrees Centigrade
Gallons (Brit)	1.2009	Gallons (US liq)
Gallons (Brit)	4.546	Liters
Gallons (US)	3.7854	Liters
Gallons (US)	0.83267	Gallons (UK)
Therm	100,000	Btu
Gallons (US)	3.7854	Liters
Gallons (US)	0.83267	Gallons (UK)

Glossary

Electric demand
Instantaneous electric load by site or equipment (kW). The amount of demand registered on your electric meter.

AFUE
Annual Fuel Utilization Efficiency indicated as a percentage. AFUE tells you how much energy is being converted to heat.

British thermal unit (Btu)
The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit; equal to 252 calories. It is roughly equal to the heat of one kitchen match.

Combustion efficiency
This measure represents the amount of fuel energy extracted from flue gases. It is a steady state measure and does not include boiler shell losses or blowdown losses. The losses identified in this efficiency calculation are the stack losses. Stack losses are an indication of the amount of energy remaining in the flue gases as they exit the boiler.

EER
Energy efficiency ratings (EER) measure the efficiency with which a product uses energy to function. It is calculated by dividing a product's BTU output by its wattage (kW).

ECM
Energy conservation measure

Foot-candle (fc)
Unit of measurement for illuminance (1 fc =1 lumen/SF).

Greenhouse Gas

Heat exchanger – A device used to transfer heat from one medium to another (e.g., air to air, air to water).

Kilowatt-hour (kWh) – Electrical energy usage rate used for utility bills—One thousand watts per hour.

Lux – S.I. unit of illuminance. It is equal to one lumen per square meter.

MMBtu – A unit of one million British thermal units.

SEER – The seasonal energy efficiency ratio is a measure of the cooling efficiency of air conditioner or heat pump. The higher the SEER number, the more efficient the system is at converting electricity into cooling power.

VAV – Variable air volume. Air flow is varied to match heating and cooling loads. Also called VFD (variable frequency drive) or VSD (variable speed drive).

Appendix E:

Where to Get More Information

Online Energy Conversion Calculator:
http://www.onlineconversion.com/energy.htm

U.S. Department of Energy (DOE):
http://www.doe.gov

U.S. DOE Best Practices:
http://www1.eere.energy.gov/industry/bestpractices

U.S. Environmental Protection Agency (EPA) Climate Change:
http://www.epa.gov/climatechange

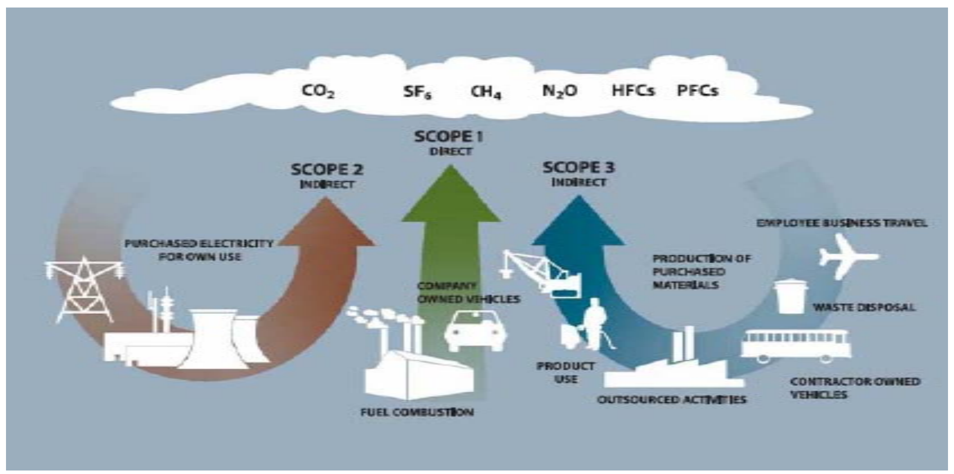
U.S. Green Building Council's Green Home Guide:
http://www.greenhomeguide.org and www.greenbuild365.org

World Resources Institute (WRI):
http://www.wri.org

Appendix F:

The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard

• **Carbon Dioxide** (CO_2): **Methane** (CH_4), **Nitrous Oxide** (N_20), **Hydrofluorocarbons** (HFCs), **Perfluorocarbons** (PFCs), and **Sulphur Hexafluoride** (SF_6):



The World Resource Institute and World Business Council for Sustainable Development developed a corporate accounting and reporting standard for

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