Energy best management practices guidebook

Implement, improve and save

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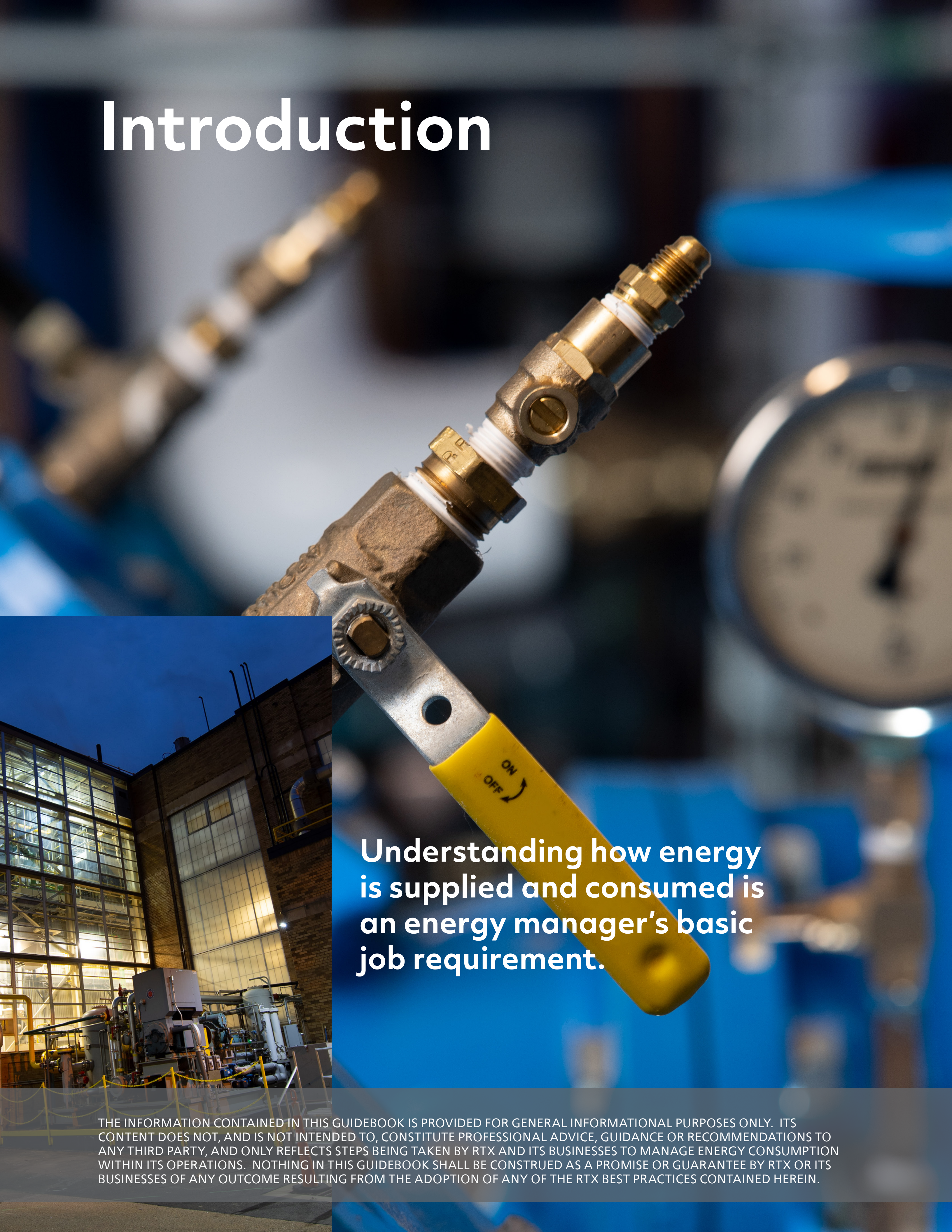


Understanding how energy is supplied and consumed is an energy manager's basic job requirement.

Advances in information technology continue to enhance the way we conduct business at RTX. Increasing availability of and demand for data are driving a transformation toward digitization. Understanding how energy is supplied and consumed is an energy manager's basic job requirement. To be effective, the energy manager needs to have access to reliable sources of data about lighting, HVAC, process equipment, personal computers and any other point of energy consumption.

Recognizing digital transformation, and the opportunities it will create, this guidebook has been reorganized to provide insight on digital integration of energy management at RTX facilities. Associates familiar with the past version of this guidebook will recognize a directional shift in the way we approach energy management. Many of the energy-reducing ideas presented in prior versions have been maintained in this version as best management practices. You will notice more emphasis on streamlined energy data collection and sharing, including utilization of building automation systems (BASs) to manage day-to-day activities.

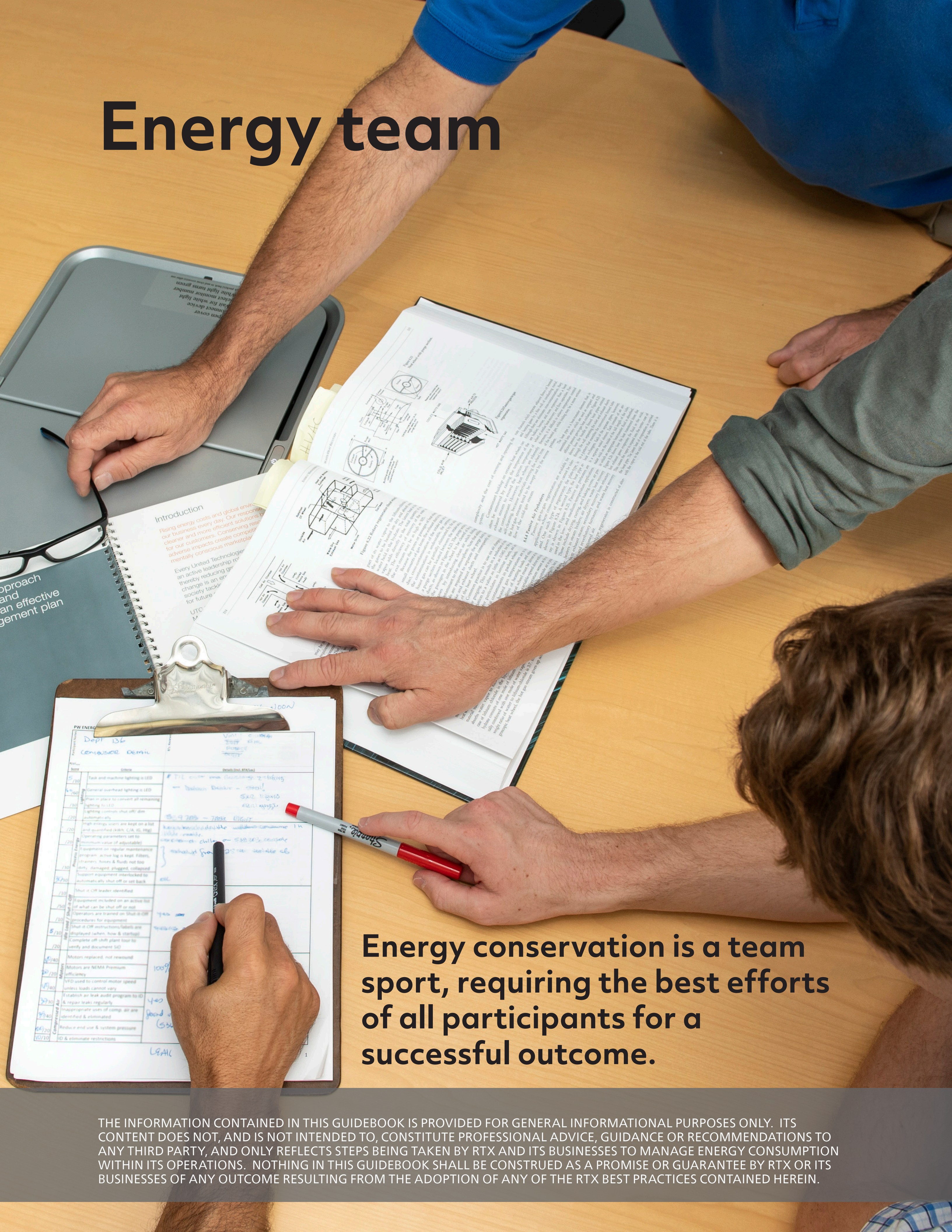
This document will introduce concepts important to energy managers in the digital age, including:

- Recommendations for implementing a BAS.
- Techniques for effectively managing all aspects of the energy portfolio, including how to collect, decipher and validate meaningful data using the BAS.
- Understanding the energy supply and procurement process.
- Understanding the value provided from accurate lists of energy-consuming equipment.
- Implementing best management practices for optimizing manufacturing operations and facilities.
- Engaging site employees to reduce energy consumption and associated greenhouse gases.

There is no doubt that the way in which we collect and manage energy-related data has changed significantly. The digital revolution now allows energy managers a holistic view of previously separate activities. As with the separate organs of the body, all building systems are interdependent and must therefore be managed in relation to each other to ensure optimum performance and minimal inefficiency. An example of this interdependence can be found in the replacement of pneumatic screwdrivers with electric units. The project will reduce the air supply required by the air compressor. The consequent reduction in electricity required by the compressor will offset the increased demand by the electric screwdrivers 10:1. Lighting replacement projects provide another example. Everyone anticipates energy savings when changing older lighting technologies to LEDs, but an often-overlooked benefit is the reduced need to operate the cooling system because the LEDs do not put out as much heat as the older lighting technologies.

When put into practice, the techniques espoused in this book will provide the reader with the ability to implement an energy management system that improves energy efficiency, reduces GHG emissions and saves money in both a practical and sustainable manner.

Let's begin.



Energy team

Energy conservation is a team sport, requiring the best efforts of all participants for a successful outcome.

The energy manager should enlist the help of others to encourage energy conservation. Energy conservation is a team sport, requiring the best efforts of all participants for a successful outcome. Enlisting the help of energy-conscious individuals is the most effective way to include various stakeholders, establish buy-in on critical issues and identify more opportunities to save energy.

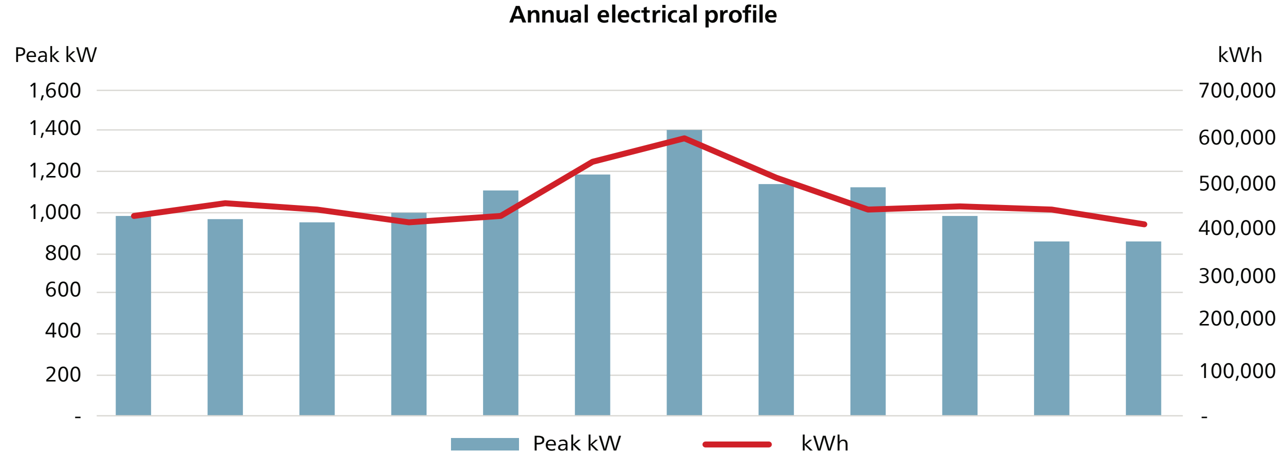
The site energy team will be the core group responsible for developing the energy management strategy and tracking progress toward energy conservation goals. The size and scope of the energy team should match the size and complexity of the site. Consider including representatives from operational areas such as facilities, EH&S, manufacturing operations, supply management, finance and communications. All members should be indoctrinated with the required reading of this guidebook, which was designed by and for RTX employees. The guidebook captures and presents energy best management practices (BMP) that have been implemented in RTX facilities around the globe. BMPs from the guidebook should be used by the energy team for developing and documenting the sites energy management plan or road map.

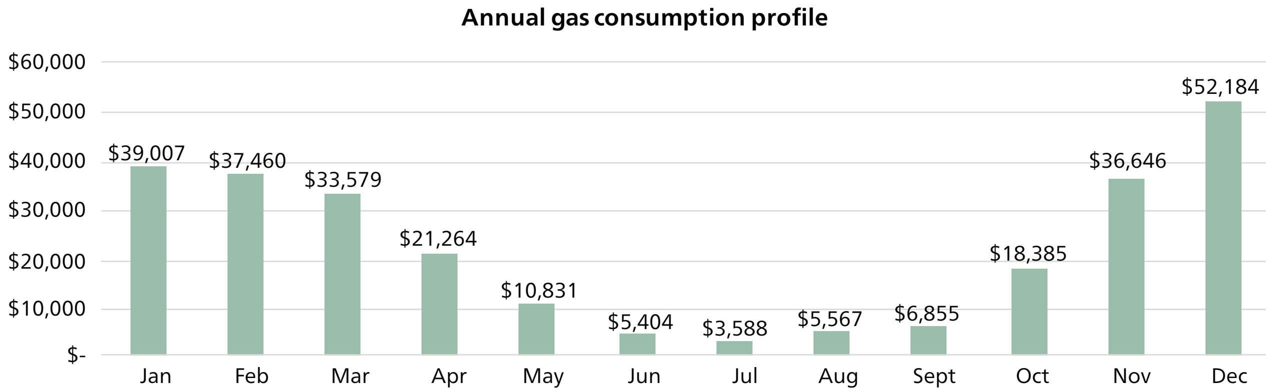
As with any management plan, current and accurate data is required to make informed strategic decisions, gauge the effectiveness of those decisions and uncover opportunities requiring new decisions. This is where the true value of a BAS lies. The BAS, under the watchful eye of a trained operator, becomes an invaluable tool for optimum facility management and performance. When properly integrated, a BAS will reduce maintenance response time, control energy costs and improve energy project decision-making, all of which make the energy management team a successful organization.

Energy and 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 GHGs in conformance with RTX's energy and environmental reporting requirements.
- Keep a detailed record of consumption profiles (hourly for electric consumption, daily for natural gas use).
- Use submetered energy data to allocate energy and cost by business unit or department, if possible.

Electrical and natural gas consumption, cost and GHG emissions



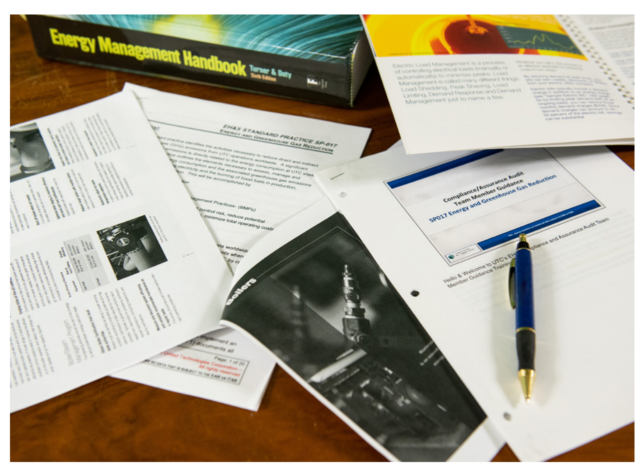


Energy conservation is the best way to accomplish the company commitment to improving the environment by reducing GHGs.

Energy audit

The energy team is responsible for conducting energy audits, assessments, treasure hunts, gemba walks and Kaizen events. The size and scope of the events are determined by the size and complexity of the site. The team should evaluate any and all resources to complete the events, including BAS trend data, in-house staff, energy service companies, local utilities, government programs and paid consultants.

The team should identify energy management training opportunities to build general awareness for all employees. Specific technical training needs, such as BASs or compressed air systems, should be conducted by industry experts for the benefit of team members.

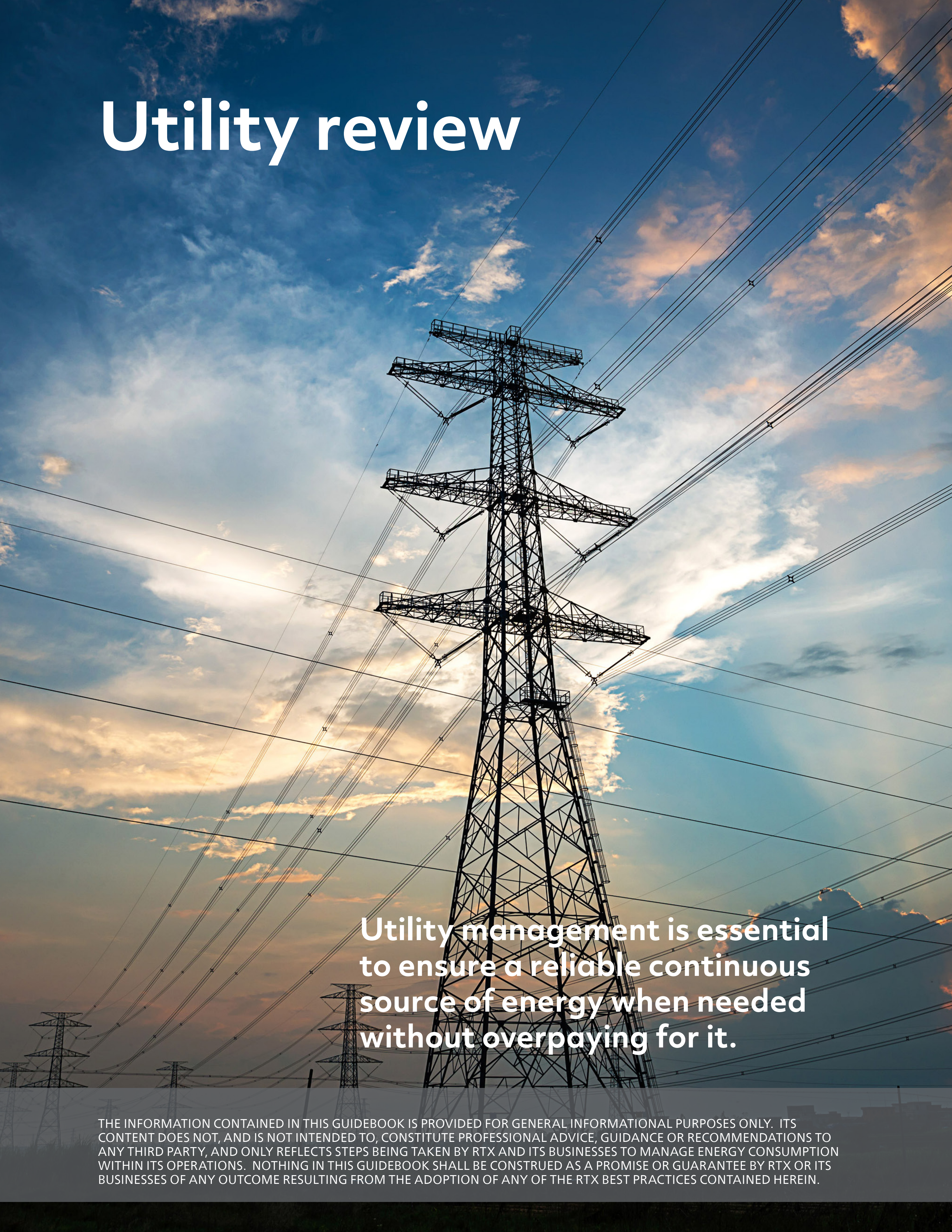


Build awareness through energy management training.

Establish site energy team minimum required actions

- Site management identifies a cross-functional team for site energy management that may include, among others, EH&S, facilities, finance and production.
- Team members and employees responsible for maintaining or purchasing energy-consuming equipment or systems – read the current version of this energy management guidebook.
- Team leader identified.
- Annual plan approved by site management sponsor.
- Previous plan percent completion tracked.
- Energy projects entered and status up to date.
- Tentative date planned for next energy audit.

Utility review



Utility management is essential to ensure a reliable continuous source of energy when needed without overpaying for it.

Utilities provide the critical commodities needed to support the day-to-day operation of facilities and business activities worldwide. From offices to industrial complexes, utilities are required to create products, conduct sales and perform repair and installation services. The ability to properly manage utilities depends on several factors: market regulation, tariffs and taxes, infrastructure, supplier competition and operating conditions, i.e., number of shifts and occupancy schedule. Utility management is essential to ensure a reliable continuous source of energy when needed without overpaying for it. An effective energy manager will be fluent in discussing energy consumption in terms of energy costs (commodity and taxes) or energy units (kWh, therms, MMBtu, etc.). Electricity, natural gas, steam, compressed air, water and industrial gases are a few of the basic utilities consumed in an industrial facility. The energy manager will also know the sites' significant energy users (SEUs), where they are located, when they operate, what utilities they consume and how much they consume. Once fully versed, the energy manager can begin to make improvements and implement changes that will reduce utility costs without impacting production.

Understanding an energy management plan

An important part of an energy management plan is to understand:

- How much energy we use.
- When we use it.
- How much it costs.

Information provided by utility companies

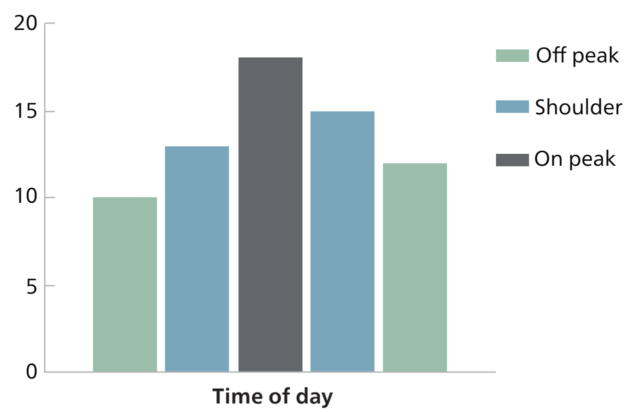
Utility companies can provide information designed to inform customers about:

- Rate structure (tariff) options that define the cost of energy.
- Load profiles that explain how much energy is used and when.
- Energy conservation guidance, rebates and incentive funds.

Utility rate review

Most natural gas and electric utility companies offer various 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 each site's specific consumption profile. Utility companies can usually compare the cost of service for different tariffs by running a computer simulation. The main objective is to select the most cost-effective tariff that fits the site's consumption pattern.



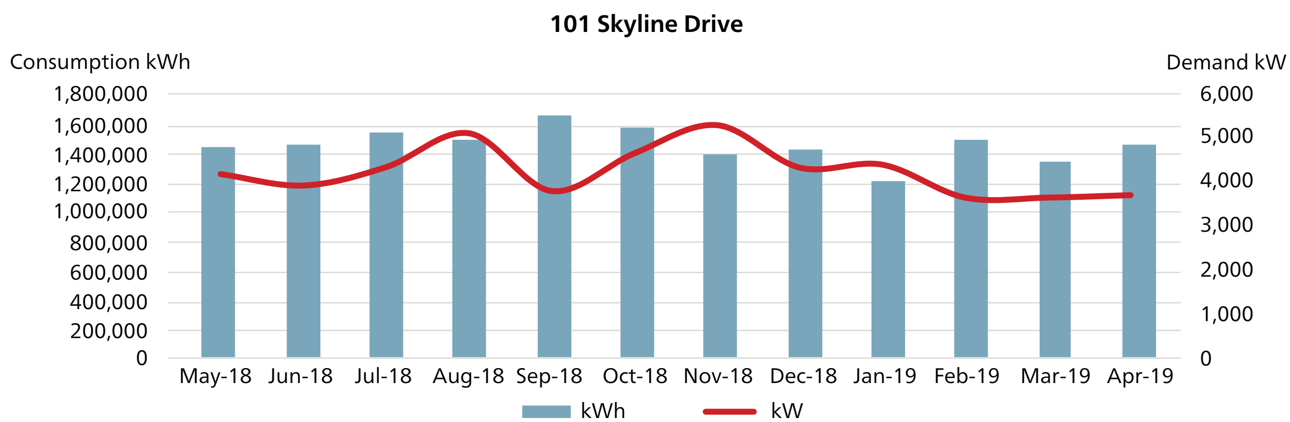
It should be noted that rates change over time due to government regulation and market conditions. Site-specific requirements also change over time. So, it makes sense to review rate structures annually.

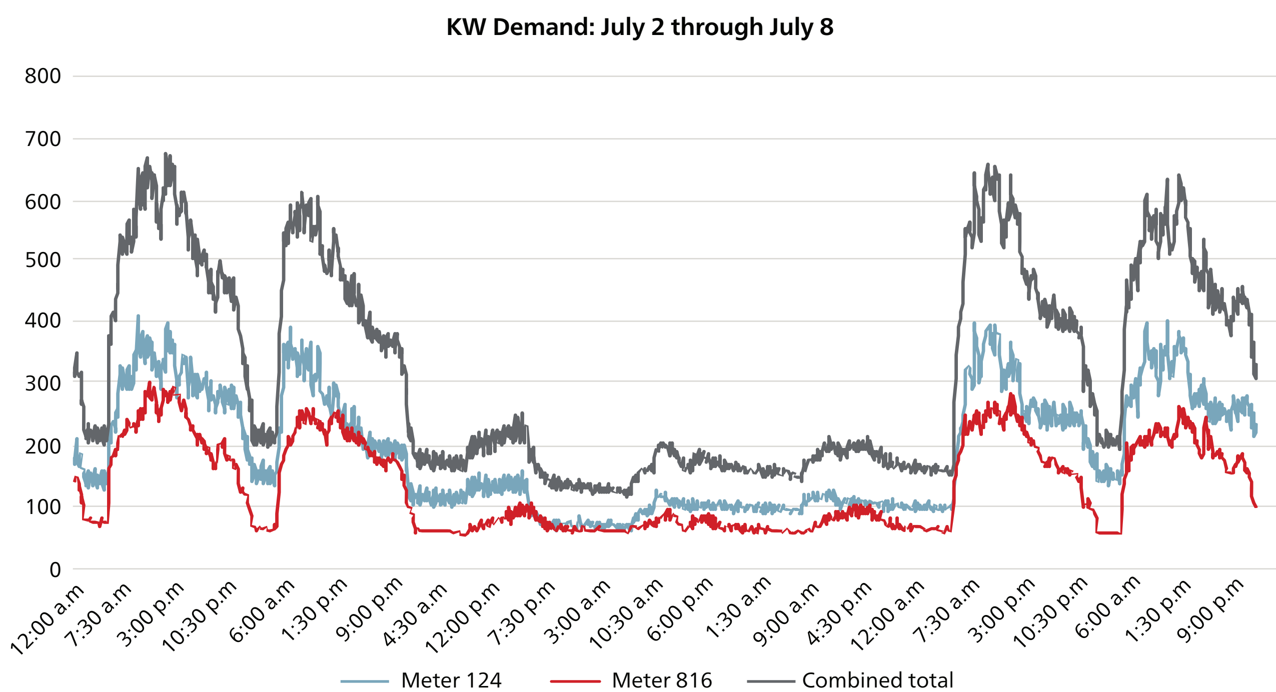
Many, if not all, utilities will provide a rate review analysis for customers. This analysis will compare a site's historical usage on different rates to determine which rate will be the most economical. This review should be conducted annually or within a few months after a usage change has occurred, i.e., a shift added or eliminated, a large piece of equipment added, etc. While utilities are required to provide service to a site, they are not required to provide the most economical rate; the customer has to request a rate review periodically.

Analyze consumption profiles

Energy consumption profiles should be analyzed for cost drivers. A review of monthly energy data (natural gas and electric) will show seasonal trends. A review of electric interval data in 15-minute or one-hour increments will illustrate key drivers.

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





Identification of SEUs

The next step in an effective energy management program is the identification of major energy consumers. A site survey should be completed and the operating characteristics (such as time of use and peak kW demand) of the SEUs 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 air conditioning units, ovens, lights and process heating.

Load management

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

Electric load management is a (manual or auto) process 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 reduce costs in two ways:

1. Electric bills typically include a demand charge in addition to an energy charge. So, by limiting peak demand (kW) on an ongoing basis, you can reduce these monthly demand charges ($/kW). Because demand charges can amount to 40% to 50% of the electric bill, savings can be substantial.
2. 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 submetering must be employed to track progress.

Sample of top 10 electric loads

ELECTRIC END USE	% OF TOTAL	KW	KWH/ YEAR	MT CO2E	COST OF OP/YEAR	NOTES/ASSUMPTIONS
Process equipment	28%	445	217,865	73	$19,727	Thermal chambers, shakers, ovens
Chiller system	18%	286	140,056	47	$12,682	Shop HVAC
Lighting shop areas	18%	286	140,056	47	$12,682	Hi-bay
Air compressors	7%	111	54,466	18	$4,932	Shop air
Air handler motors	4%	64	31,124	10	$2,818	Shop HVAC
Exhaust: all	4%	64	31,124	10	$2,818	Process
Lighting non-shop areas	3%	48	23,343	8	$2,114	Office
DX air conditioning	2%	32	15,562	5	$1,409	Offices
Computer room	2%	32	15,562	5	$1,409	Server
Lighting exterior	1%	16	7,781	3	$705	Parking lot
Totals	**87%**	**1,382**	**676,936**	**225**	**$61,294**	

Some utilities have "demand response programs" that offer incentive funding 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 costs.

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 using a BAS to monitor and automatically shed equipment when the demand (kW) hits a programmed limit.

Common rate management projects

Request an annual rate review from the utility company

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

Check accuracy

- Verify applicable tax credits/exemptions on energy invoices.
- Review electric utility invoices of billed kW vs. actual kW for saving opportunities.
- Review power factor correction penalties.
- Verify credits for interruption riders.

Check the status of all utility accounts

Large sites with multiple meters may be paying service charges for inactive meters.

Investigate the opportunity for third-party energy procurement

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

Market rules vary by location and change frequently

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

A technique where percentages of the total energy required are purchased at different time intervals, thereby fixing (locking in) the price of energy for specific quantities of energy over sequential periods of time.

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.

Alternative energy projects

Renewable power produced by solar and wind is a consideration at many facilities as a way to reduce GHG emissions. Once a site has satisfied the BMPs requirements and implemented all reasonable energy reduction initiatives, the installation of renewable technologies becomes more viable.

In some instances, space constraints prohibit the installation of solar or wind power generation. In these instances, cogeneration or trigeneration may be an option. Cogeneration or combined heat and power (CHP) are broadly defined as the simultaneous generation of electrical power and heat. Trigeneration is cogeneration with the added benefit of cooling. Compared to conventional systems, CHP significantly increase efficiency (up to 85%) by using the heat produced by electric generators.

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

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

The ability to use all of the thermal energy in heating or cooling applications is the determining factor in unit sizing. The kW output of a CHP system is usually the determining factor in technology selection.

As with solar and wind energy, CHP systems should be considered once a site has satisfied the BMPs requirements and implemented all reasonable energy reduction initiatives.

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 site's 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.

Heat rate

Denotes the amount of heat required to generate power (Btu/kWh).

Spark spread

Difference between natural gas cost and electrical power cost.

Incentives and rebates

Review the status of utility company and/or government-sponsored conservation programs. Programs may offer incentives for investments in energy conservation projects. In the U.S., the DSire.org database lists incentive programs by state: https://www.dsireusa.org.

Energy management consultants

Sites without the time or expertise may choose to enlist the services of an energy management firm. The choice of supplier depends on many variables: knowledge of regional and local utility markets; ease of data transfer; ability to support site's demand limiting, alternate energy procurement and energy reduction initiatives. Working with a single global management company across many sites affords maximum oversight with minimal time and expense to the individual.

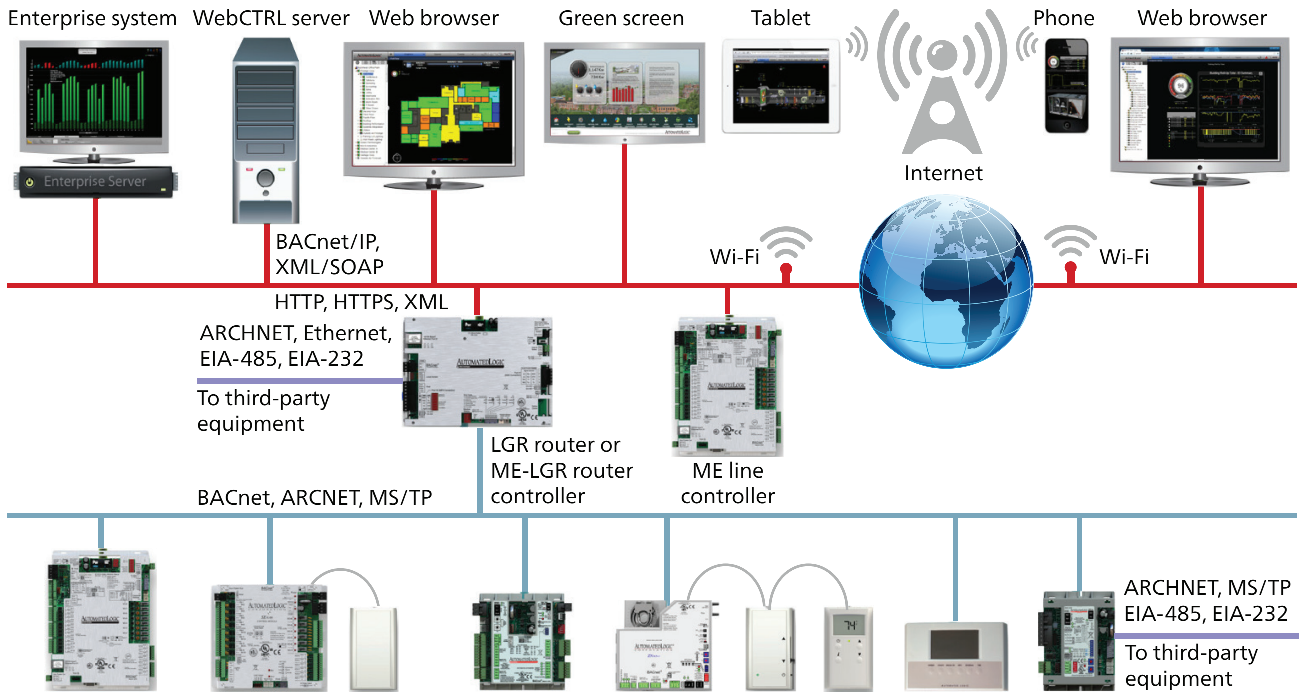
Utility review minimum required actions

- Maintain a record of monthly site energy consumption.
- Annually review facility utility rate structure options with utility providers.
- Investigate the opportunity for third-party energy sourcing.
- Investigate conservation programs and incentive options with utility representatives.
- Explore the opportunity for siting an alternate power generation source.

Building automation

The BAS can be considered the central nervous system of the facility.

In order to manage an array of diverse systems, the energy manager must have certain tools to perform the role properly. The greatest tool available to the energy manager is the BAS. The BAS can be considered the central nervous system of the facility. It is the source of data collection and informed response that the energy manager, the human element of the system, will use to make rational business decisions regarding energy procurement, energy reduction and awareness training recommendations.



Building automation is often associated with HVAC control. It is true that a number of enhancements incorporated into BASs were in response to the need for better control of indoor air requirements such as temperature, humidity and air quality (contaminant removal). Collective wisdom formerly held that BASs should only be implemented at larger facilities with multiple HVAC units requiring constant monitoring. Experience has subsequently demonstrated that smaller facilities with limited resources can also benefit from a BAS to perform many tasks, freeing resources to focus on other responsibilities. When viewed through the lens of digitization, we see that the BAS has the capability of being much more than a glorified thermostat. Today's systems have the ability to continuously monitor not only HVAC but also building occupancy using CO_2 sensors, process equipment use, utility input and much more.

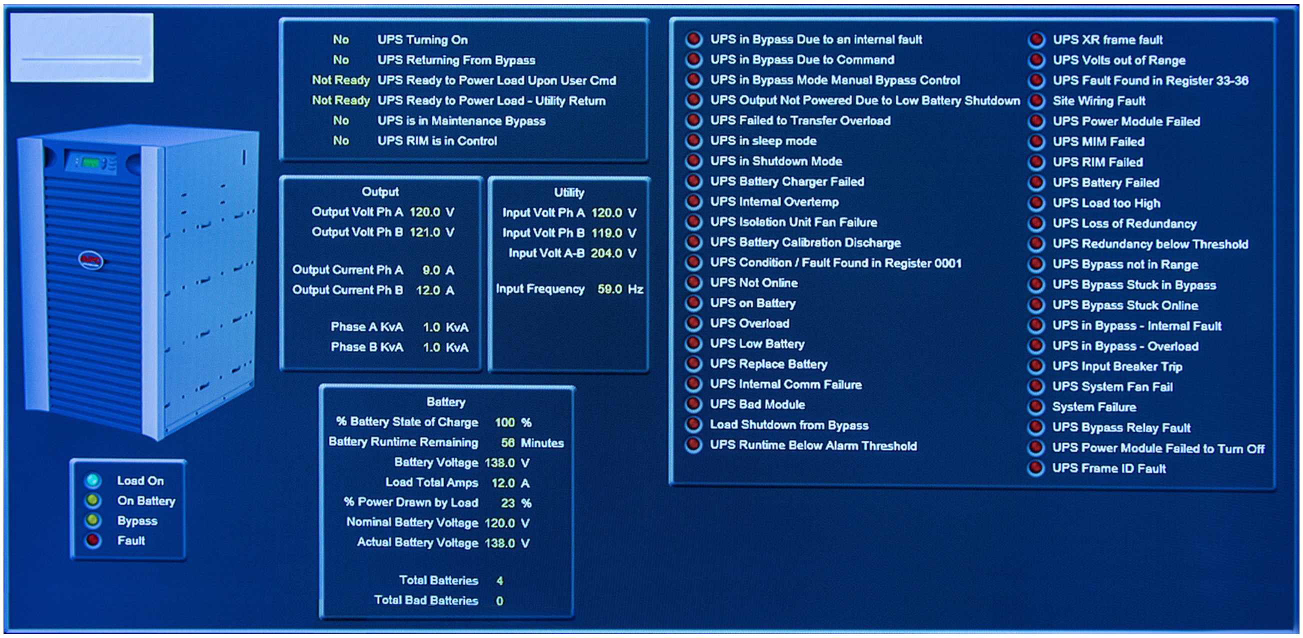
Building automation is constantly transforming, and it can now be used to monitor all functions occurring within a building simultaneously and notify proper service providers in advance or during cases of failure, thereby improving response times.

For the novice with limited building automation implementation experience, the following minimum requirements were established by RTX personnel familiar with the operational and oversight needs required in RTX facilities today. This compendium of ideas will allow the energy manager to implement a modest BAS that will yield powerful insight into the operations of the facility.

BAS requirements

General requirements:

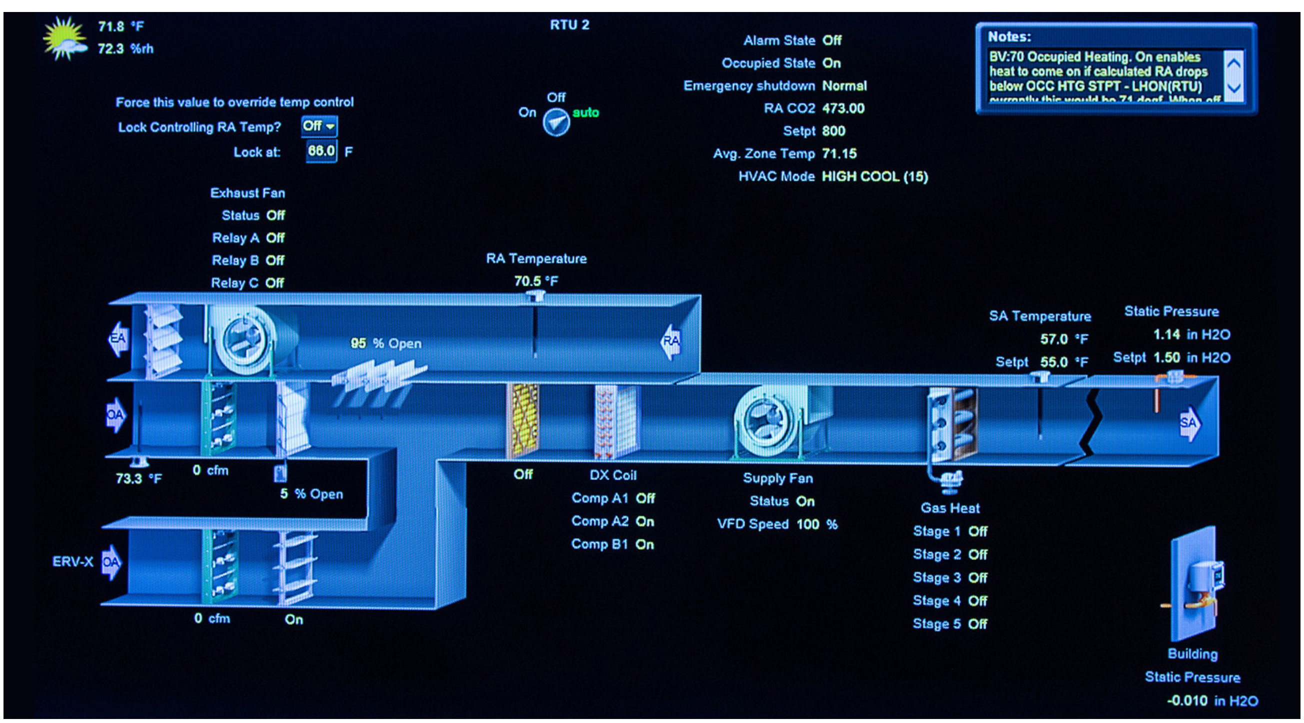
• Open protocol – BACnet, LON, MODbus	– A single primary language must be chosen by the end user for the BAS. All future suppliers must meet the site's protocol language.
• Programmable logic controller (PLC) integration	– Continuously monitors the operating state of input devices and makes decisions based on a custom program to control the state of output devices.
• All energy devices must be able to communicate to the BAS	– Communicate the protocol language and number of point requirements to original equipment manufacturers and the BAS supplier.
• Graphics interface	– Easy-to-understand visual displays.
• Dedicated individual or company to monitor control system for faults, evaluate functionality of existing equipment and integrate other data inputs to the system	– Must have the ability to analyze data and formulate understanding of the physical operation of the facility.
• Utility input monitoring	– Primary and secondary utility monitoring greater than 1200V; 1/2-inch gas line; any size water main to 3/4-inch branch line.
• Baseline all new equipment	– Collection of operational data when system is commissioned.
• Trend log with heat map dependent on severity of alarm	– A mandatory BAS collection and analysis function of errors detected by the BAS.
• Fault detection, diagnostics and alert	– Events produced from the continuous monitoring of an operating system by the BAS.
• Dashboard with color coding (red/yellow/green)	– Visual indication of severity status.
• Device energy consumption monitoring	– An instantaneous consumption metering feature of the BAS.
• Energy consumption trending	– A BAS feature that allows energy usage to be tabulated or graphed.



• Alarm function trending	– A BAS feature that allows the user to isolate and investigate system-generated alerts.
• Maintenance of equipment status	– A BAS feature that allows monitoring of system performance by a remote user.
• Interlock all ancillary equipment to primary machine	– Automated shut-it-off procedure of secondary equipment performed by the BAS.
• Easy-to-use hierarchal list of alarm recipients	– A status of alarm codes based on urgency.
• Automatically contact proper support personnel	– A function of the BAS where upon fault detection the systems notifies the appropriate personnel.
• Utility storage device monitoring: water tanks, battery systems, UPS, industrial gases tanks	– A monitoring function of the BAS that allows a user to know a device’s percentage to full capacity.

HVAC

• Control monitor temperature set points	– Allows user to fix, vary and trend site-approved temperature settings.
• Fan control on/off	– Allows user to fix, vary and trend individual unit fan operation.
• Enthalpy control	– A differential wet-bulb control strategy used to determine suitability of outside air for free cooling (i.e., cooling without the use of the refrigeration cycle).
• Compressor setpoints – discharge temps	– A BAS feature that allows monitoring of the refrigeration cycle by a remote user.
• Occupancy control/sensor	– An input device used to activate the HVAC system based on inhabitants motion or CO_2 exhalation.
• Demand control ventilation	– A BAS feature that determines spacing heating, cooling or ventilation requirements based on comparison of occupant CO_2 exhalation to ambient conditions.
• Fault detection	– A BAS feature that allows monitoring of the HVAC system by a remote user.
• Beware of wireless protocols	– Communication capability available on many OEM products. Hardwired is more reliable.



Lighting

• On/off status	– Allows user to know if a light or light system is active or inactive.
• Light output – dimming capabilities	– Allows user to fix, vary and trend site-approved light settings.
• Occupancy sensors	– An input device used to activate the lighting based on inhabitant motion.
• Daylight sensing	– An input device used to control the lighting system based on the amount of light available in the space.
• Color changing	– The ability of a control system to change the color spectrum of a lighting system based on time of day.
• Central monitoring	– Allows user the ability to view the operation of a facility's lighting system from a single location.
• Centralized control with local override	– Allows user the ability to change lighting set points from a single location.
• Monitor light activity	– Allows user the ability to monitor a lighting system from a single location.

Compressed air

• Compressor sequencing strategy for control based on demand	– An operational scheme that activates or deactivates additional air compressors based on percentage of full load operation of the lead compressor.
• On/off/part load status	– Allows user to know if a compressed air system is active, inactive or operating at reduced capacity.
• Pressure monitoring	– Allows user to know the operating conditions in PSI or BARs of the compressed air system.
• VFD monitoring	– Allows user to know the operating speed of a VFD-equipped compressor.
• Run status	– Allows user to know if the air compressor is active, inactive or operating at a reduced speed.
• Vibration monitoring	– An alarm function that monitors adverse motion of a compressor.
• Inlet filter with airflow at inlet of ambient air into the compressor	– A sensor used to monitor the amount of airflow into the compressor.
• Current sensor on compressor line – for start status	– An electrical metering function to monitor compressor operation.
• Incorporate filters, dryers and booster status into primary air compressor	– Sensor inputs that allow the user to monitor remaining life or operational status of ancillary filters and equipment.
• Dew point control algorithm for dryer	– A method of control for the system air dryer to reduce capacity based on leaving air moisture.

Process equipment

• Ovens/furnaces	– Monitor system performance to baseload condition. – Temperature reset cooling capabilities. – On/off/idle status. – Monitor all energy using ancillary equipment operating conditions. – Monitor all utility and industrial gas inputs to machine – Stack temperatures.

• Tanks	– Monitor system performance to baseload condition. – On/off/idle status. – Level monitor and alarm. – Submerged coil connectivity for leaks. – Agitation airflow. – Mixing equipment amperage. – Tank covers on/off if heated. – Auto-fill status. – Monitor all utilities to machine.
• Autoclaves	– On/off/idle status. – Operational solenoids status open/close. – Runtime. – Interlocks. – Monitor system performance to baseload condition. – Monitor all energy using ancillary equipment operating conditions, interlock to shut-off ancillaries where appropriate. – Monitor all utilities to machine.
• Test chambers	– On/off/idle status. – Amperage draw. – Heating/cooling status. – Before ordering equipment obtain the PLC information and adjust as necessary. – Monitor all utilities to machine including compressed air and industrial gas flows. – Monitor system performance to baseload condition.
• Machining	– On/off/idle status. – Amperage draw. – Heating/cooling status. – Before ordering equipment, obtain the PLC information and adjust as necessary. – Monitor all utilities to machine, including compressed.

Additional BAS considerations

• Security	– Card access monitors people entering and leaving the facility. – Low-access areas monitored using BAS lighting status, HVAC status and security cameras. – BAS receives inputs from, but does not control, security system.
• Fire panels	– Smoke detectors or manual pulls turn off equipment gas valves/AHUs/compressed air. – Emergency control sequencing: A prescheduled activation of HVAC components that assists in mitigating fire, smoke and fume spread. – BAS receives inputs from, but does not control, fire alarm system.
• Site generators	– On/off status. – Operating in auto or manual mode. – Generator temperature monitoring. – Fuel level. – Oil level. – Alarms communicated to BAS.
• UPS – data center	– Monitoring of UPS activity. – Activation or adverse condition alarms. – Low battery. – Load transfer to UPS confirmation.

• Charging stations	– Data on usage. – Current and voltage status monitoring.
• Plug load	– Wireless office and plug load sent to a router to permit shutdown of nonessential items. – Power strip controlled. – Monitor copier status.
• Other notes	– BMS reporting capabilities need to be configurable. – Conference room environment controlled by BAS based on occupancy input from electronic calendar room scheduling. – Individual offices controlled by badge reader inputs. – Telematics collection of fleet for monitoring and reporting of vehicle operation.

RTX maintains a variety of building types and sizes to accommodate the manufacture of its various products. Accurate control and preventive maintenance can be demanding on the resources of any facility. A BAS allows for central data collecting, monitoring and diagnostic trouble shooting of HVAC, lighting, processes and security. When properly implemented, the BAS becomes a critical element in maintaining employee health and building performance.

Building automation minimum required actions

- Installation of a front-end system capable of viewing utility inputs as well as energy consumption activity of all SEUs, including HVAC, lighting and compressed air.
- Develop and maintain baseline energy consumption of all SEUs.
- Use BAS as a submeter (where submeters do not exist) to track energy consumption.
- Establish alarm trends, interval data collection and maintain site temperature and lighting conditions.
- Use the BAS to deactivate lighting, HVAC and ancillary process equipment when the primary piece of equipment or functional area is idle or shutdown.

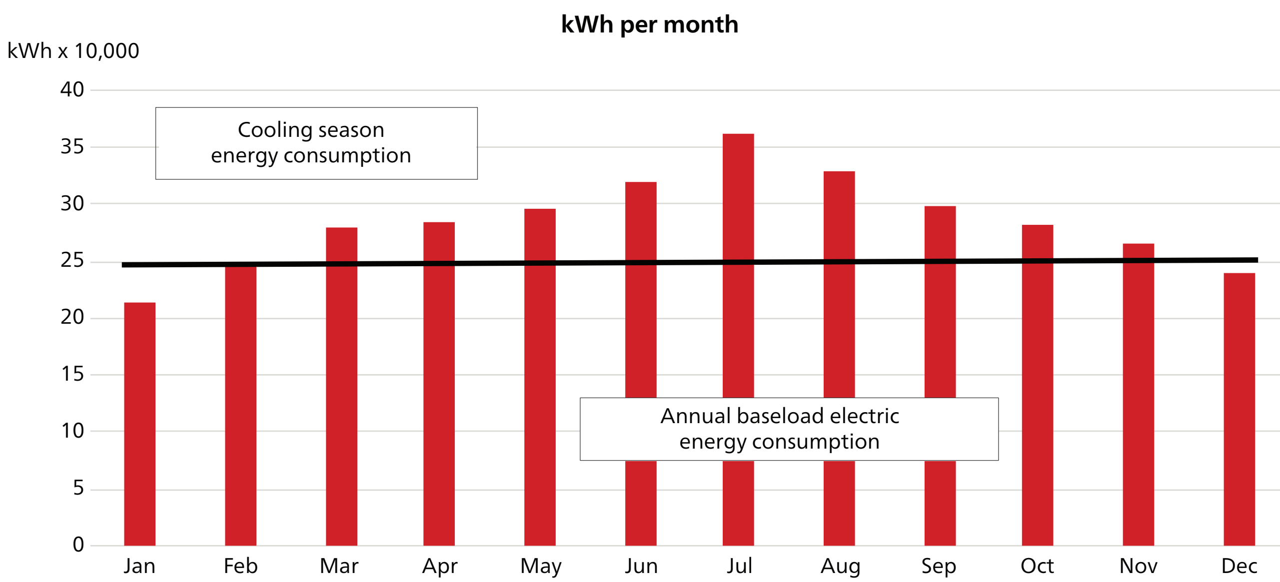
HVAC

One of the largest energy-consuming elements in the facility is often the heating, ventilation and air conditioning (HVAC) system.

With the proper BAS control system in place, the energy manager now has the capability to gather data, change set points, monitor operation and facilitate maintenance before a critical failure occurs. Current technology allows these functions to be performed remotely as well as locally.

One of the largest energy consuming elements in the facility is often the heating, ventilation and air conditioning (HVAC) system. HVAC systems are an SEU at sites in warm locations for adherence to space temperature, humidity and pressurization set points. Heating and air conditioning energy use can consume a modest 20% of total energy in some locations to as much as 70% in extreme climate regions. This amount of energy consumption makes it important for the energy manager to understand the basics of HVAC system components and fundamentals.

Every building has at least one chiller, boiler, cooling tower, circulating pump, packaged heating/cooling equipment or air handling unit. These systems are essential for providing adequate comfort levels for building occupants and proper temperature/humidity conditions for manufacturing operations. In many cases, a site's monthly energy consumption profile can provide insight into how much energy is used by the heating and cooling systems. Monitoring energy consumption trends can also indicate when systems are not operating efficiently.



Chillers

Size range: Up to 6,000 tons.

Efficiency range: Up to 0.3 kW/ton.

Expected lifetime: 15 to 23 years.

What's important

- Keeping a good operation log and maintenance records.
- Regularly scheduling operating inspections.
- Annual inspections and cleanup.

Where to focus

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

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

Note: Older water piping should be evaluated for pipe wall thickness and fouling.

Cooling towers

What's important

- Keeping a good operation log and maintenance records.
- Regularly scheduling operating inspections.
- Water treatment.

Where to focus

- Keep the tower clean to maximize heat transfer capability.
- Ensure motor drive belts are adjusted properly.
- Keep the fan blades clean and balanced for proper operation.
- Proper operation of tower fan and water-level controls.
- Good water treatment to reduce biological growth and keep concentration of suspended solids within acceptable limits.
- Ensure spray nozzles aren't clogged.
- Use variable frequency drives (VFDs) on all large pumps, fans and towers.
- Submetered make-up water can be subtracted from sewer bill water usage.

Packaged equipment

Size range: Up to 150 tons.
Efficiency range: Up to 25 SEER/18 EER.
Expected lifetime: 15 to 20 years.

What's important

- Regularly scheduling inspections at each seasonal startup (cooling and heating).

What to focus on

- Keep condenser and evaporator coils clean for maximum heat transfer.
- Ensure proper refrigeration charge.
- Replace filters to maintain proper airflow.
- 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 nonconditioned areas.

Ductless systems

Size range: Up to 5 tons.
Efficiency range: 23+ SEER.
Expected lifetime: 10 to 15 years.

What's important

- Regularly scheduling operating inspections.
- Keep heating and cooling coils clean for maximum heat transfer.
- Clean indoor and outdoor heat exchangers.
- Check space around condensing units for proper airflow.
- Occasionally check that condensate drains do not become blocked.
- Clean indoor evaporator filters regularly.

Split systems

Size range: Up to 180 tons.

Efficiency range: Up to 18 SEER.

Expected lifetime: 10 to 15 years.

What's important

- Regularly scheduling operating inspections.

What to focus on

- Keep condenser and evaporator coils clean for maximum heat transfer.
- Ensure proper refrigeration charge.
- Replace filters a minimum of four times per year to maintain proper airflow.
- 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 nonconditioned areas.

Air handling equipment

Size range: Up to 300,000+ CFM.

Expected lifetime: 10 to 25 years.

What's important

- Regularly scheduling 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 airflow.
- Keep drive belts maintained and properly aligned.
- Clean intake plenum of dirt and debris.
- Inspect fan; lubricate and clean as needed.
- Verify proper operation of dampers and valves.
- Check that associated ducts remain sealed and insulated.

Considerations for HVAC energy efficiency

- Document system components (size, location, date of installation, capacity, areas served, time and temperature operating schedule requirements).
- Maintain a separate list of cooling equipment serving process cooling applications.
- Establish replacement plan for HVAC equipment based on useful life and maintenance cost.
- In variable refrigerant flow (VRF) systems, several indoor units can be connected to a single outdoor condensing unit and independently controlled by varying the refrigerant flow. This allows efficient zone-specific temperature control by cooling and heating through the use of a heat recovery system.
- Variable speed drives or variable frequency drives (VFDs) modulate the motor speed when conditions allow. Pump and fan motors above 5 HP are often great candidates for VFDs.
- In free cooling, whenever outside air temperature conditions allow, use cooling tower water to provide free cooling for process cooling and air conditioning needs. This strategy works best in cool climates where facilities have long hours of operation. Reduced run time on mechanical cooling systems (chillers) will save energy and maintenance cost.
- Use shades and blinds to control direct sun through windows in both summer and winter to prevent or encourage heat gain.
- Control cooling tower fans with variable speed controls or variable speed motors.
- Replace constant-volume air-handling systems with VAV-variable air volume systems.
- Establish an occupancy schedule and shut off all equipment during unoccupied hours.
- Ensure building occupants do not use plug- in-type electrical space heating or cooling appliances.
- Install back draft dampers on fans discharging to the outdoors to eliminate infiltration when fans are off.
- Establishing and communicating temperature set points is a best practice. Generally temperature set points in the following comfort zone ranges will be satisfactory for most work environments.

	OCCUPIED	UNOCCUPIED
Cooling	75-77°F (25°C)	84-86°F (29°C)
Heating	68-70°F (20°C)	60-62°F (15°C)

Due to the varied ways of maintaining space conditions, the energy manager should consult with HVAC engineers and technicians for the latest in equipment performance and features. In all cases, the HVAC equipment should communicate with the BAS for optimal control and operational data collection.

HVAC – Heating ventilation and air conditioning management minimum required actions

- Document units' capacities, energy consumption and costs.
- Evaluate units for proper sizing in the areas served.
- Implement an automation system to minimize run-time operation (refer to BMP #3 BAS).
- Keep active log of maintenance performed.
- Document a plan for HVAC retro-commissioning, retrofit or upgrade.

Boilers

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

Closely associated with and often using the same air-handling distribution system, boilers and direct fired furnaces are used throughout RTX for both space and process heating applications. The overall efficiency of a boiler is a simple ratio of the energy output heat, steam or hot water divided by the energy input (primary fuel). There are, however, a few different components to the overall efficiency that require proper maintenance and control to operate at peak efficiency.

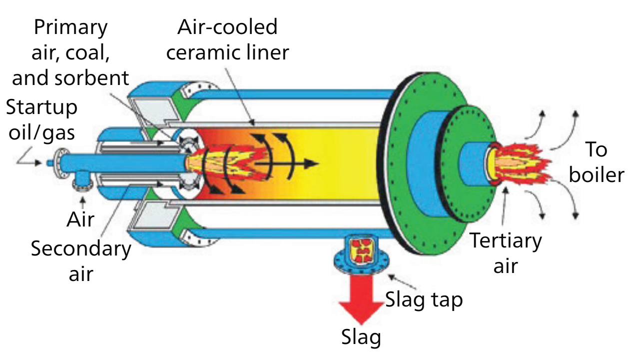
It is common for a boiler, furnace or oven to consume many times its initial capital cost in energy usage each year. For example a boiler that cost $100,000 to install can easily consume $700,000 in fuel every year. That is why it is critical to monitor boiler operations to maintain peak efficiency. When evaluating the efficiency of a boiler, be sure to confirm if the published numbers are referencing the combustion efficiency, thermal efficiency or overall boiler efficiency for the fuel of choice (natural gas or fuel oil).

Combustion efficiency

Combustion efficiency is an indication of how the burner burns fuel without sending unburned fuel up the stack or using too much air in combustion. Combustion requirements vary for different fuel types and boiler load conditions. Combustion efficiency should be monitored to maintain efficiency.

Thermal efficiency

Thermal efficiency is the measure of the effectiveness of the heat exchanger in a boiler. It does not take into account the heat loss in the boiler shell or other components and it is not a good indication of boiler fuel use.



Burner controls help maintain boiler efficiency. This diagram illustrates areas (highlighted in green) in a typical steam-generating facility where savings opportunities exist.

Overall boiler efficiency

Boiler efficiency should take into consideration combustion efficiency, thermal efficiency and all other convection and radiation losses in the system. This is typically calculated by the ratio of energy output to energy input, thereby providing a total fuel to steam efficiency ratio. This ratio can be easily maintained and monitored by the BAS.

Stack temperature can be a good indication of overall boiler efficiency. A lower stack temperature is an indication of good heat transfer in the boiler and higher fuel-to-steam efficiency. The same is true for direct fired furnaces and ovens that do not produce steam or hot water. The process is the same: combustion efficiency should be maintained at peak efficiency and stack temperature should be monitored as an indication of overall system efficiency.

Ideally, a facility should use the most 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 localized control systems exist to improve the efficiency of the boiler operation and deploy heat energy only when needed and at the capacity required.

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, a government authority has a department responsible for processing certification request applications, conducting inspections and issuing certifications.

Measure and document system efficiency, and complete recommended maintenance on a regular basis

This activity should be a part of every facility's standard operating procedure.

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

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 determine the number, kind and capacity of boilers needed in the future.

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. Localized controls should be used for daily boiler operations, trending logs of energy consumption and boiler efficiency should be communicated to and monitored by the BAS.

Boiler efficiency standards

EQUIPMENT	SIZE OF INPUT RATING	ENERGY EFFICIENCY
Gas fired	Gas fired 300,000 Btu/h or more	80% minimum combustion efficiency
Oil fired	Oil fired 300,000 Btu/h or more	83% minimum combustion efficiency

Hot water reset controls can save 14% of heating costs.

Common boiler energy efficiency projects

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

Inventory of boiler system

Document all pieces of equipment and their operating requirements.

Take advantage of fluctuating energy costs

Energy markets are volatile, and costs change all the time. Be aware of which energy sources are most cost-effective at any point in time and be prepared to take advantage of potential cost savings by being able to substitute.

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 capacities that match 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 set points

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

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.

Implement a steam trap program

Steam traps require maintenance for efficient operation. Steam traps are important for the proper operation of a steam system. Steam traps discharge built-up condensate, air and other noncombustible gases without allowing valuable steam to escape.

Microturbines put excess steam to use generating power

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

Fans enable the flow of combustion air and exhaust gases 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 steam boiler plant energy efficiency is to increase the condensate return to the boiler.

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 use 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.

Inspect the entire system for leaks, defective valves, defective flanges, corroded piping and worn-out components such as pump seals 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, condensate pipes and valves

Inspect system insulation on a regular basis and repair as needed. Proper insulation prevents loss of heat, steam and energy.

Boiler minimum required actions

- Maintain boiler certification documents.
- Insulate all exposed distribution and return piping and valves.
- Minimize boiler blow-down and reclaim the heat from the operation if possible.
- Document operating parameters – (requirements identified above).
- Establish maintenance program.
- Monitor efficiency.

Lighting

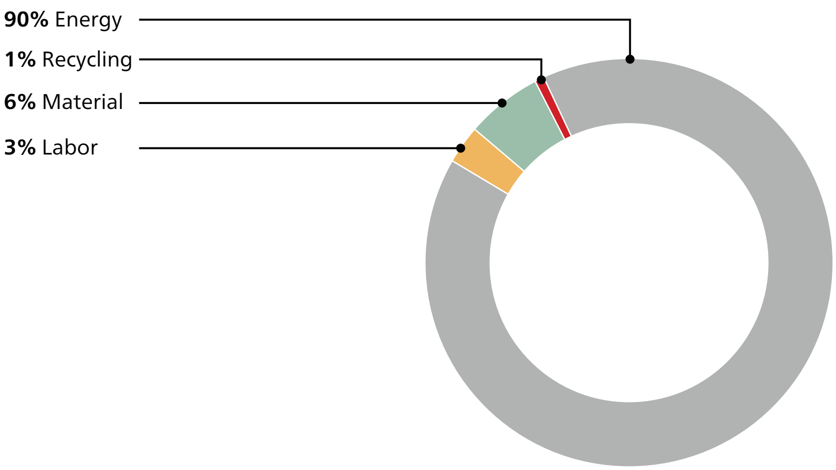
The objective of every lighting system design is to deliver the right amount of light, in the right place and at the right time.

As with HVAC, lighting is an SEU in any building. Lighting consumes 10% to 30% of the energy used. Therefore, reducing the energy consumed by lighting is crucial to a successful energy management program.

When connected to the BAS, the electricity consumed by lighting can be greatly reduced. The BAS permits control of lighting systems in several ways. First, it can be used as a timing device to activate or deactivate area lighting. Second, the BAS can use the lighting occupancy sensors to monitor employee work hours. Third, the BAS can control the lighting output based on input from daylight sensors, e.g., overcast days would cause the LED fixtures to raise their lumens output, while sunny days would cause the LED fixtures to reduce the lumens output).

For typical office buildings and factories, it’s not uncommon for light fixtures to last 20 to 30 years. So, it’s important to understand the total cost of ownership of the lighting system. As the chart indicates, energy is by far the largest cost component of a lighting system, comprising up to 90% of the total cost. Consequently, choosing an efficient, controllable light source fixture type and design will dramatically lower the lighting system energy use and cost of ownership.

Lighting cost of ownership.



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

Lighting levels

RTX follows light level recommendations published by the Illuminating Engineering Society.

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

Source: Illuminating Engineering Society of North America Lighting Handbook

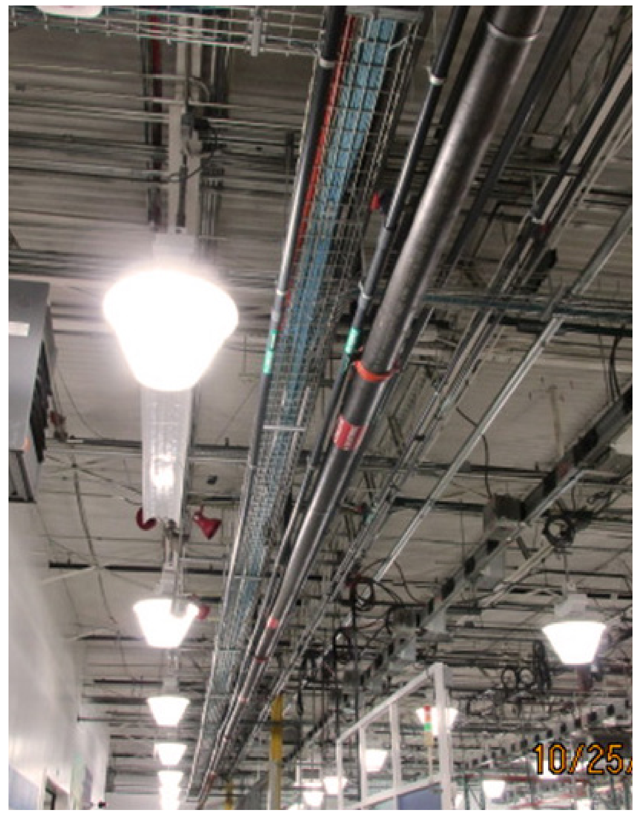
Evaluate efficiency of current lighting system

To evaluate the efficiency of a lighting system, start with an inventory of the current system, cataloging each fixture type, watts per fixture and hours of operation.

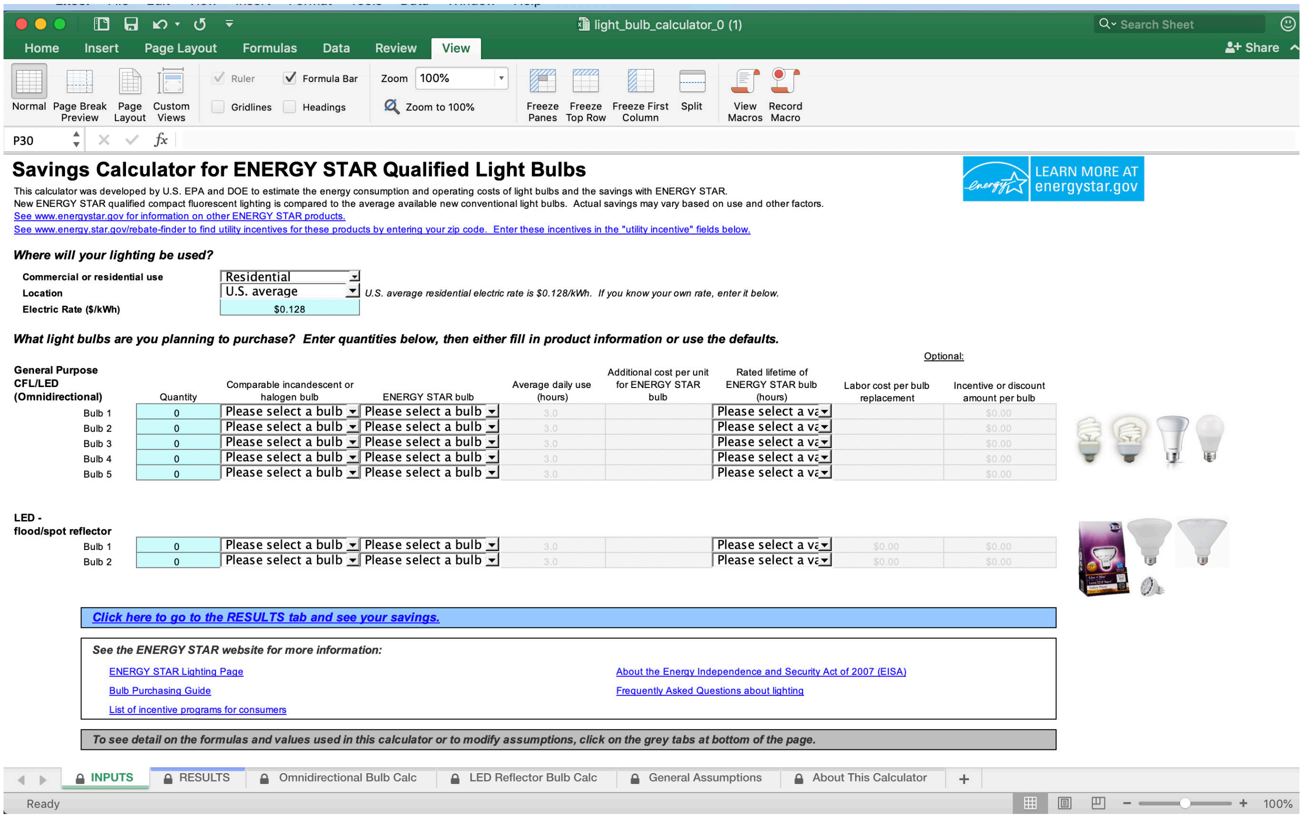
The lighting system inventory should provide a complete understanding of the current lighting system design, including:

- Number of fixtures.
- Total connected electric load (KW).
- Hours of operation.
- Lighting power density for each area (watts per square feet).
- Annual energy use (KWH per year).
- GHG emissions (mt CO2e per year).
- Annual cost of operation ($ per year).

The savings calculator for Energy Star qualified light bulbs was designed to document existing lighting system energy use and cost of operation and model the savings associated with common retrofit opportunities.



Evaluate current lightning with a lighting system inventory.



Lighting savings calculator sample screen view of a savings calculator for Energy-Star-qualified light bulbs.

Upgrade system efficiency

Modern lighting systems with integrated local control and BAS oversight use considerably less energy than previous lighting technologies. Common lamp types are organized into families based on the technology used to produce light. Each technology offers trade-offs between efficiency, lamp life and quality of light. Lighting systems should be designed to meet the specific needs of the activity (e.g., office, shop floor, test lab, inspection, warehouse or parking lot). In almost every instance, LEDs are the preferred lighting technology.

Comparing different lighting technologies.

TECHNOLOGY	CRI	EFFICACY (LUMENS/WATT)	LIFETIME (HOURS)	COLOR TEMPERATURE
CFL	80-90	60-70	6,000 to 10,000	2,700-6,500
Incandescent	100	50	750 to 1,500	2,400-2,900
Linear fluorescent	70-90	80-100+	20,000 to 46,000	2,700-6,500
Halogen	100	16-29	2,000 to 4,000	2,850-3,200
White LED	65-90	50-300+	Up to 100,00	2,700-6,500

Many RTX sites have already upgraded to LED lights. LEDs have proven to be a cost-effective and energy-saving solution for most systems, depending on the specific requirements, cost of energy and hours of operation. Typically, LEDs provide more light per fixture and last longer than traditional fluorescents.

When upgrading an existing fluorescent system to LED, simply replacing every fluorescent fixture with an LED fixture may result in a lighting system with too much light and possible glare problems.

Sites should work with lighting professionals and obtain photometric layouts to ensure the new design provides the right light levels of lumination for the given space and task. Properly designed LED systems may use up to 25% fewer fixtures than existing lighting systems, saving fixture purchases and energy costs.

Successful projects start with the installation of test fixtures to ensure proper fixture selection, spacing and height. Most lighting manufactures or vendors will work with their customers to test fixtures and confirm design specifications.

Lighting control.

Evaluate lighting control options

Another energy-saving feature associated with modern lighting system is control. Today's lighting fixtures have a variety of cost-effective control options, such as motion sensors, day-light controls, time of day controls and automatic dimming. Relamping offers the best opportunity for adding controls.

Expected energy savings from lighting control integration.

INCREMENTAL DIMMABLE CONTROL SAVINGS				
CONTROLS	FIXTURE TYPE	WORKDAY (HOURS)	WEEKLY KWH CONSUMPTION	REDUCTION
No	LED	12	168	—
Fixture mounted motion detection and daylight harvesting sensors	LED	12	111	34%
Actual study: 70 fixtures, 39W per fixture, office setting				

Key terms

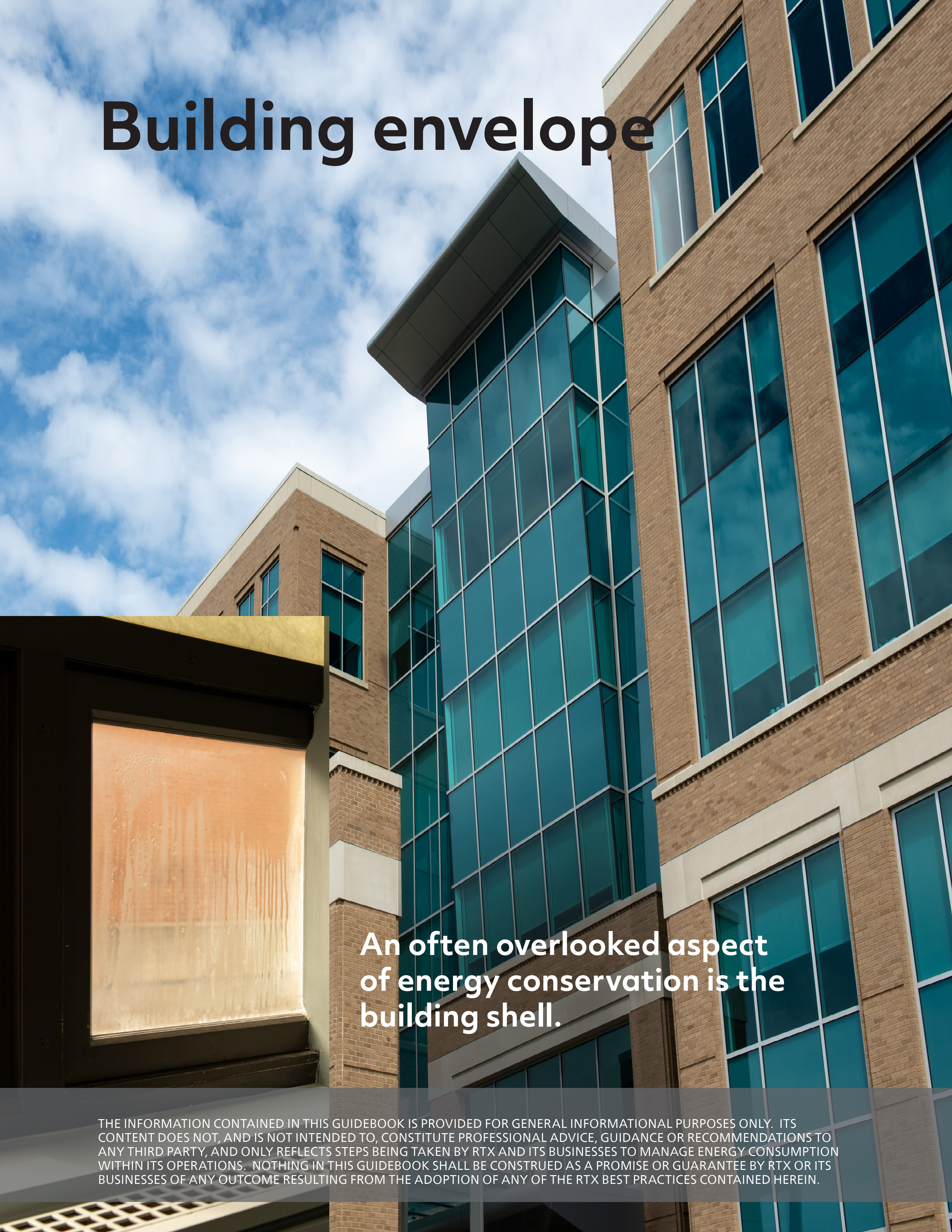
- **Lighting power density (LPD)** – Maximum lighting power per unit area of a building classification or space function (watts per square foot).
- **Color rendering index (CRI)** – A scale from 0-100 indicating the effect of a light source on color appearance.
- **Correlated color temperature (CCT)** – Determines the shade of the light (red is warmer, blue is cooler).
- **Downtime reduction** – Some lights require a restrike and warm-up time to gain full brightness, causing some production downtime (LEDs require no warm-up time).

TECHNOLOGY	CRI	LIFETIME (HOURS)	COLOR TEMPERATURE
Compact fluorescent light (CFL)	80-90	6,000 to 10,000	2,700-6,500
Incandescent	100	750 to 1,500	2,400-2,900
Linear fluorescent	70-90	20,000 to 46,000	2,700-6,500
Halogen	100	2,000 to 4,000	2,850-3,200
White LED	65-90	Up to 100,000	2,700-6,500

Lighting minimum required actions

- Maintain a current lighting system inventory (system capacity, cost of operation, energy consumption and control methods).
- Evaluate space lighting levels for conformance to RTX recommendations.
- Lighting controls evaluated and changes implemented where beneficial.
- Create a plan for lighting relamp or upgrade – fixtures and controls.
- Enable control of the lighting system through the BAS

Building envelope



An often overlooked aspect of energy conservation is the building shell.

So far, we have discussed the common energy consuming systems found within the facility. We have discussed control implementation and equipment improvements to reduce energy usage. An often-overlooked aspect of energy conservation is the building shell. Ownership of the building often plays a role in determining facility upgrades. RTX leases many of its buildings. Lease renegotiation, new construction and retrofit are the ideal times to request and implement building envelope upgrades. Here are some items to consider for building shell improvement.

Much of a building's heat loss and gain occurs through the roof. Roof integrity should be maintained each time the roof is penetrated. Installing a light-colored reflective roof will reduce solar gain in the summer. Adding insulation to the underside of the roof deck and insulating roof voids will decrease heat loss in the winter.

External doors and doors separating conditioned spaces from nonconditioned spaces offer energy-saving opportunities in the form of weather stripping. Double-spaced automatic doors are useful for maintaining interior temperatures in areas with external doors. Plastic secondary door curtains inside delivery doors are useful in reducing interior temperature changes.

Windows, like doors, have the opportunity for improved weather stripping. Along with weather stripping, windows can be tinted to reduce solar load in warm climates. While window treatments such as shades and blinds offer the opportunity to reduce temperature infiltration in the summer and winter.

The best way to maintain temperatures in conditioned spaces is with the use of insulation. Adequate ventilation must be provided to tightly sealed buildings. Installation of CO_2 sensors permits the BAS to monitor and adjust for proper space ventilation. If the conditioned space has humidity control requirements, then vapor barriers must also be considered. Consult a local engineering firm for vapor barrier options. Proper insulation of walls, ceilings and roofs can greatly reduce the cost of HVAC operations. Rapid-roll or speed-closure doors are valuable in reducing the loss of conditioned air to the outdoors or unconditioned spaces.

Building envelope minimum required actions

- Use thermal scans to test the integrity of building insulation in walls and roofs.
- Check insulation for condensation and water penetration and replace as needed. Insulation is ineffective once it becomes wet.
- Investigate exterior doors and windows for weather stripping improvements.
- Evaluate the need for window tinting or treatments to reduce climate changes.
- Use CO_2 sensors to verify accurate space ventilation.

Compressed air

A 100 hp air compressor costs up to $60,000 per year to operate. Up to 50% is waste.

(U.S. Department of Energy)

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 – in a typical RTX manufacturing site, compressed air represents 12% to 15% of the total electrical consumption and can be as much as 20%. Energy is by far the largest cost component of a compressed air system, comprising 82% of the total cost of ownership. Fortunately, there are numerous opportunities to reduce waste and increase the efficiency of the compressed air systems.

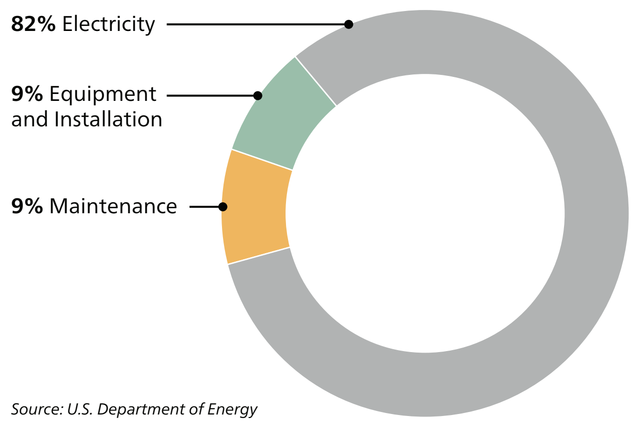
Incorporate the compressed air management system into the BAS

A properly deigned compressed air system including one or more air compressors should have a control sequencing mechanism. The control sequencing mechanism should have the ability to provide centralized monitoring, alerts and control through the BAS.

Document the compressed air system capacity

The following diagram highlights the components of a typical compressed air system and where opportunities for improvement often can be found. 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% of total system energy use.

Total cost of ownership.



Source: U.S. Department of Energy

In a typical RTX manufacturing site, compressed air represents 12% to 15% of the total electrical consumption and numerous opportunities exist to reduce waste and increase the efficiency of these systems.

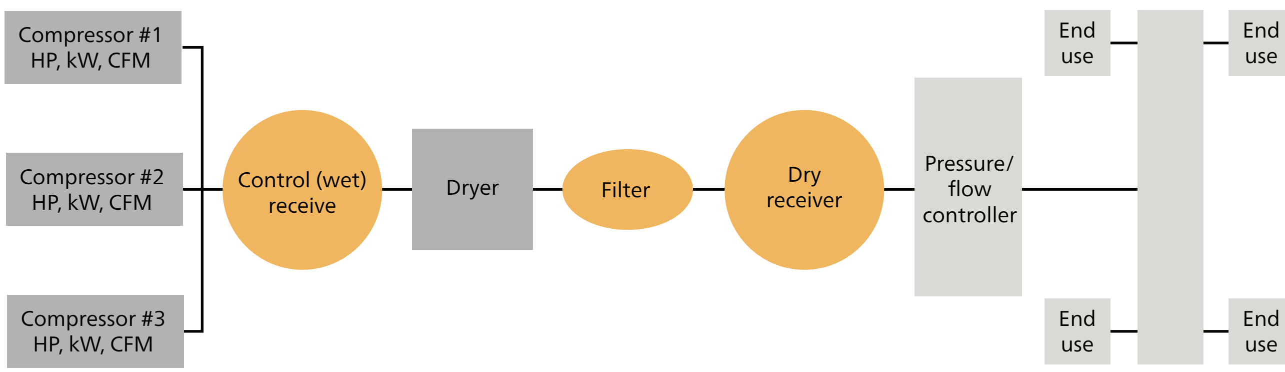
It's essential to know the component details of your compressed air system. This will ensure the system can perform at peak efficiency. On the supply side (compressors, treatment and storage) determine what type of equipment you have and the generating capacity of that equipment in horse power (hp) or kilowatts (kW) and airflow in cubic feet per minute (CFM) or cubic meters (m^3) of airflow.

On the demand side, distribution piping, storage systems and end-use equipment, determine how much compressed air you need, the level of quality, the load and pressure requirements.

A block diagram of the system is helpful for analysis purposes. Knowing the baseline and calculating your energy use and costs will allow you to establish current performance and cost levels and compare them to future levels. Use the BAS to review trends in compressed air operational data for abnormalities and fault warning signs.

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 subsystem.



Measure the baseline use of air. Calculate current energy consumption and cost

Measure and track key performance indicators including energy consumption, pressure, flow and temperature to be used to evaluate system performance in the future.

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 up 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.

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

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

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

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% of the time with a motor efficiency of 95%, and the rest of the time at 25% of full load with a motor efficiency of 90%. For the purpose of this example, let's say that the electrical rate is $0.08/kWh. Here's how to calculate the cost:

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

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

Plus

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

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

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

1 U.S. Department of Energy: "Determine the Cost of Compressed Air for your Plant."

Complete an end-use study and implement a well-defined leak management program

End-use study

After completing an assessment of the compressed air supply side documenting the generation capacity the next step is to study the demand side or uses of compressed air.

Survey the end uses and catalog the pressure and flow requirements to gain an understanding of how much air is required, at what pressure and when.

The following table can be used to list the various uses of compressed air.

The alignment of supply side capacity with demand side use will help the system operate at peak efficiency. To maximize energy efficiency the controls on each compressor will have to be synchronized with overall system controls (flow controller and pressure regulators).

OPERATION	PRESSURE (PSIG)	CONTINUOUS	AVERAGE	PEAK	CYCLE TIME	
		(DEMAND IN CFM)			ON	OFF
Air hoists	80	N/A	16.6	200	5 min	55 min
Open, handheld blow guns	90	100	100	100	N/A	N/A
Vacuum generation (venturi cups)	70-90	100	100	100	Production	Nonproduction
Automated assembly	80	200	200	200	Nonproduction	Production
Miscellaneous uses	70	N/A	160	200	N/A	N/A
Large pneumatic clamps (10 min each/hr)	85	N/A	16.6	200	10 sec	10 sec
Pneumatic actuators	80	50	50	100	Production	Production
Air leaks	80	300	300	300	N/A	N/A
Total		750	943	1,400		

Leak management

Frequently, 20% to 50% of the compressed air production in a facility is lost to leakage. Leaks can cause system pressure drops that adversely affect tool performance and production processes. Excessive air leaks can also result in compressors running longer just to keep up with demand. Leakage rates can be estimated by monitoring the compressor operation during nonproduction hours. For a compressor with load/unload controls simply monitor and record the time in minutes that the compressor operates in both loaded and unloaded state.

Leakate rate (percent) = $\frac{(T \times 100)}{(T + t)}$

Where:

T = Time fully loaded

t = Time fully unloaded

Compressed air leaks are a significant waste of energy. For example, a compressor operating at 100psi 24 hrs/day with a single 1/8-inch air leak costs you over $3,600/year at $0.08/kWh.

Leakage rates for systems with other control strategies can also be estimated using flow and pressure measurements.

An effective leak management program should reduce leaks to less than 10% of compressed air output.

Annual cost of air leaks.

PRESSURE	EQUIVALENT SIZE OF MULTIPLE LEAKS (INCHES)			
Upstream Psig (bars)	1/16	1/8	1/4	3/8
70 (4.8)	$677	$2,707	$10,829	$24,366
80 (5.5)	$757	$3,028	$12,111	$27,249
90 (6.2)	$837	$3,348	$13,392	$30,133
100 (7)	$917	$3,669	$14,674	$33,017
110 (7.6)	$997	$3,969	$15,956	$35,900
120 (8.3)	$1,077	$4,309	$17,237	$38,784

Cost of energy = $0.0800 per kWh.

Compressor efficiency = 4 CFM per bhp.

Motor efficiency = 0.925.

Eliminate inappropriate uses of compressed air

Compressed air is appropriate for some applications and processes; however, because it is one of the most expensive sources of energy in an industrial facility, it is not a cost efficient source of power for all applications. Inappropriate process uses for compressed air include cooling, vacuuming, drying, mixing and atomizing. Processes requiring delivery pressure of 25 psi or less, should use a blower, rather than compressed air.

POTENTIALLY INAPPROPRIATE USES	SUGGESTED ALTERNATIVES/ ACTIONS
Cleanup, drying, process cooling	Low-pressure blowers, electric fans, brooms, nozzles
Sparging	Low-pressure blowers and mixers
Aspirating, atomizing	Low-pressure blowers
Padding	Low to medium-pressure blowers
Vacuum generator	Dedicated vacuum pump or central vacuum system
Personnel cooling	Electric fans
Open-tube, compressed air-operated vortex coolers without thermostats	Air-to-air heat exchanger or air conditioner, add thermostats to vortex cooler
Air motor-driven mixer	Electric motor-driven mixer
Air-operated diaphragm pumps	Proper regulator and speed control; electric pump
Idle equipment*	Put an air-stop valve at the compressed air inlet
Abandoned equipment**	Disconnect air supply to equipment

*Equipment that is temporarily not in use during the production cycle.
**Equipment that is no longer in use either due to a process change or malfunction.

- Low-pressure applications often can be accomplished with fans or blowers.
- Except in cases of hazardous environments, the use of electric motors is more efficient than air motors.
- Vacuum requirements often can be served more efficiently by a vacuum pump rather than a compressed air operated venturi nozzle.
- Noisy and poor use of compressed air – Eliminate. Open blowguns may also be a violation of health and safety codes.
- Use mechanical pumps rather than air operated diaphragm pumps where possible. In an explosive atmosphere or pumping of abrasive slurries, the use of double diaphragm pumps with appropriate pressure regulation and shutoff controls may be the better choice.

One ¼-inch open nozzle used for employee cooling is roughly equivalent to 15 horsepower of compressed air.

Adhere to manufacturer recommended maintenance program.

Because air compressors are SEUs, proper maintenance is key to maintaining efficiency and eliminating downtime. Improper maintenance will increase energy costs and can also lead to pressure variability, high operating temperature, moisture problems and poor air quality, all of which can impact manufacturing.

It's important to monitor and track system performance for all SEUs, especially when manufacturing operations will not function without compressed air. Keep a log of key performance indicators such as power, pressure, flow and temperature and take corrective actions whenever one or more KPIs are outside acceptance tolerance levels.

Common compressed air energy efficiency projects

The following list of projects have been implemented in various RTX facilities and can help maximize compressed air system efficiency, minimize energy losses and reduce energy consumption and the costs associated with system operation.

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 100psi is rarely required and higher-pressure results in greater energy use, utility cost and leak 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.

Designed 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, a piping loop enables the system to deliver equal pressure to everyone along the line. Be careful not to create a dead end when adding on to your system.

Use filters with the lowest pressure drop available that are 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 proper psi filter and inspecting regularly can help reduce this form of inefficiency.

Use local storage for high-volume manufacturing operations

Manufacturing operations that require a high volume of air should include a local storage tank to absorb peak air demands.

Use cooler air intake

Compressors operate more efficiently when the source of intake air is clean and cool. Put another way, it takes less energy to compress cooler 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

Multiple compressors allow you to control the system and activate or shut down compressors as they are needed, thereby reducing unnecessary energy consumption.

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

This avoids consuming energy when it is not necessary.

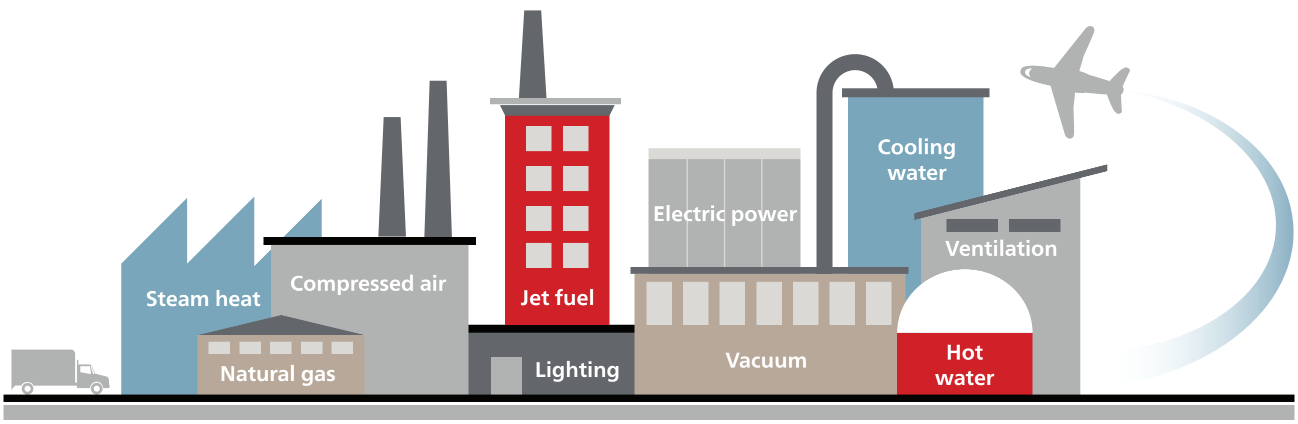
Compressed air management minimum required actions

- Document site compressed air infrastructure including:
  - Current one-line system diagram.
  - A description of system capacity.
  - Complete end use study.
- Identify and eliminate inappropriate uses – rubber hose, excessive pipe runs, tank agitation, power tools.
- Reduce end-use equipment and system pressure to acceptable minimum.
- Leak test audits scheduled minimum one per year. Repairs documented.
- Keep active log of maintenance performed.

Process energy management

Production rules all, but finance holds the purse.

Production rules all! The creation of product is the reason factories exist. A primary consideration when purchasing and operating production equipment is energy efficiency, and to ignore this will result in unnecessary expense and site GHG emissions. RTX uses improvements in energy efficiency as the best means of meeting our commitment to reduce our physical GHG emissions while at the same time reducing our costs. The purchase of new equipment and space renovations offer the best opportunity to reduce energy consumption. The site energy manager should communicate the opportunity presented by energy efficiency to capital allocation decision-makers and remind them that failure to procure the most energy-efficient production equipment available represents a lost opportunity that the facility will pay over the next 20-plus years. Additionally, all new capital equipment should be integrated to the BAS to eliminate any unnecessary expenses to the energy budget. Remember, production may be king, but finance holds the purse.



Process energy management

Manufacturing processes can consume as much as 60% of a site's energy load, not including the energy used by auxiliary equipment such as air compressors and cooling towers. In most cases, the focus of process energy management is not to change the manufacturing process but to optimize the energy inputs into the process. Capital equipment used in manufacturing can last for 40 to 50 years so the only option an Energy engineer has for managing inefficient process equipment is to monitor input energy consumption using the BAS and improve the efficiency of the auxiliary equipment serving production.

Each primary and secondary energy source in the process should be reviewed for efficiency improvements such as:

- Reducing compressed air pressure.
- Controlling ventilation to different flow rates during stages of production.
- Confirming accuracy of all temperature setpoints.
- Varying the flow of cooling water to match the load (isolate during idle mode).
- Heat recovery.
- When possible, maximize the use of production equipment, run full load batch processes.

The objective is to maintain or improve the quality of the manufacturing process while reducing energy consumption.

Common manufacturing process energy efficiency projects

Conduct an energy audit

Include an estimate of energy consumption by manufacturing equipment.

Batch process where possible

Batch process ovens, furnaces and heat-treating operations to reduce the energy used per part produced.

Reduce the weight of oven tooling

When heat-treating operations call for specific cycle times and temperature set points, reducing the weight of tooling will reduce the amount of total energy used in a cycle.

Verify operating requirements

Include start-up and shut-down procedures for the primary manufacturing equipment and the ancillary equipment (cooling towers, dust collectors, vacuums, etc.).

Interlock auxiliary equipment with production equipment

Shut off compressed air, hydraulic pumps, cooling water, vacuum pumps, ventilation – whenever production is in idle mode.

Perform an energy Kaizen

Perform an energy Kaizen on SEUs focusing on optimization.

Preventive maintenance

Verify the OEM preventive maintenance is performed.

Industrial gas monitoring

Monitor the usage and flow of industrial gases to ensure system integrity. Conduct periodic leak audits of piping and distribution system.

Develop operating and maintenance procedures to ensure peak efficiency

Facilities must develop operating and maintenance procedures to ensure peak efficiency. This can be accomplished by adhering to documented OEM maintenance requirements, documenting and posting operating procedures (start up and shut down) for manufacturing equipment and auxiliary equipment and monitoring energy consumption of production equipment to establish normal operating trends. Review data for anomalies.

Many process improvements are most cost-effective when they are conducted as part of new construction or restructuring – management of change initiatives.

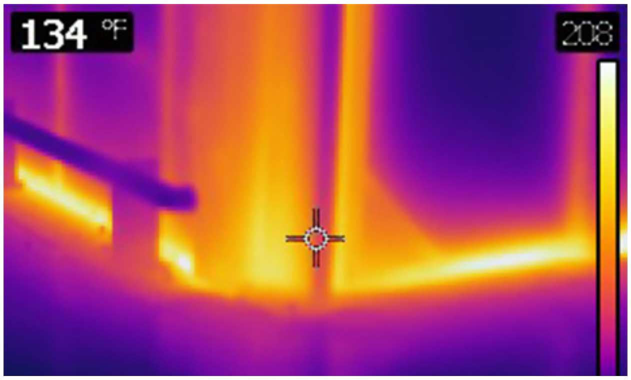
Furnaces and ovens energy management

RTX factories include a lot of furnaces and box ovens for drying, curing, holding parts and heat-treating product components. Many furnaces and ovens are used for long hours of operation and are located within air-conditioned spaces. It's extremely important to ensure the heat is used to dry or cure the part and not add heat to the workspace.

To increase the energy efficiency of industrial dryers and ovens:

- Adjust exhaust rates – Exhaust fans remove vapors, moisture and combustion byproducts. Adjust fans with variable frequency drives to the minimum air flow required.

- Heat recovery – Use the heat exchanger in the exhaust stream to recover heat for other applications (preheat air, space heating, etc.).



- Insulate oven walls – Especially in older ovens, insulation may have broken down, allowing heat to be added to the workspace. Thermal imaging will help identify areas that need additional insulation.
- Repair oven doors – Depending on the oven temperature and frequency of use, door seals are common maintenance problems and another way to lose heat to the workspace. As in the picture above, thermal imaging will help identify worn door seals.
- Door switches – Interlock heaters with a door switch to turn off heaters and possibly circulating fans whenever the oven door is open. This is another way to contain heat and keep it from flowing into the workspace.
- Idle mode controls – Many ovens and furnaces already have "idle mode" controls that have never been enabled. These controls can reduce the temperature and air circulation to preset levels during extended periods of nonproduction. Check existing control package or retrofit idle mode controls to existing equipment.
- Perform recommended maintenance – Natural gas burners and electric heater controls should be calibrated and maintained to keep equipment operating at peak efficiency.
- Energy monitoring – For large equipment, install permanent submetering equipment to track energy consumption and quickly identify problems/increased energy use.

Process energy management minimum required actions

- Document operating requirements for SEU, including kWh, compressed air, industrial gases, heating, etc.
- Operate SEUs at OEM minimum requirements.
- Keep an active log of maintenance performed.

Electric motor management

Motor-driven equipment accounts for approximately 60% of the electrical energy consumed by process industries.

Often viewed as part of a larger system, the proper sizing, control and maintenance of an electric motor can yield energy saving results of 11% to 18%.

It is beneficial to understand the energy consumption and costs associated with industrial processes and HVAC as a system. However, depending on the cost of electricity and hours of operation, the costs to replace capital equipment to improve energy efficiency can be prohibitive. A clearly defined electric motor management program will reduce the operating costs of equipment by minimizing wasteful energy consumption.

Electric motors are an integral part of RTX's manufacturing processes. The U.S. Department of Energy estimates that 60% of all U.S. electrical energy in industrial applications is consumed by electric motors. Passage of the Energy Policy Act in 1992 regulated the energy efficiency of a limited number of general-purpose motors. Since June 1, 2016, newly manufactured industrial electric motors from 1 to 500 horsepower are required to meet the National Electrical Manufacturers Association (NEMA) established Premium® efficiency standards.

Electric motor management program

Identify and document critical facility, HVAC and process electric motors (size, efficiency, rpm, location, hours of operation and date of installation).

Perform preventive maintenance to ensure operating efficiency

Maintain the minimum amount of premium efficiency motors in stock by standardizing on frame sizes and motor hp/kW.

Evaluate motor sizes

Motors sized greater than 25% of loading should be evaluated for right-sizing. Motors between 1% and 25% of loading should be identified and properly sized when the motor fails.

Purchase premium efficiency motors

Rule of thumb for motors that operate more than 2,000 hours per year should be premium efficiency.

Do not rewind motors

A typical motor rewind will cause a 1% to 2% loss in motor efficiency.

Add interlocks

When possible, interlock auxiliary items such as blowers, fans, coolant and circulator pumps to the primary equipment power switch to prevent wasteful operation.

Add timers and switches to noncritical fans

Avoid unnecessary exhaust of conditioned air space. Install timers and switches on exhaust and personnel fans to shut off equipment when area is unoccupied.

Add motor speed controls

Add variable speed drives to cooling tower fans and pumps to slow motor speeds to appropriate cooling requirements.

Install power factor correction capacitors

Many utility companies charge a penalty on facilities with poor power factor ratings (usually below 90%). A financial analysis should be performed to validate the opportunity to install capacitors at a particular motor or for the entire site.

Variable frequency motor drives (VFDs)

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 BAS the thing to do is review OEM 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.

Electric motor basics

Capacitor

An electrical device used to store an electric charge, consisting of one or more pairs of conductors separated by an insulator. Often used in power factor correction.

Frame size

A method invoked by NEMA to create a standard for common motor horsepower mounting dimensions.

Horsepower

Motor rating that defines the amount of work a particular motor can perform. 1 hp = 0.745kW or the ability to move 2,000 pounds one foot.

Load factor

Refers to the percentage of total motor horsepower required to perform the task.

Open drip proof (ODP)

A type of motor that allows air to circulate through the windings for cooling but prevents drops of liquid from falling into the motor within a 15 degree angle from vertical.

Phase

The indication of the type of power supply for which the motor is designed, typically one or three phase.

Power factor

The mathematical ratio of active power to apparent power. A power factor of less than 0.9 usually results in a penalty charge from the utility company.

Rotor

The rotary part of a motor.

Service factor

A multiplier that indicates the amount of overload a motor can be expected to handle.

Stator

The stationary part of the motor.

Totally enclosed fan cooled (TEFC)

A type of motor with fully enclosed windings that requires a fan to keep the copper windings cool.

Torque

The twisting force exerted by the shaft or rotor.

Windings

Refers to the copper used in the motor to create a magnetic field.

Electric motor.

Ventilation fan.

Common electric motor equations:

Load Factor (% Motor Load) = $$\frac{[(\text{No load speed}) - (\text{measured operating speed})]}{[(\text{No load speed}) - (\text{nameplate full load speed})]} \times 100$$

Efficiency = (746 × horsepower output)/(watts input)

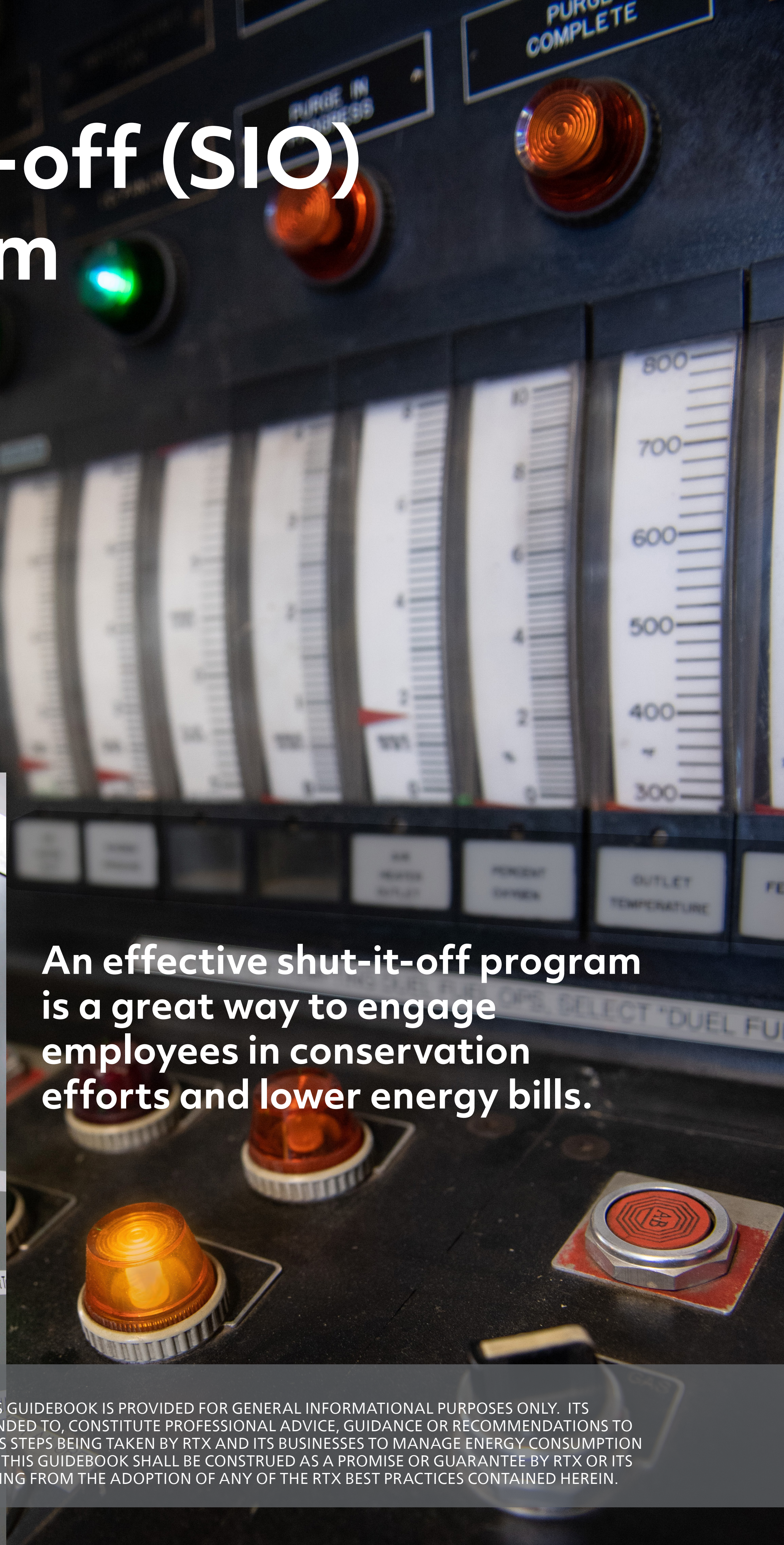
Power factor for a particular motor 3-phase = pf = watts input/(volts × amps × 1.73)

Power factor for a system = active power in watts/apparent power in VA = Cos

Motor management minimum required actions

- Maintain an inventory list of all motors. Identify “critical to production” motors.
- Evaluate the benefit of right sizing oversized motors.
- Evaluate motors less than 90% efficient for replacement.
- Evaluate the installation of VFDs on motors:
  - Greater then 5hp (3.7kW).
  - Operating continuously with alternating load requirements.

Shut-it-off (SIO) program



An effective shut-it-off program is a great way to engage employees in conservation efforts and lower energy bills.

The simplest and most cost-effective way to save energy is to shut off equipment that is not needed. Manufacturing machines, office equipment and building service devices should all be shut off, set back or put in idle mode when not needed.

Site managers should initiate an effort to evaluate the operating requirements for all primary and secondary equipment and assign responsibility for ensuring that equipment is turned off at the end of the workday. A best practice is to identify ancillary equipment by SEU and automate control of its activity from the BAS.

Electric utility meters and building energy management systems can easily monitor daytime and nighttime consumption to track the effectiveness of "shut-it-off" efforts. Electric consumption profiles should be reviewed and efforts made to eliminate waste.

You would never leave your car running overnight just because you have to go back to work in the morning! The same principal should apply for a box oven maintaining 1,300°F all weekend and no production scheduled.

Energy treasure hunts that are conducted during low-load or no-load production times in the factory are an effective way to discover systems that can be shut off when not needed.

Sleeping plant tours or energy treasure hunts are an easy way to introduce and engage employees in energy management efforts. Create a checklist and look for opportunities to:

- Turn off column fans at night.
- Turn off lights during nonproduction hours.
- Install motion sensors in manufacturing and warehouse areas to dim down or shut off lights when areas are unoccupied.
- Interlock compressed air supply with machine tool operations.
- Night setback for heating and cooling systems.
- Lower-temperature set point for furnaces and ovens in idle mode.
- Shut off dust collectors when production equipment is off.
- Implement a color-coding scheme to identify equipment requirements for shut-it-off procedures:
  - Red (never shut off).
  - Yellow (check with manager before shutting off).
  - Green (always shut off).
- Shut off exhaust fans to reduce the loss of conditioned air.

Shut-it-off (SIO) program minimum required actions

- Shut-it-off leader identified.
- Maintain an active list of equipment that can be shut off.
- Documentation that employees are trained on processes to shut-off the equipment (when and how).
- Off-hour plant energy tours documented to validate effectiveness of program.

Fleet management

The RTX fleet is often overlooked as an energy reduction opportunity.

A little realized but important part of RTX operations is the fleet of vehicles used in operations. Due to their mobility, the RTX fleet is often overlooked as an energy reduction opportunity. Therefore, it's very important to include fleet management when developing an energy management plan.

Wireless technology has transformed the way that we can manage our fleet vehicles. Telematics are used in livery, transportation and auto leases. Although it is not a standard practice in RTX facilities, telematics are being applied to vehicles across the enterprise. Control of this data currently reside with the leasing company. But one day the information will be manageable from a facility BAS. Until that time, the energy manager should use the following to manage fleet energy usage.

Create a fleet inventory

The inventory of motor vehicles must be created at the site or regional level to answer fundamental energy management questions: What's the capacity of the system we are trying to manage (number of vehicles) and how much energy does it use (miles per gallon, gallons per year)? As in other aspects of RTX energy management, the proper tracking of fuel consumption may uncover opportunities for improvement.

Improvements realized as a result of accurate fleet data:

- Fleet optimization, 38% reduction in fuel cost.
- Dispatching and routing efficiency, 20% reduction in drive time.
- Behavior modification, 44% improvement in at-fault accidents.

These improvements would not have been possible without an accurate inventory and an analysis of use patterns.

Driver training

Fleet managers and EH&S managers should ensure that drivers and motor vehicles are as safe and fuel-efficient as possible by making sure maintenance protocols are followed. Sites should initiate a motor vehicle 5S program to make sure vehicles are not carrying extra weight that is not needed, thereby reducing fuel efficiency and possibly causing safety issues.

Fuel management

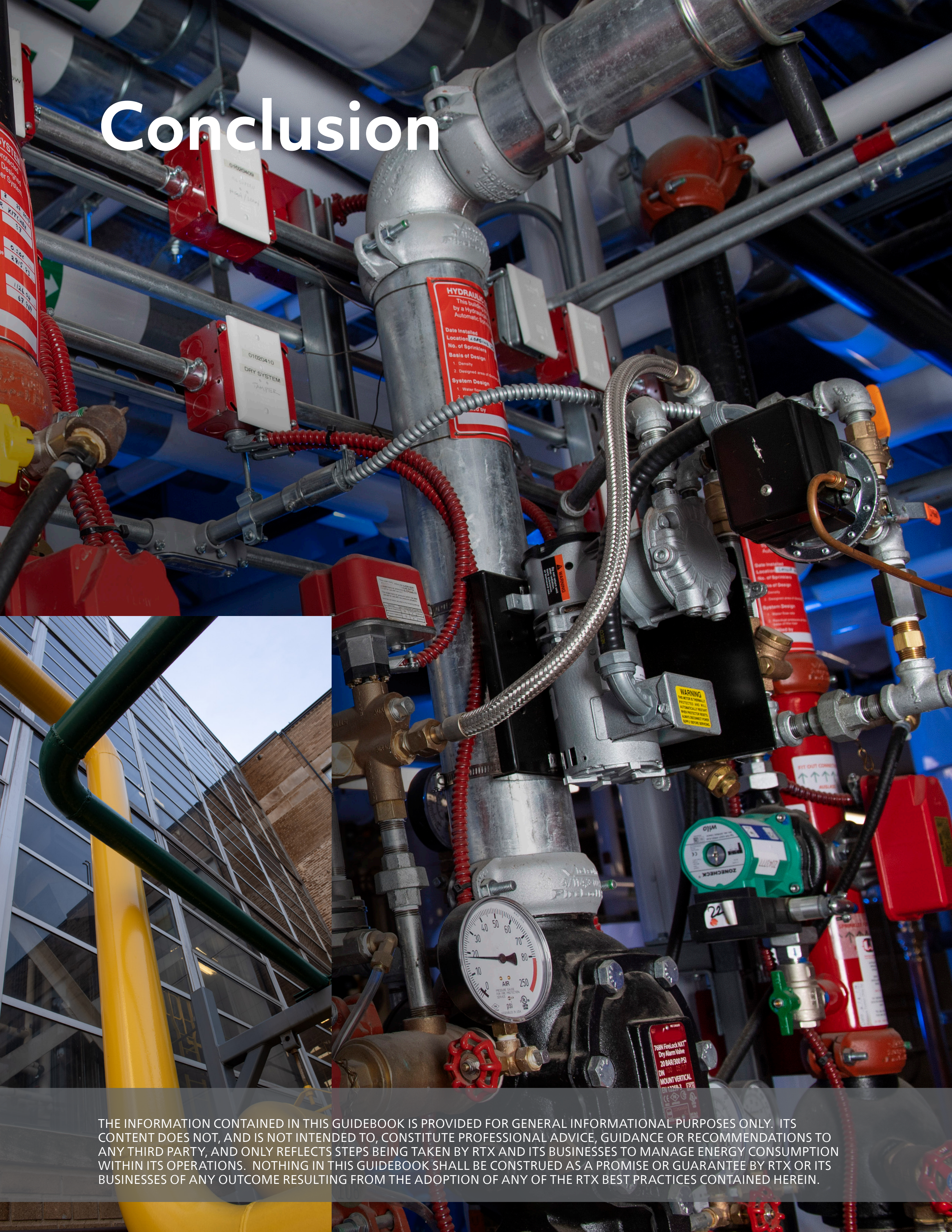
The only way to accurately track and report ongoing fuel efficiency improvements it to track actual fuel use for all company vehicles and not estimate fuel used based on distance traveled.

Work with fleet management partners to leverage telematics to improve productivity, reduce fuel use and improve driver safety by observing driver behavior and optimizing preventative maintenance measures.

Fleet management minimum required actions

- Maintain a motor vehicle inventory.
- Promote driver training and efficient vehicle operation.

Conclusion



We hope you were inspired by this introduction to energy conservation and GHG reduction at RTX. Our goals are designed to be aggressive and challenging, and attaining them requires a tremendous amount of creativity and hard work from our employees, significant capital investment and the implementation of a range of engineering solutions.

Appendices

Appendix A

Rules of thumb

Fan energy	100–1500 CFM per hp
Fan energy	400 CFM per ton of air conditioning
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 and towers	0.7–1.0 kW per ton
Domestic hot water temperature setpoint	Setpoint 105°F
Steam absorbers	18 lb. steam per ton
Boiler hot water reset controls	Saves 14% of annual heating cost

Common energy equations

Sensible air conditioning	Btu/hr	= CFM × 60 min/hr × .075 lb./cubic feet × .24 Btu/lb. × ΔT
	Btu/hr	= 1.08 × CFM × ΔT
Latent air conditioning	Btu/hr	= 60 min/hr × .075 lb./cubic feet × CFM × ΔH
	Btu/hr	= 4.5 × CFM × ΔH
Water heating/cooling	Btu/hr	= GPM × 60 min/hr × 8.33 lb./gal. × 1 Btu/lb./°F × ΔT
	Btu/hr	= 500 × CFM × ΔT
Electric power	kW	= 0.746 × HP/Motor Efficiency
	kW (3 phase)	$= \frac{\text{amps} \times \text{volts} \times 1.73 \times \text{power factor} \times \text{motor efficiency}}{1000}$
	Brake HP (3 phase)	$= \frac{\text{amps} \times \text{volts} \times 1.73 \times \text{power factor} \times \text{motor efficiency}}{746}$

Natural gas conversions

1 CF (cubic foot)	= Approximately 1,000 Btus
1 CCF	= 100 CF = 1 therm
1 Therm	= 100,000 Btus = 100 CF = 0.1 MCF
1 MCF	= 1,000 CF = 10 therms = 1 decatherm
1 MCF	= 1 million Btus = 1MMBtu
1 MMCF	= 1,000,000 CF = 1 billion Btus

Appendix B

Conversion factors

These units multiplied by...	...this factor will...	...convert to these units
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, U.S.)	42.0	Gallons (U.S.)
Horsepower	2545	Btu/hr
Kilowatt-hrs	3414	Btu (site)
Boiler horse power (BHP)	33,475	Btu/hr
Degrees centigrade	$F = (C \times 1.8) + 32$	Degrees fahrenheit
Degrees fahrenheit	$C = (F - 32) \times 0.555$	Degrees centigrade
Gallons (Brit)	1.2009	Gallons (U.S. liq)
Gallons (Brit)	4.546	Liters
Gallons (U.S.)	3.7854	Liters
Gallons (U.S.)	0.83267	Gallons (U.K.)
Therm	100,000	Btu

Appendix C
Glossary

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

Annual fuel utilization efficiency (AFUE) – 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 blow-down 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.

Energy efficiency ratings (EER) – EERs measure the efficiency with which a product uses energy to function. It is calculated by dividing a product's Btu output by its watt hour (Wh) input.

Energy conservation measure (ECM)

Foot-candle (fc) – Unit of measurement for illuminance:

(1 fc = 1 lumen/SF).

Greenhouse gas (GHG)

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 unit .

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

Appendix D
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. Environmental Protection Agency (EPA) climate change:

http://www.epa.gov/climatechange

World Resources Institute (WRI):

http://www.wri.org

DSire Database of State Incentives for Renewables & Efficiency

http://www.dsireusa.org

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