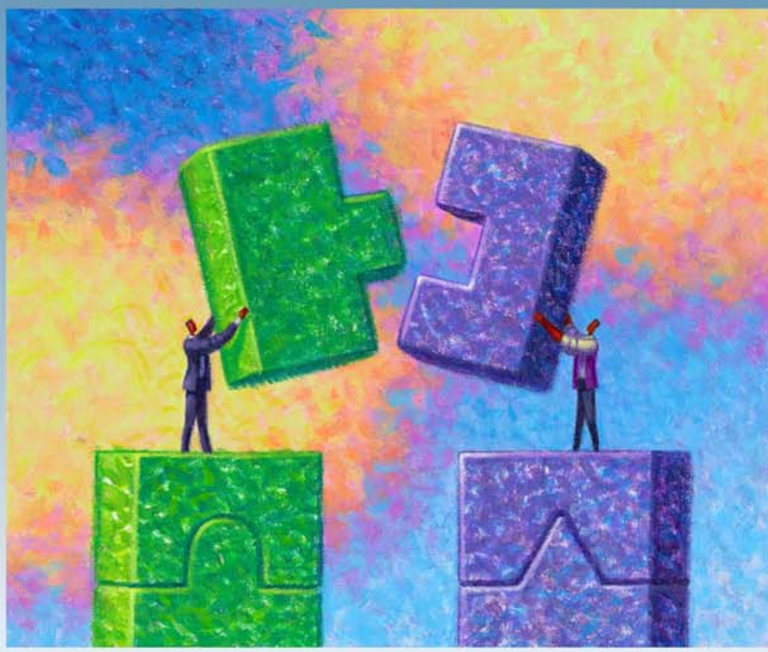
U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Energy Savings Assessment Training Manual



A practical and hands-on guide to conducting an energy savings assessment audit

U.S. Department of Energy
Federal Energy Management Program
1000 Independence Avenue, S.W.
Washington, DC 20585

For more information contact:
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov

Enviro-Management & Research, Inc.
5415-B Backlick Road
Springfield, VA 22151-3915
1-703-766-2670
www.emrinc.com

Acknowledgements
FEMP: Ab Ream (EE-2L, FEMP O&M Program Manager and Shawn Herrera (EE-2L), AARA Program Coordinator.
EMR: Ed St. Germain, Kate Kelly, Mohan Jacob, Mike Bakshi, Italo Valerio, and Toro Oni.

Table of Contents

Chapter 1
Energy Audit Basics

The U.S. Government is the world's largest consumer of energy. Federal legislation and executive orders direct Federal Agencies to better manage their energy use, reduce the carbon footprint, and use cost-effective alternative fuels and renewable energy (RE) resources. The Government's internal sense of stewardship of the nation's valuable natural resources directs it to manage them more effectively and take advantage of the underutilized and abundant renewable energy opportunities. Federal Agencies, therefore, have mandates, a significant opportunity, and the desire to help reduce the nation's energy use and dependence on imported fuels.

History

In the first part of the twentieth century there was no concern about the efficiency of a facility. The main focus was on making things work and getting them to last. Manufacturing methods and power generation abilities were limited. As the industry grew, so did knowledge about power conversion factors and efficiency. The main focus was not on conservation but on production. Through the middle part of the twentieth century there became a more growing awareness on better usage of energy to make more efficient and better products. It is not until the latter part of the twentieth century that we became conscious of conservation. The fuel oil crisis of the 1970s called attention to the need to be efficient and use less energy. As a result of the oil embargos of the 1970s, additional measures were undertaken to reduce consumption ever further. Daylight saving time was increased to include additional daylight hours in the spring, saving hundreds of thousands barrels of oil per year.

The diversity of fuels and power generating options has grown to include replenishable and renewable resources. Our dependency on fossil fuels is still high. Extensive research done in energy conservation has lead to new energy options. This has been slow moving, but is gradually gaining ground.

In This Chapter:

Our dependency in foreign sources only recently has developed in us a new awareness in the best and efficient use of our natural resources. Coupled to that are threats about global warming, human health exacerbated by pollution, national security that is affected by dependency on foreign fuel, and ecological trends that make our custodial care of our energy sources paramount.

As the century drew to a close and we dawned into the new millennium, a new wave of thinking emerged – a planet-friendly, economy conscious, and social minded approach to the next generation of building. With new initiatives of design and construction, Federal Owners and Managers are seeking to achieve a Zero Energy Building (ZEB). Programs that accentuate, through certification, the need for renewable energy and conservative construction methods have been developed. The U.S. Green Building Council has introduced LEED – Leadership in Energy and Environmental Design – , the non-profit Green Building Initiative has introduced *Green Globes*, and there are other programs that highlight maximized energy efficiency and environmental awareness. This is the natural progression from the results of energy audits.

Legislation

Six important energy legislative and executive mandates that are the current drivers for energy efficiency are the National Energy Conservation Policy Act; the Energy Policy Act of 1992; the Energy Policy Act of 2005; Executive Order 13423: *Strengthening Federal Environmental*, *Energy, and Transportation Management*; the Energy Independence Security Act of 2007 (Public Law 110-140); and Executive Order 13514: *Federal Leadership in Environmental, Energy, and Economic Performance*. In depth discussion and evaluation of these are beyond the scope of this document; however, a brief summary of their impact on Operations and Maintenance is provided.

National Energy Conservation Policy Act (NECPA)

The National Energy Conservation Policy Act (NECPA) serves as the underlying authority for Federal energy management goals and requirements. Signed into law in 1978, it is regularly updated and amended by subsequent laws and regulations. It is the foundation of most current energy requirements.

The stated purpose of the Act is “to promote the conservation and the efficient use of energy and water, and the use of renewable energy sources, by the Federal Government.”

Energy Policy Act of 1992 (EPAct 1992)

The Energy Policy Act of 1992 amended NECPA and established several energy management goals. It addresses water conservation, incentive programs, new technologies, Energy Savings Performance Contracts (ESPC), energy audits, energy-efficient product improvement, and other issues. Many of the requirements have been updated and/or superseded by subsequent legislation and Executive Orders.

Energy Policy Act of 2005 (EPAct 2005)

The Energy Policy Act of 2005 (P.L. 109-58), signed by President Bush on August 8, 2005, was the first omnibus energy legislation enacted in more than a decade. Spurred by rising energy prices and growing dependence on foreign oil, the new energy law was shaped by competing concerns about energy security, environmental quality, and economic growth. The energy conservation provisions of this law focus primarily on energy consumption by buildings, industrial processes, appliances and commercial equipment, and other stationary activity.

The law amends portions of NECPA. It updates the baseline for Federal energy savings from FY85 to FY03, and sets a new 20 percent reduction goal by FY15. By the end of FY14, DOE is to reassess progress and set a new goal for FY16 through FY25. DOE is empowered to exempt specific facilities that meet specified standards for National security or where achieving the target would be “impracticable.”

Further, the law also provides for the following (among other things) that have implications of facility operations and maintenance:

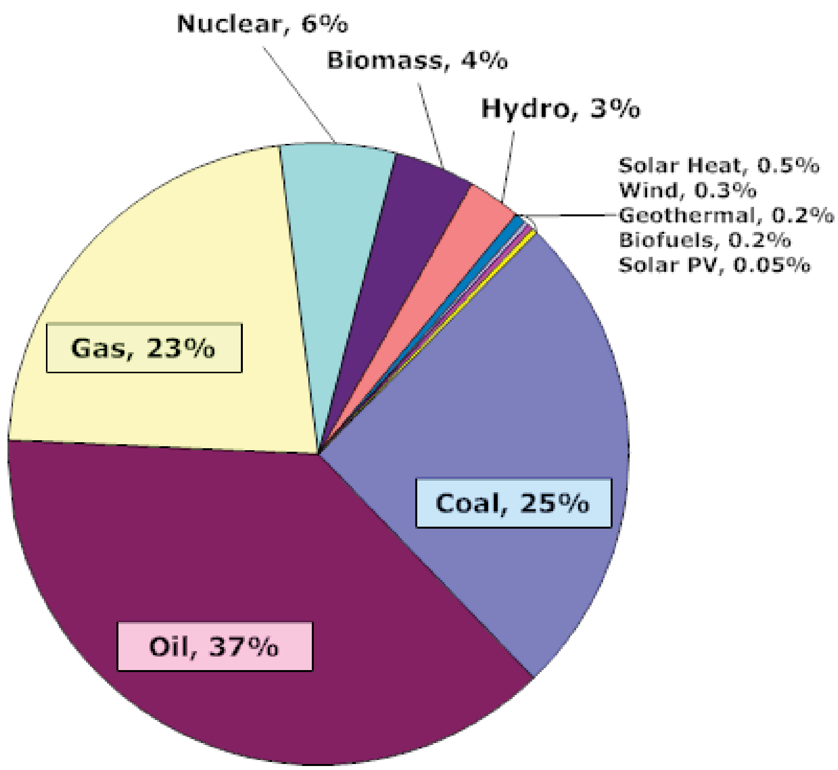
- Allows Agencies to retain appropriations for energy expenses that are saved by implementing energy efficiency measures;
- Requires Federal Buildings to be metered or sub-metered by October 1, 2012;
- Requires Federal Agencies to purchase ENERGY STAR certified or Federal Energy Management Program (FEMP) designated energy-efficient products, provided they are “cost-effective” and “reasonably available;”
- Extends the authority to enter into Energy Savings Performance Contracts (ESPC) until 2016;
- Provides statutory authority and expands the ENERGY STAR Program, which identifies and promotes energy efficient products and buildings;
- Requires DOE to convene an on-going national public education program with representatives from industry, education, professional societies, trade associations, and government agencies focused on energy efficiency and other topics;

- Requires DOE to conduct a public outreach program;
- Sets, by statute, energy conservation standards, test procedures, and labeling requirements for a myriad of products ranging from lighting lamps and ballasts to building transformers to refrigerated vending machines and commercial refrigeration equipment;
- Requires Federal agencies, to the extent "economically feasible and technically practicable," to purchase power produced from renewable sources. Agencies' renewable use, relative to total energy consumption, graduates from three percent in FY07 to five percent in 2010, then to 7.5 percent in 2013 and beyond. Renewable energy produced on a federal site is eligible for double credit; and
- Encourages the use of solar photovoltaic energy systems in new and existing federal buildings.

Executive Order 13423 (January 2007)

Executive Order 13423, *Strengthening Federal Environmental, Energy, and Transportation Management,* strengthens and establishes more aggressive key goals of the Federal Government than provided in EPAct 2005 and other prior Executive Orders. Among other items, it focuses on reducing energy intensity, increasing the use of renewable energy, reducing water intensity, designing and operating sustainable buildings, and managing federal fleets. Of particular interest:

- It requires Federal agencies to reduce energy intensity by three percent each year, leading to 30% by the end of FY2015 relative to the FY2003 baseline. The requirement is 50% more stringent than that of EPAct 2005. This requirement is codified by EISA 2007.
- It stresses renewable energy generation on agency property for energy use from new (after 1998) renewable sources.
- It mandates Federal agencies to reduce water intensity by two percent each year through FY2015 relative to FY2007 baseline. Prior Orders did not have water conservation goals.
- It requires all new and renovated buildings to comply with sustainable strategies, including resource conservation, reduction and use; siting; and indoor environmental quality.
- It increases the quantity of fleet vehicles that are alternative fuel, hybrid and plug-in hybrid electric; reduces petroleum consumption in fleet vehicles by two percent annually through 2015; and increases alternative fuel consumption by 10% annually.
- It expands the purchases of environmentally-sound goods and services.



The diversity of fuels and power generating options has grown to include replenishable and renewable sources - but our dependency on fossil fuels is still high.

Energy Independence Security Act (EISA) of 2007 (Public Law 110-140) (December 2007)

The Energy Independence Security Act of 2007 was originally named the Clean Energy Act of 2007. The stated purpose of EISA is:

> "To move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes."

The bill's key provisions address energy security, energy savings, research and development of renewable energy and carbon sequestration technologies, green jobs, transportation infrastructure, small business energy programs, smart grid, and pool safety.

Title IV, Subtitle C of the bill addresses *High Performance Federal Buildings* specifically, and is the part that affects facility operations and maintenance most directly:

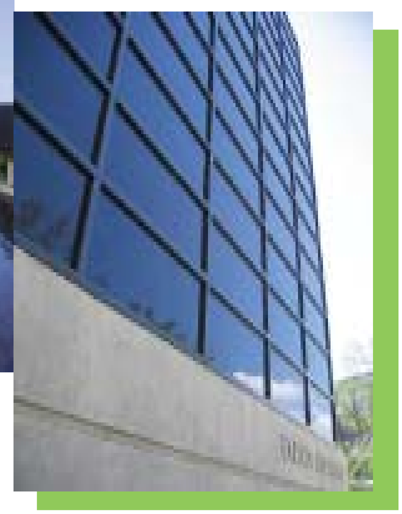
- Section 431 codifies the reduction of facilities energy intensity for new and existing buildings by three percent per year (starting at nine percent in FY2008) or by 30% by the end of FY2015 relative to the FY2003 baseline.
- Section 432 requires Agencies to identify all “covered facilities” that constitute at least 75% of the energy use.
- Section 432 requires each facility to have a designated energy manager who is responsible for:
    - Completing comprehensive energy and water audits in 25% of the covered facilities each year;
    - Implementing identified energy conservation measures (ECM);
    - Following up on implemented ECMs;
    - Certifying compliance via a DOE web-based tracking system; and
    - Entering energy use data for each facility into a benchmarking system (ENERGY STAR Portfolio Manager).
- Section 433 requires that fossil fuel-generated energy use in new buildings and major renovations is reduced by 55% starting in 2010 to 100% by 2030 relative to 2003 levels.
- Section 434 (b) requires sub-metering of natural gas and steam by October 1, 2016.
- Section 434 requires new buildings and major renovations to employ the most energy efficient designs, systems, equipment, and controls that are life-cycle cost effective.

Other provisions that may affect Federal facilities operators and maintainers include:

- Section 142 requires a 20% reduction in fleet annual petroleum reduction by 2015 and a 10% increase in annual alternative fuel consumption relative to the FY05 baseline.
- Section 323 addresses minimum performance levels of leased buildings, as well as maintenance, ENERGY STAR requirements, energy efficient lighting, and GSA guidelines.
- Section 523 requires that 30% of the facility’s hot water demand to be met with solar hot water equipment, provided it is life-cycle cost effective.

Executive Order 13514 (October 2009)

Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, expands on the energy reduction and environmental performance requirements of EO 13423. It focuses on, among other things, accountability and transparency, strategic sustainability performance planning, greenhouse gas management, sustainable buildings, water efficiency, fleet and transportation management, and pollution prevention and waste reduction. Sample provisions include:



- It establishes accountability and planning requirements for sustainable performance.
- It requires greenhouse gas management and reporting requirements, with reduction targets relative to a FY 2008 baseline.
- It requires agencies to enhance their effort in sustainable Federal building design, construction, operation and management, maintenance and deconstruction. All new construction, major renovations, or repair or alteration of Federal buildings must comply with the criteria of *Federal Leadership in High Performance and Sustainable Buildings*. Facilities must pursue cost-effective, innovative strategies that minimize consumption of energy, water, and materials.
- Building systems must be managed to reduce the consumption of energy, water, and materials and to identify alternatives to renovation that reduce deferred maintenance.
- Opportunities must be sought that will consolidate and eliminate existing assets, optimize current property performance, and reduce associated environmental impacts.
- Rehabilitation of Federally owned historic buildings will use long-term best practices and technologies.
- Water efficiency will be improved and managed by reducing water consumption intensity by two percent per year (or 26% by FY2020) relative to FY2007 baseline; reducing industrial, landscaping, and agricultural water consumption by two percent per year (or 20% by FY 2020) relative to a FY2010 baseline; and identifying, promoting, and implementing water reuse strategies consistent with State law.

- It requires facilities to ensure that 95% of its procurement actions are ENERGY STAR or DOE energy-efficient designated, water efficient, bio-based, environmentally preferable, non-ozone depleting, contain recycled content, or are non-toxic where such products meet agency performance requirements.

Clearly, there is a strong need for Federal Agencies and their respective organizations and sites to understand the need for and value of, and to conduct energy audits as a means of complying with these Federal mandates. This document is intended as a tool toward that end.

Objectives

The audience for this training ranges from residents in residential units to base-wide facility managers and energy program managers. The purpose is not to provide an in-depth, comprehensive education of the intricacies of energy management, but rather, to provide information leading to self-sufficiency in and the ability to conduct on-site energy audits – one of the pillars supporting the energy conservation and awareness movement in compliance with the mandates of the legislation and Executive Orders.

Moreover, the knowledge associated with conducting energy audits will help the reader fulfill his or her role as a steward of the natural resources under their direct and indirect control and influence. The objectives, then, are:

1 – To provide the tools necessary to comply with and satisfy legislative and executive order requirements;
2 – To instill ideas, tools, best practices, and lessons learned that generate actions that conserve energy, reduce cost, protect the environment, reduce reliance on foreign fuel, and reduce material waste;
3 – To educate and to communicate to the user current best practice energy audit terminology, definitions, and its applications;
4 – To provide the education and tools needed to conduct in-house and outsourced energy audits of Federal facilities;
5 – To provide the basics to recognize those no cost/ low cost energy savings measures that can and are often the simplest energy conservation opportunities that can be implemented immediately, without the need for high cost capital improvements; and
6 – To provide resources needed to help the Government position itself as a leader in the stewardship of the nation’s natural resources.

Selecting and Prioritizing Facilities

Section 432 of EISA requires each Federal installation to complete comprehensive energy and water audits in 25% of its covered facilities each year. This also roughly translates to conducting an audit of a facility every four years. This begs the question of which facilities should be selected for audits and in what priority.

The first step is determining if an energy audit is, in fact, needed or warranted now. Performing an audit when unnecessary can lead to increased costs with little or no return for the effort and needlessly occupying valuable manpower where it is not needed. The result can often deter other audits from being performed where they would be legitimately warranted on facilities that will benefit from the time and expense invested in a proper audit.

There are five basic questions that should be asked to help in deciding the priorities for conducting facility audits:

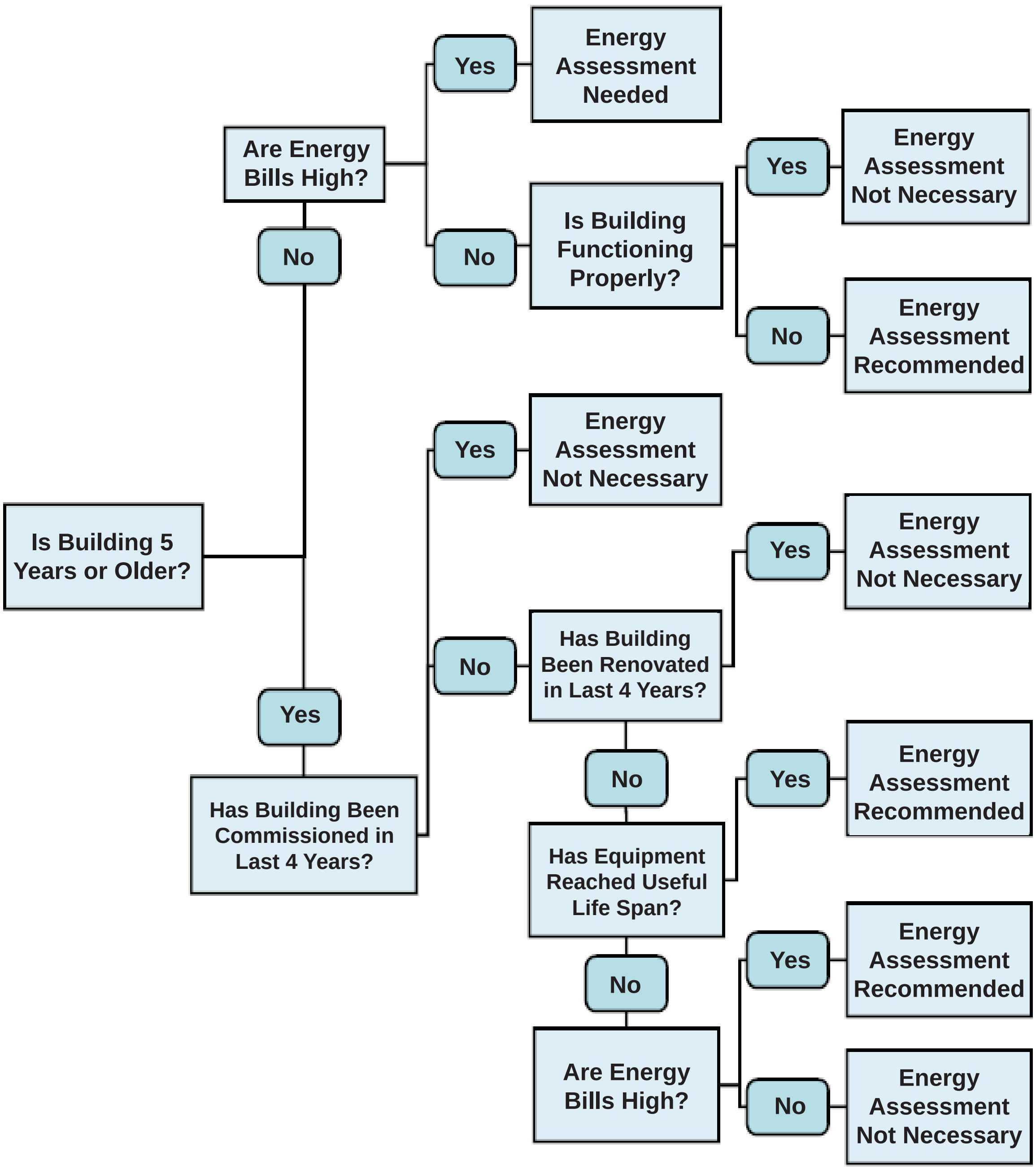
1. Is building less than 5 years old?
2. Has the building been commissioned in the last 4 years?
3. Has the building been renovated within the last 4 years?
4. Are energy bills high?
5. Has equipment reached useful life span?

1. Is the building less than 5 years old?

In general, buildings that are less than five years old and have been properly commissioned should be running properly and have a relative good efficiency. The time and expense for an audit immediately may not be a good return on investment. The potential benefits would be small and, in comparison to other facilities, would yield long payback periods. There are however exceptions where this does not hold true. If the building is not working as intended or designed, it is a good opportunity for a thorough energy audit. Catching problems in the early life of the building will reduce lifetime operating expenses. Another possible exception is if, despite proper operation, energy bills appear to be excessively high compared to other similar buildings and operations. This could be attributed to a non-energy efficient design, equipment with high energy demands, and a general lack of focus on energy savings in the original concept.

2. Has the building been commissioned in the last 4 years?

An assessment of the building and building systems every four years (or 25% of the applicable facilities every year), as stated in Federal mandates, is generally regarded as a reasonable and cost effective



periodicity. That assumes that prior commissioning deficiencies have been corrected and prior audit energy conservation measures have been implemented. Usually, new technologies have advanced, internal changes to the building operations and occupancies have transpired, and building maintenance issues have emerged sufficiently to warrant an audit (or building checkup) within the four year period. An audit should be incorporated as part of any re-commissioning effort.

3. Has the building been renovated within the last 4 years?

During the renovation process, the design *should*, but may not necessarily, consider energy efficient design. This is where commissioning of the renovation during the planning and design stages is so valuable. Designed properly, the renovation should assure that new and current equipment and strategies will yield an energy efficient building. Updated construction methods; testing, adjusting, and balancing (TAB); building efficiency certification; and current code regulation assure a tighter design. If these are integrated into the renovation, performing an audit soon after the renovation would not be a practical application. However, if the renovation has been problematic or resulted in increased energy consumption, that general rule-of-thumb would not be applicable.

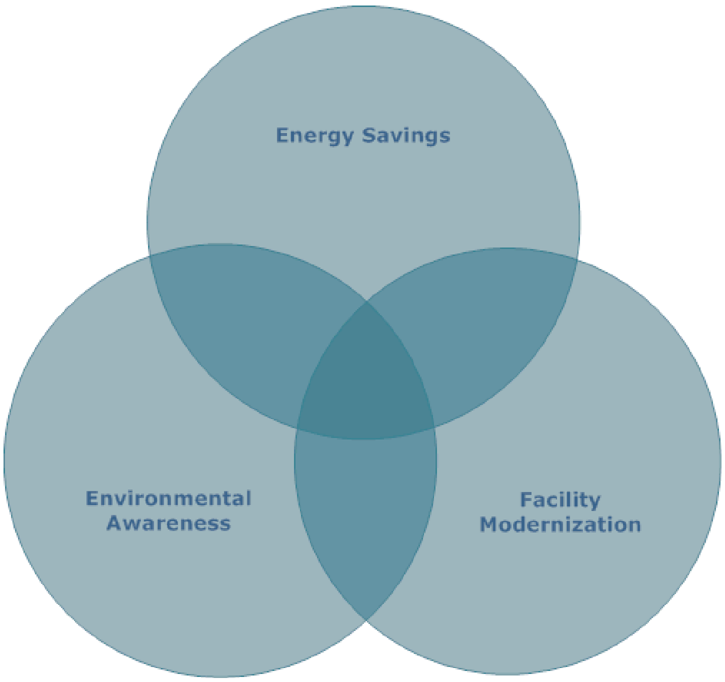
4. Are energy bills high?

When energy bills are running high, it is a very good time to invest in an energy audit. An analysis of two to three years of utility bills will uncover billing errors as well as trends and opportunities where the implementation of energy conservation opportunities will have their greatest impact – such as electric demand charges; alternative and renewable fuel sources; and implementation of new, out-of-the-box, energy-efficient technologies. By going through and evaluating the building, substantial energy saving can be achieved.

5. Has equipment reached useful life span?

Once the equipment has reached the end of its useful life, the effectiveness of an audit is severely diminished. The audit may help squeeze out a few more BTUs of energy savings, but aged and obsolete equipment lack the modern technologies and advancements and operational strategies to make significant impacts. Increased maintenance costs and difficulty in obtaining parts are prevalent with aged equipment. Repair parts many times are no longer available or are obsolete. If repairs are possible, they are generally expensive and do not solve your problem, only delay it. An audit at this stage will not have a major impact on the existing systems, but may help identify recommendations for capital improvements along with a few no-cost/low-cost measures associated with systems settings that have strayed over time.

Once you have determined the priorities of your buildings for audits, you may proceed to get them scheduled for completion. A properly conducted energy audit yields three major opportunities. The first and foremost is the considerable energy and energy cost savings that can be realized through a proper energy conservation plan and implementing the actions that evolve from it. Saving energy directly translates to



reduced operating costs. Many immediate cost savings can be realized by simple Type I audits. A return on investment (ROI) and simple payback analysis are calculated and will aid in determining the priority and criticality of the implementation measures included in the report. Type II and Type III audits will yield a more detailed and comprehensive picture of your facility, thereby better defining the saving opportunities applicable to the building. (Type I, Type II, and Type III energy audits are described in depth in Chapter 3, *Energy Audit Types*.)

A second and subsequent benefit from a good energy audit is facility modernization. Old technologies consume a significant amount of energy. They have higher maintenance costs, parts are often obsolete, mission and personnel loading changes might have taken place, and their operating parameters are non-compliant with modern energy mandates and strategies. New equipment based on old designs should not be considered. Energy conservation opportunities identified during energy audits often result in measures that will modernize a facility. New and emerging technologies bring an aging facility into the new millennium. Power, efficiency, reduced maintenance, and reduced utility consumption are benefits of upgrading equipment and equipment controls. Look at all facets of the operation, and take into account how they interact with all others. The facility should operate like the human body, everything working in conjunction with everything else in an integrated fashion.

A third benefit from performing energy audits is the environmental awareness that it creates. Environmental issues are on the forefront of most social and political agendas. Energy efficiency reduces greenhouse gases and the carbon footprint. Not only is it necessary for our climatic survival, but it also contributes to reducing our dependency on foreign nations by shifting our source energy to domestic and renewables.

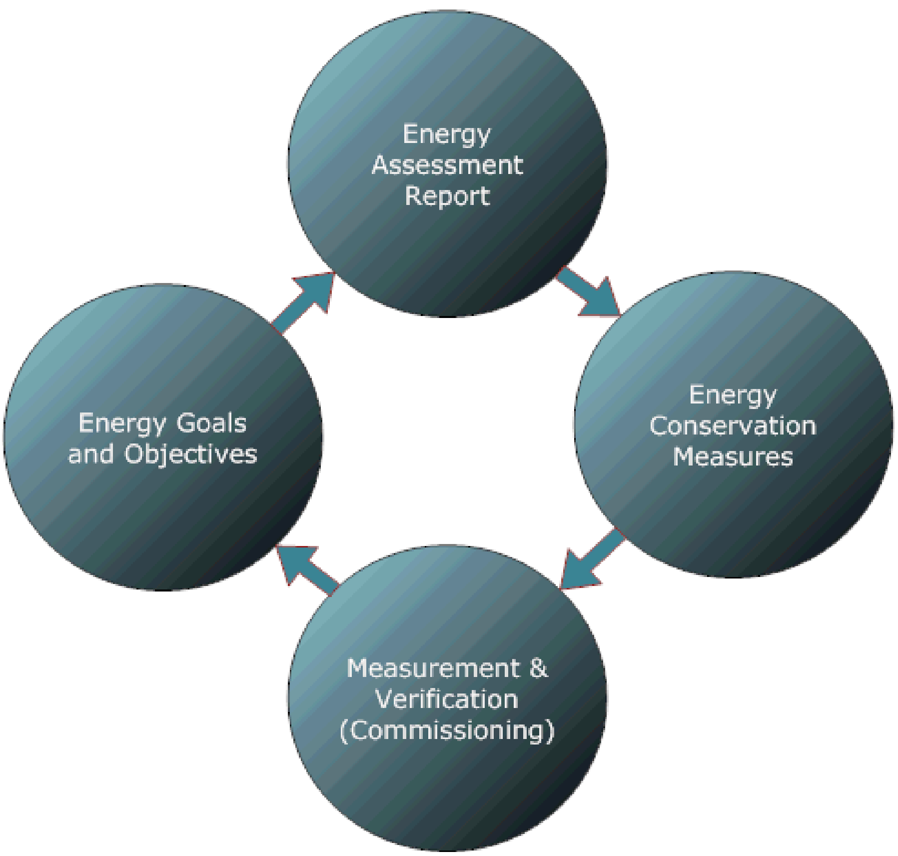
The convergence of all three – the synergy from working together so that the total effect is greater than the sum of the individual efforts – benefits the facility. In other words, energy audits are a good investment of resources for the derived effect.

Discussion

Performing an energy assessment audit is a necessary part of regular building operation and maintenance. This very much resembles a doctor's visit. To maintain our health we regularly get physical exam checkups. In a similar fashion, buildings also need checkups. Making observations, performing diagnostic tests, and running through the normal operation of a building we determine its "health." Instead of an operating system that is obese, out of calibration, and sluggish, we seek a prescription or physical and attitudinal changes to make it "lean and mean."

Until relatively recently, the use of energy in buildings largely has been overlooked. In areas where power costs are relatively low, the quantity of energy used is not a priority. As the energy climate changes and users become more aware of total costs, it has become time to implement energy conservation measures (ECM) for buildings and facilities. These ECMs will provide a more comprehensive perspective at the facility and its total energy consumption.

An energy audit may involve assessing various characteristics of the building envelope, including the walls, ceilings, floors, doors, windows, and skylights. For each of these components, the area and resistance to heat flow (R-value) are measured or estimated. The leakage rate or infiltration of air through the building envelope, which is strongly affected by window construction and quality of seals around doors, windows and ventilation openings, is of concern. A goal, then, is to quantify the building's overall thermal performance.



Another is to assess the efficiency, physical condition, and programming of mechanical systems such as the heating, ventilation, air conditioning equipment, refrigeration and special functions equipment. Another is to take a comprehensive look at the building energy monitoring and control system (EMCS) or building automation system (BAS) as an essential aspect of a fully integrated system. Yet others include looking at and recommending improvements to maintenance and operating procedures, building use and schedules, and even to look for renewable energy opportunities.

An energy audit, sometimes referred to as an energy assessment report, is an integral part of a complete energy saving program, starting with an initial assessment and identifying energy requirements, to an energy audit, to implementing the ECMs, to proper commissioning, and then ensuring persistence by repeating the process again on a pre-defined schedule and recurring basis. A thoroughly thought out program will provide substantial benefits for the facility, measurable energy savings, compliance with federal mandates, and a positive environmental impact.

An energy audit may include a written report estimating energy use given local climate criteria, thermostat settings, roof type, and solar orientation. This could show energy use for a given time period, say a year, and the impact of any suggested improvements per year. The accuracy of energy estimates are greatly improved when the facility's billing history is available showing the quantities of electricity, natural gas, fuel oil, water, or other energy sources consumed over a one or two-year period

Some of the greatest effects on energy use are user behavior, climate, and age of the structure. An energy audit may therefore include an interview of the facility managers to understand their patterns of use over time. The energy billing history from the local utility company can be used with heating degree day and cooling degree data to develop a thermal energy model of the building. A computer-based thermal model, usually associated with a type III audit, can take into account many variables affecting energy use.

An energy audit is often used to identify cost effective ways to improve the comfort, indoor air quality, and efficiency of buildings. In addition, facilities may qualify for incentives from local and federal governments. In a forward moving environment the goal to achieve a zero carbon footprint through energy conservation and renewable energy options must begin with a proper energy audit.

The challenge is to overcome the barriers in our existing buildings and to make them as efficient as possible. The starting point is a well planned energy assessment audit.

Chapter 2
Utility Bill Analysis

Government organizations are often fragmented and many functions are accomplished without knowing much about the overall picture. This is particularly true when it comes to facility utility invoicing. The Federal government is a good customer. It pays its utility providers a lot of money on time. However, the Federal government is not necessarily a preferred customer, and invoices become routine and accounts are taken for granted.

For example, where one organization purchases the utility and negotiates its rate structure, another distributes the utility and maintains the system, another monitors its usage, another provides engineering formulae for billing tenants for their estimated usage, and yet another pays the invoices – each without knowing much about the overall picture. Typically, the utility invoice is sent directly to the purchasing office and the payment is authorized and paid without validation of its accuracy.

Anecdotes exist for the anomalies of utility bills that do not reflect actual energy use. For instance, an organization paid as much as 25% higher for incorrectly rated utility bills for 11 years until the error was discovered through review, comparison, and trending. This organization was later credited with a rebate check for $294,000. In another instance, a different organization with multiple sites, after establishing a utility invoice review and management process, discovered that it had been invoiced for 15 meters that were no longer in service but had active accounts that were not closed out; 12 meters had double billings; two sites were being billed for the same meter; and the Owner was being billed for water to irrigate a public park. The resulting bill, in excess of $500,000, was paid.

Utility invoice validation should become routine for organizational elements. The site organization that is responsible for providing utilities to the tenants and occupants should make a review for the sensibility of and approve every utility invoice before it is processed for payment. Verify that the utility meter numbers correspond to the billing accounts. Verify that the meters are still active and associated with the correct facility and not, say, one that has been mothballed for some time.

Contact the local utility provider(s) to review rates, confirm that the facility is on the proper rate tariff, and request an explanation of the bill calculation procedure - particularly how excess demand and energy consumption costs during on- and off-peak periods are being charged. Also, ask for potential utility rebates that might be available as a federal facility customer. With this knowledge, managers can research other rate structures with this and other utility providers and make informed financial decisions as they do in their own personal lives as homeowners.

But utility invoice verification is more than checking for accuracy. In addition to verifying specific line item charges, invoice reviews are a valuable tool for:

- Trending usage
- Verifying facility modification impacts and efficiencies
- Identifying problem areas – such as large spikes in usage
- Proactively monitoring equipment condition
- Adjusting occupancy habits, operations, operating hours, and schedules
- Validating costs for equipment rentals, and
- Identifying areas for savings.

The overall analysis will identify where the organization spends the most money and will help in setting priorities and targeting additional conservation strategies.

Energy Data Research

Unlimited and unrestricted access to prior and current utility records is crucial to obtaining relevant information that is needed for an effective utility bill analysis. Historical data is a useful reference for establishing a baseline, mapping out an action plan, and for comparison purposes in conducting measurement and verification.

During the process of gathering and compiling energy records, utility bills are reviewed closely to determine the rate structure a utility provider charges for energy consumption. Service, demand, taxes, and environmental compliance recovery are standard billable charges that might be directly influenced by the assigned rate schedule.

pepco A PHI Company

Page 1 of 2

Account No: [redacted]
Bill Issue Date: Sep 25, 2009

[redacted]

Billing Period

Service Period: Aug 21, 2009 to Sep 23, 2009

Service Address: [redacted]

Pepco Telephone Contacts:

Customer Care - 7am-8pm	202-833-7500
Power Outages - Available Anytime	1-877-737-2662
Life Threatening Emergencies -Available Anytime	202-872-3432
Hearing Impaired (TTY) -7am-8pm	202-872-2369
Habla Español -7am-8pm	202-872-4641
Toll-Free Number(within our service territory) -7am-8pm	1-800-424-8028
Miss Utility(call before you dig) -Available Anytime	202-265-7177

THE GENERATION AND TRANSMISSION PORTIONS OF YOUR BILL WILL BE BILLED B YOUR SUPPLIER : Hess

Meter Summary

Low-, Mid-, Peak Demand History

Meter Reading Information

Meter No. Last Digits	Description	Previous Reading	Present Reading	Multi-plier	KWH Used
A71P	Kilowatt Hour Meter	12637	12881	200	48800
D 11	Off Peak	6948	7068	200	24000
D 08	Interm Peak	2797	2853	200	11200
D 05	On Peak	2890	2959	200	13800

Total KWH Billed: 49000 Non-Residential-GT

The present reading is an estimated reading.

Your next scheduled meter reading is October 22, 2009.

Rate Schedule

Account Summary

Prior Balance Pepco	$1,940.30
Payments Received Pepco	$1,940.30 C
Late Payment Charge Pepco	$19.25
Balance Forward Pepco	**$19.25**
Current Charges This Period Pepco	$2,071.90
TOTAL AMOUNT DUE	**$2,091.15**

After Oct 19, 2009, a Late Payment Charge of $20.72 will be added, increasing the amount due to $2,111.87.

Visit pepco.com and click on "Pepco Powercast" for the latest weather summary from WUSA9.
Effective with the billing month of September 2009, the surcharge for the Energy Assistance Trust Fund (EATF) will increase from $0.00040 to $0.00160 per kilowatt-hour, except for Residential Aid Discount customers. The increase recovers under-collected revenue for fiscal year 2009. The EATF will return to $0.00040 per kilowatt-hour effective with the billing month of October 2009. The amounts collected for the EATF are remitted to the District of Columbia government to fund certain low-income programs including Residential Aid Discount.

19 - 0002529 PLEASE DETACH HERE AND RETURN THIS PART WITH YOUR PAYMENT OR PAY ONLINE AT WWW.PEPCO.COM

Service Address: [redacted]

Please make your payment payable to Pep
Write your Account No. [redacted] on your paym

AMOUNT PAID $ ____.__

Due Oct 19, 2009 $2,091.15
Due After Oct 19 $2,111.87

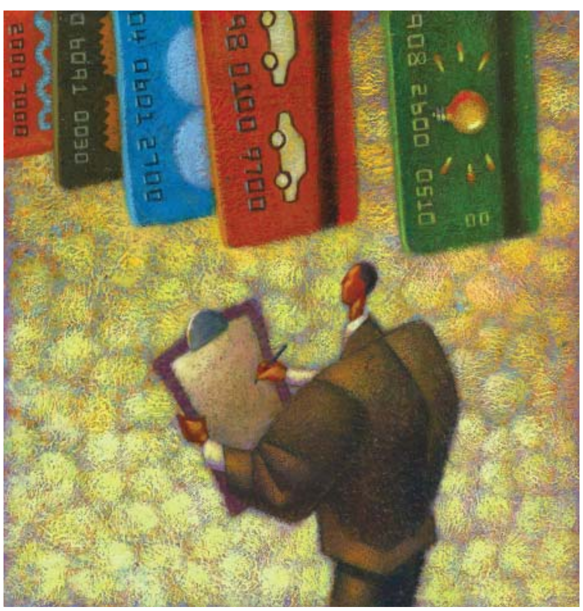
[redacted]

[redacted]

Utility bills are structured according to rates that are customized to reflect consumption patterns, consumer profiles, and frequency of consumption. Billing models, established by utility providers to characterize energy use, commonly are categorized according to the following rate schedules, but vary by provider and location:

- General Rate – This is the norm for variable and unpredictable low energy use.
- Stable Volume Rate – applies to predefined loads that accounts for seasonal time-of-use (TOU).
- Interruptible Rates – defined by a hybrid energy service that combines grid service with alternative energy resources. Within this rate structure, a symbiotic relationship exists whereby the utility provider exchanges energy service for credit to the consumer during peak periods.
- Modular Rates – characterized by variable and unpredictably high energy use.
- Real Time Rates – unknown variables are a disadvantage in this rate structure since the utility provider is credited in advance for a "known" amount of energy at a standard baseline rate.

When comparing the utility invoice against meter readings, logs, or other records, it is important to coordinate the periods of time. It is virtually unheard of for a utility invoice to be for the whole period from 12:01 am on the first day of each month to mid-night on the last day of each month. The billing periods (and quantities) vary from month to month because of the unequal number of days in each month and the different snapshots in time when the current readings are actually taken. Matching a site's records against the utility invoice can be highly challenging to say the least. However, smart meters and energy management software have now made it possible to calculate energy usage to the 15-minute interval (or better) that enables near exact comparisons for utility bill validations.



The sample electricity invoice above is typical for a large utility, but each provider has the latitude to provide more or less detail. Each invoice will display the account number, affected meter numbers, and billing period. A billing point of contact will be provided. Usually a 12-month usage history will be provided for comparison by the consumer.

The rate schedule is usually identified- but not always. If it is not, it may be necessary to contact the billing Point of Contact or to research the information on the contract with the provider. In most cases, the low-, mid- (if applicable), and high-peak usage and demand charges will be identified on the invoice – they are not on this invoice. Finally, the usage, demand, and other add-on charges are identified and summed for payment purposes.

The most effective way to reduce the total cost of energy is to reduce peak demand, as this directly affects the billed charges for the next several months (usually 12).

Coordination of Utility Data

Interpreting the utility provider's pricing mechanism presents possibilities for modifying energy use, launching a load management plan and implementing aggressive energy efficient improvements. Two- to three-year billing records reveal factual energy information such as base load, energy volume, seasonal energy use patterns, load aggregation, energy anomalies and energy spike trends. The source and pattern of cost of this data can be computed for factors such as normalization of weather-related utility consumption; abnormalities arising from unexpected variances in energy use; and modifications to the facility infrastructure, mission changes, and building use and occupancy.

Normalizing utility data for weather is useful in evaluating energy savings and cost savings of energy management programs especially as it relates to retrofits and other energy-related improvements. It is important to note that "savings" derived through these methods technically is based on a comparison to an estimated "avoided" amount that would have been used. Weather normalization uses a base year, utility bills from that year, and degree days for that billing period to define the impact of weather.

A baseline is an energy use indicator and must be modified whenever energy consumption is impacted by modifications to the facility infrastructure, mission changes, and building use and occupancy. Coupled with weather normalization, baselines and base years contribute to the accuracy of an energy management plan. These parameters can be used to calculate the amount of energy expended during the base year and anticipated energy consumption for the future.

Utility bill analysis is useful in securing nontraditional financing options such as rebates, incentives, grants and programs. Data is analyzed and used in preparing energy budgets, energy use trending reports, energy retrofit cost avoidance, and also to verify the feasibility of innovative energy initiatives.

Data generated from analyzed bills enable the eligibility of energy management proposals and energy-related purchases, infrastructure, and services for financial and/or technical support. Other specialized arrangements, such as Area Wide Agreement contracts, employ utility bill analysis data in specifying the technical terms of energy efficiency projects. Specialized energy contracts and financing options are administered by both public and private entities. Public financial support systems are designed as incentives, grants, rebates, programs, tax deductibles and tax credits.

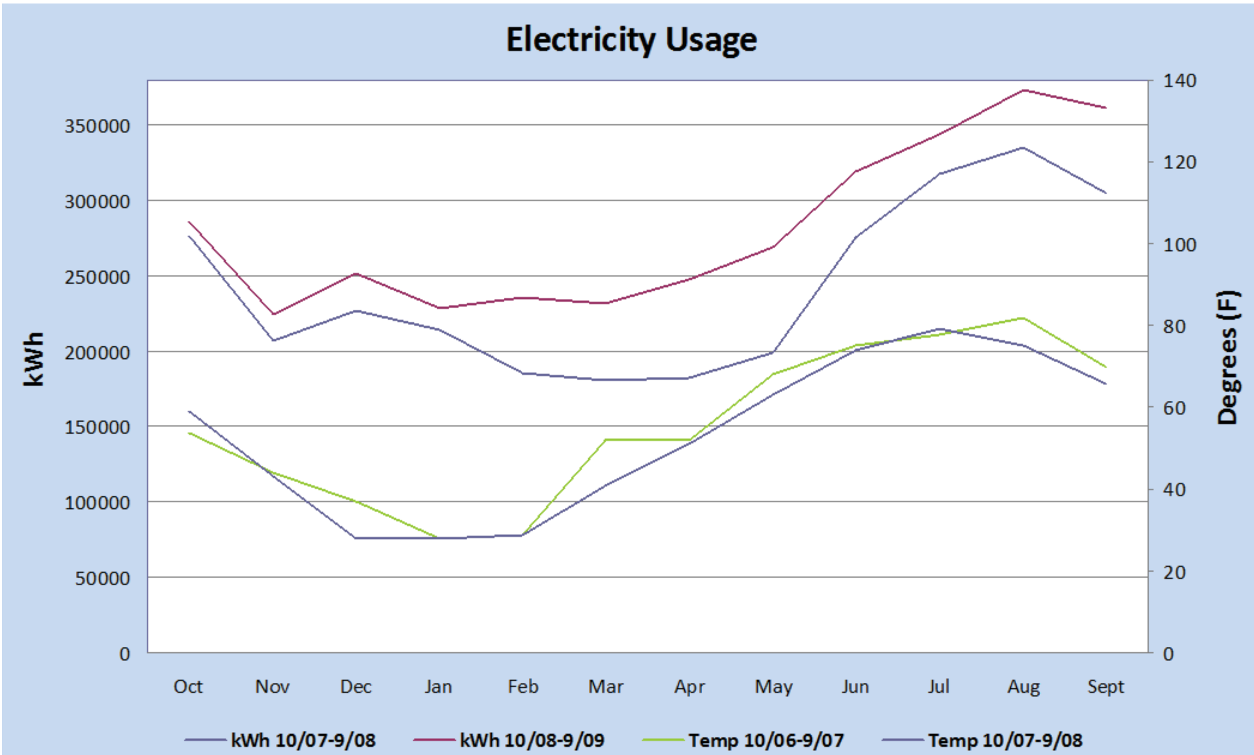
Application of Utility Bill Data

Sub-meters are the easiest and most effective way to "drill down" a site's energy usage to a specific building, system, operation, program, or operation. Data loggers can also be used, but generally these are considered to be more of a temporary tool for detecting and recording system operating parameters.

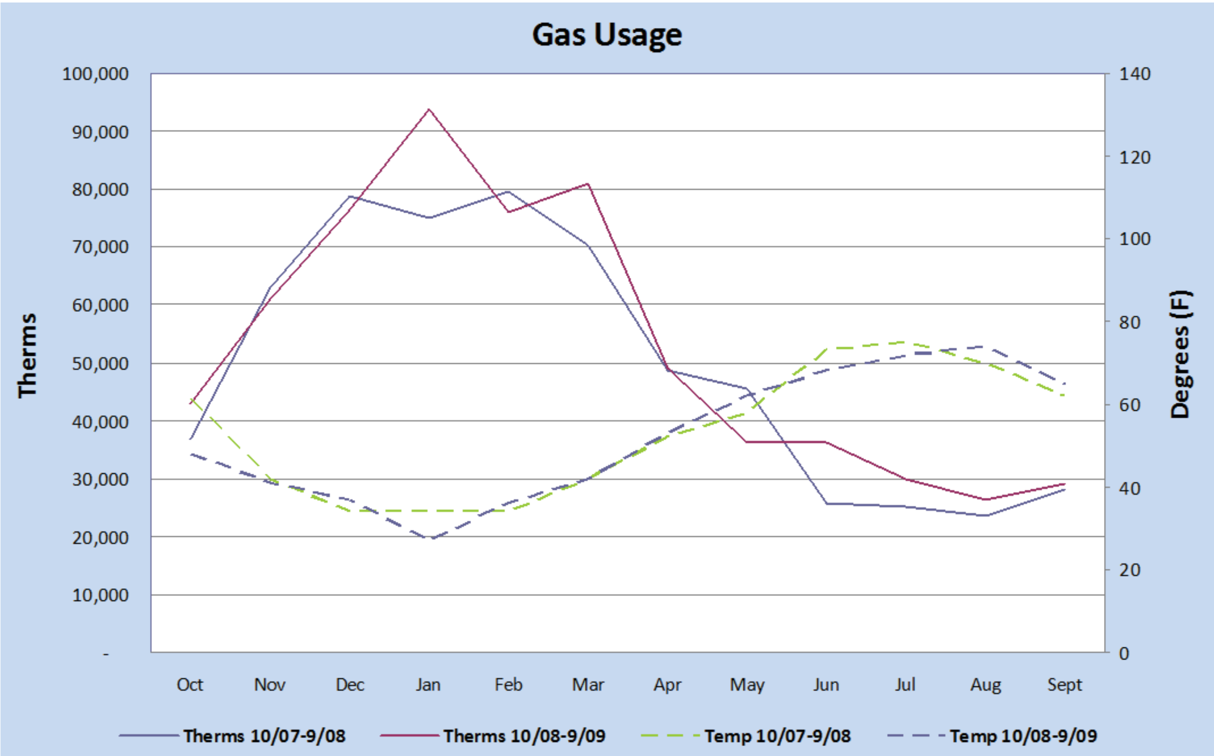
But what does one do with the data? How can it be monitored and managed to do some good? The most valuable tool is to calculate the energy use index (EUI), most simplistically by dividing the total energy use (kWh) by the area of the facility (in square feet – SF) served by that same meter/invoice. Now, one has the tools to compare the same facility from month to month, from this month against the same month prior years, against similar buildings, between similar operations or organizations, and a myriad of other combinations. Where there are multiple utility types, the energy usage reflected in each must be converted to a common denominator (usually MMBtu) and totaled before dividing by the facility square footage.

A similar calculation can be made to determine the energy cost per square foot of the facility by dividing the total utility cost by the total square footage of the facility served.

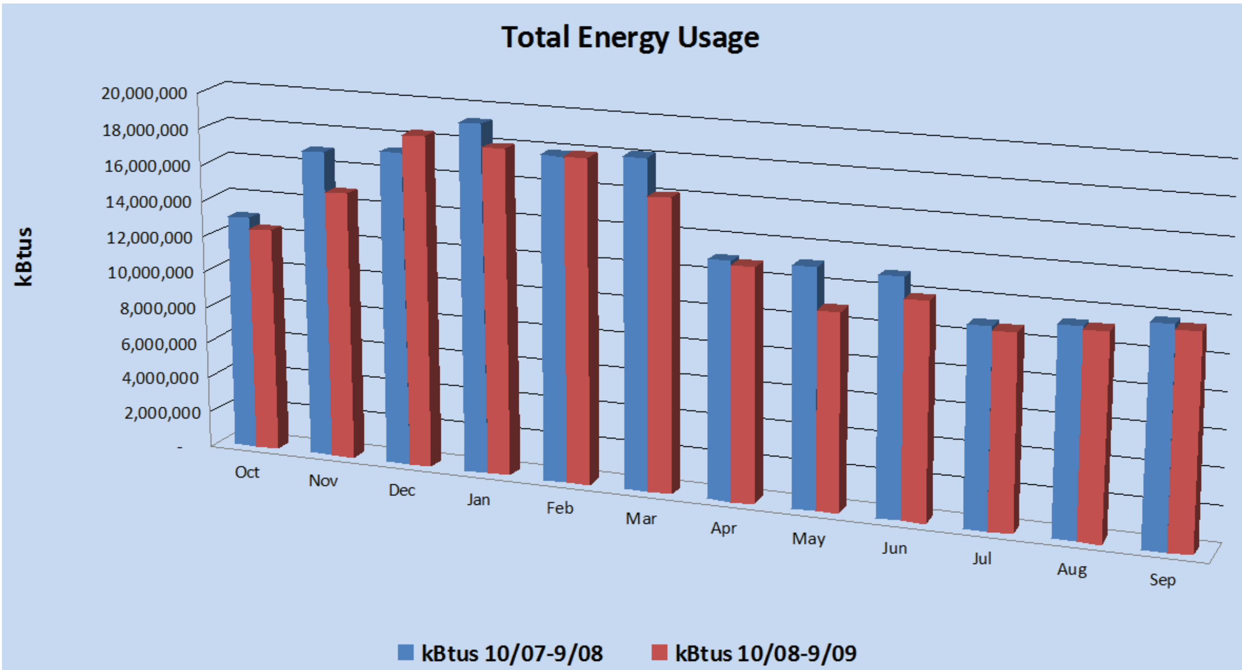
It is very helpful to graph out the utility usage from month to month to visually see trends, sudden pattern changes, and more. This can be done very simply using the free, available graphing features of a spreadsheet program. Superimpose weather data, particularly average monthly temperatures, to see if unusual weather patterns might have influenced unusually high or low utility usage during the same month. A few simple illustrative graphs follow:



With a glance, we know from this graph that the kilowatt hours used from 10/06 to 9/07 (red) is consistently higher than the kilowatt hours used from 10/07 to 9/08. The average temperatures between the two years are fairly close, but 10/06 to 9/07 is slightly warmer than the latter period. For a site where air-conditioning runs year round and heat is provided by a different utility, the patterns are as one might expect – higher electricity use during the hottest months when the air-conditioning is on and lower usage during the winter months when only operation-necessitated cooling and/or refrigeration is provided. Barring a known significant change in the facility's infrastructure, mission, or other operations, one can reasonably conclude from this graph that proactive activities to reduce electricity usage that the site implemented from one period to the next have been effective.

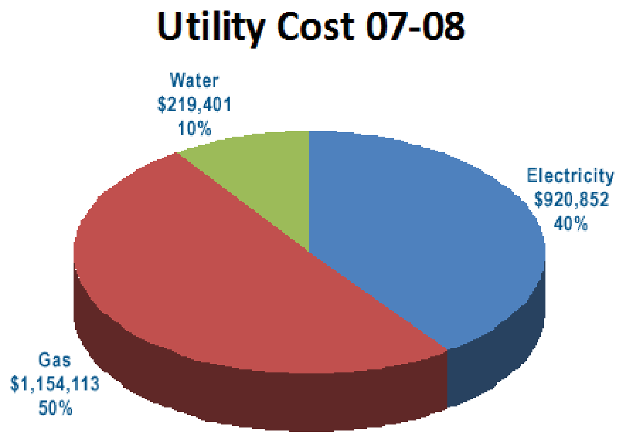


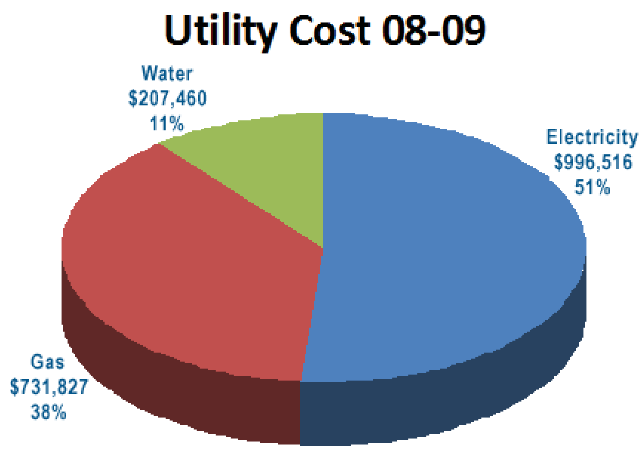
The sample graph above for natural gas is for a different site. Comparing the therm hours used from 10/2007 to 9/2008 (blue) and from 10/2008 to 9/2009 (red) shows that consumption for the 10/2008 to 9/2009 time period is higher during most of the year. The temperature average per month is fairly equivalent for the two years. The curves are as expected for steady state, HVAC and building operation that uses natural gas as the primary fuel source for heating throughout the year. As shown, the natural gas usage peaks during January, the coldest month of the year, and then drops, as one would expect, as spring and summer approach. The weather's temperature difference accounts for a minimal increase in natural gas consumption as shown by the January 2009 spike. It is likely that building systems and operations account for the majority of the year's increased energy usage since there has been no major building layout or space usage change during those time periods. This increase should be monitored and investigated further to determine the root cause.



The graph above is an example of a bar graph that displays the total energy use where electricity kWhs and natural gas therms have been converted to the common kBtus for a facility for a 24-month period. The graph makes it easy to observe that there is an overall reduction in energy use between the two time periods (actually about a five percent reduction). The site can use this information to investigate the reasons for increased energy use during any one month and to build upon the things they are doing right and to modify what they are not.

Finally, pie charts also display an effective energy management image. When comparing utility cost, the pie charts on the following page represents the portion each utility contributes to the facility's total utility cost. Both years show water to be about the same percentage of the total cost. However, the electricity costs have increased sharply in the time period from 10/08 to 09/09. Natural gas costs have reduced from 50% of the total costs to 38% in the latter time period. Reducing all utility costs should be the main focus of each site's overall energy cost reduction plan.





Electricity, fuel oil, natural gas, and other energy consumption increase or decrease in direct correlation to the efficiency of a facility's mechanical and building systems, its operations, and its people. To manage these factors, it is necessary to develop a profile of energy loads, to identify energy use patterns, and to evaluate the potential for higher performance standards. As illustrated above, utility bill analysis collects, compiles, and interprets relevant energy information. Sophisticated data collection and analysis software can be purchased and used, but as shown in the above examples, it is nice to have but not crucial to managing an effective energy monitoring and management program. *The important thing is to collect the appropriate data from utility invoices, meters and sub-meters, and other available sources and to proactively use it as a free, available resource for effectively reducing energy consumption and costs.*

Chapter 3
Energy Audit Types

The term "energy audit" commonly is used to describe a broad spectrum of site energy evaluations, ranging from a relatively quick building walk-through to identify readily observable problem areas and energy "wasters" to a comprehensive analysis of potential building and system improvements that are detailed enough to support documentation and justification for major capital improvements. The former typically is a quick analysis of the plant property, building envelope, personnel habits, procedures, and policies relative to the mission operation. The latter uses modern predictive, data collection, analytical, trending, and software simulation technologies to collect, evaluate, analyze, trend, and document equipment output data, building system and envelope characteristics, personnel procedures, and impacts of operational requirements.

To ensure that a proposed audit will be of value to the customer, it is necessary to develop a customized, detailed scope of work pertaining to the specific facility. The required degree of specificity of an energy audit depends on the purpose and object of the audit and the complexity of the site and operation being reviewed. Taking the time to prepare a thorough scope also enables a complete audit that satisfies the prescribed requirements and audit objectives.

Type I Audit

A Type I audit, also called a preliminary or walk-through audit, is the simplest and quickest type of audit. In general, it is comprised of:

- Basic utility invoice analysis;
- Interviews with site-operating personnel;
- A review of facility operations data, such as operating hours, personnel and occupancy loading, and mission requirements;
- A room-by-room walk-through of the facility to identify obvious areas of energy waste or inefficiency;

In This Chapter:

- Documentation of the observations that are largely dependent on the audit team's experience;
- Data analysis;
- Development of energy conservation measures (ECMs) or opportunities (ECOs); and
- Calculation and documentation of their energy and dollar savings, costs, and paybacks based on the data manually collected in the field (supplemented by engineering judgment and assumptions).

Description

Typically, the most obvious "low-hanging fruit" and major problem areas will be uncovered during this type of audit. The primary focus is on the 20-percent of the building's systems that consume 80-percent of the energy. Corrective measures are described briefly, and quick estimates of implementation cost, potential operating cost savings, and simple no cost/low cost solutions are offered. This level of audit, while not sufficient for reaching a final decision on implementing proposed measures, is adequate to prioritize energy-efficiency projects and to determine the need for a more detailed audit and project prioritization.

The Department of Energy Federal Energy Management Program has given a high degree of value to Type I audits, particularly to cash-poor Federal Agencies and sites. The thinking is that, with minimal cost, the Type I audit provides the site with a set of fresh eyes, objectivity, and lessons learned and best practices from others, that can be used to find no-cost/low-cost opportunities and measures. The site can begin benefiting from the changed procedures and simple improvements immediately, without having to rely on costly capital improvement projects that can take months or years to get approved and funded.

Most Type I audits can be performed easily in a matter of a few days, depending on the number of buildings, their size(s), their complexity, and their operations. They are a good starting point for a comprehensive energy saving program. The more comprehensive the audit and more detailed the report, the higher investment of resources will be required. The effectiveness of the building survey in identifying energy conservation opportunities is roughly proportional to the energy audit team's members' experience.

Advantages

The Type I energy audit:

- is the least expensive audit to perform;
- consumes the least amount of time and resources;
- can be conducted by personnel with minimum to moderate audit experience (led by at least a moderately experienced team leader);
- provides preliminary data prior to investing in more detailed audits;
- provides new ideas for no-cost/low-cost energy savings measures and opportunities;
- typically uses fresh eyes, is objective, and includes lessons learned and best practices;
- is good to identify the more obvious opportunities, "low hanging fruit," and major problem areas;
- identifies expected energy and dollar savings, estimated costs, and simple payback;
- prioritizes energy conservation opportunities and measures based on simple payback;
- provides initial documentation, photographs, and measurement data to move forward;
- is a good tool to demonstrate to Management the condition of the facility and opportunities to improve both it and "the bottom line;" and
- is compliant with Federal legislation.

Disadvantages

The Type I energy audit:

- provides information with minimal to moderate thoroughness and analysis because of its use of rough engineering estimates and rules-of-thumb calculations;
- has limited accuracy;
- provides projected savings, costs, and paybacks that are general and approximate, and that may not address all related impacts, such as impacts on maintenance, worker productivity, and on other systems;
- is insufficient by itself to support large capital improvement projects – but does provide the information required for a "go/no-go" decision to proceed;
- is not realistic in large and/or complex buildings to expect all significant energy conservation opportunities to be identified during a visually oriented building survey;

- can result in a limited set of recommended improvements; and
- may not translate easily, because of its absence of detail, into a work scope or into designs to achieve the energy savings outlined in the audit.

Type II Audit

Description

A Type II or general audit expands on the preliminary audit by collecting more detailed information about facility operations and by performing a more detailed evaluation of energy conservation measures. Utility bills are collected for a 12 to 36 month period to allow the audit team to evaluate, trend, and compare the facility's energy rate structure, demand, and usage profiles. If interval meter data is available, the available detailed energy profiles will be analyzed for signs of energy waste and potential savings opportunities. Additional sub-metering or data logging of specific energy-consuming systems or energy-intensive operations may be performed to supplement utility data. Strategically-placed energy monitoring devices extend the capability of the energy audit team by providing a steady stream of energy use information for specific building systems. The building's energy data should be correlated with historic weather data for greater accuracy.

The energy audit team should treat each building independently and as a unique entity. Like a primary care physician during a physical examination, the team should examine the building for anomalies and opportunities for improved health and health maintenance. To gain an understanding of the building's specific problems, general health, and possible improvement opportunities, the audit team should gather vital statistics and health indicators in the forms of:

- HVAC output data
- Building temperature and humidity trends
- Equipment use
- Controls strategies
- Flow rates
- Maintenance statistics
- Occupant complaints
- Indoor air quality and comfort levels

The effectiveness of the building survey in identifying energy conservation opportunities is roughly proportional to the individual energy auditor's experience.

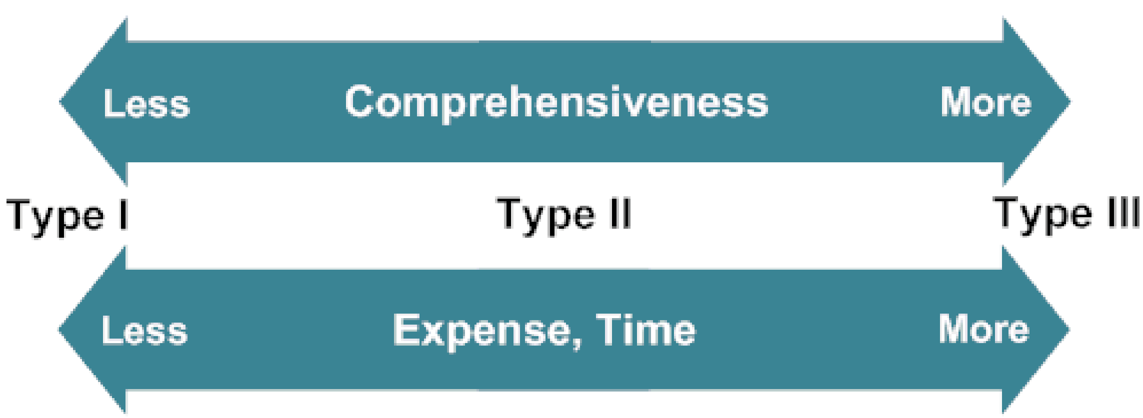
Procedures

The Type II audit goes beyond simple observation and makes energy use analysis an important element of the process. Energy data for the affected facility will be gathered, correlated to its historic weather data, and analyzed to develop energy use and cost indices. From this, the facilities can be triaged based on the energy use index and categorized as “most,” “moderate,” and “minimum energy user” to allocate your resources most effectively and efficiently.

A review of equipment condition, building documentation, and service contracts (as applicable and available) is made. The audit team conducts spot tests of equipment and controls. Schedules and control strategies are assessed to determine if the building is operated optimally or needs energy saving improvements. Building plans and blueprints are reviewed for an understanding of equipment layouts, equipment schedules, and distribution system layouts. Historical repair records and work orders are reviewed to look for recurring problems and trends.

Unlike the cursory, arms-length approach associated with a Type I audit, a more in-depth look at the facilities’ mechanical, plumbing, electrical and specialty systems is done, taking time to fully understand the processes and purpose of the equipment surveyed. Operational and maintenance issues are studied and considered.

Group and individual interviews with facility operating personnel, maintainers, building occupants, and system users are conducted to provide a better understanding of major energy consuming systems, problem areas that are symptomatic of serious energy inefficiencies, inefficient policies and procedures, and to gain insight into short and longer term energy consumption patterns.



The Type II audit can provide a starting point or baseline from which to measure the effectiveness of improvements, recommendations for more extensive measures (such as air and water testing, adjusting, and balancing (TAB)), capital improvements, and motivational and behavioral issues that affect building performance. A life cycle cost analysis can be performed for each energy conservation measure that considers more accurate implementation cost estimates, site-specific operating cost savings, related impact costs, and the owner's investment criteria. Whereas these numbers include a lot of rules-of-thumb in the Type I audit, the Type II audit is much more dependent on industry accepted standards, such *Means* cost estimating data and costs from manufacturer catalogues and web pages. The results from this documentation will generate viable and achievable solutions that provide the best Return on Investment (ROI) options and comparisons. Sufficient detail typically is provided to justify the submission of project documentation for approval.

A Type II audit can also be used in more specific scenarios, such as when a single purpose or targeted audit is needed to expand on the known information associated with a prior Type I audit or energy report. The targeted audit narrows the scope of a more general audit to a predetermined and defined area, process, or piece of equipment, thereby allowing for a more detailed, concentrated survey. Compare that to an abundance of more generalized data over a broad building area that may provide too much unnecessary information. By focusing on a particular section of the facility, the site may be able to reduce some expense, effort, and complexity.

Advantages

The Type II energy audit:

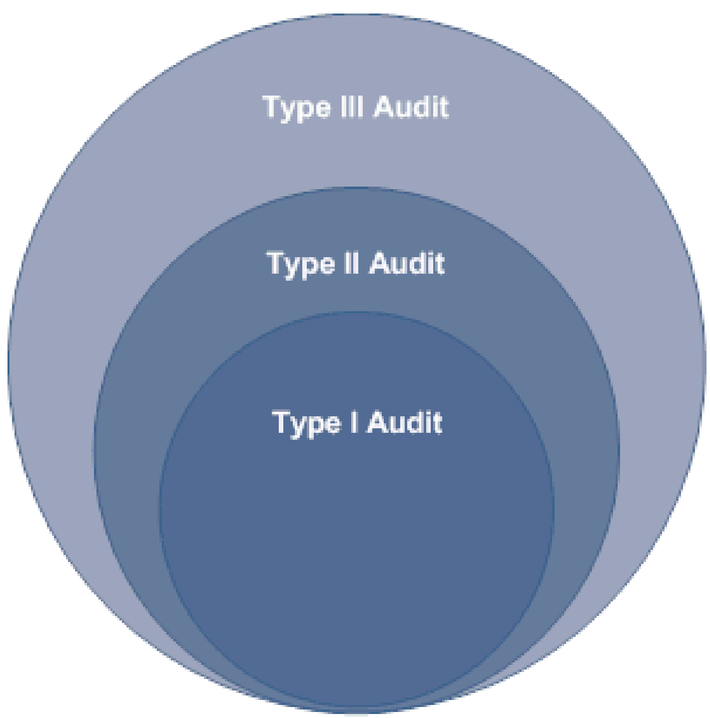
- balances time, effort, and cost with more complete, accurate, recommendations;
- is more focused on specific building systems and the things that influence them, rather than on broad observations;
- is quick and easy to perform relative to a detailed engineering evaluation;
- has a greater degree of accuracy than a Type I energy audit;
- can concentrate on and drill down into specific areas of interest or need;
- incorporates the use of strategically placed monitoring devices that help provide a steady stream of building or equipment energy use data;
- provides sufficient data to make many "go/no go" investment decisions;

- typically uses fresh eyes, is objective, and includes lessons learned and best practices;
- is good to identify the not so obvious "low hanging fruit" and more substantial energy conservation opportunities;
- identifies with greater accuracy energy and dollar savings, estimated costs, and simple payback by using more actual published cost data rather than rules of thumb;
- provides initial documentation, photographs, and measurement data to move forward;
- is of sufficient detail and accuracy to achieve points toward LEED-EB certification in the category of retro-commissioning;
- incorporates methodical data collection that maximizes savings, makes analysis easier, and documents recommendations in a way that simplifies implementation; and
- uses strategically-placed energy monitoring devices that can extend the capability of the energy audit team by providing a continuous record of energy use in building systems.

Disadvantages

The Type II energy audit:

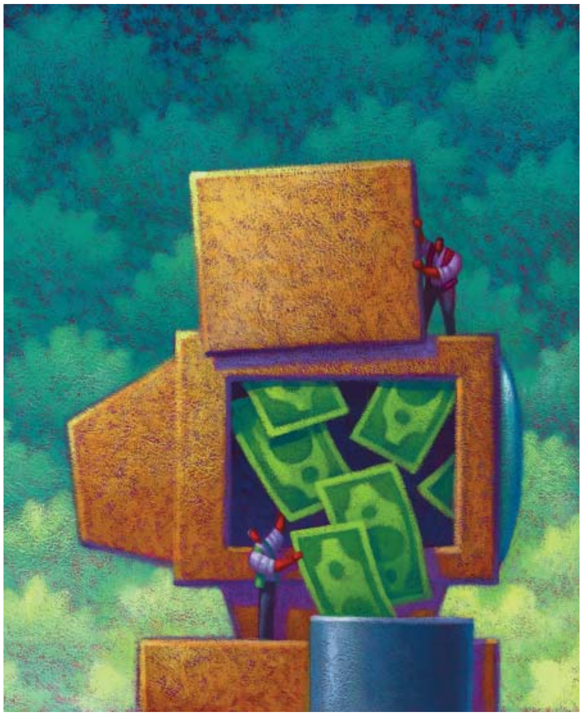
- is more costly and resource-demanding than the Type I energy audit;
- requires more time to perform than a Type I energy audit;
- lacks energy modeling detail and the different "what if" scenarios that modeling provides; and
- provides an incomplete representation of the facility, unlike modeling that considers a myriad of factors from building materials, to climate, to population and work habits.



Type III Audit

Description

A Type III or comprehensive audit, also called a detailed or technical analysis audit, expands on the general audit by providing a dynamic model of energy-use characteristics of at least two scenarios: the existing facility and with selected energy conservation measures identified. The building model is calibrated



against actual utility and weather data to provide a realistic baseline against which savings generated by implementing the proposed measures are calculated.

Extensive attention is given to understanding not only the operating characteristics of all energy consuming systems, but also of situations that cause load profile variations in the short and long terms. Daily, weekly, monthly, and annual existing utility data is supplemented with sub- metering of major energy consuming systems and data monitoring of system operating characteristics.

The Type III audit differs from the Type II in that an accounting of all energy used is performed. This procedure, known as an "energy balance," traces the energy from the meter through the various building systems. Its purpose is to prevent double counting of savings between two or more recommended improvements that affect each other. It also correctly allocates savings estimates to the end-use being recommended for improvement. The interaction among all recommended improvements should be accounted for. This balance/computer modeling is typical for large, complex facilities, but may be relaxed substantially for smaller, traditional-type facilities.

An audit this extensive is usually warranted when a facility is already efficient, when comparative solutions are desired for decision making, when warranted by higher authority for project justification, and when required for special recognition or certification, such as for Leadership in Energy and Environmental Design (LEED) or other third party green building certifications.

Procedures

Type III audits are quite comprehensive and detailed. They include evaluating all energy loads and equipment in the building – HVAC plant, HVAC distribution system, envelope improvements, lighting, plug loads, O&M improvements, training, and more. Improvements should focus not only on energy savings, but on improving indoor air quality and on resolving the root causes of recurring problems.

They include sophisticated computer modeling of the complete existing building information package and factor in things that influence it, such as building characteristics, building envelope, building materials characteristics, hour by hour energy usage profiles, operating hours and occupancy schedules, personnel loading, identification of miscellaneous equipment for internal loads, lighting usage, space temperature setpoints, climate, and more. This results in a very detailed picture of the facility. For example, it is possible to define the energy signature of a given building to include a statistical representation of the building's responsiveness to weather patterns as a function of heating or cooling degree days.

Sophisticated simulation programs typically require building characteristics, such as building envelope and materials, hour by hour usage data, occupancy schedules, internal loads, lighting usage, HVAC operations, environmental temperature and humidity conditions, and controls setpoints. This is where sub-meters and data loggers can be most valuable, since strategically- placed energy monitoring devices can greatly extend the capability of the energy audit team by providing a continuous record of energy use in building systems.

Actual metered data is enormously valuable, not only in identifying schedules and benchmarks, but also in establishing benchmarks against which simulation results can be compared.

Instrumentation

As in Type II audits, strategically-placed energy monitoring devices extend the capability of the energy audit team by providing a continuous record of energy use in building systems. Typical instrumentation used during Type III audits to determine a building's energy signature include:

- Utility sub-meters (WAGES – water, compressed air, natural gas, electricity, steam)
- Existing building instrumentation – Building Automation System (BAS), Energy Management and Control System (EMCS), and read-outs of temperature, humidity, pressure, flow, and run-time gauges.
- Temporarily installed instruments, such as data loggers and data recorders.

Advantages

The Type III energy audit:

- provides detailed and accurate information through data collection and computer simulations;
- provides a continuous record of building, system, or equipment energy use data through strategically placed monitoring devices

on specifically targeted buildings, building areas, systems, and equipment;
- provides comprehensive data on project cost and savings based on published sources;
- focuses primarily on specific building systems that are problematic, of interest, of high priority, or are otherwise designated by the site, rather than using a large, broad brush approach;
- results are usually credible and well accepted for project justification and approval, and alternatively, can demonstrate that a recommended solution is not worthwhile or cost-effective;
- is ideal for comparing alternate solutions under similar or different scenarios;
- can identify energy conservation measures that are not quite so obvious; and
- provides a detailed documentation of findings.

Disadvantages

The Type III energy audit:

- is typically the most expensive type of audit to perform;
- consumes the most time and effort to conduct and is logistically demanding;
- provides an abundance of information that may be overwhelming if it is not properly compiled and analyzed;
- despite its high cost and demanding effort, is still susceptible to "garbage in – garbage out" if the input data, assumptions used, and output results are not checked;
- requires that at least one person on the audit team has a strong technical or engineering understanding of the factors that influence the specific building systems, coupled with an understanding of the capabilities, limitations, operation, and population of the simulation software package; and
- can be "overkill" when less accuracy will suffice, depending on the audit objectives.

Summary

The following Table summarizes the characteristics of and broadly differentiates between the three types of audits commonly conducted – ASHRAE designated Types I, II, and III.

Energy Audit Type Comparison at a Glance

	Energy Audit Comparison Table		
	Type I	Type II	Type III
Cost and Resources	Least	Moderate	Most
Identifies No Cost / Low Cost Opportunities	X	X	X
Degree of Accuracy of ECM Energy Savings	+/- 30%	+/- 15%	+/- 8%
Degree of Accuracy of ECM Cost Estimates	+/- 30%	+/- 15%	+/- 8%
Identifies Simple Payback Period	X	X	X
Identifies ROI / NPV / IRR (Financial Matrix)	X	X	X
Addresses Lighting	X	X	X
Conducts Lighting Photometrics		X	X
Addresses Compressed Air	X	X	X
Addresses Steam System	X	X	X
Addresses Building Envelope	X	X	X
Conducts Thermal Imaging		X	X
Conducts Vibration Analysis			X
Conducts Ultrasonic Analysis			X
Addresses Water (Domestic)	X	X	X
Addresses Water (Process)			X
Addresses HVAC Equipment	X	X	X
Addresses HVAC Control System - Equipment	X	X	X
Addresses HVAC Control System - Sequence of Operations		X	X
Addresses HVAC Control System - Advanced Control Strategies			X
Conducts Onsite Interviews - Operations and Maintenance Staff		X	X
Conducts Onsite Interviews - Occupants and Tenants		X	X
Number of Months of Data for Utility Bill Analysis	12 mos.	12-36 mos.	36-60 Mos.
Correlates Weather and Other Impacts with Utility Analysis		X	X
Building Plans, As-Built Drawings, and Other Documents are Reviewed		X	X
Uses Data Logging		X	X
Incorporates Data from Built-In and Temporary Systems (BMS, EMCS, Data-Loggers, Recorders, Etc.)			X
Includes Mission Analysis			X
Includes an Energy Balance			X
Considers Impacts of ECMs on Each Other			X
Uses Computer Modeling to Incorporate Impacts of Outside Factors on Recommended ECMs			X

This page left blank intentionally

Chapter 4
Performing the Audits

There are four phases to an energy audit – Planning (I), Discovery (II), Correction (III) and Handoff (IV). All are important and all contribute to a successful program. However, good planning is crucial. It is important that every energy audit, despite its degree of complexity, starts with an Audit Plan. This Plan focuses on the Owner's intent, the objectives of the audit, and resets the direction to stay on track and keep from meandering. This chapter discusses the elements and characteristics of each phase.

Phase I – Planning

Management Support

The first step in developing a plan is to obtain the active support of building Management. This is necessary because Management has the capability – and responsibility – to make go/no-go decisions at key points during the audit, to prioritize funding and assets favorably or unfavorably relative to an audit, and to authoritatively support a particular audit process or results, thereby affecting its acceptance by others and persistence of the program.

Energy audits and building retro-commissioning are still viewed by many Managers as an added cost. If they were free of charge, they would most likely be adopted by Management across the board. But cost is just one barrier against an aggressive auditing program. Common barriers include the following:

- Up-front costs to conduct a formal audit may be considered high, particularly where there is no *guarantee* of cost savings – The audit process does not necessarily have cost savings as its primary objective. It is designed to optimize all building system and equipment operation, policies, and occupant procedures for energy use reduction, greenhouse gas emission reductions and reduced carbon footprint. Actual cost savings is a by-product in the form of *avoided* costs.

- Responsible parties do not want to get into a position where they look “bad” or appear to be responsible for the existing inefficient conditions for whatever reason.

- While Management is likely to approve in principle any attempt to conserve energy and energy costs, they may balk at having to outlay funds for services that do not yield *immediate* savings. Many energy conservation measures (ECM) take years to achieve full payback.

- There is not a sense of “need” for an energy audit, particularly with relatively new construction. There is a feeling that new buildings are already energy efficient, and if older ones have a robust maintenance program, the facility staff is able to detect and correct energy inefficiencies without having the expense of a formal audit. The Federal Government’s new emphasis on LEED or other third-party green building certification programs for existing buildings, which require either a formal energy audit or retro-commissioning, and Federal statutes have only recently begun to increase a sense of importance.

- If a building has already gone through an audit or through the commissioning or retro-commissioning process, there is a feeling that there no additional benefit from an energy audit. This attitude fails to realize that buildings, occupants, and missions change over time, and any impact on the design intent, coupled with equipment age and old technologies, can impact the equipment’s and system’s efficiency.

There are five recognized times that Management support is needed in a typical audit program:

Stage I – Management must be willing to have the energy audit conducted in the first place. There is some cost involved. However, there are many reasons why Management may be willing to make the investment – to identify, reduce, and/or eliminate costs that negatively impact the bottom line; to comply with Federal mandates; to “do the right thing” to reduce energy use, greenhouse gas emissions, and the carbon footprint; or for a myriad of other reasons.

Stage II – Occurs after the audit report is complete. At this time, Management spends time to review, assess, and prioritize the outcome. Further commitments of time and money are made as Management commits to a “go” in the go/no-go decision to move forward.

Stage III – This stage of commitment occurs during design of the ECMs. Management reviews the "fixes" in terms of feasibility, impact on operations, life cycle costs, other systems, on people, and on other long range plans. Management, at this stage, ensures that everyone is on board and ready to commit.

Stage IV – Here the capital investment is made. This capital investment may be financial or even personal, such as in cases where policy is changed or commitments to guaranteeing specific quantities of energy savings will be made to obtain grants and special funding and support. Management may need to demonstrate that substantial energy and energy cost savings may be achieved only through substantial up front investment.

Stage V – The fifth stage involves continuing the program. To be effective, all activities, savings, and costs must be monitored, documented, and the plan updated to ensure persistence. If bottom line value can be demonstrated, future commitments through Management's chain of command will be easier to achieve.

Management should be kept informed throughout the process to maintain their active participation and support. It is strongly recommended that, for maximum effectiveness, a single Manager – a "champion" – be designated to head the energy auditing program from start to finish. A fragmented approach is less effective and often creates confusion.

Identify Project Objectives and Scope

The Owner, with input as appropriate from facilities staff and building occupants, identifies the objectives for the energy assessment, including specific equipment, buildings, and building areas; potentially problematic areas; and applicable utility systems. This serves as guidance for maintaining focus on possible energy conservation opportunities and measures.

Guiding questions that should be asked to help determine the objectives and scope of the assessment include:

Where have problems consistently occurred?

What is the energy use index of the facility buildings relative to similar buildings on and off site?

Based on experience and available utility invoices, where is the greatest potential for energy, greenhouse gas emission, and carbon footprint reductions?

Have there been prior energy audits, assessments, and/or retro-commissioning reports conducted on these buildings, and if so, what ECMs have been implemented?

Is there potential in any building for renewable energy applications?

Is water an issue?

Assembling the Audit Team

An energy audit can be a time consuming process, especially if only one person performs it. A team is the best approach to performing a successful energy audit. The team should consist of a team lead, and two to five team members depending on the size and complexity of the facility.

The makeup of the energy audit team is important. The effectiveness of the building survey to identify ECMs is roughly proportional to the energy audit team members' experience. The people must be dedicated to the concept of saving energy, should be in the position of being able to put recommendations into action, and should have the time to dedicate to the responsibility (i.e., full time for a period of time versus part-time, collateral duty).

The recommended composition of the energy audit team includes the following team members:

Representative of Management – acts as the energy "champion". Preferred traits:

- Holds a position of responsibility
- Must provide guidance and obtain the needed cooperation
- Good communicator
- Able to work with others

Representative from O&M – provides technical guidance on how to implement various energy management options. Preferred traits:

- Knowledge of equipment and controls features, limitations, and histories
- Understanding of maintenance procedures
- Ability to interact and work with Management and other team members

- Open-mindedness to think “outside the box”
- Objective

Facilities Staff – provides equipment histories and information specific to the facilities, systems and equipment being assessed for energy conservation opportunities. Preferred traits:

- Knowledge of equipment and building systems and their idiosyncrasies
- Able to provide input regarding occupant complaints
- Ability to provide access, open, start, and stop equipment, and explain associated control systems
- Objective

Representatives of Different Departments – provides the user/occupant/customer perspective. Preferred traits:

- Ability to represent and communicate the interests and concerns of others
- Ability to work objectively with other team members
- Knowledgeable of the interests he or she represents; for example, a researcher who can explain the requirements for laboratory fume hoods and how they operate, or a kitchen supervisor who explains the kitchen operations and procedures, cooking equipment operations, and use of kitchen hoods

Consultants – provide expertise in TAB, controls, boiler operations, and other specialties. Preferred traits:

- Subject matter expertise
- Thorough knowledge of systems interaction and causes and effects
- Ability to think outside the box and able to see the “big picture”
- Objective

It is particularly beneficial to involve the O&M staff in conducting energy audits for numerous reasons:

- They know the building systems
- They have access to all the sections of the buildings
- They have logs and service records
- They know the equipment and system Standard Operating Procedures (SOP) that must be followed and personnel protective equipment that must be worn
- They know the facility users and occupants by reputation and have established character profiles
- They have access to additional and specialized equipment
- They know how the control system operates
- They can make on-the-spot minor repairs

The entire team needs to realize, however, that theirs is *not a fault-finding mission*. Rather, it is to work collectively to optimize and improve the building's efficiency and to reduce energy and water use.

Energy Audit Plan

The Energy Audit Plan lays out the strategy and process that will be followed. It identifies the audit team members. The Plan will be updated and revised as necessary throughout the audit process. Management should identify the building(s), building areas, and systems that will be targeted for energy assessment. The most likely candidates are facilities with high energy use indexes and where no cost/low cost measures are expected.

The following information typically is included in the Energy Audit Plan:

- Overview and General Information
  - General Building Information
  - Objectives
  - Scope
  - Facilities, building areas, and systems targeted for assessment
- Audit Team Members
- Roles and Responsibilities
- Audit Plan Strategy and Process
  - Utility bill analysis
  - Document review
  - Staff interviews
  - General building walk-through
  - Detailed system assessment
  - Measuring Energy Savings
- Audit documentation and project final report

Preparing for an Energy Audit

Before the team visits a facility, the site should make a list of any possible problems such as conditions and uncomfortable, drafty or stuffy areas and of building features where energy losses are expected. The audit team will use this information to establish what to look for during the audit. Further, the team should prepare a checklist of focus items upon which to pay special attention. Having a familiarity with the building will help coordinate and manage the audit team's efforts into a productive session.

Tools and Test Equipment

The following instrumentation may be required to conduct an energy audit, depending on the site configuration and installed systems, and should be considered as part of the auditors' complete tool bag. Detailed description of the most valuable and widely used in audits instrumentation is included in Chapter 6.

Instrument	Purpose
Camera (with 12-inch white-board)	To record condition of equipment. White board is used to identify equipment nomenclature; it can be mounted on equipment and included in photo for easy equipment and/or problem identification.
Infrared Scanning Device	To identify building heat loss, check integrity of steam traps, inspect power transmission and distribution equipment, locate water leakage into roof insulation, check for poor building insulation, inspect coils for plugged tubes, examine electronic circuits, detect plugged furnace tubes, and find leaks in buried steam lines.
"Stick on" Dataloggers	To record system output parameters over time. Common dataloggers include temperature, humidity, equipment on/off, and light levels.
Ultrasonic Listening Device	To check for leaks in compressed air, vacuum, steam distribution, and other gas systems. Also to check integrity of steam traps.
Vibration Transducer and Analyzer (with sound discs, cables, etc.)	To check rotating equipment for misalignment, defective bearings, and bent or loose parts. Allows user to evaluate condition of equipment and avoid pending failures.
Ammeter	To measure alternating current to determine motor oversizing or undersizing.
Voltmeter	To check for overvoltage and undervoltage conditions.
Wattmeter	To measure electrical demand and determine if high-efficiency motors can be used.
Power Factor Meter	To determine sources of low power factor.
Light Intensity Meter	To ensure that lighting levels meet IES standards.
Lamp Sensor	To identify whether lamps and ballasts are T-8/electronic or T-12/magnetic.
Energy and Demand Meter	To identify equipment that incurs high demand during peak demand periods.
Power Monitoring Meter (Dranetz or BMI)	To measure and monitor all necessary electrical parameters to provide power quality, energy, and harmonic analysis.
Thermometer	To measure air, liquid, and surface temperatures.
Surface Pyrometer	To identify heat loss through walls and test steam traps.
Psychrometer	To measure relative humidity.
Air Velocity Measurement Device	To measure HVAC system performance, air velocity, and air movement in the space.
Pressure Measurement Device	To measure pressure in HVAC system.
Flow Measurement Device	To measure pressure differential, velocity, and positive displacement of water, steam, oil, and gas.
Combustion Efficient Measurement	To evaluate fireside boiler operation; contains carbon dioxide, oxygen, and carbon monoxide gas analyzers and stack conditions.
Portable PH Meter	To measure acidity or alkalinity of water treatment systems.
Tachometer and Stroboscope	To measure rotating speed of fans and motors.
Indoor Air Quality Measures	To measure temperature and humidity;pressure differentials at fans, intakes, and ducts; airborne particles and airflow at diffusers; carbon dioxide, carbon monoxide, and other contaminants; and find pollutant pathways.

In addition, the following common tools may be necessary to access equipment, remove panels, view conditions, and access above-ceiling and other difficult spaces:

Step ladder	Binoculars	Crescent wrenches set
Pliers set	Extension cord and inspection lights	Flashlight and spare batteries
3/8-inch drive socket set and ratchet	Vise-grip pliers set	Measuring tape
Screwdrivers set (standard and Phillips head)	Protective gloves (appropriate for job and environment)	Personal protection equipment (PPE) appropriate for the area and equipment systems

Phase II – Discovery

During the discovery phase, the audit team works with the facility management and O&M staff to investigate the building, its equipment and systems, and maintenance and operations procedures and policies. The result of discovery is a prioritized list of improvements to make during the implementation phase.

Document Collection

The energy audit team collects general facility and equipment and system-specific data during this phase. With the caveat that many of the original documents may not exist or may be grossly out-of-date, the following documents should be collected and made available, if possible, to the audit team:

- Buildings general information - sizes, usage, occupancy, general hours of operation; a public-affairs type description of the complex would also be helpful
- Identification of those buildings that consume 80% of the site energy use (building identification, use, area (sq.ft.), estimated energy consumption)
- Available as-built construction drawings
- Equipment inventory, including size, capacity, and age data
- Equipment maintenance information
- Control sequences of operation
- Copies of the most recent available two years of utility invoices, and if on a utility contract, its current terms and expiration date
- Information about the site's renewable energy systems from the Renewable Energy Registry
- Number, locations, and account numbers of installed utility meters

- Copy of the two most recent combustion efficiency analyses for each boiler (as applicable)
- Inventory of lighting fixture types and estimated quantities
- Copies of other energy audits and/or retro-commissioning reports that have been conducted within the last 10 years
- Any energy program procedures or conservation guidance communicated to occupants (e.g., load shedding plan, energy awareness guidance)
- List of any capital improvement projects planned or programmed that will affect energy usage

Document Review

The audit team reviews the documentation developed and/or compiled during the planning and discovery phases. An analysis is conducted to look for signs of building, equipment, and system deterioration, sub-optimal performance, and energy inefficiencies. Maintenance histories and operations trends are reviewed for indications of problems that may have root causes initiated with system design, maintenance procedures, personnel qualifications and training, scheduling, changed conditions resulting in over- or under-sizing, controls issues, component failure, inefficient operations procedures and policies, and other deficiencies.

Review and analysis of energy data and utility bills will also indicate problematic trends, as well as opportunities where both energy and energy cost savings may be achieved.

Energy Audit Survey

The energy audit survey is provided to the responsible Building Manager weeks in advance of the audit for pre-visit preparation by the audit team. The Building Manager or designee completes the survey, which is returned to the team prior to the visit.

The survey serves three purposes. First, it provides a snapshot of the Building Manager’s (and staff’s) understanding of their building’s utility, mechanical, and controls systems; second, it provides the team with some idea of what to expect when it arrives on site; and third, it becomes a guide for talking points during the interviews with Management and staff. Each survey form should be tailored as needed to the specific facility. The following tables in this section describe one suggested format.

The first section seeks general point of contact and building information that can be used for future reference. The next few questions seek to understand the general perceived conditions of the building, its condition history, and the effectiveness of the maintenance program. Questions regarding elevators, escalators, and vending machines are provided to obtain the number of these units for which there are specific technical energy conservation opportunities and for which energy savings can be calculated.

ENERGY, DEMAND MANAGEMENT, AUDIT SURVEY				
Facility/Installation Name:				
Address:				
Facility Manager:			Phone:	
			Email:	
Energy Manager:			Phone:	
			Email:	
General Facility/Installation Data *Please provide requested data for conditioned areas (areas that are heated and/or cooled) only.*				
1.	Number of buildings in this facility/installation:			
2.	Range of net conditioned area of buildings in this facility/installation:			
3.	Range of number of floors of buildings in this facility/installation:			
4.	Range of age of buildings in this facility/installation:			
5.	Predominant uses of buildings in this facility/installation:			
6.	Average daily number of occupants in buildings in this facility/installation			
7.	Identify individual buildings that together consume about 80% of your total facility/installation energy:			
	Building Name	**Building ID**	**Approx. SF**	**Approx. % Energy Use**
8.	What are the most common complaints that generate trouble calls?			
9.	Have any of the buildings in the facility/installation ever been formally commissioned? If so, when? Provide a copy of the commissioning report if available.			
10.	Are you seeking LEED certification? If so, at what level?			
11.	When was the last time the buildings' HVAC was tested, adjusted, and balanced (TAB)?			
12.	How do you characterize the buildings' comfort levels?			

ENERGY, DEMAND MANAGEMENT, AUDIT SURVEY				
13.	How do you characterize the buildings' lighting levels?			
14.	How do you characterize the buildings' noise levels?			
15.	How many elevators and escalators are on site?			
16.	What is the approximate number of chilled and standard vending machines on site?			
17.	Who/what organization provides facilities maintenance? (In house or contracted?)			
18.	What percentage of facilities maintenance work is: (should add up to 100%)			
	Proactive?		Preventive?	
	Predictive?		Reactive?	
19.	Do you have up-to-date drawings of the buildings' layout, mechanical, and electrical systems that can be made available at the start of the site visit?			

The next section asks questions regarding the facility's meters, sub-meters, utilities serving the facility, and utility's points of contact. This information is used during the energy use analysis portion of the energy audit.

METERING INFORMATION				
1.	How many separate electric utility meters serve the facility/installation?			
		How many are "smart" meters?		
		How many are standard meters?		
2.	How many separate gas meters serve the facility/installation?			
3.	Is steam/HTHW generated at a central plant? GSA?			
4.	How do you characterize the buildings' noise levels?			
5.	Please provide contact information for the utilities that serve your facility/installation:			
		Electricity	Natural Gas	Fuel Oil
	Supplier Name:			
	Contact:			
	Phone:			
	Fax:			
	Email:			

If the mechanical equipment represents the brawn of the mechanical system, the controls represent the brain. For that reason, background information regarding the Energy Management and Controls System (or Building Automation System) is asked for an understanding of system type, its capabilities, and limitations.

ENERGY MANAGEMENT SYSTEMS CAPABILITY AND OPERATION							
1.	Does the facility/installation have an Energy Management and Control System (EMCS)? *[If you have an outside contractor that provides maintenance services to your facility's/installation's EMCS, that contractor may be able to provide assistance in completing this survey.]*						
2.	When was the system installed?						
3.	Is the EMCS centralized (operated from one central location regardless of the number of different systems or buildings it controls)?						
4.	What type of control systems interface with the EMCS in the facility/installation?						
	Pneumatic		Electric		Direct Digital Control		
5.	What is the make of the EMCS?						
	Manufacturer:			Model No.:			
6.	How many points are monitored and controlled by the EMCS? *(Points refers to inputs and outputs to the EMCS - signals coming into the EMCS from sensors in the facility and signals going out from the EMCS to units it controls.)*						
7.	What systems does the EMCS control?						
	Chillers		Boilers		Unitary Air Conditioners		
	Air Handling Units		Lighting		Variable Speed Drives		
	Service Hot Water		Fan Coil Units				
	Other (Describe):						
8.	Check off the functions that your facility's EMCS can and currently does perform:						
		Does the EMCS currently have the capability to perform this function?		If it has the capability, does it currently perform this function in the facility?			
	On/Off Control						
	Optimized Start/Stop						
	Load Shedding						
	Chiller Optimization						
	Boiler Optimization						
	Duty Cycling						
	Demand Limiting						
	Chilled Water Reset						
	Hot Water Reset						

ENERGY MANAGEMENT SYSTEMS CAPABILITY AND OPERATION						
9.	What reports are generated by the EMCS?					
	Energy Consumption and Demand Information			Chiller and Boiler Profiles		
	Trending Reports			Alarms		
10.	Identify the non-critical load types that are shed by the EMCS for control purposes:					
	HVAC		Lighting		Domestic Hot Water	
	Other:					
11.	Do you have a written plan for demand control or load shedding that identifies loads (and their priorities) that are to be shed during peak period?					
12.	Does the EMCS perform load shedding automatically?					
	Yes		No		Possibly	
13.	Does your facility use an outside contractor to provide maintenance and service to the EMCS? Yes: _____ No:_____ *(If yes, provide contact information below.)*					
	Name of contractor/representative:					
	Phone:			Email:		

Basic information is asked regarding the emergency generators. The purpose of this is to see if there is potential for using them for load shedding and other demand and energy conserving strategies. For example, if the generators are large, old, and/or problematic, and if the purchased power is unreliable or poor quality, one might consider installing in their place a fuel cell or other renewable energy system and an energy conservation measure.

EMERGENCY GENERATOR (BACK-UP) OPERATION		
1.	Are there emergency generators serving the facility/installation? If so, what is their capacity?	
2.	Are the emergency generators used to control peak demand?	
3.	Are the emergency generators started automatically for demand control?	

In preparation of the site visit, the audit team needs to know what kind of energy conservation measures and renewable energy systems have been implemented – or considered for implementation – in the past. Understandably, this audit should be conducted independent of previous actions; however, if an initiative was considered, and either adopted or rejected for any reason, there is no need to waste time and assets to repeat the analysis. Be mindful, however, that even something as common as a utility rate increase, can move a previously rejected energy conserving recommendation into a feasible and acceptable payback.

ENERGY CONSERVATION MEASURES IMPLEMENTED					
1.	Have any of the following energy conservation measures been implemented at the facility/ installation within the last five years?				
	Lighting and Control Upgrade		Chiller Replacement and/or Chiller Optimization	
	Motor Retrofit		Variable Speed Drive Upgrades	
	HVAC Controls Retrofit		Cooling Tower Energy Use Optimization	
	Ice Storage			
	Other:				
2.	Have any renewable energy measures been implemented (such as photovoltaics, wind, ground source heat pumps, fuel cells, etc.)? *(If so, provide details below.)*				
3.	Have there been any energy or utility savings studies or reports completed for the facility/ installation within the past 10 years? *(If so, provide a copy at the start of the site visit.)* Which recommendations have been adopted? *(Provide details below.)*				

Finally, the survey addresses annual consumption of all utilities. This information is needed for preparation of the energy consumption analysis and determination of the energy conservation opportunities.

ANNUAL ENERGY CONSUMPTION AND COST					
Please complete for your building(s) the following table on annual energy consumption and cost for all applicable energy sources. *(Previous 24 months; identify period e.g., 1/08-1/10.)*					
	Electricity kWh	Natural Gas Therms	Fuel Oil Gallons	Water Gallons	Other
Annual Consumption					
Annual Cost $					
Peak Demand KW					
Other Energy Source					

Kick Off Meeting

The kickoff meeting sets the stage for the energy audit that is about to take place and provides the opportunity for introductions between the energy audit team members, Management, facilities staff, and other attendees. It is the time when:

- Introductory, background information is provided
- Introductions between audit team members, Management, the facilities staff, and other attendees are made
- Objectives are communicated
- Ground rules are established
- Procedures and technologies that will be used are outlined
- Protocols are discussed
- Schedules are provided
- Procedures and logistics matters are agreed to
- Emergency and safety procedures and concerns are discussed, including alarm notifications, locations of emergency assembly areas, and other general visitor requirements
- Potential impact of starting, stopping, opening, and/or modifying equipment is discussed

Most important, the site personnel need to be comforted in knowing that this assessment ("audit" has a negative connotation) is not an inspection of their facilities, personal qualifications, procedures, policies, or practices. It must be impressed on them that the purpose of the site visit is to find ways to save energy and to reduce greenhouse gas emissions and carbon footprint. Often, if they know that the energy conservation opportunities that are developed may be supportive (as warranted) of initiatives they have been trying to get an authority's attention on unsuccessfully, a floodgate of information often opens.

Group Interview

It is best to proceed directly into the group interview from the kick-off meeting while the major players are still in the room and in the mood to participate actively. The interview may be regarded as the most valuable tool of the audit. Here, the filled-out survey is used as a guide for talking points and to prompt additional and follow-on questions regarding the facility, its personnel, their procedures, policies, and more. Specific areas of concern are discussed. The team should pay specific attention to recurring and previously unsolved problems.

A group interview with the maintenance staff, building occupants, and Management will help determine *their specific perception* of current problems that may be associated with the equipment and systems, facility design, the facility O&M culture, O&M practices, or other influential factors on energy saving opportunities, system efficiency, system reliability, personnel comfort, and required conditions for operations. Ask the occupants if they hear “strange sounds” or “noise” from the mechanical and ventilation systems. The interviews should also help the audit team better understand operating strategies and equipment condition.

Records of the interviews should be maintained for future reference. The interviewers need to be aware that the information may be factual, hearsay, perceived, or even political in nature. Look for patterns.

Individual Interviews

A very valuable practice is to speak to individuals separately and informally after the group interview, sometime early during the site visit. Whereas the group interview is valuable for prompting comments and generating discussion, it is during the informal individual discussions where people open up. For example, an occupant who is trying to maintain a good relationship in public may be more vocal and brutally honest about maintenance response time

Effective Interviewing

- Don’t readily accept the first thing anybody tells you – they will be telling you symptoms or results
- Ask the same question 3 different ways to drill down beyond their concern to the root cause
- Be patient
- Allow for silence – people are uncomfortable with silence and will begin talking

out of earshot of the Maintenance Director. Or, the maintenance staff typically is more open and vocal about criticizing Management support on a viable but unsupported and unfunded initiative when they are not in front of the boss.

As opinions and perceptions emerge, keep pulling the string further and further until a determination of fact versus fiction, as well as applicability, can be made.

Site Assessment

See also Chapters 5 and 6, *Implementation* and *Tools and Techniques*, respectively. The audit team next conducts a walk-through site assessment to evaluate the energy efficiency of and how a building, its envelope, its equipment, and its systems are currently operated and maintained.

The site assessment will document, in writing and in digital photographs, occupancy and space utilization, inefficient practices, and building features such as:

- Both good and bad equipment and system condition
- Lighting types and room light levels
- Controls system functionality (e.g., damper operation and integrity, actuator responsiveness, sensor operation)
- Existing conditions, including poor original design, that are causing energy inefficiencies and an unacceptable working or operational environment
- Air conditioning units that are inaccessible for maintenance or its registers are blocked by modular furniture
- Potential energy saving retro-fits, such as replacement of domestic water heaters by instantaneous water heaters
- Opportunities for maximizing the use of the natural resources, such as daylighting and ground source loops

Thermographic images should be taken of the building envelope and utility distribution systems, including steam traps, to document undesirable heat transfer. Other technologies should be used as needed to determine building, equipment, and system energy loss, such as ultrasound to check for compressed air and steam leaks. Check-off sheets should be used to organize the data.

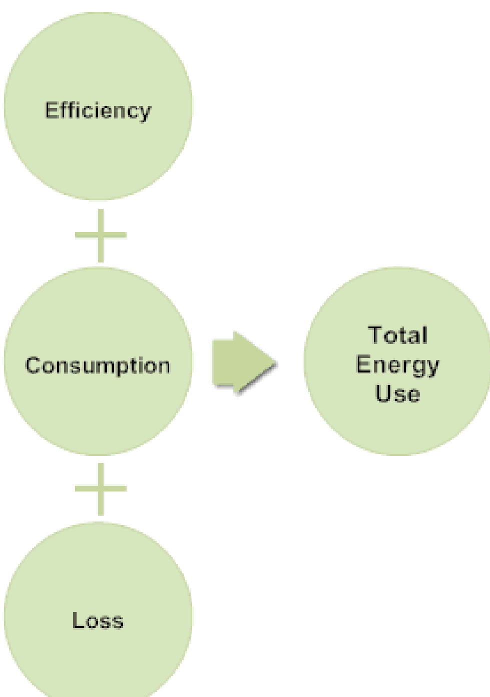
There are three main groups of energy use:

- The first is actual **energy consumption**. We use energy in all forms for our benefit and is the first place to look for savings. As the team walks the site, the obvious question to ask is “Is all the energy used needed or is there waste?”

- The second is **efficiency**. When energy is consumed, the usable output relative to the input is the efficiency. The higher the efficiency, the greater is the productive output of a given unit of a utility. As the team walks the site, it should look to see if the installed equipment and building features are as efficient as they can be. Efficiency, as tested by the manufacturer, is usually clearly marked on motors, HVAC systems, and appliances that have an attached ENERGY STAR rating label. There are probably many energy saving opportunities here too in the form of system upgrades.

- The third **energy loss** is in the form of heat transfer. This loss can be subdivided into three different forms: conductive, convective, and radiative.
  - Conductive is heat transfer through contact with surfaces, such as glass, and metal.
  - Convective takes the form of heat loss through the air and is spread through infiltration, and exfiltration.
  - Radiative takes the form of heat transfer through electromagnetic waves mostly in the infrared region.

  The team should look for situations of unwanted heat transfer. Examples include uninsulated steam pipes and doors and windows that need a form of weatherstripping.



Those are the types of energy loss. With those in mind, the team will assess all aspects of the facility in an organized manner. It is important to remember, however, that although energy savings is the primary focus of attention, there are other considerations that need to be factored in (and probably documented) – life safety, mission requirements, comfortable working environment, security at all levels, building code, and more.

The site assessment typically addresses the following major issues:

- Building occupancy and space utilization
- System and equipment condition
- Controls operation
- Building, system, and equipment energy efficiency
- Envelope integrity
- Habits and conditions that affect energy efficiency

(e.g., room fan coil units with grills covered by books or blocked by modular furniture; thermostats directly behind refrigerators and other heat-emitting equipment)

- Overall building energy use and demand
- Areas of highest energy use and demand
- Utility bill analysis and benchmarking
- Air and water flow rates, calibrations, and flow coefficients
- Actual versus design control sequences for each piece of equipment
- Equipment nameplate information
- Equipment maintenance approaches and issues
- Facility zone temperature and humidity levels
- Requirements to maintain negative or positive pressures (such as in laboratories)
- Facility lighting and CO2 levels
- All significant control and operational problems
- All significant occupant comfort problems
- Locations of building trouble spots
- Current O&M practices
- Renewable energy opportunities

And a few more words of advice - The assessment is a review of things that consume or affect energy. Be sure to examine the building envelope. It is unwise to recommend costly energy conservation opportunities if their effect is negated by a porous or problematic envelope. Also, seek to identify the root cause of the problem ("fix forever") and not just the immediate symptom. And, be sure to consider the purpose and location of the system being assessed, and ask "who is affected and how?" by a potential energy saving measure.

Diagnostic Monitoring and Testing

Diagnostic monitoring and testing, though usually more associated with retro-commissioning, provides information on operating parameters such as power consumption, demand, power quality, system temperatures, operating hours, critical flows, pressures, and volumes under typical operating conditions. By analyzing this information, the audit team determines whether the systems are operating correctly and in the most efficient manner. Diagnostic methods that are commonly used include energy management control system (EMCS) trend logging, meters and sub-meters output diagnostics, stand-alone portable data logging, and manual functional performance testing.

Functional performance testing, conducted by the maintenance staff, is the dynamic testing of systems (rather than just components) under full operation. For example, a chiller pump would be tested interactively with the chiller to see if the pump ramps up and down to maintain the differential pressure set point. Components are verified to be responsive per the prescribed sequences.

Energy Conservation Measures

The survey information is reviewed and analyzed by the energy audit team. Based on the input from the site assessment, the team brainstorms and develops energy conserving strategies and prepares energy conservation measures (ECM), or energy conservation opportunities (ECO). These are recommendations that provide the site with solutions and improvements to the current situation that will generate energy and energy cost savings. These will range from no-cost/low-cost improvements to costly capital improvements, possibly with lengthy periods of payback. This forms the basis of the project decision making and problem prioritizing process. Specific solutions to the problems found are identified.

Every problem, deficiency, or opportunity for increased efficiency that is found during the investigation phase is summarized on a master list, typically located in the executive summary of the audit report. The list includes, for each identified issue, identification of the recommendation, estimated energy savings, estimated energy cost savings, estimated implementation costs, and simple payback. Target completion dates may also be recommended. The comprehensiveness and accuracy of this information will vary by the type of audit – Type I, II, or III. Recommendation priorities are usually listed in order of simple payback – immediate to longest.

The audit team should oversee “quick fixes” as part of the Discovery Phase. These are simple repairs and adjustments, such as adjusting temperature settings on a seven-day programmable thermostat, removing piles of books from atop a fan coil unit, or tightening a fan belt. Though relatively insignificant in nature, these may be masking a real problem.

Exit Briefing

The exit brief occurs at the end of the site visit. This format varies, depending on the site, from formal presentation to informal round table discussion. In many cases, the attendees may be the same as those who attended the in-brief.

This meeting constitutes the wrap up. Understandably, the ECMs may not yet be finalized, but site attendees and the project sponsor should be left with an informal list of potential recommendations that will be analyzed further. Some of these items will survive and others will be eliminated. Some preliminary and general discussion can take place to emphasize points and to answer questions. By doing this, the attendees will have a sense of the thought patterns of the audit team and an indication of the success of the audit.

It is good practice to precede the actual list of recommendations with a list of “things that are going right.” This recognizes personal and organizational achievements and sets a positive tone for the remainder of the meeting.

Following the discussion of recommendations, attendees need to be informed of the close-out schedule and assigned actions. Here, follow up items, such as when the draft and final reports can be expected and follow-up satisfaction surveys, will also be discussed.

Finally, the audit team should acknowledge any help received and good hospitality that might have been shown. Good-byes are expressed, points of contact are reiterated (possibly through the exchange of business cards), and the team’s availability to answer additional questions is expressed.

Draft and Final Audit Reports

The draft and final audit reports typically include:

- An executive summary that summarizes the most important information found and assumptions made, and features a master list summary of energy savings opportunities

- Site, team and sponsor points of contact
- Scope of work
- Audit objectives
- General facility information (e.g., facility size and features; utility unit quantities and costs for available years; energy use index and energy cost index for available years)
- Climate data (historical and on the site visit dates)
- Identification of prior audits and retro-commissioning and major findings
- Discussion of survey and interview results
- Synopsis of maintenance procedures
- Energy analysis for all utilities
- Benchmarking (may include *ENERGY STAR Portfolio Manager*)
- Plant property listing and assessment
- Thermographic assessment
- List of energy saving measures (ECM)
- ECM calculations (Appendix)
- Backup and supporting information (Appendix)

Digital photographs of existing conditions, problematic areas, and other noteworthy observations should be included throughout the report to illustrate points and to familiarize the reader with the context of the discussion.

Phase III – Correction

Selection of Cost-Effective Measures for Implementation

Based on the findings of the site assessment and diagnostic monitoring and testing, and using the master list as a guide, site Management (or sponsor) determines which recommended improvements to implement. Items should be prioritized according to payback, cost effectiveness, criticality, how effectively they meet the project objectives, and impacts on mission. To aid further in the decision making, the audit team can provide additional, more accurate and more comprehensive economic analyses (estimated cost, savings, payback, and return on investment) on those items that can be quantified. If needed, Type III audit computer simulations can be conducted on recommendations requiring large capital investments. It is likely that many of the recommendations will have no cost/low-cost solutions that can be implemented right away, such as modifying personnel behavior. Additionally, certain improvements may be used as a progression from the Type I audit into the Type II audit, or the Type II audit into the Type III audit.

Phase IV – Handoff

Feedback

Within a couple of weeks of completing the audit, the audit sponsor should send a survey form to the appropriate site manager with direct questions regarding the site's degree of satisfaction with the audit operation, with the results, with its comprehensiveness, with the quality of the audit team, and other metrics of interest. The purpose of this is to copy best practices and incorporate lessons learned in future audits.

At about quarterly intervals after the audit, the audit sponsor should follow up with site Management and either telephonically (and manually recorded) or by official written survey, determine what actions have transpired with the recommended energy conservation measures or opportunities, and specifically, which ones have been acted on. Of these, actual resulting measured savings is of particular interest.

Diagnostic Monitoring

For persistence, diagnostic monitoring and testing may be performed, where applicable, again after the recommendations have been implemented. Post-implementation data is compared to pre-implementation data to confirm that the improvements have the desired effect on energy reduction. Diagnostic monitoring and testing may also be used to benchmark the performance of the improvements. This establishes parameters for measuring the performance of the improvements throughout the life of the equipment and systems.

O&M Staff Training

Ongoing O&M staff training should be included as a recommendation in the audit report. If a building is highly sophisticated, the staff's maintenance capabilities need to be aligned with that sophistication. For that reason, if training deficiencies are found during the assessment (incorrect procedures is a leading root cause of problems), or ECM changes are made that require new training, it is the responsibility of the site Management to ensure that training is conducted.

Best Practices

1 – Plan in advance. Review utility data and survey response feedback prior to the site visit.

2 – Based on your knowledge of the facility and the type of audit being conducted, consider comprising the team of the optimal mix of subject matter experts – controls systems, HVAC, thermographer, lighting, water, O&M, building occupant, etc. – customized for that site.

3 – Conduct a group interview immediately following the in-brief while all interested parties who might have contributing input are present.

4 – Make sure everyone knows that the team is NOT conducting an inspection or fault-finding audit – the team's objective is to help the site find energy savings by sharing best practices and lessons learned from other prior site visits.

5 – Speak to individuals "on the side" to get their candid opinions of what's going well and what is not relative to energy use and savings opportunities.

6 – Take lots of photos – and use erasable white boards to identify buildings and specific equipment. How quickly one forgets!

7 – Come prepared with the required tools to access spaces and equipment – step ladder, flashlights, and common handtools to remove panels and covers.

8 – Conduct the assessment in an orderly fashion, preferably together as a single team. The reason for this is that usually a question asked by one member triggers additional questions and observations by the others. Also, some teams like to start with the most problematic or energy inefficient facilities first.

9 – Review facility drawings as needed to trace HVAC distribution systems, to identify specific components, and to detect building and system changes that might have taken place over the years.

10 – Think "outside of the box." Recommending the replacement of a problematic or inefficient system with a new one of the same type just prolongs the same problems for a longer period of time.

11 – Identify the root cause of the problem – not the symptom. Adjusting the temperature setpoint in a room because it is hot addresses the symptom but neglects the root cause, such as a broken damper mechanism or incorrect controls sequence of operations.

12 – Brainstorm potential ECOs as a team at the end of each day and then present it as a "draft shopping list" to Management during the outbrief with the caveat that its intent is to provide an idea of the thoughts of the team and that some items may fall out or be added during further analysis.

Chapter 5 Implementation

This chapter addresses implementation of the energy audit process in terms of the building envelope, air distribution system, heating and cooling, lighting, water distribution, and compressed air. This is not all-inclusive. Be sure to address other energy consuming systems – *including people*!

Building Envelope

The first thing to assess in a building is the envelope. The building envelope is comprised of all exterior facing surfaces. This encompasses all building barriers starting from the foundation, to walls, windows, doors, and roof. When evaluating the building the first observation should be to note its orientation. This is especially critical in noting the sun load on the surfaces. In the northern hemisphere, the southwest facing barrier is especially susceptible to higher heat gains. Surfaces facing the sun will require sufficient thermal barrier to overcome the heat gain. Conversely the north east facing surfaces are susceptible to higher heat loss. Special attention must be given to this.

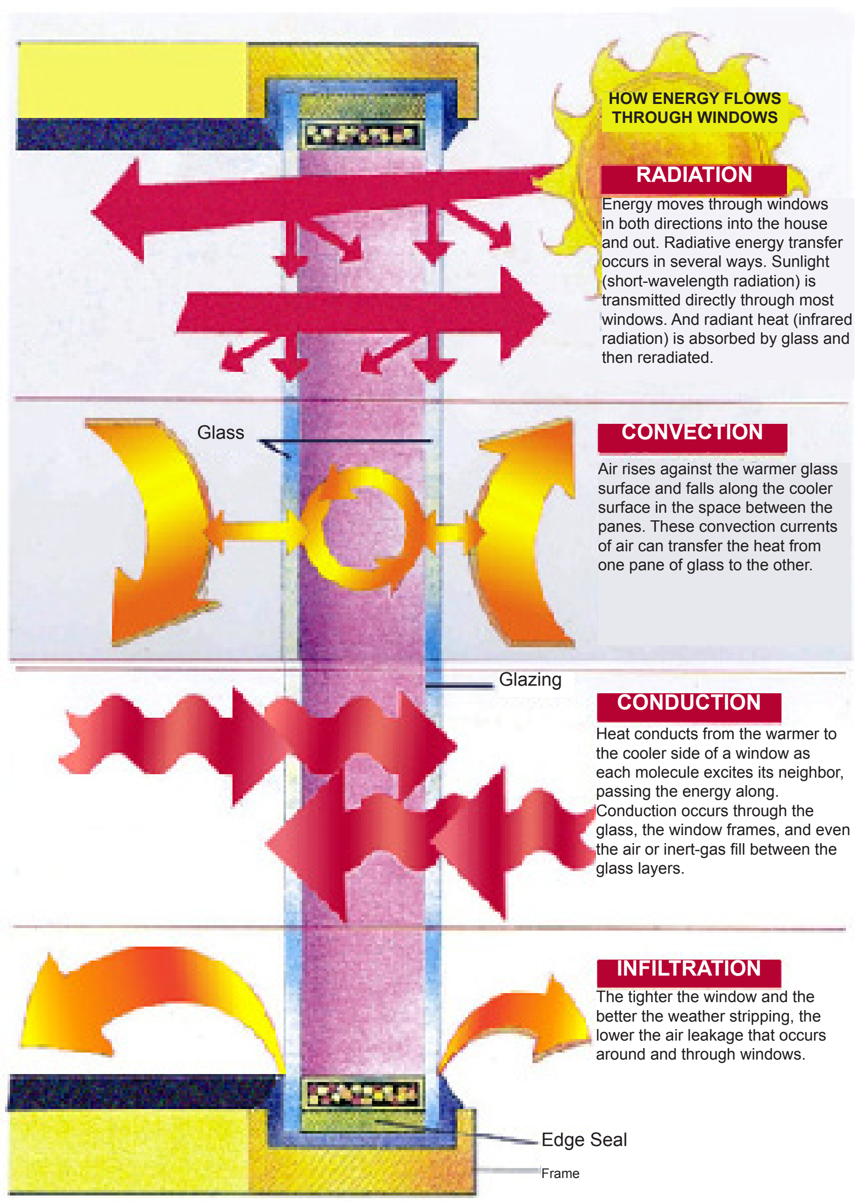
After determining the orientation of the structure, the integrity of the shell is evaluated. Visually inspect the structure from the outside to make sure there are no obvious deficiencies to the building envelope. Pay specific attention to large gaps creating air leaks. The potential energy savings from reducing drafts in a structure reduce operating costs and generally make the building much more comfortable.

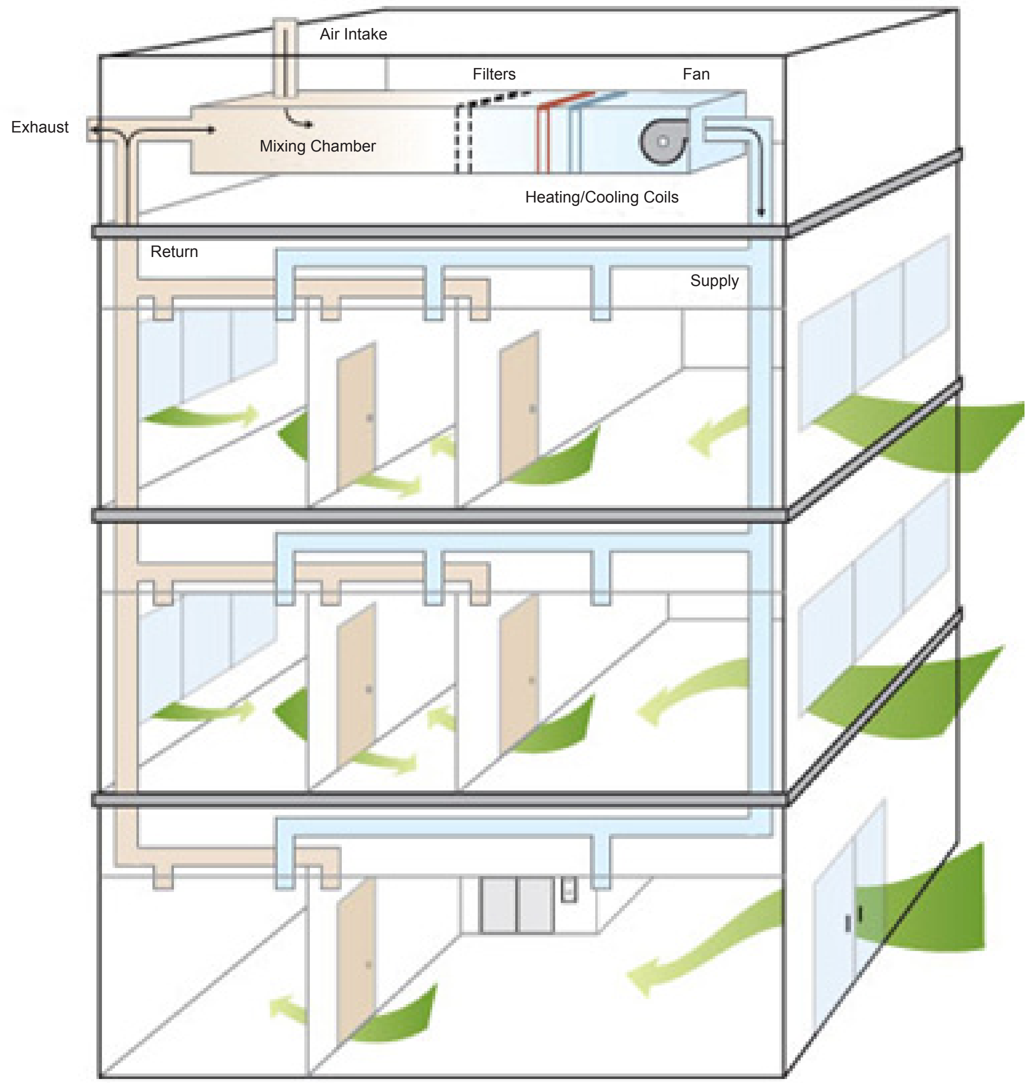
Infiltration and Exfiltration

A thermal imaging scan will help the audit team find areas of exfiltration, especially those not readily visible to the naked eye. Exfiltration is the uncontrolled passage of indoor air out of a building through unintended openings in the building envelope. A thermal scan will also point out areas of poor or damaged insulation and areas with high heat conductivity, such as windows, doors, and other architectural features that are not insulated.

As the team moves inside the building, take a look at the envelope from the inside. Another thermographic scan will catch infiltration from outside. Infiltration is the uncontrolled passage of outdoor air into a building through unintended openings in the building envelope.

The sources of indoor air leaks, such as gaps along the baseboard or edge of the flooring and at junctures of the walls and ceiling, are common place in structures. Also look for gaps around pipes and wires, and foundation seals. Check to see if the caulking and weather





Infiltration

stripping are applied properly, leaving no gaps or cracks, and are undamaged and making a good seal. Check for air seepage in electrical outlets, switch plates, window frames, baseboards, weather stripping around doors, wall or window-mounted air conditioners. Visually verify if you can see daylight around a door or window frame, and then the door or window itself for leaks.

Infiltration and exfiltration are driven by static air pressure inside the building relative to the outside. These air pressure differences are the result of natural forces (e.g., wind and temperature) and manmade forces (e.g., exhaust and make up air fans), HVAC system design, and envelope integrity.

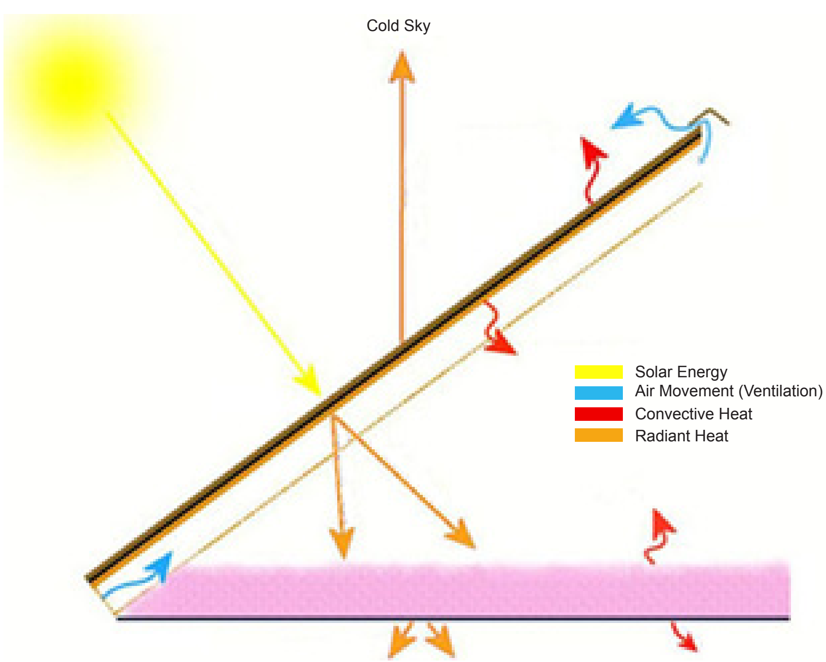
The other influences acting on the building envelope are convection, conduction and radiation.

Conduction

In conduction heat is transferred from the warmer to the cooler side of a surface as each molecule excites its neighbor, passing the energy along. Conduction usually occurs through solid surfaces including glass, windows and doors (including air as inert-gas fill between layers), all solid frames, and exposed structural features.

Convection

In convection, air rises against the warmer surface and falls along the cooler surfaces. These convection currents of air transfer the heat from one source to the other. This is best reduced by using proper insulation on solid surfaces and double glazed windows with low "E" ratings. Insulation is a thermally resistant material that creates a barrier against heat transfer. There are many insulating materials with varying degrees of heat resistance, referred to as an "R" Value (see appendices). Insulation prevents air movement from adding or removing heat in a building by convection, and provides minimal heat conduction itself. In addition to energy loss, air leaks can cause condensation to form inside wall cavities and internal walls leading to numerous serious problems. Air leakage can also be a source of noise pollution.



Radiation

Radiation is the transfer of heat energy through empty space. No medium is necessary for radiation to occur since it is transferred through electromagnetic waves, primarily in the infrared region.

In radiation, energy moves through windows and translucent surfaces in both directions. Radiant energy is absorbed by glass and then re-radiated in longer wavelengths. These varying energy signatures can be captured with a thermal imaging device, i.e. an infrared camera.

Radiant barriers are materials that reflect radiation and therefore reduce the flow of heat from radiation sources. Good insulators are not necessarily good radiant barriers, and vice versa. Metal, for instance, is an excellent reflector and poor insulator. Proper window insulation, applying modern “cool” or white roofing technologies, and planting trees will help reduce radiant heat loads.

Envelope Characteristics

The climatic differences throughout the country are mirrored in the traditional buildings that range from un-insulated, usually heavy construction in the south (designed mainly for summer conditions) to fairly well insulated heavy or light construction in the north that is designed for winter conditions. Improving the thermal properties of the existing building envelope is, in many cases, one of the most overlooked, but one of the most important, solutions for reducing building energy consumption.

There are two key components to a super-insulated building shell: (1) high levels of insulation with minimum thermal bridges, and (2) airtight construction. High levels of insulation are accomplished by constructing a thicker than normal wall and filling it with an insulation material. However, simply adding more insulation does not turn a conventional assembly into a high-performance assembly.

The wall system and junctions between building components have to be designed carefully to be airtight and void of thermal bridges. As more insulation is added, the thermal discontinuities become more important.

The cost effectiveness of building envelope intervention is a critical issue: so it should be remembered that the first layer of insulation is the most effective. The law of diminishing returns dictates that each additional layer of insulation is less effective than the previous layer.

On the next page is a brief but comprehensive checklist of what to look for in a building envelope.

BUILDING ENVELOPE CHECKLIST	
	Verify that outside wall insulation is consistent with area building requirements and codes.
	Verify that ceiling/roof insulation is consistent with area building requirements and codes. **Note:** About 40 percent of energy loss can occur through poor ceiling insulation.
	Check windows used for good seals and thermal barriers. **Note:** Determine the feasibility of replacing with double or triple pane low "E" windows.
	Identify areas with infiltration or wind draft problems; seal leaking areas.
	Determine if any passive measures can be taken to reduce solar loading on buildings. **Note:** The use of passive measures depends on the orientation of the building and its surrounding trees.
	Ensure that doors are appropriate for their intended purpose. **Note:** Consider installing revolving doors, vestibules, or air curtains for high traffic areas.
	Check for ways to minimize heat loss (or heat gain) from loading dock doors.
	Check exterior joints around windows and door frames.
	Check exterior and interior joints around windows and frames.
	Check between wall sole plates, floors, and exterior wall panels.
	Check penetrations for plumbing, electricity, communications, refrigerant, and gas lines in exterior walls.
	Check service to access doors and hatches.
	Check attic insulation and ventilation.
	Check roofing for damages.
	Check all other openings in the building envelope.
	Inspect caulk around electrical wall openings and wiring penetrations.
	Check differential static pressure in building. **Note:** 0.2" to 0.3" positive pressure maintains low infiltration levels.

Air Distribution System

Once the integrity of the building envelope has been verified, one must address the air movement that is needed to be maintained. Proper air distribution to all areas of the facility is critical not only for occupant comfort and operational necessity, but also because it will reduce energy use. Getting the air delivered to the right place at the right temperature will expend much less energy than forcing poorly distributed air to do the same thing. Air flow has very special characteristics that need to be observed when investigating air patterns. The travel path for supplying conditioned air to the desired space needs to be as short as possible, and for this, the proper duct static pressure needs to be maintained.

A dichotomy is that as building efficiency against energy loss is improved with insulation and weather stripping, buildings become more air-tight. But buildings require a source of fresh air. While opening a window does provide ventilation, it also imposes the undesired effects of unconditioned heat and humidity. Both are undesirable for the indoor environment and for energy efficiency, since now the building's HVAC systems must compensate.

At certain times of the year it may be more thermally efficient to bypass the building heating and cooling system. By taking advantage of the natural outside ventilation, and cooler temperatures one can achieve free cooling along with improved air quality. To make this work, the enthalpy, a combination of sensible heat (air and water vapor) and latent heat (heat required for evaporation at dew point) must be low enough to create a comfortable environment.

In the energy control business it is usually necessary to monitor humidity, as well as temperature. Sensing humidity cannot be done as easily or as accurately as temperature sensing. For example, an outside air temperature sensor should provide dependable service for the life of the mechanical equipment. However, an outside humidity sensor that must withstand temperatures from -20° to 100°F, as well as the effects of pollution, typically may provide dependable readings for only six months before it requires service or replacement. Outdoor humidity sensors require protection from the elements. Although a shield provides protection, an aspirated enclosure may provide the best solution.

Sensing the return air is generally a more accurate method than using outdoor sensors. It is important to have the temperature sensors and humidity sensors located in the path of the return air stream. Warm air has the capacity to hold more moisture than cold air. This increases the relative humidity. Because changes in humidity are actually changes in vapor pressure, these changes are transmitted through the conditioned space much faster than changes in temperature.

In addition to checking the condition of the air, check the condition of the ductwork that transfers and distributes it. Check the ductwork for dirt streaks, especially near seams, that are indicative of air leaks, as well as more obvious holes, splits, and disconnections. The ductwork usually has access panels and doors. Check these for proper seals and tightness.

VENTILATION SYSTEM CHECKLIST	
	Check filters. **Note:** Generally, filter maintenance is geographically dependent; pre-filters should be changed about once every month or two, especially during periods of high equipment usage; secondary and special filters should be changed per manufacturers' recommendations.
	Check natural ventilation.
	Check economizer.
	Check ductwork - insulation, sealed joints, access panel seals, leaks, and overall integrity.
	Check for ways to control solar gain to reduce the cooling load on buildings.

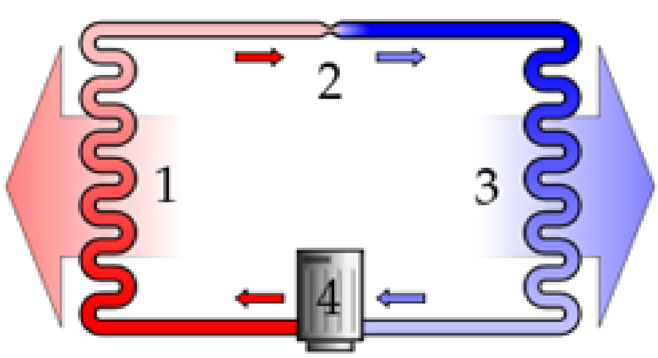
Heating and Cooling

Cooling

Heating and cooling are methods of adding and removing heat energy from the air stream. Cooling is achieved by a myriad of evaporative means ranging from simple evaporative swamp coolers, where water directly in contact with the air stream reduces its temperature, to mechanical cooling.

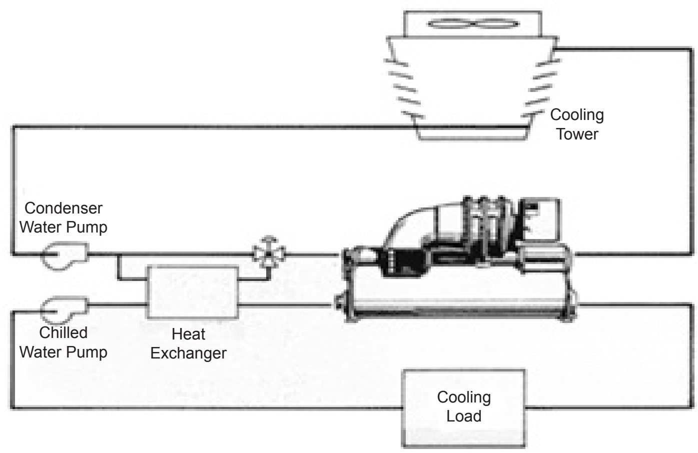
This usually involves the compression of a refrigerant (freon) by mechanical means and sending the high pressure liquid refrigerant to the cooling coil. Heat is absorbed when the liquid quickly sublimates into vapor. A large amount of heat energy is required for this change of state, and cooling results. The hot gas is condensed by releasing its heat in another coil. This creates a complete closed loop.

In a thermodynamically closed system, any energy input into the system that is being maintained at a set temperature (which is a standard mode of operation for modern air conditioners) requires a corresponding energy removal rate from the air conditioner as well.



Heat is usually removed from the condenser coil by air or water. During direct air to air exchange, cooler air is blown through the coil, directly removing heat from the refrigerant. This technique is particularly suited well for heat pumps.

Heat is also removed from the condenser coil by water in an air to water exchange. A cooling tower is normally used for this purpose in commercial and industrial applications. By passing water through the



coils, the heat is transferred to the water. The water is then cooled by evaporative means and forced air.

An alternative method of cooling the water is by employing a geo-exchange loop. By burying a pipe loop in the ground, the earth acts as a heat sink absorbing the heat from the pipe and cooling the water. This is a much more energy efficient method of cooling condenser water, and is environmentally friendly.

These methods actively cool the space as needed. However a lot of energy is consumed in the processes. With the cost of electricity generally higher during the day and peak hours, there is an alternative. During the ice storage process, ice is manufactured during the night when both rates and process losses are at their lowest. Ice storage provides inexpensive daytime cooling by melting the ice in the exchanger to generate the required quantity of chilled water.

In mild weather the site should take advantage of free cooling. Here, to remove its heat, the condenser water is passed through a heat exchanger that is connected to a cooling tower without any extraordinary mechanical intervention.

Heating

As the outside seasonal temperature grows cold, the process is reversed and heat is added to the air stream. There are two primary methods of adding heat – direct and indirect. The most common example of direct heat is a fossil fuel furnace, in which the air passes in direct contact with the combustion chamber and thereby heating the air stream.

Alternatively, electric resistance heating can be used in place of the fossil fuels when they are inconvenient or not possible. Resistance heating is not as efficient as a furnace. Normally, this is used as a secondary or back up heat source.

A problem with direct heating is that the quality of the air is greatly reduced. Humidity levels are drastically reduced, and foreign particles, like dust and other debris, not caught by the filter will burn when in contact with the heaters. In essence, the air is getting burned. Because of this, a heat transfer medium is introduced. This indirect method of heating first heats the medium, which in turn heats the air stream. A variety of transfer methods are also available.

Heat Pumps

A system that serves dual function as stated above is the heat pump. This is a particular good application since it uses the cooling system already in place. No additional heating apparatus is required since heat is expelled into the air stream. Heat pumps are more popular in milder winter climates, where the temperature is frequently in the range of 40-55°F (4-13°C), and become inefficient in more extreme cold. For that reason, heat pumps are commonly installed in tandem with a more conventional form of heating, such as a furnace or heat strip, which is used instead of the heat pump during harsher winter temperatures. In this case, the heat pump is used efficiently during the milder temperatures, and the system is switched to the conventional heat source when the outdoor temperature drops below a given setpoint.

Hot Water

The second most common medium is hot water. Hot water is heated to 180°F to safely and efficiently transport and transfer it to the terminal devices. The heat is retained and delivered in insulated pipes to the coils for exchanging it to the air stream. This is a convenient and successful means of heat transfer. The water is returned at about 20°F cooler, ready for reheating. By using the return water, the system does not have to bring the water temperature up from nominal city water temperature of 50°F. Using preheated water conserves energy. The transmission methods are safe, clean and reliable.

Steam

A step up from hot water is steam. Steam has higher heat content than water and does not require pumps to move it. It has a natural up draw to the terminal device. However, there is no return steam and must collect condensate prior to going back to the boiler. Steam traps are used to maintain a seal between steam and condensate return. The job of the steam trap is to get condensate, air and CO_2 out of the system as quickly as they accumulate. Because mechanical steam traps have mechanical parts, they will fail eventually. And when they do so in the open position, live steam is unnecessarily wasted. If they fail in the closed position, the application will flood with condensate and stop the heat transfer. These traps are highly susceptible to damage, and must be maintained regularly, and many times replaced. A regular preventive maintenance program will extend the life of steam traps significantly.

A combination of steam and hot water may be used in certain application, combining the high heat transfer of steam and the convenience of hot water. By implementing a heat exchanger downstream from the boiler, steam is converted to hot water for final distribution to terminal devices. Inspect heating and cooling equipment regularly, or as recommended by the manufacturer.

COOLING SYSTEM CHECKLIST	
	Check for water leaks.
	Check chilled water supply temperatures of 50 degrees F or higher. **Note:** The temperature of leaving chilled water in centrifugal chiller is usually maintained at 42-45 degrees F by a chilled water set point. This may be lower than required to meet the cooling demand of the building air handling systems, particularly in moderate weather.
	Check controls that reset the chilled water supply temperature based on the return chilled water temperature. **Note:** This allows the supply chilled water temperature to rise as the return chilled water temperature drops. The chiller follows the actual building load more efficiently, rather than supplying chilled water according to design conditions.
	Check for controls that reset the chilled water supply temperature according to the cooling coil with the highest cooling demand. **Note:** In this manner, the chiller delivers only as much cooling as is actually required.
	Check condenser water temperature. **Note:** Lower entering condenser water temperature is preferred.
	Determine the condition of cooling towers and bypass valves (if applicable). **Note:** Ensure that the bypass valve closes completely before the cooling tower fans operate. If chilled water is not needed during the winter, close the tower bypass valve permanently.
	Determine the condition of forced draft cooling towers. **Note:** If chilled water is not needed in the winter, make sure the fan discharge dampers are kept completely open or remove them, if possible
	Determine whether or not heat transfer surface coils are clean.
	Check the refrigerant level. **Note:** Investigate whether or not units can be shut off when not needed.
	Check whether or not time clocks are installed on window air conditioners.
	Verify that the most efficient EER units are used.
	Record cooling equipment nameplate data.
	Record transfer and other equipment nameplate data.
	Verify piping system insulation.
	Verify equipment operations.

HEATING SYSTEM CHECKLIST	
	Check for boiler pressure.
	Check for furnace operation.
	Check distribution lines.
	Check heating coils.
	Check steam traps. **Note:** By piping the vent off a blow down unit's recovery unit to the de-aerator, steam normally lost to the atmosphere can be recovered.
	Check condensate return.
	Check supply and return pumps.
	Check heating generating equipment nameplate data.
	Check fuel usage - natural gas, LP gas, petroleum, coal.

Lighting

Electric power is defined as the rate at which electrical energy is transferred by an electric circuit. The standard unit of power is the watt.

Electrical power is transmitted with overhead lines and underground cables. After generation and transmission, it falls on the end user to use as little as possible. All other energy conservation measures are meant to bring our power usage down, and in turn, reduce costs all around.

The most obvious and relevant power consumption is lighting. There are many variables when looking at lighting. Old, inefficient lighting is a primary use of inefficient energy, followed by over lighting a work area and leaving the lights on. Approximately 90% of the power consumed by an incandescent light bulb is emitted as heat, rather than as visible light. Many light sources, such as the T-8 fluorescent lamp and light-emitting diode (LED) lamp offer higher efficiency, and some have for convenience been designed to be retrofitted in the already existing fixtures.

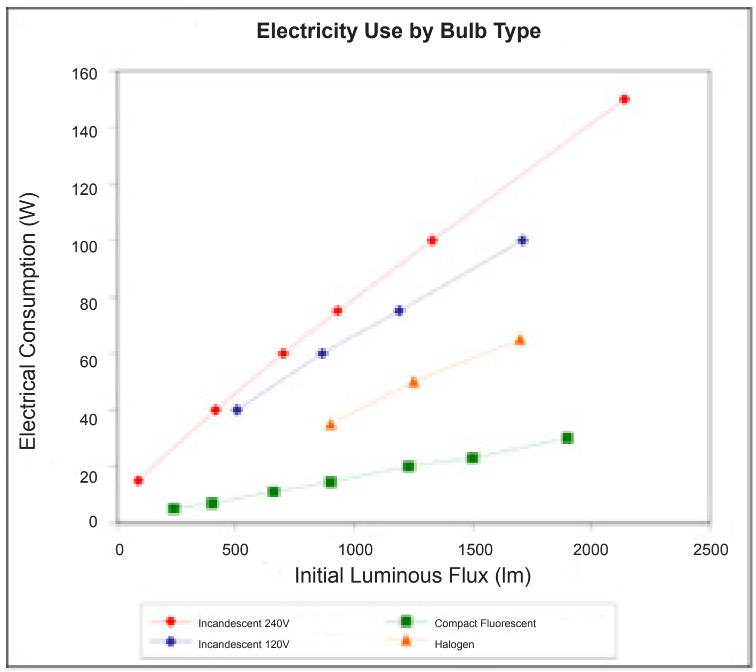
As efficient technologies become more commercially viable, they should be adopted and implemented throughout. Alternatives to standard incandescent lamps for general lighting purposes include: Fluorescent lamps, compact fluorescent lamps, High-intensity discharge lamps, and LED lamps. These devices do not rely on incandescence to produce light. Instead, all of these devices produce light by the transition of electrons from one energy level to another.

The compact fluorescent lamp (CFL) has several benefits over incandescent. The average rated life of a CFL is between 8 and 15 times that of incandescent. CFLs typically have a rated lifespan of between 6,000 and 15,000 hours, whereas incandescent lamps are usually manufactured to have a lifespan of 750 hours or 1,000 hours. Some incandescent bulbs with long rated lifespan of 20,000 hours have reduced light output. The lifetime of any lamp depends on many causes, mechanical shock, how frequent the light on turned on or off, and ambient operating temperature, among other factors

LEDs likewise offer many benefits. The chart below highlights many of the advantages of LEDs.

Efficiency:	LEDs produce more light per watt than incandescent bulbs.
Color:	LEDs can emit light of an intended color without the use of color filters that traditional lighting methods require. This is more efficient and can lower initial costs.
On/Off Time:	LEDs light up very quickly; a typical red indicator LED will achieve full brightness in microseconds.
Cycling:	LEDs are ideal for use in applications that are subject to frequent on/off cycling. Contrasting fluorescent lamps that burn out more quickly when cycled frequently, and HID lamps that require a long time before restarting.
Dimming:	LEDs can very easily be dimmed either by pulse-width modulation or lowering the forward current.
Cool Light:	In contrast to most light sources, LEDs radiate very little heat in the form of IR that can cause damage to sensitive objects or fabrics. Wasted energy is dispersed as heat through the base of the LED.
Slow Failure:	LEDs mostly fail by dimming over time, rather than the abrupt burn-out of incandescent bulbs.
Lifetime:	LEDs can have a relatively long useful life. Estimates of 35,000 to 50,000 hours of useful life, though time to complete failure may be longer. Fluorescent tubes typically are rated at about 10,000 to 15,000 hours, depending partly on the conditions of use, and incandescent bulbs at 1,000-2,000 hours.
Shock Resistance:	LEDs, being solid state components, are difficult to damage with external shock, unlike fluorescent and incandescent bulbs which are fragile.
Focus:	The solid package of the LED can be designed to focus its light. Incandescent and fluorescent sources often require an external reflector to collect light and direct it in a usable manner.
Toxicity:	LEDs do not contain mercury, unlike fluorescent lamps.

The chart below shows the energy usage for different types of light bulbs operating at different light outputs. Points lower on the graph correspond to lower energy use. For a given light output, CFLs use 20 to 33 percent of the power of equivalent incandescent lamps. If a building's indoor incandescent lamps are replaced by CFLs, the heat produced due to lighting will be reduced. At times when the building requires illumination and cooling, then CFLs also reduce the load on the cooling system compared to incandescent lamps, resulting in two concurrent savings in electrical power.



ELECTRICAL SYSTEM CHECKLIST	
	Check whether or not motors are properly sized for their loads. Load motors fully where possible.
	Replace or switch motors as necessary. Use super or premium efficiency. **Note:** Ensure that the highest practical power factor is used for electric motors.
	Shut down elevators during unoccupied hours in buildings.
	Check power distribution system - meter, incoming power, distribution panel, MCC, feeder circuits, subpanels, branch circuits, outlets.
	Measure foot-candles at workplaces. **Note:** The Illuminating Engineering Society (IES) has recommended foot-candle levels by type of workplace. Other lower lighting standards exist including one promulgated by the U.S. Department of Energy (DOE). (See appendices.)
	Ensure correct type of lighting is the most appropriate for the application (e.g., fluorescent, mercury, sodium, quartz).
	Reduce illumination level by delamping. **Note:** Ensure that wattage of each lamp is appropriate.
	Turn off lights when not needed. **Note:** Check for lights that are left on when not needed. Install automatic sensors to control lighting in these areas. Reduce the overall lighting hours of operation.
	Use spot lighting to replace unnecessary lighting of an entire work area. **Note:** When lamp removal is appropriate, first remove lamps over nonessential task areas.
	Install switches for selective control of illumination where spaces require different lighting levels for different activities, and/or where daylight can be used to supplement or replace electric lighting. **Note:** To minimize glare and ceiling reflection, the light source should be to one side of the work task area rather than directly in front of or over it.
	Make maximum use of daylight. Encourage workers to use natural lighting by using windows and skylights. **Note:** Using daylight helps lessen heat requirements. Natural sunlight should cross perpendicular to the line of vision.
	Evaluate whether or not there are too many unnecessary lamps.
	Replace existing T-12 fixtures with more efficient T-8 or T-5 lamps with electronic ballasts. **Note:** When replacing ballasts in fluorescent fixtures, use 430-milliampere (mA), high power factor, low-wattage ballasts with appropriate lamps. (See appendices.)
	Replace incandescent bulbs with compact fluorescent lights (CFL). **Note:** Payback for lamp conversion will vary depending on wattage reductions, electricity rate structures, and the number of hours electric lighting is used in a particular location.
	Install timer switches or electronic personnel sensor switches in areas used infrequently or for only a few minutes at a time.
	Install photoelectric cells for turning outside lighting on and off.
	Relocate or remove light fixtures when the light is blocked by over stacked materials or other obstructions. **Note:** Consider lowering light fixtures so that they are closer to task work areas in high bay areas and other spaces.

Water Distribution

The most undervalued utility is water. Even though our planet is mostly water and we get free rain, water conservation is becoming an increasingly important concern and issue. In a typical commercial building, as much as 48% of the water consumption is used for cooling and heating, 31% for domestic use and restrooms, 18% for landscaping, and 3% for other purposes.[1]

The water audit should include a detailed inventory of all restroom, kitchen, and domestic water users, such as toilets, lavatories, dishwashers, clothes washers, and showers, including their locations and flow rates. Conserving water can be as easy as replacing fixtures with modern low consumption units, making sure aerators are in place in all faucets, and installing ENERGY STAR certified and water conserving appliances.

In mechanical systems, check the rate for bleeding and the blowdown of cooling tower and boiler water. This periodic "flushing" is required to dispose of chemicals and suspended solids in the equipment water systems at the expense of requiring replacement water to make up the loss. The rate at which the bleeding and blowdown takes place may need to be adjusted for optimal efficiency relative to the prescribed cycles of concentration.

Also, in particularly hot and humid climates, air handling units will likely be disposing of a large amount of condensate. See if it is cost effective to divert this water to a nearby cooling tower as makeup water. This water is already cool (about 50^{o}F), pure, and will reduce city makeup water by water that will otherwise go down the drain.

Identify any refrigeration equipment that may have a single pass through of water. This is the same as having an open faucet run continuously into a drain. These equipment units are usually top candidates for replacement by more efficient units. And, as with the air handler condensate, maybe this water can be diverted to cooling tower makeup water rather than down the drain.

Consider implementing water harvesting techniques from rainwater, condensate, and one-pass water systems for garden and lawn irrigation use. Also review automatic on/off schedules for the irrigation system's effectiveness during the current season. Consider if installing ground moisture sensors to prevent sprinkler activation during or soon after a rainfall is a good investment.

[1] California Urban Water Conservation Council (2001), BMP 9 Handbook: A Guide to Implementing Commercial, Industrial, Institutional Conservation Programs, June 2001.

WATER CHECKLIST	
	Check meter.
	Check backflow preventer.
	Check water distribution lines.
	Check hot water tank operation. Note: Consider installing decentralized water heating.
	Inspect insulation on hot water pipes. Re-insulate if required.
	Check and seal leaking seals.
	Use low flow valves on bathroom fixtures.
	Make sure aerators are on all faucets.
	Look for water harvesting opportunities.
	Check hot water circulating pumps.

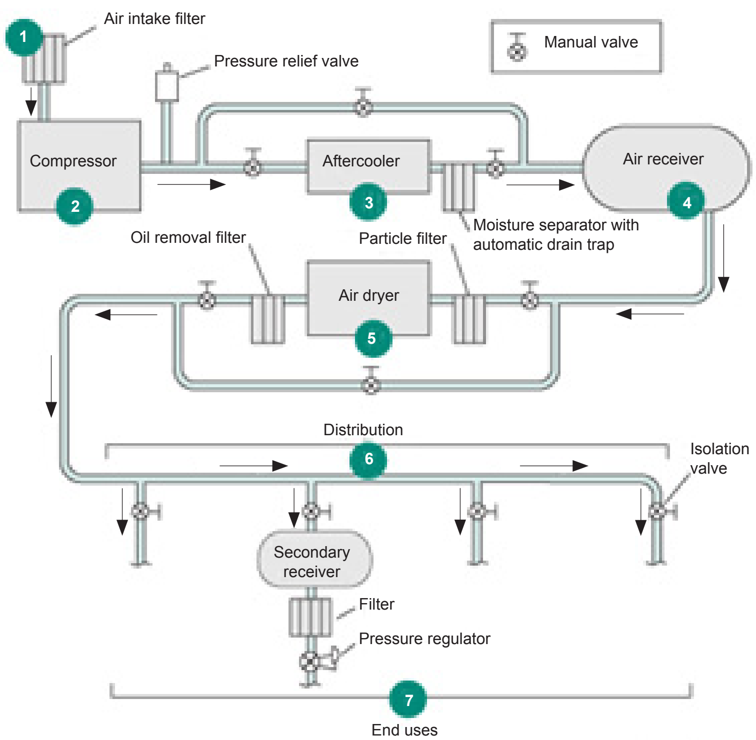
Compressed Air

Compressed air is considered industry's fourth utility, but is seldom considered as a contributing cost of production. Instead, compressed air costs are typically blended into overhead and often thought of as "free." Such ambiguity can hide cost savings that can positively impact your bottom-line and affect your ability to account for production costs.

Many of today's compressed air systems have been "pieced together" over the years in an attempt to meet the growing needs of the facility expansion. The result is often an unbalanced system with various components negatively interacting to create artificial demands and poor air quality. This missed opportunity can have a great impact on both man-hours and production.

A compressor running at part-load is generally less efficient than when it is running at full-load. Compressed air is vital to the operation of nearly every industrial plant. An efficient compressed air system can increase productivity and ensure better product quality. The more reliable a compressed air system is, the more cost effective will be its operation.

"In the U.S., compressed air systems account for $1.5 billion per year in energy costs, and 0.5 percent of emissions. Many industries use compressed air systems as power sources for tools and equipment used for pressurizing, atomizing, agitating, and mixing applications. Optimization of compressed air systems can provide energy efficiency improvements of 20 to 50 percent" -- U.S. Department of Energy



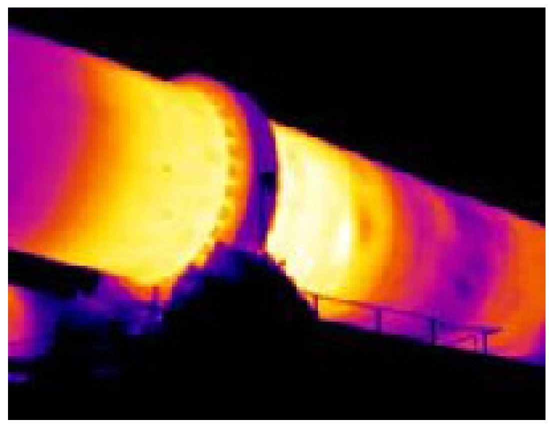
Source: Scales Air Compressor Corp.

COMPRESSED AIR SYSTEM CHECKLIST	
	Check compressor for proper operation.
	Check dryers for proper operation.
	Verify pressure reducing valves (PRV) are working.
	Check that separators are not clogged.
	Check that filters are clean.
	Check that supply lines are not leaking.

Chapter 6
Diagnostic Tools

This chapter describes diagnostic tools commonly used in energy audits, including thermal imaging, vibration analysis, ultrasonic testing, data loggers, energy management systems, hand held meters, and digital cameras.

Thermal Imaging

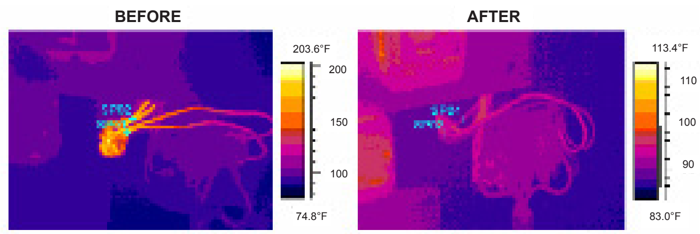


Infrared thermography (IRT), thermal imaging, or thermographic imaging, is a type of infrared imaging science. Thermographic cameras detect radiation in the infrared range of the electromagnetic spectrum and produce images of that radiation, called thermograms. Thermography makes it possible to see the amount of radiation emitted by an object as temperature variations. IRT is a predictive technology. Because IRT is a non-contact technique, it is especially attractive for identifying hot and cold spots in energized electrical equipment or accessing the building envelope.

A qualitative inspection is interested in relative temperature differences, hot and cold spots, and deviations from normal or expected temperature ranges. The thermographer can obtain highly accurate temperature differences (DT) between like components and materials. IRT can be used to identify deficiencies in facilities' electrical systems, such as building electrical distribution systems, panelboards and switchboards, bus connections, electrical connections, transformers, motor control centers, and switchgears. In mechanical systems, IRT can identify such items as high resistance electrical connections and hot bearings. IRT is useful to find blocked flow conditions in heat exchangers, condensers, transformer cooling radiators, pipes and steam traps. IRT can be used to verify the integrity of VAV terminal box registers. IRT is also a reliable technique for finding the moisture-induced temperature effects that characterize roof leaks and

In This Chapter:

- Thermal Imaging
- Vibration Analysis
- Airborne Ultrasound
- Data Loggers
- Energy Management System
- Hand Held Meters
- Digital Cameras
- Portable Power Meters

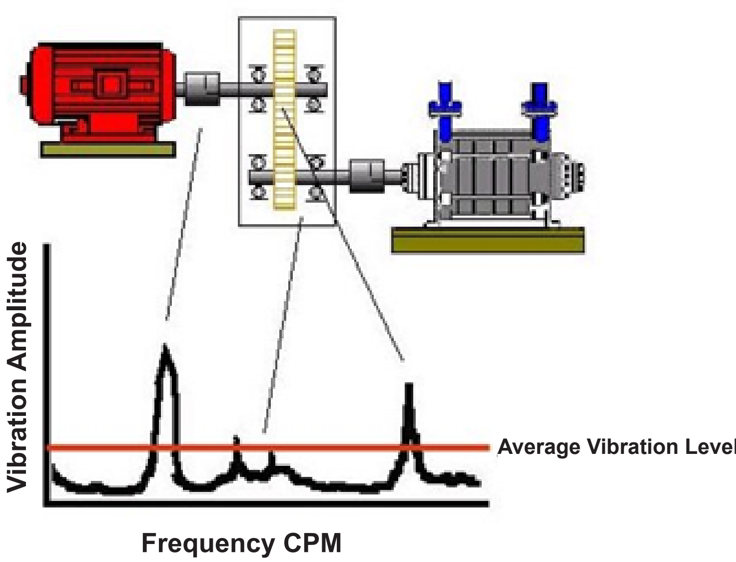


for determining the thermal efficiency of facility systems such as heat exchangers, water heaters, and building envelopes.

Infrared thermography is a quality control tool, to aid in detecting installation problems. A comprehensive thermographic inspection should be made on the interior and exterior. Interior thermographic scans will reveal infiltration of outside air into the building. An exterior scan will reveal exfiltration of conditioned air outside. A quality infrared camera with analyzing, temperature indicating, and IR image recording capability should be used. The energy audit team should scan its mechanical system, electrical connections, and building envelope as part of the energy assessment to look for facility deficiencies.

Vibration Analysis

Vibrations are an undesirable side effect of deteriorating equipment. Many times this is unnoticeable until the damage is done and it is too late. Vibrating equipment consumes more energy, created undesirable noise, and unexpected results. Vibration damage is usually subtle and begins very small. If untreated, the vibrations will increase exponentially and so will the damage. Unscheduled downtime may cost tens of thousands of dollars per hour. Fortunately, modern vibration analysis equipment predicts developing problems so that repair happens before disaster strikes. Plant maintenance personnel that use vibration analysis will have fewer emergencies, better functioning equipment, and less downtime. By using vibration analysis it is possible to distinguish component misalignment, defective bearings, and bent or loose parts. By using this technology it allows the user to evaluate the condition of equipment and avoid pending failures. Maintenance personnel can minimize unplanned downtime by scheduling needed repairs during normal maintenance shutdowns.



The most important step is to gather complete data. This means obtaining a full-spectrum vibration signature in the three axes - horizontal, vertical, and axial (X, Y, Z) - on both ends of the motor and the motor driven equipment. It is critical to takes readings in all three axes. Failing to get a reading on all three axes will give incomplete and deceptive misleading information resulting in faulty data and therefore incorrect remedies.

A thoroughly conducted vibration analysis will catch small problems before they become large problems and costly repairs. It is an excellent tool to use as part of a regular preventive maintenance (PM) program that includes predictive measures. It is also an excellent procedure for the audit team to use to assess an equipment condition

Airborne Ultrasound

Steam distribution systems, including converters and steam traps, as well as compressed air and vacuum systems, makes airborne ultrasound technology particularly attractive for improving the efficiency of its steam, compressor, pneumatic controls, and vacuum systems. The intent is to detect, tag, repair, and document costly and wasteful steam and air leaks.

The Department of Energy estimates that upward of 30 percent of all compressed air produced in the U.S. is lost to leaks. At many sites, compressed air leaks account for as much as 40-percent of the demand. Industry considers 5-percent to be reasonable.

One common source of steam leaks is steam traps. Properly operating steam traps release condensate from the steam line while preventing the loss of live steam. The only way to reduce steam loss from failed steam traps is to identify the failed traps and replace or repair them. Typical failure rates for failed open steam traps are between 15 and 30-percent of a facility's steam trap population. Traps failing in the open position allow steam to pass continuously, as long as the system is energized.

Energy savings from leak repairs and steam trap replacement can be substantial. See the Tables that follow. It has been estimated that the energy saved by the replacement of a single trap can pay for seven new traps. A facility with 1,000 steam traps that has just 15-percent of them failed faces estimated steam loss costs of $141,912 per year.

Each system should be surveyed using ultrasound during the energy assessment and again at least annually as part of the PM program to check on the repair of reported air and steam leaks and to detect new ones. Airborne ultrasound can also be used in other applications including as an aid to equipment lubrication and to help detect failing bearings. These do not save energy directly but identify leaks and traps that have failed and whether they failed in the open or closed position.

Steam Loss Chart					
Estimated $ in Steam Loss Per Year					
% Traps Failed Open	Number of Traps				
	250	500	1,000	5,000	10,000
15%	$35,478	$70,956	$141,912	$709,560	$1,419,120
20%	$47,304	$94,608	$189,216	$946,080	$1,892,160
25%	$59,130	$118,260	$236,520	$1,182,600	$2,365,200
30%	$70,956	$141,912	$283,824	$1,419,120	$2,838,240
35%	$82,782	$165,564	$331,128	$1,655,640	$3,311,280
40%	$94,608	$189,216	$378,432	$1,892,160	$3,784,320
45%	$106,434	$212,868	$425,736	$2,128,680	$4,257,360
50%	$118,260	$236,520	$473,040	$2,365,200	$4,730,400

STEAM LOSS THROUGH ORIFICES DISCHARGING TO ATMOSPHERE														
Orifice Diameter (inches)		Steam Flow, lb/hr, when steam gage pressure is:												
		2	5	10	15	25	50	75	100	125	150	200	250	300
		psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi
1/32	0.03125	0.40	0.47	0.58	0.70	0.94	1.53	2.12	2.72	3.31	3.90	5.08	6.27	7.45
1/16	0.0625	1.58	1.86	2.34	2.81	3.76	6.13	8.49	10.86	13.23	15.59	20.33	25.06	29.80
3/32	0.09375	3.36	4.20	5.26	6.33	8.46	13.78	19.11	24.44	29.76	35.09	45.74	56.39	67.04
1/8	0.125	6.32	7.46	9.35	11.25	15.03	24.50	33.97	43.44	52.91	62.38	81.32	100.25	119.19
5/32	0.15625	9.88	11.66	14.62	17.57	23.49	38.29	53.08	67.88	82.67	97.47	127.06	156.65	186.24
3/16	0.1875	14.23	16.78	21.05	25.31	33.83	55.13	76.44	97.74	119.05	140.35	182.96	225.57	268.18
7/32	0.21875	19.37	22.85	28.65	34.45	46.04	75.04	104.04	133.04	162.04	191.03	249.03	307.03	365.02
1/4	0.25	25.29	29.84	37.41	44.99	60.14	98.01	135.89	173.76	211.64	249.51	325.26	401.01	476.76
9/32	0.28125	32.01	37.77	47.35	56.94	76.11	124.05	171.99	219.92	267.86	315.79	411.66	507.53	603.40
3/16	0.3125	39.52	46.62	58.46	70.30	93.97	153.15	212.33	271.51	330.69	389.87	508.23	626.59	744.94
11/32	0.34375	47.82	56.42	70.74	85.06	113.70	185.31	256.92	328.52	400.13	471.74	614.95	758.17	901.38
3/8	0.375	56.91	67.14	84.18	101.23	135.31	220.53	305.75	390.97	476.19	561.41	731.84	902.28	1072.72
13/32	0.40625	66.79	78.79	98.80	118.80	158.81	258.82	358.85	458.85	558.86	658.87	858.90	1058.9	1258.96
7/16	0.4375	77.46	91.38	114.58	137.78	184.18	300.17	416.16	532.15	648.15	764.14	996.12	1228.1	1460.09
15/32	0.46875	88.93	104.90	131.54	158.17	211.43	344.58	477.74	610.89	744.04	877.20	1143.5	1409.8	1676.12
1/2	0.5	101.18	119.36	149.65	179.96	240.56	392.06	543.56	695.06	846.56	998.06	1301.0	1604.0	1907.06

Data Loggers

Data loggers used in energy auditing are electronic devices that can record information over duration of time. They are generally small, discrete devices that contain a digital processor, batteries, internal storage, and various types of sensors. The data loggers applicable to building systems are ones that can record information on a multi-hour cycle. Upon activation, data loggers are typically deployed and left unattended to measure and record information for the duration of the monitoring period. This allows for a comprehensive, accurate picture of the environmental conditions being monitored, such as air temperature, relative humidity, light levels, barometric pressure, on/off cycling, etc. Once the data loggers have recorded deployed for the desired time frame, they can be collected and the data and be analyzed by using a computer as an interface. Most data loggers have a very easy data connection port that utilizes software supplied with them on almost any computer. The software will take the data and provide the user with the measured variable vs. time graph.

An example application is a given facility may be experiencing high humidity levels but when measured at any one given point the humidity appears be in the normal range. A data logger would be the ideal device to detect when the humidity levels rise. Once it was activated inside the troublesome space, it would monitor humidity on a continuous basis. Once it is collected and analyzed it would provide the user with detailed data and well graph. There are countless uses that a data logger can be used as a facility is surveyed. Not only does it provide trend data rather than just a few sample points, it gives precise data over a long duration and provides an easy to analyze visual representation.

Energy Management System

An energy management system (EMS) is a computer system comprised of sensors, operators, processors, and a front-end user interface that controls and monitors electrical and mechanical building systems. Such systems provide automated control and monitoring of the heating, ventilation lighting and other needs of a building or group of buildings such as university campuses, office buildings or factories. Most of these energy management systems are capable of providing facilities for the reading of electricity, gas and water meters.

By having building systems monitored from a central location it enables the operator to be able to receive alerts and foresee future problems when a failure or troublesome condition occurs. Also, the data obtained from these can then be used to produce a trend analysis and annual consumption forecasts. From these trends energy saving strategies can be developed. Advanced control strategies of energy savings that can be obtained using these systems are time scheduling, optimum start and stop, night set-back, and peak demand limiting. The auditor will be able to use the EMS to diagnose current building system problems as well as tailor specific energy savings strategies that utilize the full capability of the given EMS.

Hand Held Meters

Digital Multimeter

An electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter may include features such as the ability to measure voltage, current and resistance. A multimeter is a hand-held device useful for basic fault finding and field service work or a bench instrument which can measure to a very high degree of accuracy. Digital multimeters can be used to troubleshoot electrical problems in a wide array of industrial and household devices such as batteries, motor controls, appliances, power supplies, and wiring systems. These meters typically will have a Liquid Crystal Display (LCD) for reading what was measured, and offers exceptional reliability, accuracy, and speed when it comes to measure electrical properties to trouble shoot or diagnosis. They also demonstrate magnificent speed when it comes to performance.

Clamp-on Amp Meter

A clamp-on amp meter is an electrical device having two jaws that open to allow clamping around an electrical conductor. This allows the electrical current in the conductor to be measured, without having to make physical contact with it, or to disconnect it for insertion through the probe. These meters make excellent tools for determining the amperage drawn by a piece of equipment. The measurement then can be used to compare to the manufactures' specification to ensure proper equipment function.

Anemometer

An anemometer is an electronic and mechanical device that is used for reading air speed. As air passes through the vanes, the speed is shown on the LCD screen. Because of its low weight structure, the ease of handling and measuring at remote places is greatly increased. Not only may anemometers now be comfortable in size, but they are also very reliable devices, which helps an auditor to obtain a very exact airflow reading. For building systems they are very useful to give a quick measurement of airflow from supply registers, fume hoods, and return grilles.

Airflow Capture Hoods

When buildings are initially designed, all supply registers and return grilles are designated a specific air flow measured in cubic feet per minute. That amount of air is designed to be delivered or returned to the air distribution system based on space size and use. After a building is in use for a few years it is common that the air distribution system becomes unbalanced. Airflow capture hoods enable an auditor to measure air volume and verify air flow distribution by placing the device over a diffuser or grille. The resulting measurements then can be compared to design specifications. If the CFM deviate from the requirements set forth by the clients needs, a recommendation can be made such as rebalancing, VFDs, EMS modifications, etc.

Digital Cameras

One of the handiest tools an auditor can carry is a simple point and shoot digital camera. The camera can be obtained with a high resolution at a relatively low price. Not only will the camera help clearly illustrate important points, document equipment specs/condition, and copy design drawings, they can refresh the auditor's mind when writing the report with items such as what piece of equipment was where and where problems were found. It will bring the auditor's mind back to the facility he or she surveyed. A camera with sufficient zoom and resolution can also be used to read details that are not easily seen by our eyes.

Portable Power Meters

Portable power meters measure voltage and current thousands of times per second. The minimum voltage display shows the line quality and voltage dips. Minimum current and minimum watts can be used to monitor variances in appliances that run continuously. Portable power meters measure true RMS power (including power factor). True RMS power is what utilities charge for, which can be different than a simple voltage and current measurement (or apparent power). The duty cycle display shows the percent of time a load is above a preset threshold level. For instance, this threshold can be set to 100 watts and with a refrigerator the duty cycle display will show the percent of time that the compressor is running. A high reading may indicate a bad motor or low freon.

Conclusion

Federal legislation and executive orders direct Federal Agencies to better manage their energy use, reduce the carbon footprint, and use cost-effective alternative fuels and renewable energy resources. Federal Agencies have mandates, a significant opportunity, and the desire to help reduce the nation's energy use and dependence on imported fuels.

There are a variety of energy audit types, from simple – a relatively quick building walk-through to identify readily observable problem areas and energy wasters – to complex – a comprehensive analysis of potential building and system improvements that is detailed enough to support documentation and justification for major capital improvements. A myriad of organization priorities and economics will determine which energy audit is performed, but it is important to realize that a facility, even a newer one, can benefit from *any* level of energy audit.

Many of the energy audit techniques, tools, and checklists discussed in this guidebook should already be familiar to a well-run facilities maintenance management organization, and adoption of the techniques and tests described herein can have cost and manpower savings well beyond the energy audit itself.

Appendices

List of Appendices

This page left blank intentionally

Appendix A, Sample Survey Form

ENERGY, DEMAND MANAGEMENT, AUDIT SURVEY				
Facility/Installation Name:				
Address:				
Facility Manager:			Phone:	
			Email:	
Energy Manager:			Phone:	
			Email:	

General Facility/Installation Data
Please provide requested data for conditioned areas (areas that are heated and/or cooled) only.

1.	Number of buildings in this facility/installation:	
2.	Range of net conditioned area of buildings in this facility/installation:	
3.	Range of number of floors of buildings in this facility/installation:	
4.	Range of age of buildings in this facility/installation:	
5.	Predominant uses of buildings in this facility/installation:	
6.	Average daily number of occupants in buildings in this facility/installation	

7. Identify individual buildings that together consume about 80% of your total facility/installation energy:

Building Name	Building ID	Approx. SF	Approx. % Energy Use

8. What are the most common complaints that generate trouble calls?

9. Have any of the buildings in the facility/installation ever been formally commissioned? If so, when? Provide a copy of the commissioning report if available.

10. Are you seeking LEED certification? If so, at what level?

11. When was the last time the buildings' HVAC was tested, adjusted, and balanced (TAB)?

12. How do you characterize the buildings' comfort levels?

ENERGY, DEMAND MANAGEMENT, AUDIT SURVEY				
13.	How do you characterize the buildings' lighting levels?			
14.	How do you characterize the buildings' noise levels?			
15.	How many elevators and escalators are on site?			
16.	What is the approximate number of chilled and standard vending machines on site?			
17.	Who/what organization provides facilities maintenance? (In house or contracted?)			
18.	What percentage of facilities maintenance work is: (should add up to 100%)			
	Proactive?		Preventive?	
	Predictive?		Reactive?	
19.	Do you have up-to-date drawings of the buildings' layout, mechanical, and electrical systems that can be made available at the start of the site visit?			

METERING INFORMATION				
1.	How many separate electric utility meters serve the facility/installation?			
		How many are "smart" meters?		
		How many are standard meters?		
2.	How many separate gas meters serve the facility/installation?			
3.	Is steam/HTHW generated at a central plant? GSA?			
4.	How do you characterize the buildings' noise levels?			
5.	Please provide contact information for the utilities that serve your facility/installation:			
		Electricity	Natural Gas	Fuel Oil
	Supplier Name:			
	Contact:			
	Phone:			
	Fax:			
	Email:			

<table>
<tr><th colspan="9">ENERGY MANAGEMENT SYSTEMS CAPABILITY AND OPERATION</th></tr>
<tr><td>1.</td><td colspan="6">Does the facility/installation have an Energy Management and Control System (EMCS)? [If you have an outside contractor that provides maintenance services to your facility's/installation's EMCS, that contractor may be able to provide assistance in completing this survey.]</td><td colspan="2"></td></tr>
<tr><td>2.</td><td colspan="6">When was the system installed?</td><td colspan="2"></td></tr>
<tr><td>3.</td><td colspan="6">Is the EMCS centralized (operated from one central location regardless of the number of different systems or buildings it controls)?</td><td colspan="2"></td></tr>
<tr><td rowspan="2">4.</td><td colspan="8">What type of control systems interface with the EMCS in the facility/installation?</td></tr>
<tr><td>Pneumatic</td><td></td><td>Electric</td><td></td><td colspan="2">Direct Digital Control</td><td colspan="2"></td></tr>
<tr><td rowspan="2">5.</td><td colspan="8">What is the make of the EMCS?</td></tr>
<tr><td colspan="4">Manufacturer:</td><td colspan="4">Model No.:</td></tr>
<tr><td>6.</td><td colspan="6">How many points are monitored and controlled by the EMCS?
(Points refers to inputs and outputs to the EMCS - signals coming into the EMCS
from sensors in the facility and signals going out from the EMCS to units it controls.)</td><td colspan="2"></td></tr>
<tr><td rowspan="5">7.</td><td colspan="8">What systems does the EMCS control?</td></tr>
<tr><td>Chillers</td><td></td><td>Boilers</td><td></td><td colspan="3">Unitary Air Conditioners</td><td></td></tr>
<tr><td>Air Handling Units</td><td></td><td>Lighting</td><td></td><td colspan="3">Variable Speed Drives</td><td></td></tr>
<tr><td>Service Hot Water</td><td></td><td>Fan Coil Units</td><td></td><td colspan="3"></td><td></td></tr>
<tr><td colspan="8">Other (Describe):</td></tr>
<tr><td rowspan="11">8.</td><td colspan="8">Check off the functions that your facility's EMCS can and currently does perform:</td></tr>
<tr><td></td><td colspan="4">Does the EMCS currently have the capability to perform this function?</td><td colspan="3">If it has the capability, does it currently perform this function in the facility?</td></tr>
<tr><td>On/Off Control</td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>Optimized Start/Stop</td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>Load Shedding</td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>Chiller Optimization</td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>Boiler Optimization</td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>Duty Cycling</td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>Demand Limiting</td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>Chilled Water Reset</td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>Hot Water Reset</td><td colspan="4"></td><td colspan="3"></td></tr>
</table>

ENERGY MANAGEMENT SYSTEMS CAPABILITY AND OPERATION						
9.	What reports are generated by the EMCS?					
	Energy Consumption and Demand Information			Chiller and Boiler Profiles		
	Trending Reports			Alarms		
10.	Identify the non-critical load types that are shed by the EMCS for control purposes:					
	HVAC		Lighting		Domestic Hot Water	
	Other:					
11.	Do you have a written plan for demand control or load shedding that identifies loads (and their priorities) that are to be shed during peak period?					
12.	Does the EMCS perform load shedding automatically?					
	Yes		No		Possibly	
13.	Does your facility use an outside contractor to provide maintenance and service to the EMCS? Yes: ______ No:______ *(If yes, provide contact information below.)*					
	Name of contractor/representative:					
	Phone:			Email:		

EMERGENCY GENERATOR (BACK-UP) OPERATION		
1.	Are there emergency generators serving the facility/installation? If so, what is their capacity?	
2.	Are the emergency generators used to control peak demand?	
3.	Are the emergency generators started automatically for demand control?	

ENERGY CONSERVATION MEASURES IMPLEMENTED				
1.	Have any of the following energy conservation measures been implemented at the facility/ installation within the last five years?			
	Lighting and Control Upgrade		Chiller Replacement and/or Chiller Optimiza-tion	
	Motor Retrofit		Variable Speed Drive Upgrades	
	HVAC Controls Retrofit		Cooling Tower Energy Use Optimization	
	Ice Storage			
	Other:			
2.	Have any renewable energy measures been implemented (such as photovoltaics, wind, ground source heat pumps, fuel cells, etc.)? *(If so, provide details below.)*			
3.	Have there been any energy or utility savings studies or reports completed for the facility/ installation within the past 10 years? *(If so, provide a copy at the start of the site visit.)* Which recommendations have been adopted? *(Provide details below.)*			

ANNUAL ENERGY CONSUMPTION AND COST					
Please complete for your building(s) the following table on annual energy consumption and cost for all applicable energy sources. *(Previous 24 months; identify period e.g., 1/08-1/10.)*					
	Electricity kWh	Natural Gas Therms	Fuel Oil Gallons	Water Gallons	Other
Annual Consumption					
Annual Cost $					
Peak Demand KW					
Other Energy Source					

This page left blank intentionally

Appendix B, Glossary of Terms

Atm	Atmosphere
BAS	Building Automation System
BTU	British Thermal Unit
CFL	Compact Fluorescent Lamp
ECM	Energy Conservation Measure
ECO	Energy Conservation Opportunity
EMCS	Energy Management and Control Systems
EMS	Energy Management System
HMI	Human Machine Interface
HVAC	Heating, Ventilating and Air Conditioning
IRR	Internal Rate of Return
IRT	Infrared Thermography
K	Temperature Measurement 0 Celsius = 273.15 Kelvin
LEED	Leadership in Energy and Environmental Design
lm/W	Lumens per Watt
Lumen	Power of Light as Perceived by the Human Eye
NPV	Net Present Value
Pa	Pascal
PC	Personal Computer
PM	Preventive Maintenance
Psi	Pound-force per Square Inch
RE	Renewable Energy
ROI	Return On Investment
SCADA	Supervisory Control And Data Acquisition
SPP	Simple Payback Period
Synergy	Benefits Resulting from Combining Multiple Groups, People or Processes
TAB	Testing, Adjusting and Balancing
Therm	100,000 BTU
WCM	Water Conservation Measure
WCO	Water Conservation Opportunity
ZEB	Zero Energy Building

This page left blank intentionally

APPENDIX C, CALCULATIONS AND FORMULAS

LEGEND	
kWh	Kilowatt Hour
MCF	1,000 Cubic Feet
CCF	100 Cubic Feet
CF	1 Cubic Foot
Btu	British Thermal Unit
Btu/hr	BTU/hour
kBtu (Mbtu)	1,000 BTUs
MMBtu	1,000,000 BTUs
CM	Cubic Meter
CC	Cubic Centimeter
CY	Cubic Yard
GPM	Gallons Per Minute
LS	Liters Per Second
CFM	Cubic Feet Per Minute
CMS	Cubic Meters Per Second
PSI	Pounds Per Square Inch
KG/SC	Kilograms Per Square Centimeter
KG/SM	Kilograms Per Square Meter
kPa	Kilopascal
HP	Horsepower
J/S	Joules Per Second
AC	Air Conditioning

Lighting		
From	**To**	**Multiply By**
FT Candles	Lumens/SF	1
FT Candle	LUX	10.764
Volume		
From	**To**	**Multiply By**
CF	CM	0.02832
CF	CI	1,728
CF	CY	0.037
CM	CC	1,000,000
Temperature		
From	**To**	**Multiply By**
Celsius	Fahrenheit	(Cx9/5)+32
Fahrenheit	Celsius	(F-32)x5/9
Volume Flow Rate		
From	**To**	**Multiply By**
LS	GPM	15.85
LS	CFM	2.119
CMS	CFM	2,199
Pressure		
From	**To**	**Multiply By**
Bar	PSI	14.504
KG/SC	PSI	14.22
KG/SM	PSI	0.000142
kPa	PSI	0.145

Fuel Oil		
From	**To**	**Multiply By**
Gal. #2 Fuel Oil	Btu	139,000
Gal. #2 Fuel Oil	kBtu (MBtu)	139
Gal. #2 Fuel Oil	MMBtu	0.139
Gal. #4 Fuel Oil	Btu	145,000
Gal. #4 Fuel Oil	kBtu (MBtu)	145
Gal. #4 Fuel Oil	MMBtu	0.145
Gal. #6 Fuel Oil	Btu	150,000
Gal. #6 Fuel Oil	kBtu (MBtu)	150
Gal. #6 Fuel Oil	MMBtu	0.15
Steam		
From	**To**	**Multiply By**
lb	Btu	1,000
lb	kBtu (MBtu)	0.1
lb	MMBtu	0.001
Power		
From	**To**	**Multiply By**
HP	Watt	746
HP	J/S	746
Ethanol		
From	**To**	**Multiply By**
Gallon	Btu	76,000
Gallon	kBtu (MBtu)	76
Gallon	MMBtu	0.076

Electricity		
From	**To**	**Multiply By**
kWh	Btu	3,412
kWh	kBtu (MBtu)	3.412
kWh	MMBtu	0.003412
Natural Gas		
From	**To**	**Multiply By**
Therm	Btu	100,000
Therm	kBtu (MBtu)	100
Therm	MMBtu	0.1
MCF	Therms	10
CCF	Therms	1
CF	Therms	0.01
Propane		
From	**To**	**Multiply By**
Gallon	Btu	91,600
Gallon	kBtu (MBtu)	91.6
Gallon	MMBtu	0.0916
CF	Btu	2,500
CF	kBtu (MBtu)	2.5
CF	MMBtu	0.0025
Other		
From	**To**	**Multiply By**
Ton of AC	Btu/hr	12,000
Gallon	kBtu (MBtu)	76

Length		
1 centimeter (cm)	=	10 millimeters (mm)
1 inch	=	2.54 cm
1 foot	=	0.3048 meters (m)
1 foot	=	12 inches
1 yard	=	3 feet
1 meter (m)	=	100,000 cm
1 meter (m)	about	3.280839895 feet
1 furlong	=	660 feet
1 kilometer (km)	=	1,000 m
1 kilometer (km)	about	0.62137119 miles
1 mile	=	5,280 feet
1 mile	=	1.609344 km
1 nautical mile	=	1.852 km

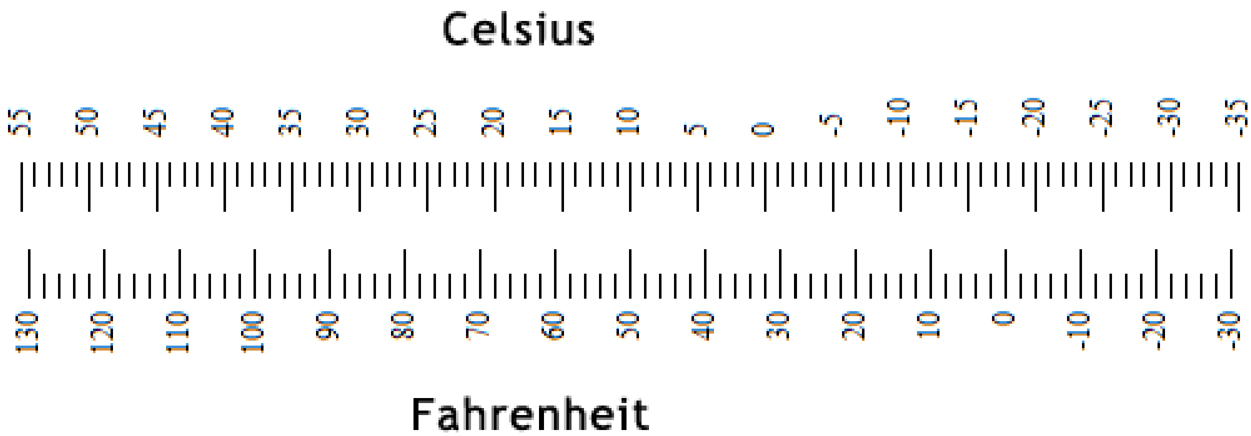
Area		
1 square foot	=	144 square inches
1 square foot	=	929.0304 centimeters (cm)
1 square yard	=	9 square feet
1 square meter	about	10.7639104 square feet
1 acre	=	43,560 square feet
1 hectare	=	10,000 square meters
1 hectare	about	2.4710538 acres
1 square kilometer	=	100 hectares
1 square mile	about	2.58998811 square kilometers
1 square mile	=	640 acres

Volume		
1 US tablespoon	=	3 US teaspoons
1 US fluid ounce	about	29.57353 milliliters (ml)
1 US cup	=	16 US tablespoons
1 US cup	=	8 US fluid ounces
1 US pint	=	2 US cups
1 US pint	=	16 US fluid ounces
1 liter (l)	about	33.8140227 US fluid ounces
1 liter (l)	=	1,000 ml
1 US quart	=	2 US pints
1 US gallon	=	4 US quarts
1 US gallon	=	3.78541178 l

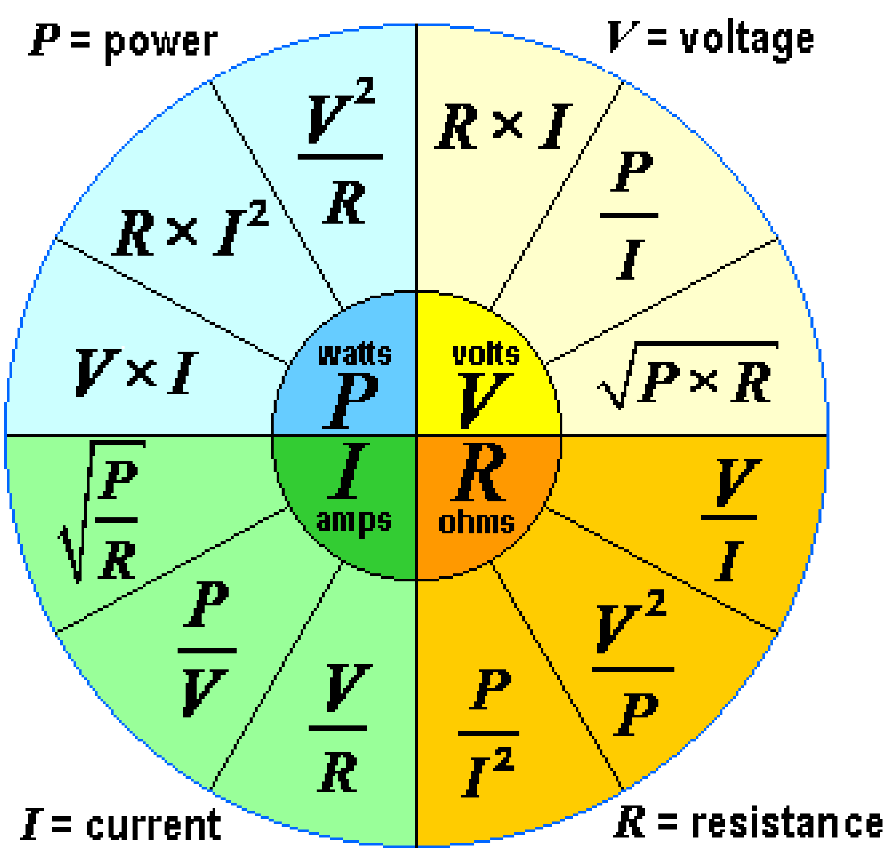
Weight		
1 milligram (mg)	=	0.001 grams (g)
1 gram (g)	=	0.001 kilogram (kg)
1 gram (g)	about	0.035273962 ounces
1 ounce	=	28.34952312 g
1 ounce	=	0.0625 pounds (lb)
1 pound (lb)	=	16 ounces
1 pound (lb)	=	0.45359237 kg
1 kilogram (kg)	=	1,000 g
1 kilogram (kg)	about	35.273962 ounces
1 kilogram (kg)	about	2.20462262 lb
1 stone	=	14 lb
1 short ton	=	2,000 lb
1 metric ton	=	1,000 kg

Pressure Units						
	Pascal (Pa)	**Bar (bar)**	**technical (at)**	**atmosphere (atm)**	**torr**	**pound-force (psi)**
1 Pa	≡ 1 NM/m^2	10^{-5}	1.0197×10^{-5}	9.8692×10^{-6}	7.5006×10^{-3}	145.04×10^{-6}
1 bar	100,000	≡ 10^6 dyn/cm^2	1.0197	0.98692	750.06	14.5037744
1 at	98,066.5	0.980665	≡ 1kgf/cm^2	0.96784	735.56	14.223
1 atm	101,325	1.01325	1.0332	≡ 1 atm	760	14.696
1 torr	133.322	1.3332×10^{-3}	1.3595×10^{-3}	1.3158×10^{-3}	≡ 1 Torr; ≈ 1	19.337×10^{-3}
1 psi	6.894×10^3	68.948×10^{-3}	70.307×10^{-3}	68.046×10^{-3}	51.715	≡ 1 lbf/in^2

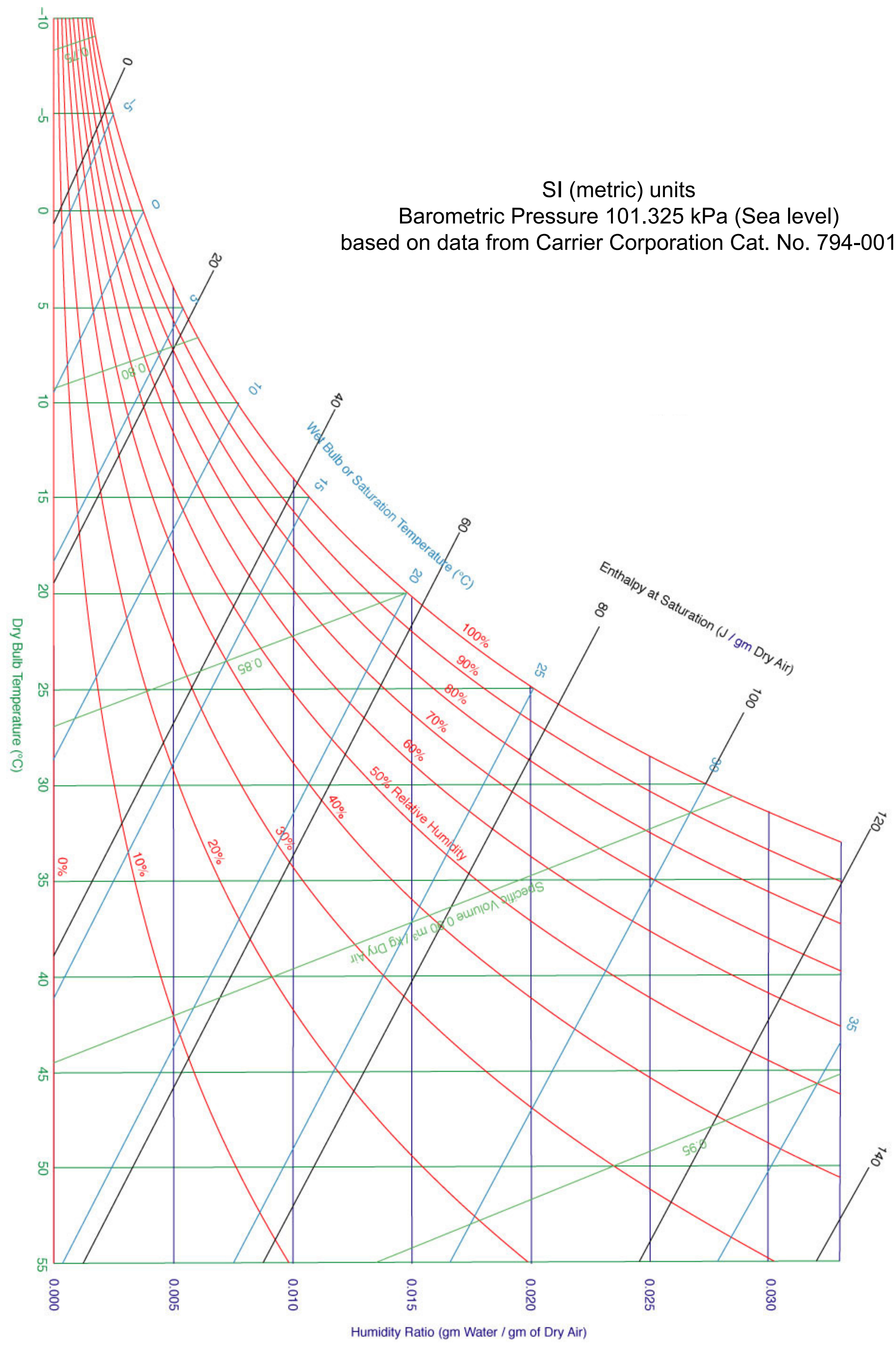
Temperature



Power Wheel



Appendix D, Psychrometric Chart



Relative Humidity in Celsius

Relation between dew point, air temperature, and relative humidity.

Relative Humidity (%)

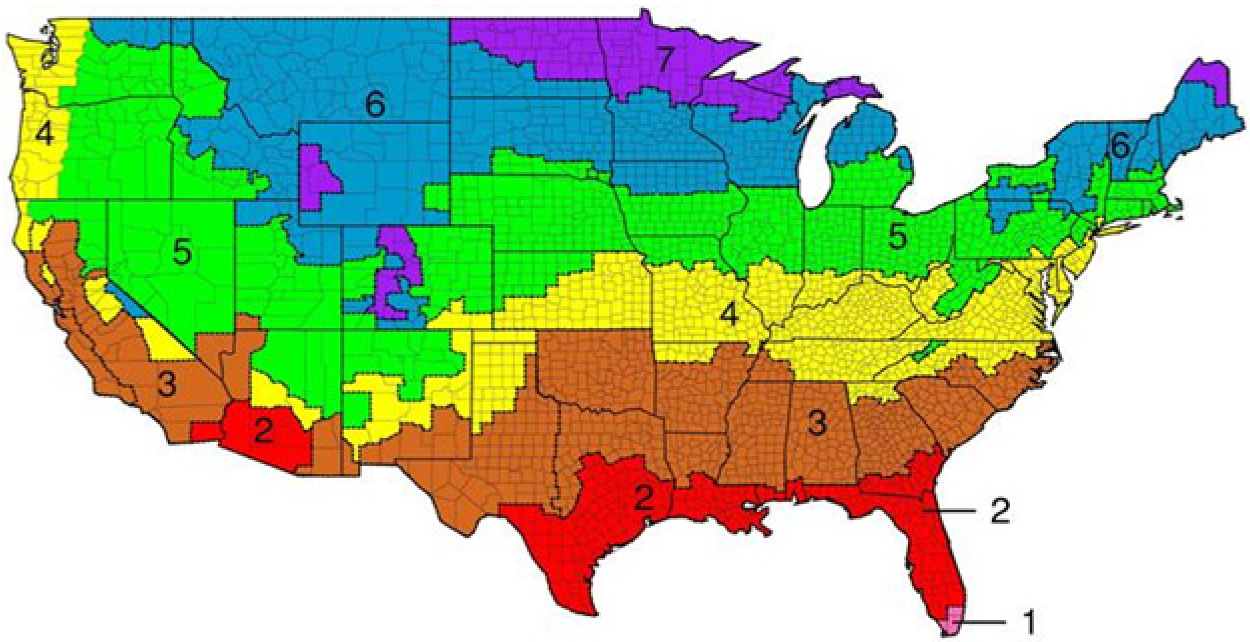
Air Temperature °F	40	45	50	55	60	65	70	75	80	85	90	95	100
110	136												
108	130	137											
106	124	130	137										
104	119	124	131	137									
102	114	119	124	130	137								
100	109	114	118	124	129	136							
98	105	109	113	117	123	128	134						
96	101	104	108	112	116	121	126	132					
94	97	100	103	106	110	114	119	124	129	135			
92	94	96	99	101	105	108	112	116	121	126	131		
90	91	93	95	97	100	103	106	109	113	117	122	127	132
88	88	89	91	93	95	98	100	103	106	110	113	117	121
86	85	87	88	89	91	93	95	97	100	102	105	108	112
84	83	84	85	86	88	89	90	92	94	96	98	100	103
82	81	82	83	84	84	85	86	88	89	90	91	93	95
80	80	80	81	81	82	82	83	84	84	85	86	86	87

Appendix E, Insulating Values

INSULATING VALUES		
Typical per-inch R values for material		
Material	**Value per inch (minimum)**	**Value per inch (maximum)**
Brick	R-0.2 (0.3)	
Wood chips and other loose-fill wood products	R-1 (0.18)	
Snow	R-1 (0.18)	
Hardwood (most)	R-0.71 (0.12)	
Softwood (most)	R-1.41 (0.25)	
Straw bale	R-1.45 (0.26)	
Wood panels, such as sheathing	R-2.5 (0.44)	
Vermiculite	R-2.13 (0.38)	R-2.4 (0.42)
Perlite loose-fill	R-2.7 (0.48)	
Rock and slag wool loose-fill	R-2.5 (0.44)	R-3.7 (0.65)
Rock and slag wool batts	R-3 (0.52)	R-3.85 (0.68)
Fiberglass loose-fill	R-2.5 (0.44)	R-3.7 (0.65)
Fiberglass rigid panel	R-2.5 (0.44)	
Fiberglass batts	R-3.1 (0.55)	R-4.3 (0.76)
High-density fiberglass batts	R-3.6 (0.63)	R-5 (0.88)
Cementitious foam	R-2 (0.35)	R-3.9 (0.69)
Cellulose loose-fill	R-3 (0.52)	R-3.8 (0.67)
Cellulose wet-spray	R-3 (0.52)	R-3.8 (0.67)
Cotton batts (Blue Jean Insulation)	R-3.7 (0.65)	
Icynene spray	R-3.6 (0.63)	
Icynene loose-fill (pour fill)	R-4 (0.70)	
Urea-formaldehyde foam	R-4 (0.70)	R-4.6 (0.81)
Urea-formaldehyde panels	R-5 (0.88)	R-6 (1.06)
Polyethylene foam	R-3 (0.52)	
Phenolic spray foam	R-4.8 (0.85)	R-7 (1.23)
Phenolic rigid panel	R-4 (0.70)	R-5 (0.88)
Molded expanded polystyrene (EPS) low-density	R-3.7 (0.65)	
Molded expanded polystyrene (EPS) high-density	R-4 (0.70)	
Extruded expended polystyrene (XPS) low-density	R-3.6 (0.63)	R-4.7 (0.82)
Extruded expended polystyrene (XPS) high-density	R-5 (0.88)	R-5.4 (0.95)
Open-cell polyurethane spray foam	R-3.6 (0.63)	
Closed-cell polyurethane spray foam	R-5.5 (0.97)	R-6.5 (1.14)

INSULATING VALUES		
Typical per-inch R values for material		
Material	**Value per inch (minimum)**	**Value per inch (maximum)**
Polyurethane rigid panel (Pentan eexpanded) initial	R-6.8 (1.20)	
Polyurethane rigid panel (Pentane expanded) aged 5-10 years	R-5.5 (0.97)	
Polyurethane rigid panel (CFC/HCFC expanded) initial	R-7 (1.23)	R-8 (1.41)
Polyurethane rigid panel (CFC/HCFC expanded) aged 5-10 years	R-6.25 (1.10)	
Polyisocyanurate spray foam	R-4.3 (0.76)	R-8.3 (1.46)
Foil-faced polyisocyanurate rigid panel (Pentane expanded) initial	R-6.8 (1.20)	
Foil-faced polyisocyanurate rigid panel (Pentane expanded) aged 5-10 years	R-5.5 (0.97)	
Silica aerogel	R-10 (1.76)	
Vacuum insulated panel	R-30 (5.28)	R-50 (8.80)
Cardboard	R-3 (0.52)	R-4 (0.70)
Thinsulate clothing insulation	R-5.75 (1.01)	
Urea foam	R-5.25	
Poured concrete	R-0.08	
Glass	R-0.24	
Polystyrene board	R-5.00	
Air-entrained concrete	R-3.90	
Vermiculite	R-2.13	
Home Foam (Registered Trademark)	R-3.9	
R-values given in imperial units of square feet F h/Btu and in parenthesis the SI unit (square meters K/W). Typical values are approximations, based on the average of available results. Ristinen, Robert A. and Jack J. Kraushaar. Energy and the Environment. 2nd ed. Hoboken, NJ: John Wiley & Sons, Inc., 2006.		

Appendix F, U.S. Insulation Zones



All of Alaska is in Zone 7 except for the following boroughs in Zone 8: Bethel, Southeast Fairbanks, Nome, Northwest Arctic, Fairbanks N. Star, Yukon-Koyukuk, Dellingham, Wade Hampton, North Slope.

Zone 1 includes: Hawaii, Guam, Puerto Rico, U.S. Virgin Islands.

Zone	Add Insulation to Attic		Floor
	Uninsulated Attic	Existing 3-4 Inches of Insulation	
1	R30 to R49	R25 to R30	R13
2	R30 to R60	R25 to R38	R13 to R19
3	R30 to R60	R25 to R38	R19 to R25
4	R38 to R60	R38	R25 to R30
5 to 8	R49 to R60	R38 to R49	R25 to R30

							Wall		
Zone	Gas	Heat Pump	Fuel Oil	Electric Furnace	Attic	Cathedral Ceiling	Cavity	Insulation Sheathing	Floor
1	✓	✓	✓	✓	R30 to R49	R22 to R38	R13 to R15	None	R13
2	✓	✓	✓		R30 to R60	R22 to R38	R13 to R15	None	R13
2				✓	R30 to R60	R22 to R38	R13 to R15	None	R19-R25
3	✓	✓	✓		R30 to R60	R22 to R38	R13 to R15	None	R25
3				✓	R30 to R60	R22 to R38	R13 to R15	R2.5 to 55	R25
4	✓	✓	✓		R38 to R60	R30 to R38	R13 to R15	R2.5 to R6	R25-R30
4				✓	R38 to R60	R30 to R38	R13 to R15	R5 to R6	R25-R30
5	✓	✓	✓		R38 to R60	R30 to R38	R13 to R15	R2.5 to R6	R25-R30
5				✓	R38 to R60	R30 to R60	R13 to R21	R5 to R6	R25-R30
6	✓	✓	✓	✓	R49 to R60	R30 to R60	R13 to R21	R5 to R6	R25-R30
7	✓	✓	✓	✓	R49 to R60	R30 to R60	R13 to R21	R5 to R6	R25-R30
8	✓	✓	✓	✓	R49 to R60	R30 to R60	R13 to R21	R5 to R6	R25-R30

Appendix G, Window Insulating Factors

Window A
single glazing
clear
U = 1.25
SHGC = 0.72
VT = 0.71

Window B
double glazing
clear
U = 0.60
SHGC = 0.60
VT = 0.63

Window C
double glazing
bronze tint
U = 0.60
SHGC = 0.42
VT = 0.38

Window D
double glazing
reflective coating
U = 0.54
SHGC = 0.17
VT = 0.10

Window E
double glazing
low-E, bronze tint
U = 0.49
SHGC = 0.39
VT = 0.36

Window F
double glazing
spec. selective low-E tint
U = 0.46
SHGC = 0.27
VT = 0.43

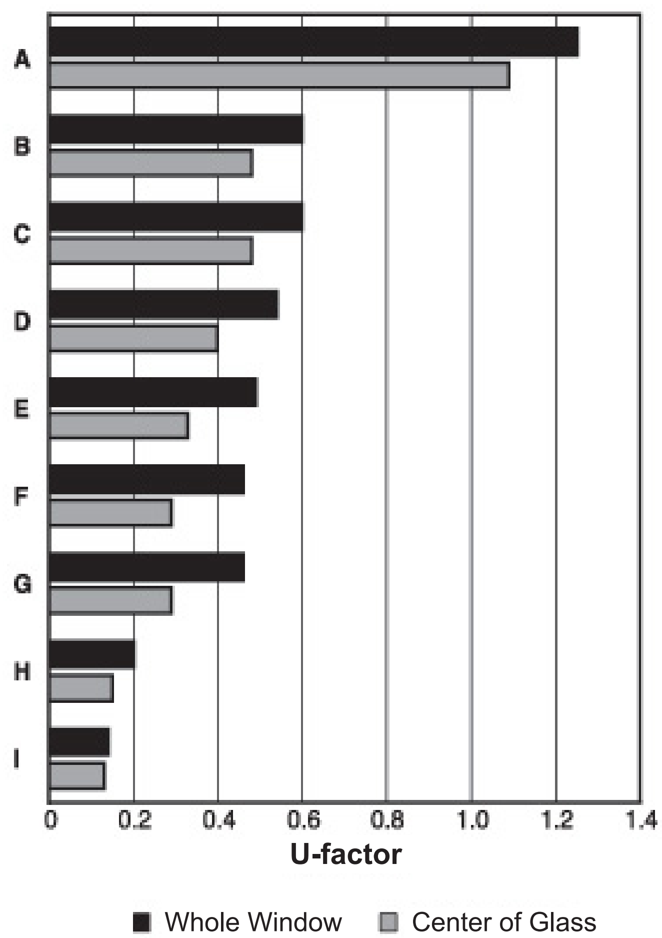
Window G
double glazing
spec. selective low-E clear
U = 0.46
SHGC = 0.34
VT = 0.57

Window H
triple glazing
1 low-E layer, clear
U = 0.20
SHGC = 0.22
VT = 0.37

Window I
quadruple glazing
2 low-E layers, clear
U = 0.14
SHGC = 0.20
VT = 0.34

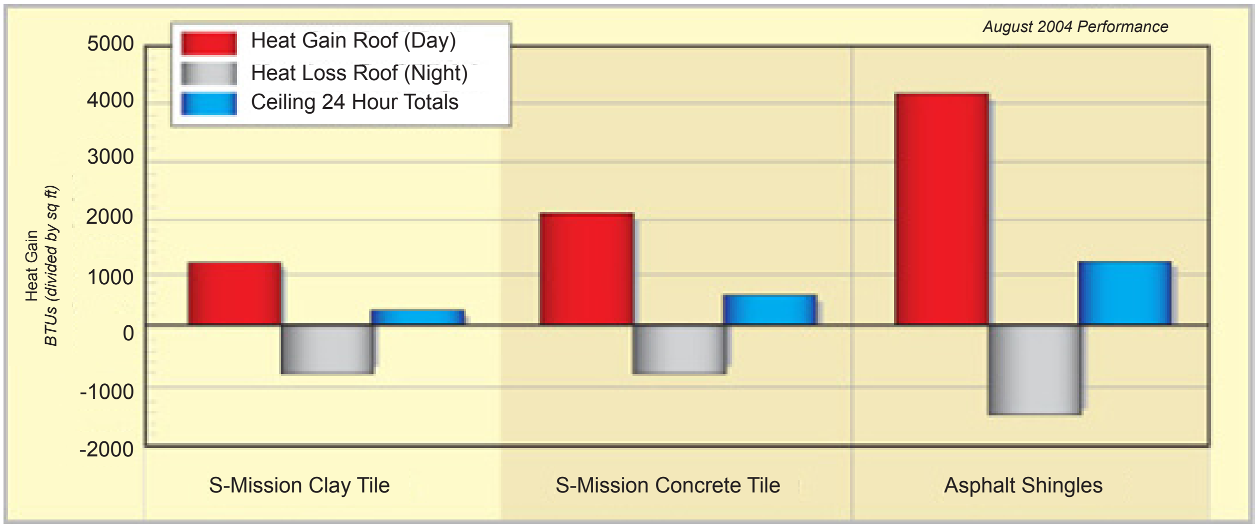
U = U-factor in Btu/hr-sf-˚F
SHGC = solar heat gain coefficient
VT = visible transmittance
All window properties are for the whole window. Windows A-G have aluminum frames (all but A are thermally broken). Windows H and I have insulated frames.

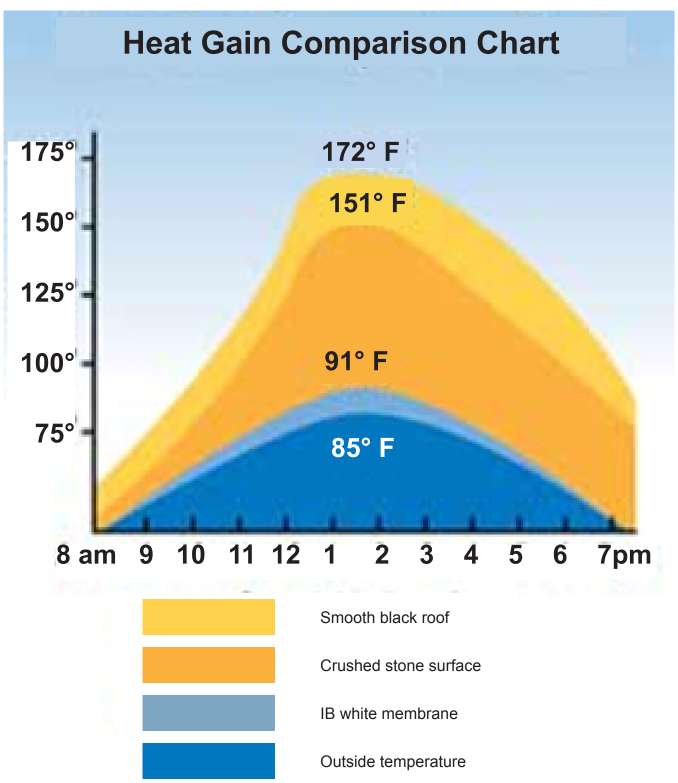
U-factors for typical glazings and windows



This page left blank intentionally

Appendix H, Cool Roofs





DOE Cool Roof Calculator
Energy Savings Estimate (Cooling, $/sq ft/yr)

	Chicago	Los Angeles	Miami
White Modified Bitumen	0.022 (0.002)	0.018 (0.006)	0.067 (0.001)
Black Modified Bitumen	0.009	0.007	0.029
White PVC	0.022 (0.002)	0.018 (0.006)	0.067 (0.001)
White TPO	0.022 (0.002)	0.018 (0.006)	0.067 (0.001)

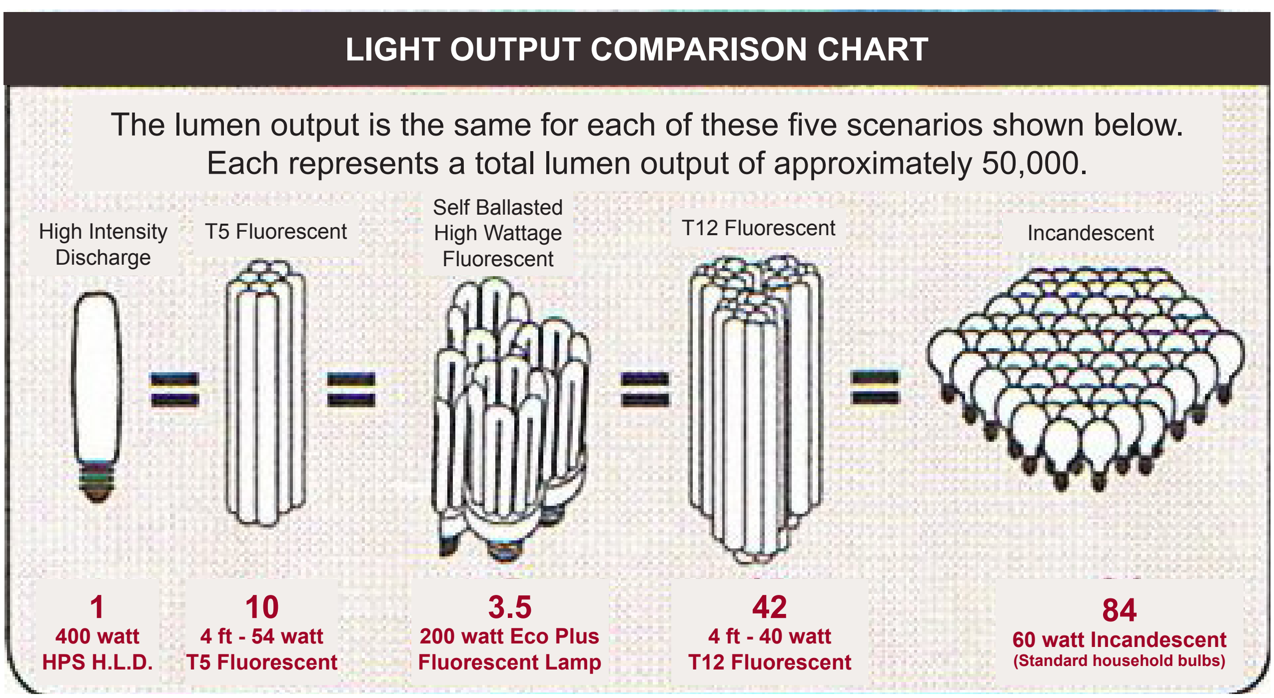
Input data: High R-value, reflectance and emittance (white, avg. black), cooling and heating efficiency, energy cost, electric heat Los Angeles and Miami, gas heat Chicago.

This page left blank intentionally

Appendix I, Lighting

Recommended Illumination Levels

Task		IESNA Illuminance Category	Recommended Footcandles
Drafting	High contrast (ink, soft lead)	E	50-75-100
	Low contrast (hard lead)	F	100-150-200
Inspection	Simple	D	20-30-50
	Moderate	E	50-75-100
	Difficult	F	100-150-200
Machine Work	Medium, grinding, etc.	E	50-75-100
Materials Handling	Picking, packing, wrapping, labeling	D	20-30-50
Other	Lobby, corridor, waiting area	C	10-15-20
	Toilets, rest rooms	C	10-15-20
	Teller stations, ticket counters	E	50-75-100
Reading	General	D	20-30-50
	Soft pencil (#2), pen, good copies, keyboards, > 8 pt. type	D	20-30-50
	Hard pencil (#3), phone books, poor copies, < 8 pt. type	E	50-75-100
Schools	Science laboratories	E	50-75-100
Storage	Inactive	B	5-7.5-10
	Active, large items	C	10-15-20
	Active, small items	D	20-30-50



Type	Overall Luminous Efficiency	Overall Luminous Efficacy (lm/W)
40 W tungsten incandescent	1.9%	12.6
60 W tungsten incandescent	2.1%	4.5
100 W tungsten incandescent	2.6%	17.5
Glass halogen	2.3%	16
Quartz halogen	3.5%	24
High-temperature incandescent	5.1%	35
Ideal black-body radiator at 4,000 K	7.0%	47.5
Ideal black-body radiator at 7,000 K	14%	95

Fluorescent Tube Diameter Designation Comparison						
Tube diameter designations		Tube diameter measurements			Extra	
Imperial Based	Metric Based	Inches		Millimeters	Socket	Notes
T2	N/A	approx 2/8		7		Sylvania's Fluorescent Miniature (FM) tubes only
T4	N/A	4/8		12	G5 bipin	Slim lamps; power ratings and lengths not standardized between manufacturers
T5	T16	5/8		15.875	G5 bipin	Original 4-13 W range from 1950s or earlier; two newer ranges high efficiency (HE) 14-35 W, and high output (HO) 24-80 W introduced in the 1990s
T8	T26	8/8	1	25.4	G13 bipin / single pin / recessed double contact	From the 1930s; more common since the 1980s
T9	T29	9/8	1-1/8	28.575		Circular fluorescent tubes only
T12	T38	12/8	1-1/2	38.1	G13 bipin / single pin / recessed double contact	From the 1930s, not as efficient as new lamps
PG17	N/A	17/8	2-1/8	53.975	Recessed double contact	General Electric's Power Groove tubes only

Appendix J, Specific Heat Capacities

Note that especially high values, as for paraffin, water and ammonia, result from calculating specific heats in terms of moles of molecules. If specific heat is expressed per mole of atoms for these substances, few constant-volume values exceed the theoretical Dulong-Petit limit of 25 J/K/mole = 3 R per mole of atoms.

Table of specific heat capacities at 25 degrees C unless otherwise noted substance	Phase	C_p J/(g*K)	$C_{p,m}$ J/(mol*K)	$C_{v,m}$ J/(mol*K)	Volumetric heat capacity J/(cm³*K)
Air (sea level, dry, 0 C)	Gas	1.0035	29.07	20.7643	0.001297
Air (typical room conditions	Gas	1.012	29.19	20.85	
Aluminum	Solid	0.897	24.2		2.422
Ammonia	Liquid	4.700	80.08		3.263
Animal (and human) tissue	Mixed	3.5	--		3.7
Antimony	Solid	0.207	25.2		1.386
Argon	Gas	0.5203	20.7862	12.4717	
Arsenic	Solid	0.328	24.6		1.878
Beryllium	Solid	1.82	16.4		3.367
Bismuth	Solid	0.123	25.7		1.20
Copper	Solid	0.385	24.47		3.45
Carbon dioxide	Gas	0.839	36,94	28.46	
Diamond	Solid	0.5091	6.115		1.782
Ethanol	Liquid	2.44	112		1.925
Gasoline	Liquid	2.22	228		1.64
Glass	Solid	0.84			
Gold	Solid	0.129	25.42		2.492
Granite	Solid	0.790			2.17
Graphite	Solid	0.710	8.53		1.534
Helium	Gas	5.1932	20.7862	12.4717	
Hydrogen	Gas	14.30	28.82		
Hydrogen sulfide	Gas	1.015	34.60		
Iron	Solid	0.450	25.1		3.537
Lead	Solid	0.127	26.4		1.44
Lithium	Solid	3.58	24.8		1.912
Magnesium	Solid	1.02	24.9		1.773
Mercury	Liquid	0.1395	27.98		1.888
Methane 275K	Gas	2.191			

Table of specific heat capacities at 25 degrees C unless otherwise noted substance	Phase	C_p J/(g*K)	$C_{p,m}$ J/(mol*K)	$C_{v,m}$ J/(mol*K)	Volumetric heat capacity J/(cm^3*K)
Nitrogen	Gas	1.040	29.12	20.8	
Neon	Gas	1.0301	20.7862	12.4717	
Oxygen	Gas	0.918	29.38		
Paraffin wax	Solid	2.5	900		2.325
Polyethylene (rotomolding grade)	Solid	2.3027			
Polyethylene (rotomolding grade)	Liquid	2.9308			
Silica (fused)	Solid	0.703	42.2		1.547
Silver	Solid	0.233	24.9		2.44
Tungsten	Solid	0.134	24.8		2.58
Uranium	Solid	0.116	27.7		2.216
Water at 100 C (steam)	Gas	2.080	37.47	28.03	
Water at 25 C	Liquid	4.1813	75.327	74.53	4.186
Water at -10 C (ice)	Solid	2.05	38.09		1.938
Zinc	Solid	0.387	25.2		2.76

Substance	Phase	C_p J/(g*K)
Asphalt	Solid	0.920
Brick	Solid	0.840
Concrete	Solid	0.880
Glass, silica	Solid	0.840
Glass, crown	Solid	0.670
Glass, flint	Solid	0.503
Glass, pyrex	Solid	0.753
Granite	Solid	0.790
Gypsum	Solid	1.090
Marble, mica	Solid	0.880
Sand	Solid	0.835
Soil	Solid	0.800
Wood	Solid	0.420

Appendix K, Affinity Laws

The affinity laws are used in hydraulics and HVAC to express the relationship between several variables involved in pump or fan performance (such as head, volumetric flow rate, shaft speed, and power). They apply to pumps, fans, and hydraulic turbines. In these various rotary implements, the Affinity Laws apply both to centrifugal and axial flows.

The affinity laws are useful as they allow one to predict the head discharge characteristic of a pump or fan from a known characteristic measured at a different speed or impeller diameter. The only requirement is that the two pumps or fans are dynamically similar, that is the ratios of the fluid forced are the same.

Law 1. With impeller diameter (D) held constant:
Law 1a. Flow is proportional to shaft speed:

$$\frac{Q_1}{Q_2} = \left(\frac{N_1}{N_2}\right)$$

Law 1b. Pressure or Head is proportional to the square of shaft speed:

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$$

Law 1c. Power is proportional to the cube of shaft speed:

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3$$

Law 2. With shaft speed (N) held constant:
Law 2a. Flow is proportional to the impeller diameter raised to the power of three:

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^3$$

Law 2b. Pressure or Head is proportional to the square of impeller diameter:

$$\frac{H_1}{H_2} = \left(\frac{D_1}{D_2}\right)^2$$

Law 2c. Power is proportional to impeller diameter raised to the power of five: $$\frac{P_1}{P_2} = \left(\frac{D_1}{D_2}\right)^5$$

Where

- Q is the volumetric flow rate (e.g. CFM, GPM or L/s),
- D is the impeller diameter (e.g. in or mm),
- N is the shaft rotational speed (e.g. rpm),
- H is the pressure or head developed by the fan/pump (e.g. ft or m), and
- P is the shaft power (e.g. W).

These laws assume that the pump/fan efficiency remains constant. In other words, $\eta_1 = \eta_2$. When applied to pumps the laws work well for constant diameter variable speed case (Law 1) but are less accurate for constant speed variable impeller diameter case (Law 2).

Appendix L, Thermodynamics Laws

Zeroth Law of Thermodynamics

When two objects or systems are in thermal equilibrium with each other, the heat energy flowing from the first object to the second is the same as that flowing from the second object to the first. Hence they are at the same temperature. This law is equivalent to the basic rule in algebra that if a=b and b=c, then a=c.

First Law of Thermodynamics

The first law of thermodynamics is the law of conservation of energy applied to work and heat engines. A heat engine or any other system will have some energy input. This law states that the energy input for a system equals the total energy output. Simply stated, you can't get more out than you put in.

Second Law of Thermodynamics and Entropy

The second law of thermodynamics states that the efficiency of any system must always be less than 100%. There will always be some waste heat. The second law also deals with the theory of entropy. Entropy is the measure of the randomness or disorder of a system. A more random or disordered system will have a higher entropy. Heat is a random form of energy, so adding heat energy to a system will increase its entropy. The second law states that any process will generate some waste heat energy. This heat energy is random and increases the entropy (or disorder) of a system. Therefore an different form of the second law of thermodynamics states that any process in a closed system will increase the entropy of the closed system. If a system is not closed, any process will increase the total entropy of the universe. The entropy of the universe can never decrease.

Third Law of Thermodynamics

Absolute zero (0 Kelvins (about -273 C)) is the lowest possible temperature. It is the temperature of no random molecular motion. The third law of thermodynamics states that it is not possible to reach a temperature of absolute zero.

This page left blank intentionally

Sustainable Sites

Choosing a building's site and managing that site during construction are important considerations for a project's sustainability. The Sustainable Sites category discourages development on previously undeveloped land; minimizes a building's impact on ecosystems and waterways; encourages regionally appropriate landscaping; rewards smart transportation choices; controls storm water runoff; and reduces erosion, light pollution, heat island effect and construction-related pollution.

Water Efficiency

Buildings are major users of our potable water supply. The goal of the Water Efficiency credit category is to encourage smarter use of water, inside and out. Water reduction is typically achieved through more efficient appliances, fixtures and fittings inside and water-wise landscaping outside.

Energy & Atmosphere

According to the U.S. Department of Energy, buildings use 39% of the energy and 74% of the electricity produced each year in the United States. The Energy & Atmosphere category encourages a wide variety of energy strategies: commissioning; energy use monitoring; efficient design and construction; efficient appliances, systems and lighting; the use of renewable and clean sources of energy, generated on-site or off-site; and other innovative strategies.

Materials & Resources

During both the construction and operations phases, buildings generate a lot of waste and use a lot of materials and resources. This credit category encourages the selection of sustainably grown, harvested, produced and transported products and materials. It promotes the reduction of waste as well as reuse and recycling, and it takes into account the reduction of waste at a product's source.

Indoor Environmental Quality

The U.S. Environmental Protection Agency estimates that Americans spend about 90% of their day indoors, where the air quality can be significantly worse than outside. The Indoor Environmental Quality credit category promotes strategies that can improve indoor air as well as providing access to natural daylight and views and improving acoustics.

Locations & Linkages

The LEED for Homes rating system recognizes that much of a home's impact on the environment comes from where it is located and how it fits into its community. The Locations & Linkages credits encourage homes being built away from environmentally sensitive places and instead being built in infill, previously developed and other preferable sites. It rewards homes that are built near already-existing infrastructure, community resources and transit, and it encourages access to open space for walking, physical activity and time spent outdoors.

Awareness & Education

The LEED for Homes rating system acknowledges that a green home is only truly green if the people who live in it use the green features to maximum effect. The Awareness & Education credits encourage home builders and real estate professionals to provide homeowners, tenants and building managers with the education and tools they need to understand what makes their home green and how to make the most of those features.

Innovation in Design

The Innovation in Design credit category provides bonus points for projects that use new and innovative technologies and strategies to improve a building's performance well beyond what is required by other LEED credits or in green building considerations that are not specifically addressed elsewhere in LEED. This credit category also rewards projects for including a LEED Accredited Professional on the team to ensure a holistic, integrated approach to the design and construction phase.

Regional Priority

USGBC's regional councils, chapters and affiliates have identified the environmental concerns that are locally most important for every region of the country, and six LEED credits that address those local priorities were selected for each region. A project that earns a regional priority credit will earn one bonus point in addition to any points awarded for that credit. Up to four extra points can be earned in this way.

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

For more information contact:
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov