In this chapter, we will discuss efficiency, potential problems, and suggested upgrades to central heating and cooling systems.

5 HEATING AND COOLING

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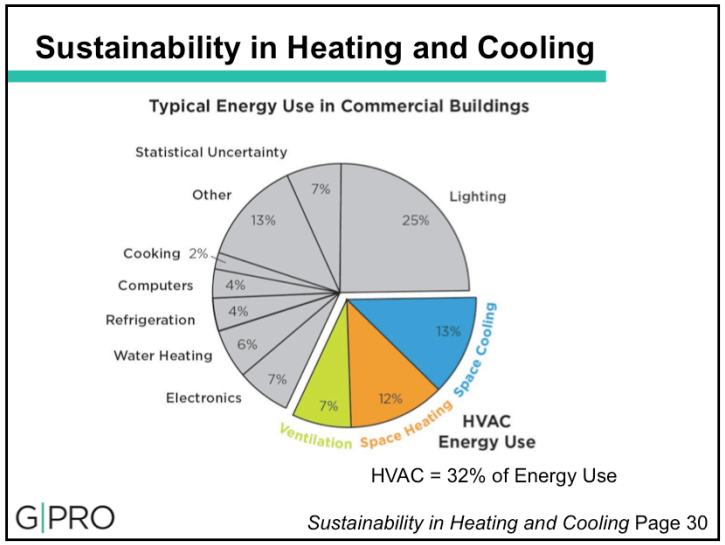

As you can see, heating and cooling systems can take up as much as 25% of energy use in a commercial building. HVAC as a whole takes up 32%, slightly less than 1/3!

When heating and cooling systems aren't properly operated and maintained, large amounts of energy are needlessly wasted.

You can take simple steps to reduce energy losses in heating and cooling systems by integrating maintenance checks into your daily operating procedures.

Combustion Efficiency

Combustion efficiency measures how much energy is lost "up the stack" by a piece of fuel-burning equipment.

$$\text{EFFICIENCY} = \frac{\text{USEFUL OUTPUT}}{\text{PAID INPUT}}$$

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Most buildings large enough to have operations staff will have a central heating system and possibly a central cooling system.

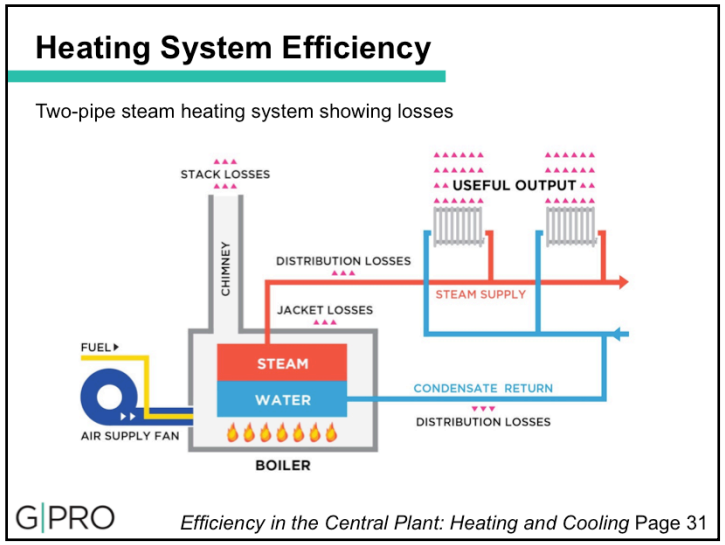
Combustion efficiency measures how much energy is lost "up the stack" by a piece of fuel-burning equipment. Any energy that goes up the stack will not be available for useful heat in the building.

For example, if 20% of the input fuel's energy is lost in the flue gas outlet, the equipment has 80% combustion efficiency.

This number will always be higher than overall thermal efficiency, which also includes jacket losses from the outside surface of the equipment, an energy lost when the unit cycles on and off.

Combustion efficiency is measured with a relatively easy-to-use handheld instrument that analyzes flue gases while the boiler is firing.

Contractors should perform this test annually, before the heating season begins and should get "before and after" printouts from the efficiency test to demonstrate that boiler combustion efficiency has improved as a result of the work performed.



Although you will never achieve 100% efficiency, there are things you can do to maximize the amount of heat extracted from the fuel.

For a given quantity of each fuel, there is a precise amount of air that will provide just the right amount of oxygen.

If there is not enough air, there will be unburned fuel in the exhaust.

A little bit of excess air is needed to ensure complete combustion, but beyond that, efficiency drops off as the amount of oxygen in the exhaust increases and the temperature of the flame drops. (You are heating air that then passes up the stack, so that energy didn't help.)

If the flame is starved for oxygen it will produce carbon monoxide, an obvious safety concern. To compensate for this, some building engineers provide more air than is needed, resulting in inefficient combustion. This balance between safety and efficiency can be addressed by using combustion test instruments to make any necessary system adjustments (such as ensuring adequate air supply) or to identify any other needed maintenance. If you have taken a more advanced course in boiler operations and maintenance, you will be able to take these steps yourself, but even if an outside contractor does the work, it is best if

Combustion Efficiency Ranges

Device	Typical Combustion Efficiency Range
Home Fireplace	10 - 30 %
Space Heater	50 - 80 %
Commercial Gas Boiler	70 - 82 %
Residential Gas Boiler with Atmospheric Burner "Low Efficiency"	70 - 82 %
Oil Burner Heating System	73 - 85 %
Induced Draft Furnace "Medium Efficiency"	74 - 80 %
Boiler with Gas Burner	75 - 85 %
Condensing Furnace (Gas & Oil) "High Efficiency"	85 - 93 %

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As you can see, the range of combustion efficiencies for different devices varies widely. You can't influence the intrinsic design of your unit (you're stuck until it's replaced), but you can influence its actual efficiency through good operations and maintenance.

To be at the higher end, boiler testing and maintenance are key.

Periodic Maintenance for Combustion Efficiency

- Perform combustion-efficiency tests
- Perform probe tests and stack gas analysis
- Ensure make-up fans and filters are in good condition
- Establish proper waterside maintenance, including low water cut-off, mud leg blow-downs, and water treatment

Additional resource: www.heatinghelp.com + all courses and books by Dan Holohan

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Periodic maintenance steps for maintaining combustion efficiency include:

- Perform full combustion-efficiency tests at least once a season.
- Perform probe tests and stack gas analysis frequently. Manually clean the fire tubes a minimum of once a year. Fouled boiler tubes inhibit heat transfer to the water and dramatically lower efficiency.
- Ensure that make-up fans for the boiler room operate properly and filters are inspected once a month. These fans use all outside air and require a more aggressive filter schedule than recirculated interior air. Ensure that all inlets are free from obstructions. Inadequate air supply leads to improper air-to-fuel ratio at the burner and causes incomplete combustion and energy loss.
- Conduct proper waterside maintenance, including low water cut-off, mud leg blow-downs, and water treatment.

Other Simple Tasks to Maintain Combustion Efficiency

- Log stack temperature
- Clean the burner
- Note flame color
- Clean oil burner nozzles
- Change filters and clean coils
- Replace fuel oil strainers and filters regularly
- Install automated dampers to reduce stack losses
- Reduce jacket losses by insulating boiler, pipes, and related equipment

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- Note and log stack temperature, as this is a good indicator of combustion efficiency loss. Permanently mount a stack thermometer for easier logging – if the temperature suddenly changes out of its normal range, the boiler probably needs maintenance.
- Clean the burner – if it is dirty, fuel and air will not be delivered in the right ratio.
- Pay attention to the color of the flame. For gas, it should be blue and steady (never orange). For oil, a fluctuating yellow flame is normal.
- Clean nozzles of oil burners a minimum of once a week to ensure proper atomization of the fuel.
- Change filters and clean coils per manufacturer's specifications.
- Check and replace fuel oil strainers and filters regularly.
- Reduce stack losses by installing an automated damper that is open only during combustion.
- Reduce jacket losses by insulating the boiler, pipes, and related equipment. An overheated boiler room is a sign of poor insulation.

Chillers

A chiller cools water for distribution throughout a building.

This chilled water supply may be used in:

- Air handling units (AHUs): distributes air to ducts
- Fan coil units: cools air directly

Chiller

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An air conditioner directly cools air for space comfort. Many larger buildings are equipped with central chillers, which make cool water for distribution throughout the building. This chilled water supply may be used in air handling units (AHUs), which cools air to be distributed in ducts. It may also be used directly in fan coil units installed in occupied spaces, which cool the room air directly.

Electrically driven compression chillers are very common in commercial buildings. Parts of an electric chiller system include a liquid refrigerant, an evaporator (which cools the water by putting its heat into the refrigerant), a condenser (which takes the heat out of the refrigerant so it's ready for its next cycle through the chiller), pipes, pumps, and some means to cool the condenser (either fans or a cooling tower).

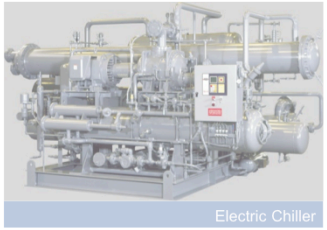
There are also absorption chillers, which use a heat source to create chilled water, but these are less common unless a source of low-cost heat is available.

In either type of chiller, supply water is cooled to temperatures around 44ºF and pumped through a chilled water circuit for use in cooling air before returning to the chiller for another cycle.

Chiller capacity is generally measured in "tons". One ton is 12,000 Btu per hour.

Determining Chiller Efficiency

- Determine kWh per ton of cooling and compare to the unit's design efficiency, or
- Monitor electric use and compare Cooling Degree Days (CDD).



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There is no simple efficiency test for chillers as there is with boilers.

One approach is to determine the kWh used per ton of cooling and compare to the unit's design efficiency. Newer chillers have built-in meters which will display this information. Older chillers may need to have separate meters installed.

Another way to test efficiency in chillers is to monitor energy input (electricity or heat) into the chiller and compare it to Cooling Degree Days (CDD).

An inexpensive meter dedicated to the chiller is a worthwhile addition to the system. If the chiller is kept clean and maintained properly, the efficiency will not stray far from specified values unless there is a malfunction. If the chiller starts to use more energy for the same number of CDDs, it is a sign that you should look for a problem.

Note: The national average reference point is 65ºF but your building could be different. An engineer can help you determine the "balance point", the temperature at which your building starts to need cooling, which is used to calculate CDD.

Determining Chiller Efficiency

Ways to determine and maintain chiller efficiency include:

- Monitor energy consumption vs. CDD
- Determine how much energy *should* be required to generate a ton of cooling compared to actual use figures, in kWh/ton
- Track supply and return water temperatures
- Use manuals to determine different efficiencies by load
- Use a BMS to set chiller schedules
- Monitor and log operating parameters to spot leaks and unusual behavior

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As with heating, proper operation and maintenance of the chiller plant is critical to efficient energy usage and occupant comfort. Although some of the following procedures may need to be performed by a professional HVAC technician, you can apply the general and specific tasks to monitor the efficiency of your unit.

Ways to determine and maintain chiller efficiency include:

- Monitor energy consumption vs. CDD
- Determine from equipment specifications how much energy should be required to generate a ton of cooling (electric chillers only) and compare with actual use figures, in kWh/ton-hour.
- Track and log supply and return water temperatures
- Use manuals to determine the difference efficiencies for full loads and part loads
- If available, use a Building Management System (BMS) or Energy Management System (EMS) to set chiller schedules. You may also be able to monitor energy input and chilled water output to develop an energy-use profile.
- Monitor and log operating parameters at least weekly to spot leaks and unusual behavior.

Maintaining Chiller Efficiency

Specific tasks you can do to maintain chiller efficiency:

- Keep water pump strainers clean
- Keep water properly chemically treated
- Ensure capacity-control devices are functioning
- Manually punch condenser tubes once a year
- Keep coils and fins clean of dust
- Check condenser water flow at cooling tower against specifications
- Check chilled water circulation whenever capacity complaints arise

Absorption Chiller

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Specific tasks you can perform to maintain chiller efficiency include:

- Keep all water pump strainers clean and the water properly chemically treated
- Ensure that all capacity-control devices are functioning properly. (A good indication that they are not is excessive cycling of the chiller)
- Manually punch condenser tubes once a year
- Keep coils and fins free of dust
- Check condenser water flow at cooling tower against specifications
- Check chilled water circulation whenever capacity complaints arise

Chillers: Schedules and Setbacks

Schedule HVAC systems and equipment properly:

- Set up schedules that take all work into account
- Use setbacks on the thermostat to let temperatures drift up when space is unoccupied
- Don't chill for peak loads on shoulder days: Allow chilled water temperature to drift up on days with lower peak temperature (another setback)

In commercial buildings, you can anticipate the peak load to be between 12 p.m. and 5 p.m.

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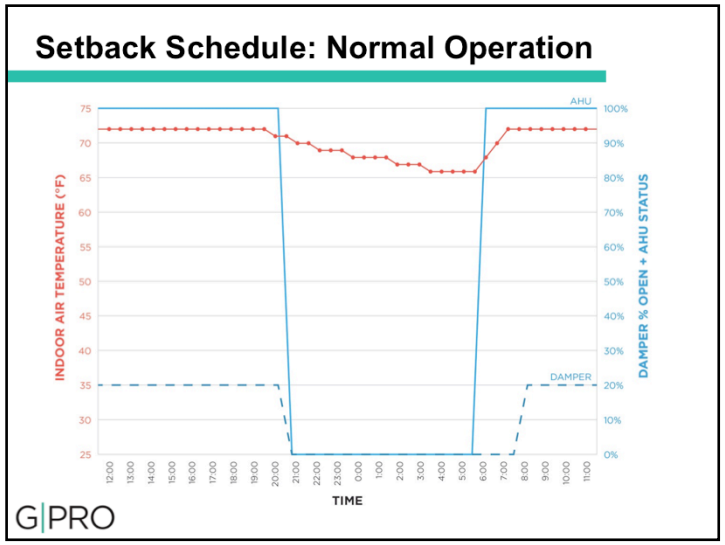
Some building operators simply turn on heating and cooling equipment and let it run, missing opportunities to reduce the amount of energy needed to run an efficient and comfortable building.

In commercial buildings, you can anticipate the peak load to be between 12 p.m. and 5 p.m. Therefore, you should set up your controls around those parameters.

Understanding the way energy is used and needed throughout the day helps you schedule HVAC systems and equipment properly.

Assess whether it is necessary to heat or cool your building 24 hours/day. If it is not necessary, use a programmable thermostat or BMS at night to set the temperature back when the building is unoccupied, rather than letting the boilers or chillers run all night.

If you have multiple chillers, they should be used at the right load and in the right order for maximal efficiency. An engineer can help set up the controls for your building.



Here is a system graph of an AHU in **heating** mode. Let's use it to talk about schedules and setbacks.

This AHU (air handling unit) graph depicts a properly operating system for an office building.

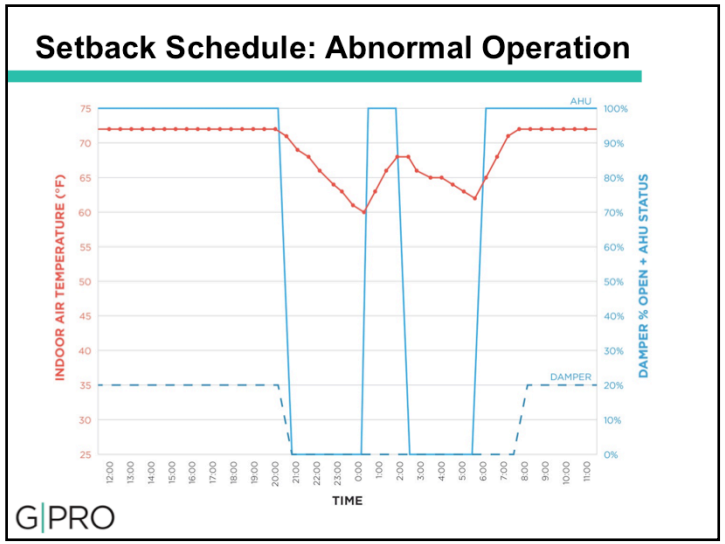
- The horizontal axis shows one full day, from Noon to Noon
- The left vertical axis shows the air temperature inside the building (in degrees Fahrenheit)
- The right vertical axis shows the operation of the AHU system and the actions of the outside air damper

As you can see, the AHU shuts down at 20:00 (8:00pm) with the outside air damper closing to 0% as occupancy ends.

The building temperature slowly drops overnight (while the building is unoccupied), until the AHU begins automatic warm-up mode at 6:00am. At that time, the temperature begins to increase back up from 66ºF to 72ºF.

The outside air damper opens to 20% at 8:00am when normal occupancy starts. Terminal units provide regular reheat as required, keeping the temperature constant and the system balanced until the next shutdown.

[Setback schedule from: www.betterbricks.com/DetailPage.aspx?Id=597]



This graph shows a similar system with abnormal operation.

Instead of the temperature gradually decreasing overnight, this figure shows that something is causing the building to cool off too rapidly between 20:00 (8:00pm) and 0:00 (midnight). This could be due to a failure in the building envelope's integrity or an exhaust fan operating when it shouldn't.

Because the building temperature drops so rapidly, the lower set point for the unoccupied period (60ºF) is reached in the middle of the night instead of at 6:00am.

As a result, the AHU comes on at midnight for about two hours to warm the unoccupied building back up to the upper limit of 68º, and the cool down process is forced to repeat.

Under correct operation, the AHU runs 16 hours per day (6am to 10pm). With the nighttime cycle added, it runs 18 hours per day – over a 10% increase in energy use for this one small issue!

[Ask students: How would you fix this problem?]

[Setback schedule from: www.betterbricks.com/DetailPage.aspx?Id=597]

Efficiency in Distribution

- Check for and repair all loose or missing insulation
- Make sure all ducts are properly sealed
- Make sure duct dampers and diffusers are open when they are supposed to be
- Calibrate controls to ensure they are operating correctly
- Use an infrared temperature gun to ensure steam traps are working properly



G|PRO *Efficiency in Distribution* Page 34

Whether the distribution medium is steam, hot water, chilled water, or air, the purpose of the system is to move heat or cool air to the points in the building where it is needed without losses along the way. Some common problems and solutions are:

- When hot or cold water or air moves through a pipe or duct, it will lose or gain heat quickly if insulation is inadequate. Check for and repair all loose or missing insulation.
- When uninsulated pipes and ducts pass through unconditioned spaces, 10-40% of the heat can be lost by the time it reaches the intended location. Make sure all pipes are properly insulated.
- Holes and gaps in ducts will leak hot air and cause substantial losses. This will cause the equipment to work harder to deliver conditioned air. Make sure all ducts are properly sealed.
- Make sure duct dampers and diffusers are open where and when they are supposed to be open and pneumatic controls are calibrated and operating correctly.
- Use an infrared temperature gun to ensure steam traps are working properly. There should be a substantial temperature difference between the piping on either side of the steam trap.

Efficiency in Distribution

A **Building Management System (BMS) or Energy Management System (EMS)** collects information from throughout the building, including HVAC, ventilation, fire safety, and sometimes even lighting and security systems.

It can use this data to control central systems like boilers and chillers, as well as fine-tune distribution in HVAC systems. Properly managed, this can substantially reduce waste.

It is important that building staff receive training in the proper use of these systems. (Untrained staff have been known to disconnect them, leading to inefficient operation.)

G|PRO *Efficiency in Distribution* Page 35

An energy management system (EMS) or **building management system** (BMS) is a computer system that collects data from throughout the building. It may gather information from HVAC, ventilation, fire safety, and sometimes even lighting and security systems. It can then use this information to control the building. Boilers and chillers, as well as HVAC distribution systems, can be managed with this method. For a BMS or EMS, it is especially important that building staff receive training in their proper use. Staff who have not been trained in the use of these systems have been known to disconnect them, ensuring inefficient operation.

Standard boiler controls such as a heat timer base the boiler firing time only on the outdoor temperature, resulting in substantial overheating much of the time.

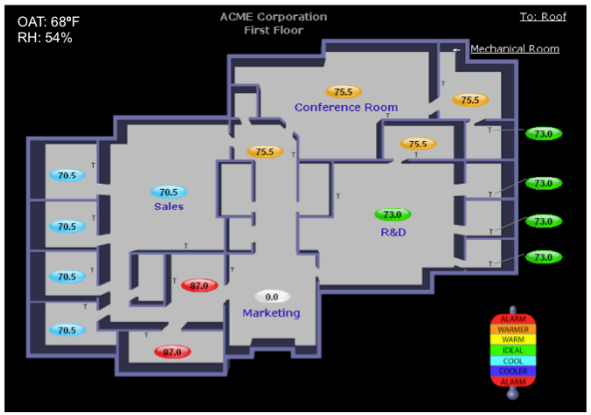
But an EMS/BMS will also read a set of internal temperatures and use them to determine boiler firing, lower overheating and substantially reduce waste. For example, the system could be controlled by the temperature in the apartment farthest from the boiler, or by the temperature of the system water returning to the boiler.

[For areas where Heat Timers are in use, explain that they were designed for the NYC market to meet legal obligations.

Heat Timer and Similar Controls:

- *Adjusts duration of hourly boiler firing in response to outside temperature*
- *Doesn't know if wind is blowing or sun is shining]*

Using a BMS or EMS



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In this snapshot from the BMS computer display (sometimes called the “front end” or “head end”), the operator can tell at a glance how an entire floor is performing in terms of temperature setpoints.

You can tell from the upper left hand corner that the Outside Air Temperature, OAT, is 68ºF. So the system is probably in cooling mode.

Rooms in green mean the current temperature matches the setpoint – 73ºF. A group of rooms in Sales are too cool, only 70.5ºF. They are all gathered together at the same temperature, probably because they share a VAV. Perhaps a damper is stuck open, allowing cold supply air to overcool the space. It should be investigated.

Another group of rooms near the conference room is too hot – 75.5ºF. Again, since there are several rooms they are probably all on the same VAV. These spaces are not getting enough cooling – maybe a VAV damper is stuck closed or a cooling coil is not getting enough flow.

Two rooms below the Sales area read 87.0ºF. Is a reheat coil turned on by accident? That is very hot.

And Marketing shows 0.0ºF. That is a sensor problem that needs to be fixed, as the room won’t be controllable by the BMS/EMS unless the temperature sensor is working properly.

Avoiding Overheating and Overcooling

Improperly sized or controlled equipment is most often the source of overheating or overcooling.

An oversized boiler may overheat the space or adequately heat the space but waste energy.

An oversized chiller can short cycle and never function as efficiently as it was rated.

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Efficiency in Distribution Page 35-36

Improperly sized or controlled equipment is most often the source of overheating or overcooling. An oversized boiler may overheat the space or adequately heat the space but waste energy when doing so.

An oversized chiller can short cycle and never function as efficiently as it was rated. Cooling systems are meant to pull humidity from the air, but if the system is too big, it will cool the space without removing enough humidity, leaving occupants uncomfortable, using more energy than is needed to do the job, and possibly creating a mold situation.

We'll discuss how to deal with overheating, first in the central plant and then in distribution. Overcooling can be addressed with some of these same principles.

Stop Overheating: Central Plant

Observation:

- Look for open windows in winter
- Is it building-wide overheating or poor balance in some areas?

Controls:

- The warmer it is outdoors, the less heat is needed
- "Reset" control lowers circulating water temperature as load falls

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Observe:

- Look for open windows in winter.
- Is it building-wide overheating or poor balance in some areas?

Controls:

- The warmer it is outdoors, the less heat is needed.
- “Reset" control lowers circulating water temperature as load falls.
- Advantages:
    - System operates on long cycles.
    - Lower temperatures allow more efficiency from condensing boilers.

Stop Overheating: Central Plant

Vari-Vac and similar systems:

- Lower steam temperature by maintaining a vacuum through pumping
- Allow boiler to fire continuously
- Require a two-pipe system
- Can use internal temperatures
- Require more maintenance than other systems, but are more cost effective

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Efficiency in Distribution Page 35

One common means of managing efficiency in steam distribution is a Vari-Vac system, a vacuum based system.

It consists of a modulating steam valve and a combination vacuum pump and condensate return pump.

The vacuum pump lowers the pressure throughout the steam system based on readings from an outside air sensor. This will also lower the temperature of the steam.

As the outside air temperature climbs, the temperature of the steam is reduced. Due to the vacuum condition created, steam rises very quickly at lower temperatures to the coils or radiators. The temperature of the steam can be varied to better reflect the load conditions.

A Vari-Vac allows steam systems to work over the same range of temperatures as a hydronic system and to go up to standard steam temperatures on very cold days.

Balancing Hydronic and Air Systems

TRVs
VAVs
Zoned EMS/BMS

- Good controls don't resolve poor balance
- Poor balance is caused by
  - Solar heat gain
  - Wind-driven infiltration
  - Resident idiosyncrasies
  - System "drift" over time
- Meeting the requirements of the coldest apartment or space leads to overheating in the rest of the building.

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Efficiency in Distribution Page 36

Proper balancing of steam, hydronic, and air systems is essential to avoid overheating and overcooling.

Initial set points and adjustments are normally performed by a licensed technician, taking into account the interaction between multiple supply sources, depending on the type of systems in use. However, conditions at the building are not always the same as they were when the technician balanced the system. And, the system will "drift" over time.

Following are descriptions of systems that allow for control at individual supply sources, and which require balancing across multiple units.

Balancing Hydronic and Air Systems

TRVs
VAVs
Zoned EMS/BMS

Thermostatic Radiator Valves (TRV)

- Individual, thermostatically driven valves on each radiator
- Work very well on two-pipe steam
- Work well on hydronic systems if plumbed correctly
- Work adequately on one-pipe steam if operated at 1.5 psi or less
- TRVs with wall-mounted sensors & dials work better

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Efficiency in Distribution Page 36

Thermostatic radiator valves provide individual temperature controls for each radiator. These have a remote bulb sensing element that should be placed at the floor level in front of the radiator.

The valve will have set-point numbers (usually 1 to 5) that will correspond to different temperature settings. The user or maintenance staff can choose a comfortable set point, and the TRV will open and close the steam to that radiator accordingly. TRVs work well on two-pipe steam systems and on hydronic systems that are plumbed correctly (so that shutting off one radiator doesn't shut off others). A TRV is available for one-pipe steam systems, but will work only if the system is operated at steam pressures below 1.5 psi. TRVs can improve efficiency and comfort, and their capital cost will be repaid in fuel savings. The placement of the sensing bulb is critical to ensure that they are not exposed to colder temperatures from outside wall drafts, which would lead to overheating.

Balancing Hydronic and Air Systems

TRVs
VAVs
Zoned EMS/BMS

Variable Air Volume (VAV) and similar controls

- In systems where air is heated or cooled and then blown into a space, the fan or duct can be controlled by a local thermostat.
- In systems with central fans and ducts, T-stats can be added to boxes to close off flow, but balance in the ductwork must be maintained, perhaps by variable frequency motors on the fans.
- Note: In PTACs (Packaged Terminal Air Conditioner), using only local air, control with a thermostat is simple!

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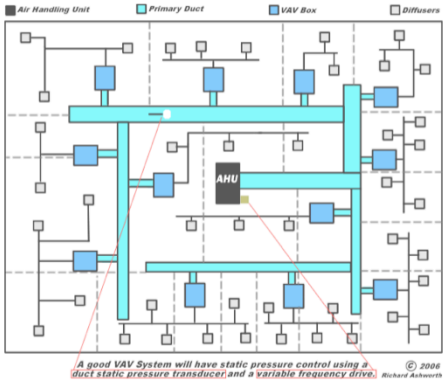
Variable air volume boxes are used to regulate temperature by regulating the flow of air to a space. They can be controlled by electric, pneumatic, or electronic thermostats to open and close a damper. More-efficient systems use variable frequency drives on the fans providing conditioned air. As an area's heating or cooling needs are satisfied, the VAV box closes down, causing the static pressure in the duct to go up. The variable frequency drive is controlled by static pressure and responds by slowing down. Working together, the VAV and variable frequency drive match the amount of air and energy required for the load. They are also configured with minimum air flow to allow for proper ventilating when there is no call for heating or cooling.

If you just have PTACs, control is simple – just have a thermostat regulate how the unit runs. They can even be put on occupancy sensors (common in the hotel industry, but gaining ground in commercial real estate).

Balancing Hydronic and Air Systems

TRVs
VAVs
Zoned EMS/BMS

Diagram of a VAV system (This decision happens in the design stage)



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[The "Zoned EMS/BMS" subsection is not in the manual, but the information is included in the list on page 35.]

Balancing Hydronic and Air Systems

TRVs
VAVs
Zoned EMS/BMS

Zoned EMS/BMS

- With steam or hydronic heat, risers can be grouped into zones, each controlled independently by the EMS/BMS in response to internal temperature.
- Zones should be based on thermal characteristics, such as N, S, E, W exposure.
- Can be added to existing systems at reasonable cost

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The Operating Engineer's Key Roles: Improving Performance

Measurements
- Verify hydronic water temperatures
- Measure flow of air and temperature at registers

Occupant Feedback
- Solicit feedback from occupants

Overrides
- Look for open windows while heating or cooling systems are running
- Look for blocked registers
- Manually override BMS controls
- Use BMS to analyze the whole system

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The Operating Engineer's Key Roles in Improving Performance Page 36-37

Sustainability in heating and cooling is ultimately dependent on your awareness of how the systems are operating and how occupants are using the building. In doing so, you will identify problems and areas for improvement that might otherwise go unnoticed. Observation and documentation of ongoing conditions is the simplest tactic and should be employed on a daily basis. Make sure you incorporate the following practices into your operations.

The Operating Engineer's Key Roles: Improving Performance

Sensor Drift and Failure

- Water Temperature Sensors
- Smoke & CO Detectors
- Sensor Accuracy
- Timers for Daylight Saving

Leaks that can't be easily seen

- Inside Boilers
- Inside Walls
- Inside Cooling Towers
- Inside Condensate Tanks

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The Operating Engineer's Key Roles in Improving Performance Page 37

Along with general observations, spend time making sure all controls and sensors are operating as intended. This practice should be considered a permanent part of your maintenance strategy.

Sensors are sensitive and need to be maintained for accuracy:

- Sensors that measure water temperature can malfunction over time when minerals from hard water build up, possibly making the water dangerously hot.
- Smoke detectors can degrade due to age or a build-up of dirt/dust.
- Carbon monoxide (CO) detectors should be replaced every five years.
- Timers may need to be reset for daylight saving time changes.
- Air temperature sensors (thermostats) may lose calibration, giving false readings. Check with a handheld air temperature.

Leaks that can't be easily seen:

- Inside boilers: Read water levels on a regular basis to notice leaks.
- Inside walls: Look for leaks and moisture from sweating pipes.
- Inside cooling towers

The Operating Engineer's Key Roles: Improving Performance

Testing and Balancing (TAB)

- Primarily for central air, valuable but use certified (NEBB or AABC) contractors

Annual Boiler Tune-Ups

- Full bore maintenance by licensed contractor at least annually
- Chemical maintenance, etc. weekly or per schedule Energy Audits & Commissioning (discussed in Chapter 9)

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The Operating Engineer's Key Roles in Improving Performance Page 37

Testing and Balancing:

- These technicians measure air and water flows in the building and are responsible for resetting them to "design" or desired levels.
- There are two nationally recognized organizations that certify technicians for this kind of work. These are the National Environmental Balancing Bureau (NEBB) and the Associated Air Balance Council (AABC).
- It is wise to use a certified testing and balancing contractor. There have been problems with some uncertified technicians faking the numbers. Certification from NEBB or AABC helps to prevent this, since these technicians can lose certification if the job is not done correctly.

Annual Boiler Tune-Up:

- To maintain the warranty, have factory-authorized technicians check and clean the boiler at least annually.
- Have the service contractor do a combustion-efficiency test, stack gas analysis, inspect boiler for functional problems, identify sensor drift, and adjust the boiler to perform at maximum efficiency.
- Ask questions of the service technicians. This is an opportunity for you to learn more about how your equipment works and is meant to function.

EXERCISE QUESTION:

The south-facing rooms of the top five floors of a fifteen story residential building are overheating.

The lower floors are shaded by an adjoining building.

Are zone controls or TRVs a better approach? Why?

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TEST YOURSELF:

1. What does combustion efficiency measure, and how do you measure it?
2. What can building operators do to maintain equipment and prevent boiler malfunctions?
3. How do you monitor chiller efficiency?
4. Give three examples of problems that can arise with HVAC distribution, and ways to manage those problems.

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[OPTIONAL]

1. Combustion efficiency measures how much energy is lost "up the stack" by a piece of fuel-burning equipment. It is measured with a handheld instrument that analyzes flue gases while the boiler is firing.
2. Clean the burner—if it is dirty, fuel and air won't be delivered in the right ratio. Pay attention to the color of the flame. For gas, it should be blue and steady and never orange. For oil, a fluctuating yellow flame is normal. Clean nozzles of oil burners a minimum of once a week to ensure proper atomization of the fuel. Change filters and clean coils per manufacturer's specifications.
3. Monitor efficiency by tracking supply and return water temperatures, logging electric energy consumption vs. CDD, determining how much energy should be required to generate a ton of cooling and compare with actual use, use BMS to set chiller schedules.
4. When hot or cold water movies through pipes, it will lose or gain heat if insulation is inadequate – repair all loose insulation. When uninsulated pipes pass through unconditioned spaces, heat can be lost – make sure pipes are properly insulated Holes in ducts will leak hot air – make sure all ducts are sealed.

6 LIGHTING

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Page 39

Lighting accounts for approximately 25% of the electricity used in commercial and residential buildings.

As a building operator, your understanding of how different lighting types operate can have a big impact on the amount of energy used and the quality of the lighted environment.

In this chapter, we focus on:

- How to measure light outputs and qualities
- The different types of bulbs and their uses
- Using lighting controls to reduce energy usage

Green Lighting

Green Lighting is an equal combination of:

- Efficiency
- Application
- Comfort and Aesthetics

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Green Lighting is an equal combination of Efficiency, Comfort and Aesthetics, and Application.

All three of these issues are equally important and need to be considered for any green lighting strategy.

For lighting, **efficiency** means providing high-quality light with intensity suitable for the intended activities while using the least possible amount of electric energy.

Good lighting will be **comfortable** for the occupants and will make a space appealing.

Proper **application** means that you have the correct fixtures and equipment for the intended use.

Green lighting practices improve a building's electrical performance. Lighting retrofits have some of the best paybacks of any sustainable strategies, typically one to two years depending on installation costs and equipment.

Green Lighting Terms

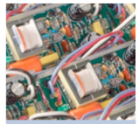
Lamp: Basic light source; examples: incandescent, fluorescent, or LED bulb.

Ballast: High-voltage transformer controls flow of current through the lamp.

Fixture: Holds the lamp and ballast securely, fastened to the wall or ceiling or free-standing.

Luminaire: The entire assembly of lamps, ballasts, and fixtures.

Lamp



Ballast

Luminaire

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Lighting: Basic Background Page 39

First we want you to know proper lighting terms to be part of the conversation with the sustainability team.

Construction is moving towards more green practices. By using the same terms as the sustainability team, the green electrician can be part of the conversation, so we'll start with a little vocabulary:

[adjust to knowledge level of your audience]

A bulb or "**lamp**" is the basic light source, such as an incandescent, fluorescent, or LED.

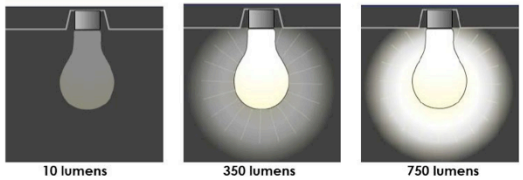
Often a lamp will need associated electronic equipment to make it work, such as a high-voltage transformer called a "**ballast**."

The "**fixture**" holds the lamp and ballast securely and is either fastened to a wall or ceiling or is free-standing.

The entire assembly of lamps, ballasts and fixtures is called the "**luminaire**."

Lighting Levels

Lumen: The lumen is the basic unit of visible light emitted from a source.



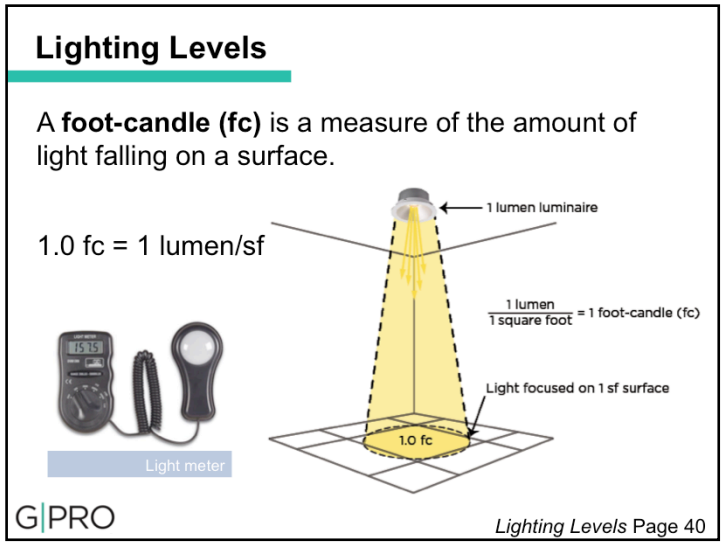
A 100 W incandescent or a 33 W CFL can each emit 1,500 – 1,600 lumens.

G|PRO *Lighting: Basic Background* Page 40

It is important to understand what lumens are and their relationship to visible light.

A **lumen** is the basic unit of visible light, similar to the power in watts produced by a generator or the gallons per minute of water from a faucet.

Since lumens measure only visible light, it is based on the sensitivity of the human eye, rather than actual power from the source. One lumen is a small amount of light, although easily visible. A typical Christmas tree light is only 2 – 5 lumens! A 100 watt incandescent bulb or a 23 watt compact fluorescent lamp (CFL) produces 1,500 to 1,600 lumens.



Lumens tell us how much light a source is emitting. We also need a way to describe how brightly a surface is lit.

A **foot-candle (fc)** measures the amount of light falling on a surface.

A foot-candle is one lumen uniformly distributed on a one square foot surface; in other words, one lumen per square foot.

Foot-candles are a common unit of measurement used in the U.S. lighting industry to calculate and specify proper lighting levels indoors and outdoors.

Foot-candle levels can be calculated or measured using a light meter, which is a relatively inexpensive and easy-to-use handheld device.

Foot-candle levels change based on how far the meter is from the light, so with overhead lighting, the levels will be lower on the floor than on a desk in the same room. Make sure you are checking the levels at the correct location.

[If a light meter is available, please show students and let them try it.]

Legal Lighting Requirements

- Minimum lighting levels provide safety and comfort
- Use the most current local code

Examples of minimum light levels from the International Building Code:

- Habitable rooms: 10 fc at desk height (30" above floor)
- Means of egress: 1 fc
- Parking garages: 1 fc
- Theatres during performances: 0.2 fc

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Legal Lighting Requirements Page 40-41

Legal Lighting Requirements are the minimum adequate lighting levels required for health and safety.

Means of egress must be sufficiently well lit to permit rapid exiting in case of emergency, and places of work or assembly must be lit well enough to permit the activity to proceed without eyestrain.

Use the most current local code.

For example, International Building Code requires:

- Average illumination of 10 foot-candles at desk height
- An illumination level of at least 1 foot-candle on stair treads and means of egress
- Parking garages are 1 fc
- An illumination level at least 0.2 foot-candles during performances in auditoriums, theatres, and similar places of assembly

Key Lighting Efficiency Terms

- Lamp Efficacy (lamps)
- Luminaire Efficiency (luminaires)
- Ballast Factor (ballasts)

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Lighting Efficacy Pages 41-42

Here are four key lighting efficiency terms we are going to discuss next.

- Lamp Efficacy relates to lamps
- Luminaire Efficiency relates to luminaires
- Ballast Factor relates to ballasts

Lamp Efficacy

Lamp efficacy is the effectiveness of a lamp measured in:

$$\frac{\text{Output Lumens}}{\text{Input Watts}}$$

Efficacy of Various Lamps

Type	Efficacy (lumens/W)
Incandescent	8 – 20
Halogen	14 – 25
CFL	40 – 70
T-12 Fluorescent	50 – 80
T-8, T-5 Fluorescent	50 – 100
LED	35 – 75
Low Pressure Sodium Vapor	100 – 180
High Pressure Sodium Vapor	64 – 140
Metal Halide	80 – 120

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Lighting Efficacy Page 41

Efficacy is a term we use for efficiency in lighting.

The **efficacy** of a lamp or other light source describes the effectiveness of a lamp, measured by the ratio of output lumens to input watts (lumens/w).

The greater the efficacy, the less power will be used to meet a given requirement for a lighting level.

But as we will see, we also need to consider comfort and aesthetics; light quality must sometimes be traded off against efficacy.

Let's calculate the efficacy of an incandescent lamp.

EXAMPLE #1:
LAMP EFFICACY

QUESTION:

A 100 W incandescent lamp emits 1,600 lumens as specified by the manufacturer.

What is the lamp efficacy?

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Lighting Efficacy Page 41

QUESTION:

A 100 W incandescent lamp emits 1,600 lumens as specified by the manufacturer.

What is the lamp efficacy?

EXAMPLE #1:
LAMP EFFICACY

ANSWER:

$$\text{Efficacy} = \frac{\text{output lumens}}{\text{input watts}}$$

$$\text{Efficacy} = \frac{1{,}600 \text{ lumens}}{100 \text{ W}} = \frac{16 \text{ lumens}}{\text{W}}$$

$$\text{CFL Efficacy} = \frac{1{,}600 \text{ lumens}}{23 \text{ W}} = \frac{69.9 \text{ lumens}}{\text{W}}$$

A CFL lamp is much more efficient!

G|PRO *Lighting Efficacy* Page 41

[Calculate lamp efficacy and compare results from incandescent to CFL.]

ANSWER

Efficacy of the incandescent bulb in this example =

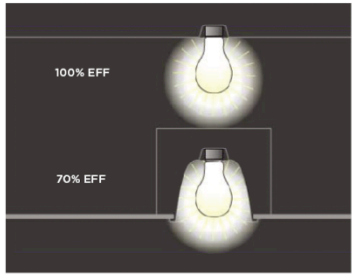
$$\frac{1600 \text{ lumens}}{100 \text{ W}}$$

or 16 lumens/W

The lamp efficacy of a comparable 23 W CFL emitting the same 1,600 lumens = 1,600 lumens / 23 W = 69.6 lumens/W, which is much more efficient!

Luminaire Efficiency (EFF)

Luminaire efficiency (EFF) is a percentage measuring how much of the light emitted by the lamps actually comes out of the luminaire.



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Lighting Efficacy Page 41-42

Lamp efficacy is not the end of the story.

Lamp performance within a particular luminaire must be taken into account. Many luminaires have reflectors, grilles to protect the lamp or to diffuse glare, and other components that may absorb or deflect some of the lamp's output.

The **luminaire efficiency (EFF)** is a percentage measuring how much of the light emitted by the lamps actually comes out of the luminaire.

Luminaire efficiency can range anywhere from 65% to 85% when new, and will decrease slightly as the finish ages and dust accumulates.

Color in Lighting

Two Issues with Color in Lighting:

1. **Color Temperature** – hue of the light
2. **Color Rendering Index (CRI)** – how well light renders color of objects

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Color in Lighting Page 42-43

The color of the light (color temperature) and its ability to render color (CRI) are very important in lamp choice.

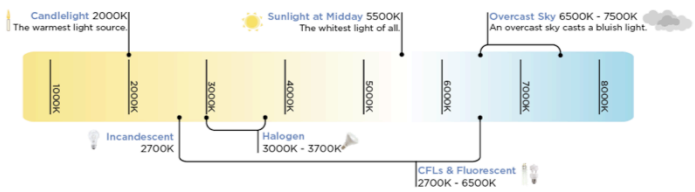
There are two issues with color:

1. The hue of the light: some lamps are warmer (yellower) and some lamps are cooler (whiter, bluer).
2. How well the light renders color of objects.

Color Temperature

Kelvin temperature scale (K)

- Warm – Lower Color Temperature in K
- Cool – Higher Color Temperature in K



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Color in Lighting Page 42

The hue of light emitted from a source is described by its color temperature and presented in Kelvin.

For the filament of an incandescent lamp, or for the sun, the color temperature corresponds to the actual temperature of the source.

Lamps with lower color temperatures, 2700K – 3500K, produce yellower or visually "warmer" light and are typically used in residential spaces.

2700K is approximately equivalent to incandescent light. CFLs and LED lamps can be found that are close in color.

Lamps of higher color temperatures, 4000K – 6500K, produce bluer or visually "cooler" light and are typically used in offices or commercial spaces.

Color Temperature

Warm lighting in a home

Cool lighting in an office

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Color in Lighting Page 42

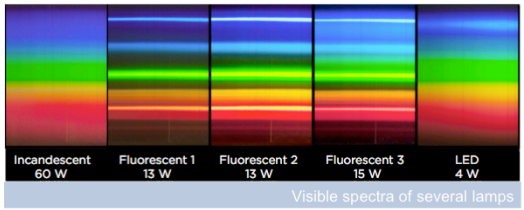
Note that the use of "warmer" and "cooler" to describe light is purely descriptive and is actually opposite to the Kelvin scale.

It's probably better to just look on the box and use the color temperature in K instead of the description. Always make sure new lamps match the old ones, unless you're changing them all at once!

Color temperature data is available for all lamps, and should be used to ensure that the light provided is appropriate to the uses of the space.

Color Rendering Index (CRI)

Not all lamps can render all colors.



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Color in Lighting Page 43

Not all lamps render all colors.

Regardless of color temperature, lamps differ in their ability to render colors accurately because some lamps do not provide all colors of visible light.

This shows the visible spectra of several lamps as compared to incandescent.

You can see that different colors are missing in the spectrum for different lamps which means that those colors cannot be reproduced under those lamps.

Note that not all colors are present in the spectra of fluorescent light but that color rendering of LED is pretty close to incandescent.

Color Rendering Index (CRI)

CRI is a scale from 0-100 that represents the ability of a light source to render color.

Higher CRI renders colors more accurately.

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Color in Lighting Page 43

The color rendering index (CRI) is a scale that represents a lamp's ability to render color on a scale of 0 – 100.

A good fluorescent lamp will have a CRI of 85 or better.

These pictures show the same vegetables under different lamps.

The image on the left was lit with fluorescent lamps with a CRI of over 92. The image on the right was lit with a fluorescent lamp with a CRI of about 80.

The orange peppers and radishes have about the same colors in both pictures, while the other vegetables have richer colors under the lamp with the higher CRI.

High CRI may be important in retail or food service applications or museums.

Color Rendering Index (CRI)

Only sunlight and incandescent lamps emit all colors and reveal all colors with CRIs of 100!

SOURCE	CRI
Sunlight	100
Incandescent lamp	100
CFL	80-90
Metal halide lamp	60-80
Low pressure sodium vapor	0-3

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Color in Lighting Page 43

Sunlight and incandescent lamps both render all visible colors and have the best possible CRI of 100.

A very yellow low pressure sodium street light has a CRI of about 3; there is no color information at all, and all objects appear either yellow or dark.

CRI should be listed on the box or data sheet provided by the manufacturer, but it is often hard to find. If it is not provided, you should ask the supplier or manufacturer.

A building operator needs to know which kinds of lamps have higher or lower CRI, because if you are switching out lamps to achieve greater efficiency, but the occupants dislike the color rendering of the light, your efforts may be wasted.

POP QUIZ:

A quick review of lighting metrics.
5 questions…GO!

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POP QUIZ:

1. What is a fc and what does it measure?

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POP QUIZ:

A foot-candle is measure of the amount of light falling on a surface.

$$1.0 \text{ fc} = \frac{1 \text{ lumen}}{1 \text{ sf}}$$

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POP QUIZ:

2. What is a lumen?

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POP QUIZ:

A lumen is the basic unit of visible light emitted from a source (a rate, similar to the power in watts produced by a generator or the gallons per minute of water from a faucet).

A 100 W incandescent or a 33 W CFL emits 1,500 – 1,600 lumens.

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POP QUIZ:

3. What does lumen/watt tell you?

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Lamp Efficacy will tell you the ratio of output lumens to input watts. Higher lumens per watt means a lamp uses energy more efficiently.

POP QUIZ:

Lumens/watt is the unit for Lamp Efficacy.

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POP QUIZ:

4. How is color temperature measured?

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POP QUIZ:

Color temperature is measured in Kelvin (K).

2700K – 3500K = yellow, "warmer" light

4000K – 6500K = bluer, "cooler" light

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POP QUIZ:

5. What is CRI and what does it measure?

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POP QUIZ:

CRI (Color Rendering Index) is a scale from 0 (low pressure sodium) to 100 (sun, incandescent) that gives you an idea of how well a lamp renders the color of objects.

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GOOD WORK!

Now let's talk about lamps.

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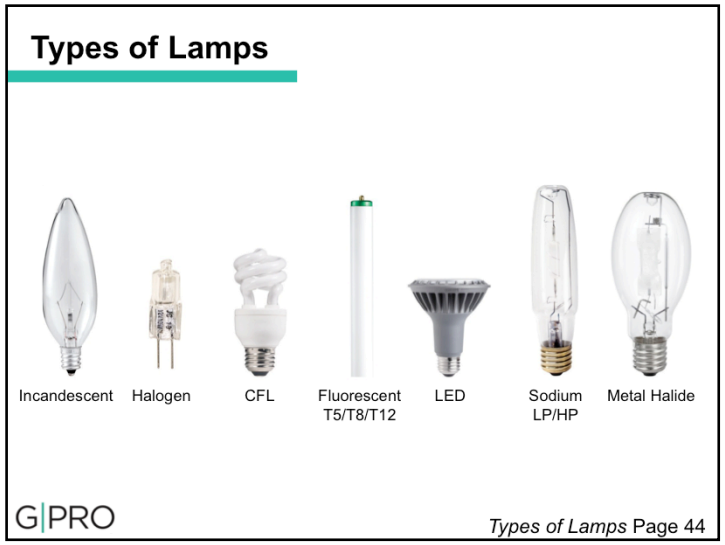

There are a wide variety of lamps available, it is important to know what is the right application for each one.

Rather than discussing how these lamps work, we will focus on the best applications for each lamp type as well as pointing out some of the pros and cons for each one.

The full list of pros and cons, as well as a basic description of how each lamp works, is available in your manual.

We're going to use many of the terms we just discussed to compare these lamps.

Incandescent Lamps

Pros:
- CRI of 100 (full color spectrum)
- "Warmer," yellow light
- Inexpensive

Cons:
- Low lumens/watt efficiency
- Produces heat in hot weather
- Short life span

Incandescent Lamp

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Incandescent Lamps Page 44

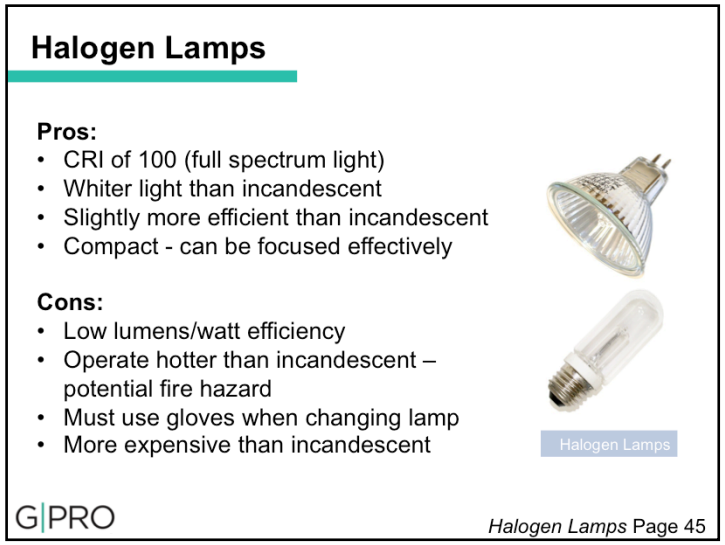
Incandescent lamps are still commonly used in residential and some commercial applications.

They have a CRI of 100, but are extremely inefficient and have a large carbon footprint.

More than 95% of the energy used is given off as heat instead of light.

Pros:
- High CRI
- Inexpensive

Cons:
- Low lumens/watt efficiency
- Produces excess heat in hot weather
- Short life span



Halogens are incandescent bulbs that are brighter, whiter, more compact and more efficient.

The installer should avoid touching the lamp head as oils from one's hands can cause the lamps to burn out prematurely.

Pros:

- High CRI
- Whiter light than incandescent
- Slightly more efficient than incandescent
- Compact

Cons:

- Low lumens/watt efficiency
- Operates hotter than incandescent
- Must use gloves when changing lamps
- More expensive than incandescent

Types of Fluorescent Lamps

- Tubular Fluorescents
- Compact Fluorescent Lamps (CFLs)

T-5 Fluorescent Lamp

Compact Fluorescent Lamp (CFL)

G|PRO *Fluorescent and Compact Fluorescent Lamps* Pages 46

Fluorescent lamps are very efficient, and recent advances in technology have improved the aesthetic quality of the light by improving their CRIs and range of color temperatures.

The two most common shapes of fluorescent lamps are

- Tubular
- Compact fluorescent lamp (CFL)

Tubular Fluorescents

- T represents the diameter of the lamp in eighths of an inch
- Narrower tubes are more efficient
- T-8s can be retrofit into T-12 fixtures but only T-5s can fit into T-5 fixtures
- Don't substitute T-5s if T5 HO is specified

G|PRO *Fluorescent and Compact Fluorescent Lamps* Pages 46-47

Fluorescent lamps convert electrical power into useful light almost 4 times more efficiently than incandescent lamps and can last 10 times longer.

Recent advances in fluorescent lamp technology have improved the aesthetic quality of the light by improving their CRIs and range of color temperatures.

Tubular lamps are very common, and labeled with the letter T. The number following the T represents the diameter of the lamp in eighths of an inch: a T-12, at 1-1⁄2" (12/8") is the largest, T-8, has a 1" (8/8") diameter. The newer T-5 has a 5/8" diameter, which is the smallest common lamp size used in building fixtures.

While T-8s can be installed in existing T-12 fixtures, T-5s can only be installed in T-5 fixtures.

"HO" stands for "high output." A T-5 CANNOT be substituted for a T5 HO or the lamp will not provide sufficient light.

In general, lamps with narrower tubes are more efficient, but also more fragile.

Compact Fluorescent Lamp (CFL)

- 4x more efficient at converting electrical power into useful light than incandescent lamps
- Last 10x longer than incandescent lamps
- Pin-mounted CFLs are a good choice for public areas like hallways

Compact Fluorescent Lamp (CFL)

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Fluorescent and Compact Fluorescent Lamps Pages 46-47

Compact fluorescent lamps (CFLs) are "socket-ready" and can replace incandescent lamps in most applications.

CFLs pay for themselves in under a year when compared to the frequent replacement of incandescent lamps.

Another mount available for CFLs is the "pin" mount. With these, the ballast is in the base fixture, so only the tube must be replaced at end of life, and the lamps are less likely to be stolen since they cannot be used in standard fixtures. Pin-mounted CFLs are a good choice in public areas like hallways.

Fluorescent Lamps

Pros:

- Large color temperature range
- Almost 4x more efficient at converting electrical power into useful light than incandescent lamps
- Can last 10x longer than incandescent lamps
- Available in various shapes and sizes

G|PRO *Fluorescent and Compact Fluorescent Lamps* Pages 46-47

Fluorescent lamps convert electrical power into useful light almost 4 times more efficiently than incandescent lamps and can last 10 times longer.

In the past, fluorescent lamps would only be found in office buildings, public spaces, and some residential kitchens as they are inexpensive to operate.

Recent advances in lamp technology have improved the aesthetic quality of the light by improving their CRIs and range of color temperatures.

Fluorescents can now be found in a much larger variety of building lighting applications.

Fluorescent Lamps

Cons:

- Lower CRI than incandescent lamps
- May take a few seconds to reach full brightness
- Bulkier, more expensive, and more fragile than incandescent lamps
- Lifespan shortens when used inconsistently
- Contains mercury, which requires recycling for safe disposal
- Dimming lamps require dimming ballasts
- Older magnetic ballasts need to be replaced with electronic ballasts
- Need special lamps for temperatures below 50ºF

G|PRO *Fluorescent and Compact Fluorescent Lamps* Pages 46-47

There are some disadvantages to fluorescent lamps and it is important to understand what they are, but generally the pros outweigh the cons.

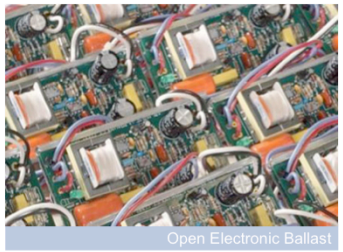
All fluorescent lamps, including CFLs and tubes, contain small amounts of mercury, which can be dangerous if people are exposed to it. This is not a reason to avoid their use since the production of incandescent lamps in coal-fired manufacturing plants releases much larger amounts of mercury into the atmosphere.

The manufacturing of one incandescent lamp actually produces more mercury than the amount contained within one CFL plus the coal emissions needed to light it!

All fluorescent lamps should be disposed of through a registered recycling service. To learn more contact your local waste disposal agency, or go to www.epa.org.

Ballasts for Fluorescent Lamps

- Tubular: separate ballasts
- CFLs: "socket ready" ballasts built into bulb



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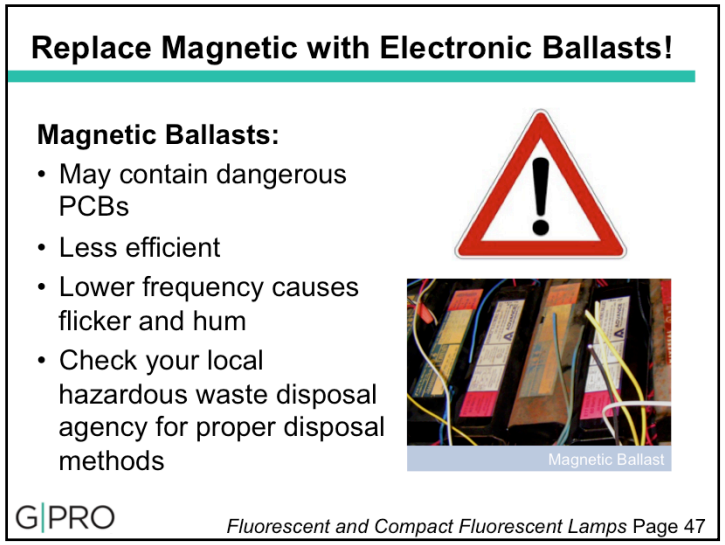
Fluorescent and Compact Fluorescent Lamps Page 47

Fluorescent lamps require a ballast, an electronic circuit that regulates the flow of current through the lamp.

For tube fluorescent lamps, the ballasts are separate components.

For CFLs, which are sized to fit into fixtures that take incandescent bulbs, the ballasts are in most cases built into the base of the bulb, making the bulb itself larger than an incandescent. For this reason it may be necessary to test a few different brands to get a lamp that fits a particular fixture.

As for dimming, only a CFL with a specifically designed dimming ballast should be used. Others will burn out or blow circuit breakers.



Magnetic Ballasts

- Used from 1940s to 1990s
- Used with T-12 lamps and come in pin-type CFLs
- Inefficient by today's standards
- May contain dangerous PCBs (Polychlorinated biphenyls)
- Lower frequency causes flicker and hum

Older tube fluorescent fixtures had "magnetic" (60-cycle) ballasts that would hum and flicker and contained dangerous oils (PCBs). Replace with electronically ballasted T-8 fixtures.

Contact your local waste disposal agency for information on proper disposal.

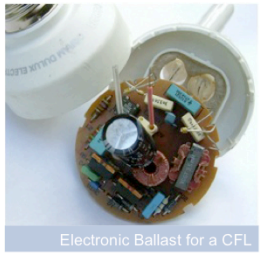
Electronic Ballasts

- Use transistorized circuitry
- Create very high frequency AC – eliminate flicker
- Smaller and lighter
- More precise control of on/operate cycle
- More efficient

Simple, inexpensive instruments are available that can distinguish magnetic from electronic ballasts. Replacing old magnetic ballasts with electronic ones can save energy and improve the quality of the light.

Ballasts: Start-Up Cycles for Fluorescents

- Instant Start
- Rapid Start
- Programmed Start



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Fluorescent and Compact Fluorescent Lamps Page 47

The method by which a fluorescent lamp is started affects its performance.

There are three typical start-up cycles for fluorescent lamps:

"**Instant start**" applies a high voltage to cold cathodes; it is energy efficient, but results in short life if lamps are cycled on and off repeatedly.

"**Rapid start**" includes a cathode heater, so the lamps last longer but use more electric power.

"**Programmed start**" provides the best cycling, by preheating the filaments and ramping the voltage up more slowly; used with occupancy sensors and similar controls.

The choice should be driven by the application, but the increased use of occupancy sensors and similar controls makes programmed start ballasts increasingly common.

Dimmable and Multi-Level Ballasts

- Use dimmable and multi-level ballasts wherever controls can take advantage of them
- Bi-level lighting works with occupancy sensors to set higher lighting levels when the space is occupied and minimum code levels at other times

G|PRO *Fluorescent and Compact Fluorescent Lamps* Page 47

Dimmable and multi-level ballasts are available and should be specified wherever controls can take advantage of them.

For example, public hallways and stairwells must be continuously illuminated at 1 fc in most of the U.S., but should be illuminated at 5 fc or more when actually in use.

An occupancy sensor controlling a bi-level ballast can provide a safe, legal, and satisfying lighting system for this application using the least possible energy.

Use with dimming controls and multi-level switching. We will cover types of controls after this discussion on types of lamps.

Metal Halide Lamps

Pros:
- Even higher lamp efficacy than fluorescent lamps
- Longer lifespan than fluorescent lamps
- Can be focused effectively

Cons:
- Low CRI
- Operate at high pressure – safety issue
- Slow on/off
- Small amount of mercury

Metal Halide Lamp

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Metal Halide Lamps Page 48

Like fluorescent lamps, metal halide lamps utilize a high-intensity discharge in mercury vapor, but they also include argon and halide salts to provide color control.

Metal halide lamps have higher lamp efficacy but because of their poor color rendering, they are used mainly in industrial applications, outdoor lighting, specific uses that require ultraviolet (UV) or blue frequency light, and indoor growing environments.

Metal halide lamps also need special fixtures with ballasts to operate safely.

Sodium Vapor Lamps

Sodium Vapor Lamps:
- Very high efficacy
- Low CRI

Low pressure sodium vapor lamps (LPS):
- Very yellow light
- Commonly used for street lights, security lighting

High pressure sodium vapor lamps (HPS):
- Higher CRI than LPS
- Used for indoor horticulture, outdoor and industrial applications

Sodium Vapor Lamp

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Sodium Vapor Lamps Page 48

Since this is a course about buildings, and metal halides and sodium vapor lamps are more common in exterior and industrial uses, this presentation does not go into great detail, but there is more information in your manual.

There are two types of sodium vapor lamps: low pressure and high pressure.

Low pressure sodium vapor lamps (LPS) contain solid sodium along with a small amount of neon and argon gas. They produce a very yellow light and are commonly used for street lights and security lighting.

High pressure sodium vapor lamps (HPS) contain a small amount of mercury in addition to sodium, neon, and argon. The result is better color rendering. These types of lamps are ideal for conditions where it is important to distinguish color and are used for indoor horticulture and outdoor and industrial applications.

Sodium vapor lamps also require special fixtures with ballasts to operate safely.

Light-Emitting Diodes (LEDs)

Pros:

- Lamp efficacy almost as good as fluorescents
- Extremely long life
- Easily dimmable
- Small size
- No mercury
- Less heat waste than incandescents

LEDs

Cons:

- Lower CRI than incandescent
- Expensive (but prices starting to fall)
- Requires heat management within fixture

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Light-Emitting Diodes Page 48-49

LEDs have no filament or electrodes to burn out and have very long lifetimes.

Though they don't burn out, the light output decreases with age. When the output is reduced to 70% - 80% of the original light, they must be replaced. The useful lifetime of LEDs can still exceed 50,000 hours.

LEDs produce an approximation of white light comparable to that emitted by typical fluorescent lamps. But neither fluorescent lamps nor LEDs produce the full spectrum of visible light available from the sun or incandescent lamps. Although LEDs can provide general purpose illumination, they do not do this any better than fluorescent lamps and they cost more.

LEDs are great for applications where it's difficult or expensive to change lamps, and where spotlighting is needed, as in store displays.

LED lamp technology is rapidly developing.

Safe Mercury Disposal for Discharge Lamps

In case of breakage, clean up properly!

- Air out space, ventilate and turn off all forced air equipment
- Collect glass and powder with paper and tape – don't touch with bare hands, don't use a vacuum
- Place in sealed container for proper recycling in accordance with local law
- Wash hands, continue to ventilate

Broken CFL

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Safe Mercury Disposal for Discharge Lamps Page 49-50

Recycling:

- All discharge lamps, including fluorescent lamps, contain a very small amount of mercury sealed within the glass tubing and must be recycled properly.
- Contact the local waste disposal agency to determine recycling procedures in your area.

In case of breakage:

- When any type of discharge lamp is broken it must be cleaned up properly.
- Once the lamp is broken the space should be evacuated for about 5 -10 minutes to air out the room. If possible open a window or door to the outside, and shut off any forced air heating or air conditioning system.
- The broken glass and visible powder should be collected with a stiff piece of paper and shouldn't be touched with your bare hands. Tape can be used to pick up the remaining small fragments, and the area should then be wiped with damp paper towels.
- Do not use a vacuum for this cleanup.
- Place everything in a sealed container outdoors until materials can be disposed of properly, in accordance with local law.
- Wash hands and continue to air out the space for several hours.

Lighting controls make lighting systems more sustainable by reducing the number of illumination hours.

Fewer illumination hours not only save energy but also extend the amount of time between re-lamping

Lighting Controls

Lighting Controls:

- Save energy by reducing the number of hours that the lights are on
- Extend the amount of time between re-lamping

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Lighting Controls Page 50

Lighting Controls

- Multi-Level Lighting
- Vacancy Sensors
- Occupancy Sensors
- Timers
- Daylighting

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Lighting Controls Page 50

Multi-level lighting: Used in places like hallways or stairwells, where occupancy is variable and typically low, but where building codes require certain minimal levels of light, typically 1 to 4 foot-candles. Bi-level lighting keeps lighting low when the space is unoccupied.

Vacancy sensors: Are used to manually light up the fixtures when someone enters the space. A vacancy sensor turns off the lights when it senses no motion in the room. Since they must be manually turned on, they tend to result in a higher level of savings than occupancy sensors.

Occupancy sensors: Can be used in storage or work rooms that are often left unoccupied for long periods of time and seldom require light. These sensors light up the space only when occupied, leaving the space completely dark when occupied.

Timers: Can also curb usage costs. Programmable timers can be set to power lights on and off depending on a room's occupancy schedule. Lighting timers are turned on manually by the person entering a room for only the amount of time they select, usually 1 to 60 minutes.

Daylighting: Makes better use of natural light to illuminate a space. When daylight is available, automatic sensors turn the artificial lights down or off.

Improving Your Lighting

Reduce inefficiencies in your building's lighting system by:

- Replacing incandescent lamps with CFLs
- Replacing T-12 lamps with T-8
- Installing occupancy and vacancy sensors
- Installing LED exit signs

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Lighting Controls Page 51

In the short term, there are simple steps that you can take to reduce inefficiencies in your building's lighting system. Where appropriate, replace incandescent lamps with compact fluorescent lamps to realize quick, significant savings.

Similarly, you can install inexpensive retrofits to lighting fixtures, such as occupancy sensors, vacancy sensors, and LED exit signs that result in greater efficiency while cutting electricity costs.

For a quick return on your investment, replace T-12 lamps and ballasts with T-8 lamps. In many cases, this is the easiest upgrade, since the T-8 lamps and ballasts will fit the same fixture.

Lighting retrofits can provide electrical savings greater than 40% while improving the quality of the lighting.

GROUP EXERCISE:

See Classroom Exercise #2 on page 92 of your manual:

- 8 story building
- 2 stairwells
- Two fixtures per floor, each with one 40-watt bulb (currently on 24/7)
- Proposed change: Replace with two bi-level fluorescent lighting: 32 watts on 4 hours/day and 13 watts 20 hours/day.
- Fixtures cost $250 installed, electricity is $0.20/kWh

Is this cost effective?

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TEST YOURSELF:

1. Give 2 pros and 2 cons for each of the following types of lamps: incandescent, fluorescent, metal halide, and LED.
2. What is CRI and what does it measure?
3. How does lighting affect a building's HVAC system?
4. Why is it important to consider lamp disposal?
5. How can sensors and timers increase lighting efficiency?

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1. (**A**) **Incandescent:** Pros - CRI of 100 produces full spectrum light, inexpensive; Cons – Low efficacy, short lifespan (**B**) **Fluorescent:** Pros – Higher efficacy, longer lifespan than incandescent; Cons – Lower CRI, contain mercury (**C**) **Metal Halide:** Pros – Higher efficacy, longer lifespan than fluorescent; Cons – Low CRI, contain mercury (**D**) **LED:** Pros – Higher efficacy than incandescent, longest lifespan; Cons – High initial cost, require precise heat management
2. CRI stands for Color Rendering Index and is a scale that represents a lamp's ability to render color on a scale of 0-100, based on an actual test of its ability to display eight specific color samples accurately
3. With electricity being the most expensive fuel, the financial savings from lighting upgrades are substantial. Additional benefits include a reduction in HVAC costs due to less heat being generated by the lighting system.
4. All fluorescent lamps, CFLs, tubes, and other shapes contain small amounts of mercury, a toxin. They should be disposed of through a registered recycling service. This will reduce the amount of mercury released into the environment .
5. Sensors automatically turn lights off when spaces are unoccupied and can save up to 70 percent on energy costs for lighting. Programmable timers are another easy and effective way to curb usage costs. They can be set to power lights on and off depending on the room's or building's occupancy schedule.

LET'S TAKE A BREAK!

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Green Professional Building Skills Training

Indoor air quality (IAQ) refers to the condition of the air within and around buildings, especially as it affects the health and comfort of building occupants.

IAQ is determined by both the **sources of pollution** within the building and the **amount of ventilation** that dilutes and removes those pollutants.

Ensuring proper IAQ may require a trade-off in building management practices. On the one hand, excessive ventilation results in unnecessary heat losses and thereby higher expense and greenhouse gas emissions, while inadequate ventilation can result in poor air quality and a higher risk of condensation and mold.

Striking the right balance is the key. A green building is one that not only operates efficiently, but also one that has a high level of IAQ and provides a healthy, pleasant place in which to live or work.

In Chapter 3 we discussed building air tightness and air sealing, and pointed out that uncontrolled infiltration was a poor way to provide fresh air.

In this chapter, we'll assume that the building is well sealed, and discuss the factors that cause poor IAQ, why it matters, and what techniques the building manager can use to ensure good IAQ.

What Causes IAQ Problems and Why it Matters

- Prevent "sick building syndrome"
- Happy, comfortable and productive occupants

G|PRO *What Causes IAQ Problems and Why it Matters* Page 53

You may have heard the term, "Sick Building Syndrome," defined by the EPA as:

> "situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified."

It might be localized or building-wide.

Poor IAQ also leads to numerous specific health problems. More than 20 million people in the U.S. suffer from asthma, which is often triggered by indoor contaminants and irritants such as dust mites, molds, volatile organic compounds (VOCs), and others.

Millions more suffer from other respiratory conditions brought on by bad air, ranging from mild allergic sneezing to lung cancer. Other symptoms include rashes, headaches and flu-like symptoms.

In this section, we'll discuss strategies to improve the quality of indoor air.

Indoor Air Pollutants:
Volatile Organic Compounds (VOCs)

- Paints & lacquers
- Sealants
- Adhesives & caulks
- Cleaning supplies
- Pesticides
- Carpets
- Furnishings
- "New car smell"

G|PRO *What Causes IAQ Problems and Why it Matters* Page 53

VOCs are gases emitted from certain solids and liquids that contain a variety of chemicals that can have both short- and long-term adverse health effects.

Concentrations of many VOCs can be up to 10 times higher indoors than outdoors.

Items that can have high levels of VOCs include:

- Paints and lacquers
- Paint strippers
- Cleaning supplies
- Pesticides
- Adhesives, caulk, and solvents
- Carpets and furnishings
- Office equipment such as copiers and printers
- Synthetic fabrics, plastics, and sealants. These are often the source of "new car" or "new shower-curtain" smell, resulting from the off-gassing of chemicals

Negative health effects from VOCs can include:

- Eye, nose, and throat irritation
- Headaches
- Loss of coordination
- Nausea
- Damage to liver, kidney, or central nervous system

Indoor Air Pollutants: Moisture

- Relative Humidity between 40% - 55% is considered a comfortable range.
- Porous building materials, such as insulation or drywall, need to be kept moisture-free to prevent mold.


Batts of Insulation

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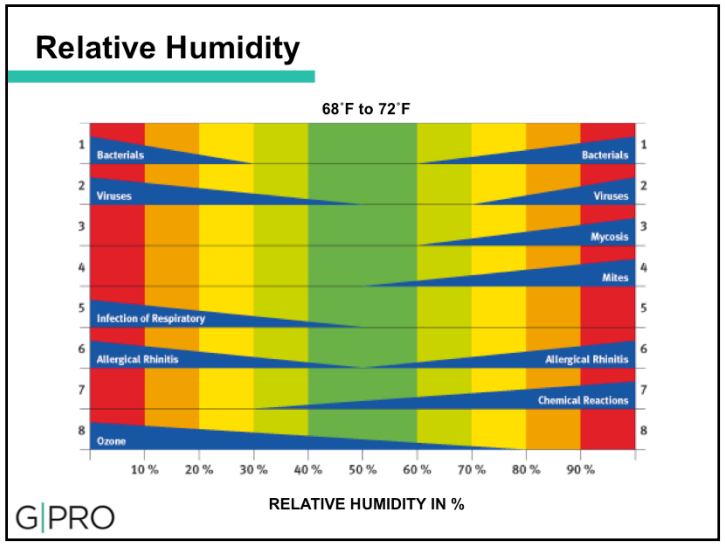
Moisture is considered a major indoor air pollutant. The issue is not the moisture itself, but the fact that high levels of relative humidity (RH) encourage the growth of mites, mold, and mildew.

Conversely, excessively low levels of RH produce negative reactions such as coughs, asthma, and other respiratory illnesses.

Maintaining a consistent level of exactly 50% RH is extremely difficult. For optimal health, RH should be between 40 and 55%, but this is not always possible.



On either extreme of a comfortable RH (BPI says 40-55 and ASHRAE says 40-60), the risk for unhealthy contaminants like viruses, bacteria, and ozone pollution is increased.

This chart shows the "sweet spot" of healthy relative humidity. As you can see, negative effects such as infections, allergies, and mold growth occur as RH increases or decreases away from the healthy range.

Indoor Air Pollutants: Dust

- Dust can carry pollutants and pathogens, including dust mites
- Can trigger asthma in those allergic to dust

Strategies to control dust:

- Tight envelope
- Integrated cleaning program
- HEPA vacuum

G|PRO *What Causes IAQ Problems and Why it Matters* Page 54

Dust control is an important IAQ issue for building operators, as dust can carry many pollutants and pathogens, including dust mites that act as one of the major triggers of asthma in those who are allergic to dust.

Maintaining a tight envelope to prevent air flows, developing an integrated cleaning program, and using a HEPA (high-efficiency particulate air) vacuum are all effective ways to control dust and other indoor air pollutants.

We will discuss these strategies in more detail later in this chapter.

Dust mites are one of the major triggers of asthma in those who are allergic to dust.

For this reason, and because dust can carry many other pollutants and pathogens, dust control is an important indoor air quality issue for building operators.

As we discussed earlier, maintaining a tight envelope, preventing air flows within the building, developing an integrated cleaning program, and using a HEPA (high-efficiency particulate air) vacuum will help control dust and other indoor air pollutants. We'll discuss these in more detail later in this section.

Indoor Air Pollutants: Combustion Equipment Pollutants

Gases or particles caused by burning fuels:

- CO_2 - Carbon Monoxide (colorless, odorless gas that makes people sick at low concentrations and can kill at high concentrations)
- NO_2 - Nitrogen Dioxide
- SO_2 - Sulfur Dioxide
- Particulates (combine with steam to create ordinary smoke)

Personal CO Detector

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Most combustion pollutants come from burning fuels such as natural gas, fuel oil, kerosene, wood, and coal in water heaters, boilers, and furnaces.

Some of the common pollutants produced from burning these fuels are:

- Carbon monoxide (CO)
- Nitrogen dioxide (NO_2)
- Particulates (which together with steam make up ordinary smoke). Particulates are largely active carbon compounds and can have other hazardous chemicals attached to them.
- Aldehydes
- Sulfur dioxide (SO_2)

Combustion pollutants found indoors include:

- Tobacco smoke
- CO from poorly adjusted gas ovens, stoves and ranges
- CO and other exhaust gases from furnaces, boilers, and water heaters with malfunctioning flues
- Outdoor air carrying exhaust, smoke, or other pollutants from equipment located near operable windows or fresh air intakes or from cars and trucks on nearby roads

Indoor Air Pollutants: Carbon Dioxide (CO_2)

- CO_2 indicates the presence of people breathing
- Excess CO_2 may indicate a lack of oxygen or excess pollutants

G|PRO *What Causes IAQ Problems and Why it Matters* Page 55

Carbon dioxide is inert and harmless by itself, but it indicates the presence of people breathing (or combustion equipment operating).

The presence of high levels of carbon dioxide is a warning that there may also be low levels of oxygen, which can be a serious health hazard.

The level of carbon dioxide in a room is also a good indicator of the degree of general pollution in the room.

CO_2 detectors in large rooms can be used to cycle on the ventilation systems based on how many people are present. Otherwise, the ventilation might run at its maximum capacity all the time.

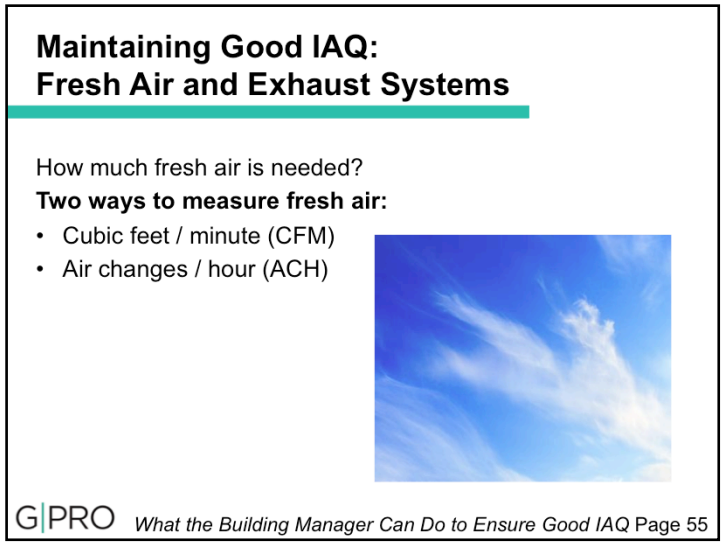
Indoor Air Pollutants: Lack of Air Exchange

- Fresh air in
- Bad air out
- Ventilation system must be balanced

G|PRO *What Causes IAQ Problems and Why it Matters* Page 55

Energy efficiency and indoor air quality are closely linked. If you tighten up a building to make it more efficient, you may decrease ventilation levels, thereby negatively affecting IAQ. Without proper air exchange — pulling fresh air in and getting the bad air out — indoor air quality is compromised, and occupants can become uncomfortable and ill.

Often, a building will have adequate total ventilation and fans of adequate nominal size driving the exhaust vents and still not be comfortable. The issue is balance — being sure that air is pulled through all occupied spaces, and knowing that for every measure of air being exhausted, there is a way for that amount of fresh air to enter the building. We'll offer some tips for balanced ventilation in the next section.



What Can the Building Manager Do to Ensure Good IAQ?

In this section we will examine how to maintain good air quality in a typical building through proper fresh air ventilation.

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), maintains a standard for ventilation, ASHRAE Standard 62.1, which is often incorporated into state and local building codes.

This standard specifies the amounts of outside air that must be provided by natural or mechanical ventilation systems to various areas of the building to maintain acceptable IAQ. These standards inform design engineers of the criteria they must meet.

While the building operators may never need to refer to the actual standards, it's nevertheless good to understand the basic principles, so we'll spend a few minutes explaining them.

There are two ways to measure airflow in buildings. The first is *cubic feet per minute* (CFM), a direct measure of the volume moving through the space. Alternatively, ventilation of a space can be expressed in *air changes per hour* (ACH), how many times the entire volume of air in the room is exhausted and replaced with fresh air each hour.

Maintaining Good IAQ:
Fresh Air and Exhaust Systems

CFM = Cubic feet / minute
ACH = Air changes / hour
V = Volume of the space

$$ACH = \frac{60 \times CFM}{V}$$

G|PRO *What the Building Manager Can Do to Ensure Good IAQ* Page 55

CFM and ACH are related. If you know the volume of the space being ventilated in cubic feet, then

$$ACH = \frac{60 \times CFM}{V}$$

where V is the volume into which the air is flowing and the "60" converts from minutes to hours.

For a room, V will be equal to the habitable area (in square feet) times the ceiling height (in feet).

As we'll see, sometimes the volumetric flow (CFM) is more useful, and sometimes the air changes per hour (ACH) is more useful.

According to ASHRAE and common practice, a building must have a minimum rate of either 0.35 ACH or 15 CFM per person (whichever is greater) to be considered adequately ventilated.

CLASSROOM EXERCISE:

Auditorium Dimensions:
1,500 sf
15' ceiling height

Maximum Seating Capacity: 125 People

What is the minimum required ventilation?

According to ASHRAE and common practice, a building must have a minimum rate of either 15 CFM per person or 0.35 ACH (whichever results in a greater value of total CFM)

G|PRO *What the Building Manager Can Do to Ensure Good IAQ* Page 55

SOLUTION

CFM = Cubic feet / minute
ACH = Air changes / hour
ACH = (60 x CFM) / V

V = Room Volume = 1,500sf x 15 ft = **22,500 cf**

Step #1: Calculate total air flow based on 15 CFM/person:
15 CFM x 125 people = **1,875 CFM**

Step #2: Calculate total air flow based on 0.35 ACH:

$$ACH = 0.35 \qquad ACH = \frac{60 \times CFM}{V} \qquad 0.35 = \frac{60 \times CFM}{22{,}500\ cf} \qquad CFM = \frac{0.35 \times 22{,}500\ cf}{60}$$

= 131 CFM

G|PRO *What the Building Manager Can Do to Ensure Good IAQ* Page 55

This would require the fans and ducts to be capable of this volume. Also, because bringing that much cold air in during winter is expensive, controls should be included on the fan to drop it back to the lower level when the room is not occupied. This is referred to as demand controlled ventilation (DCV).

SOLUTION

CFM = Cubic feet / minute
ACH = Air changes / hour
ACH = (60 x CFM) / V

Step #3: Compare 15 CFM per person to 0.35 ACH:

15 CFM per person gives total air flow of 1,875 CFM

0.35 ACH gives total air flow of 131 CFM

1,875 CFM > 131 CFM

ASHRAE requirement would be to provide 1,875 CFM of supply air to the auditorium, since it is the

G|PRO *What the Building Manager Can Do to Ensure Good IAQ* Page 55

Energy Efficiency vs. IAQ

An energy efficient building is well sealed, which could compromise the amount of fresh air circulating.

With less air naturally circulating through cracks, the IAQ could become worse. Make sure the IAQ is maintained by mechanical ventilation.

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Air Management Practices to Protect Building Occupants

- Proper ventilation
- Minimize moisture
- Monitor humidity levels

An anemometer can detect very low airflows, localizing leaks and testing ductwork framework.

G|PRO *What the Building Manager Can Do to Ensure Good IAQ* Page 56

1. Make sure that all apartments or commercial spaces are getting the correct level of ventilation by actually measuring air flow at the exhaust or supply registers. A small device to do this, called an anemometer, can be purchased for under $100.

2. Minimize uncontrolled moisture released into the building by ensuring that all moisture-producing fixtures and appliances are vented, including showers, clothes dryers, and kitchens.

3. If necessary, mechanical dehumidification can be used in moist areas

4. Hot air furnaces can be equipped with humidifiers, and radiators with evaporation cans, if humidity runs too low during the heating season.

The primary takeaway lesson here is that managing ventilation is an important job requiring careful attention to detail, but one that will result in a much healthier and "greener" building if carried out correctly.

Integrated Green Cleaning Plan

- Keep out dirt
- Train staff
- Limit use of products with harsh chemicals and toxins
- Use low VOC products

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What the Building Manager Can Do to Ensure Good IAQ Pages 56-57

Green cleaning has become an important component of improving IAQ because it can contribute to a healthier and safer working environment at very reasonable cost. Green cleaning involves both an "integrated cleaning" plan and the use of environmentally benign materials and techniques.

Integrated cleaning involves planning and implementing some basic techniques in an organized way:

- Keep the tracked-in dirt out by using walk-off mats and grates at entry doors. Focus cleaning on entryways so they do not become a virtual source of tracked-in dirt.
- Provide ongoing training for custodial staff about cleaning methods that reduce exposures, such as those discussed just below.
- Do a review of your cleaning products and remove those that contain toxins and irritants; use green cleaning products instead.

Green Cleaning Certifications

- Green Seal certified products
- EcoLogo certified products
- UL Environment
- CRI (The Carpet and Rug Institute)

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What the Building Manager Can Do to Ensure Good IAQ Pages 56-57

Green cleaning techniques and products avoid the use of chemically reactive, toxic cleaning products that contain various toxic chemicals, some of which emit VOCs, causing respiratory and dermatological problems. Green cleaning can also describe the way residential and industrial cleaning products are manufactured, packaged and distributed. If the manufacturing process is environmentally friendly and the products are biodegradable, the term "green" or "eco-friendly" may apply.

There are several rating systems and certifications that can help you determine which products are truly green.

Certifications:

- Green Seal: Third-party, nonprofit certifier of environmentally preferable products and services. Its methodology is consistent with the criteria of the U.S. EPA.
- EcoLogo: Third-party certification and the oldest environmental standard in North America.
- UL Environment: Third-party organization offering expertise to green businesses and manufacturers.
- CRI (The Carpet and Rug Institute): A nonprofit trade association and research organization offering program, partnerships and informative publications aimed at the carpet industry.

Green Cleaning Technologies

- HEPA filters
- Microfiber rags

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What the Building Manager Can Do to Ensure Good IAQ Pages 56-57

High Efficiency Particulate Air (HEPA): A high-efficiency air filter that can trap a large amount of small particles, at least 99.97% if airborne particles 0.3 micrometers in diameter.

Microfiber rags and mops: Provide exceptional cleaning capacities without the use of chemicals. This method of cleaning is easier, quicker, more efficient, and better for your health.

Interior Retrofitting and Renovation

- Demolition
- Construction dust
- Designs that interfere with ventilation
- Fumes & off-gassing (VOCs)

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Interior Retrofitting and Renovation Page 58

Renovation and retrofits can be a major cause of poor indoor air quality, especially since these projects often take place while the building is occupied.

Four potential problems to avoid during retrofitting and renovation activities are:

- Demolition that releases toxic materials (e.g., lead, asbestos, mold)
- Construction dust and fumes
- Designs that interfere with ventilation
- Off-gassing from new building materials and products (i.e., VOCs)

Maintaining Good IAQ: Managing Construction

- Testing
- Timing
- Distance
- Barriers
- Containment
- Clean Up

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Interior Retrofitting and Renovation Pages 58-59

Although mitigation of these problems will be the responsibility of the contractor, it will be your job to confirm that they are complying with the building's rules and relay complaints to them and to help them devise and implement solutions such as polyethylene dust barriers and appropriately sized exhaust fans. Some tips from the U.S. EPA to protect residents during renovations:

Testing: Before performing any demolition, check for lead-based paints and asbestos.

Timing: When possible, perform work at times when the occupants are not in the building, such as vacation breaks, weekends, or evenings.

Distance: Keep building occupants as far from renovation activities as possible. The greater the distance between pollutants and occupants, the less concentrated the pollutants will be upon reaching the occupants.

Barriers: Install temporary barriers (e.g., plastic sheeting) to seal the work areas from the occupied areas. Cover all supply and return air grilles if the HVAC system in the renovation area also serves occupied areas. Directly exhaust air from the construction area outside so that pollutants cannot flow from the construction area to the occupied areas.

Containment: Whenever possible, keep pollutants confined to as small an area as reasonably possible, rather than allowing them to spread to larger areas. Examples include wet sanding or vacuum sanding drywall to prevent the spread of dust, misting asbestos with water to prevent it from easily becoming airborne during demolition, and keeping containers of chemicals such as solvents, adhesives, paints, and other coatings closed as much as possible. Do not operate the heating and cooling equipment in spaces where work is causing pollutants to be airborne. when work is causing dust to be visible in the air.

Cleanup: At least daily, construction debris, dust, and scraps should be adequately cleaned up so that there is less chance that these pollutants will enter occupied areas. See also construction and demolition (C&D) debris a reduced opportunity for these pollutants to enter occupied areas.

Managing Cigarette Smoking Issues

Cigarette smoke is one of the most common occupant complaints related to IAQ.

- Establish an effective smoking policy for your building
- Place cigarette receptacles 25' or more from the building
- Place signs on the main entrance doors, reminding smokers to smoke at least 25' from the building
- Incorporate smoking policies into employee manuals

G|PRO *Interior Retrofitting and Renovation* Pages 59

Cigarette smoke infiltration is one of the most common occupant complaints related to IAQ, and a relatively simple problem to deal with. If the building does not already have an effective smoking policy, you can work to establish one, depending on what is appropriate for your building and its occupants.

Controlling cigarette smoke infiltration is mostly about controlling the behavior of occupants who smoke. Here are some things you can do to address behavior related to smoking:

- Place cigarette receptacles 25 feet or more from the building so smokers will naturally gravitate toward this area, not near the building.
- Place signs on the main entrance and exit doors reminding smokers to please smoke at least 25 feet from the building.
- Incorporate this policy into employee manuals and use interoffice communication systems to reiterate this message when needed.

IAQ Assessment and Resolution Procedures

- Be Prepared
- Assess the problem
- Resolve issues
- Maintain & Monitor

G|PRO *IAQ Assessment and Resolution Procedures* Pages 59-60

The building manager or operator has a critical role in proactively managing IAQ through control of pollution sources, ensuring proper ventilation, use of nonpolluting cleaning products, and attention to renovation practices. In addition, it is important that you are able to effectively respond to occupant concerns as they come up. Establishing effective procedures for handling IAQ complaints is an essential part of good building operation and management.

Be Prepared

1. Become knowledgeable about how your building's air handling, ventilation, and heating systems operate. Also be aware of all activities (cleaning, renovation, etc.) currently under way that may create pollution sources.
2. Keep a log of identified occupant concerns and how they have been resolved in the past.
3. Develop trouble-shooting protocols for common problems specific to your building.
4. Provide clear directions to all occupants on whom to contact when there are concerns.

Assess the Problem

When an IAQ problem has been identified, gather information from all concerned parties and investigate possible impacts on other potentially affected spaces.

Resolve Issues

1. Take action within your control to resolve immediate problems.
2. Bring in an outside professional IAQ specialist or HVAC technician for system-level problems.

Maintain and Monitor

1. Modify operating procedures or policies as required to ensure that problems don't reoccur.
2. Undertake ongoing monitoring to identify and address potential problems as they develop.

Handling IAQ Complaints:
Be Sensitive and Competent

- Do not disrespect complainants
- Implement a system to log and track complaints
- Respond with promptness, seriousness, and transparency
- Train and equip in-house staff
- Hire outside consultants in a timely manner

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- Do not disrespect complainants
- Implement a system to log and track complaints
- Respond with promptness, seriousness, and transparency
- Train and equip in-house staff
- Hire outside consultants in a timely manner

TEST YOURSELF:

1. Describe the trade-off that occurs between IAQ and HVAC energy consumption.
2. What are some products than contain pollutants that can cause sick building syndrome?
3. Describe one or two problems that occurs when relative humidity is too high, and one that occurs when it is too low.
4. Name three causes of poor IAQ and what building managers can do to ensure they don't occur in their building.

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[OPTIONAL]

1. On one hand, excessive ventilation results in unnecessary heat losses that increase the building's greenhouse gas emissions. On the other hand, inadequate ventilation can result in poor IAQ and a higher risk of mold.

2. Paints, lacquers, paint strippers, cleaning supplies, pesticides, adhesives, caulk, solvents, carpets and furnishings, etc.

3. When RH is too high, mold on interior surfaces is likely. When RH is too low, dry skin conditions are aggravated.

4. **Volatile Organic Compounds:** Limit the use of VOCs. **Dust:** Maintain a tight envelope, prevent airflows within the building, develop an integrated cleaning program and use a HEPA (high-efficiency particulate air) vacuum. These actions will help control dust and other indoor air pollutants. **Lack of Exchange Air:** Provide adequate air flow (outside air that must be provided by natural or mechanical ventilation systems) in a room/ building

In *Fundamentals*, we discussed the concepts of "Reduce, Reuse, Recycle" as a way to lessen our negative impacts. Why does it matter? Basically, because we purchase, use, and discard so much stuff.

8 DEALING WITH WASTE

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Page 55

Why Waste Matters: We Produce So Much!

The average American creates 4.43 pounds of household garbage each day.

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Why Waste Matters Page 55

The average American home has more than doubled in size over the past 50 years.

Larger homes have led to the purchasing of more material items, or "stuff," and more "stuff" has led to more waste.

The average American creates 4.43 pounds of household garbage every day. In 2010, Americans generated about 250 million tons of trash.

This garbage goes mostly to landfills, where it is compacted and buried. Once buried, it can produce greenhouse gases such as methane as it decays.

As this waste stream continues to grow, so does pressure on our landfills, resources, and environment. Anything we can do to reduce this waste stream will be beneficial.

This graph shows the dramatic increase in U.S. waste generation.

The blue line shows total municipal solid waste generation.

The red line shows waste generation per person.

From 1960 to 2010, the total amount of waste has more than doubled, but so has population.

The good news is that while the amount of waste per person increased 85%, it has leveled off over the past two decades and the trend seems to be reversing.

You may think that when you throw something out, it's "gone". But there is no actual "away". All we can do is move the problem to another location.

Where Does Trash Go?

There's no such thing as "away"

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Reduce

- Bulk purchasing of cleaning supplies, etc.
- Use washable, re-usable wash cloths, towels, etc. where possible
- Use fresh water & refillable bottles
- Have non-disposable cups, mugs, dishware, and silverware available
- Compost where safe and practical
- Purchase durable, reusable O&M tools and supplies instead of disposables

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Reduce Page 55-56

The most effective way to reduce waste is to reduce consumption. You can probably think of many ways to do this within your building, but this list is a start:

1. Purchase concentrated cleaning supplies in bulk to reduce the quantity of containers purchased and packaging.
2. Use washable, reusable cleaning cloths, drop cloths, and dust curtains instead of throw-away towels or other disposable products.
3. Eliminate bottled water (replaced with water filtration system, or just city water if your municipal water supply provides good water).
4. Have non-disposable cups, mugs, dishware, and silverware available for staff use.
5. Compost on-site to eliminate the need for purchased soil amendments and fertilizers.
6. Purchase durable, reusable O&M tools and supplies instead of disposables such as heavy duty paint brushes and trays, reusable vacuum bags, and hand tools with rechargeable batteries.

The reduction of electricity and fuel use is a critical part of reducing the environmental impact of our buildings.

Reuse

Deconstruction, not Demolition:

- One person's trash is another's improvement
- Some salvage yards make house calls
- Large-dimension lumber is increasingly valuable

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Reuse Page 56

Deconstructing refers to taking apart a whole building or a portion of a building such as an apartment or office and then reusing salvaged material rather than tossing it in the dumpster.

Although opportunities for this do not come up often in custodial duties, a reconstruction project will generate large quantities of construction debris that need not be wasted.

If the contractor is not willing to separate and save large-dimension lumber, carpeting, old gypsum wallboard, and other material that can be used again, it may well be worth your while to remove material for resale or re-use. It is very likely that the contractor will be glad you are removing material on which he or she would have to pay a tipping fee.

Even without a construction project, one person's discarded sink or stove will often be another's improved new appliance. As a building manager or operator, you are in a good position to know what potentially useful items are being abandoned by their current owners. If you are responsible for several buildings, you may be able to encourage reuse of significant numbers of fixture and appliances.

Recycle

- Protect U.S. jobs
- Reduce landfills and incineration
- Prevent waste from new manufacturing
- Reduce energy use
- Reduce greenhouse gas emissions
- Conserve resources
- Save the environment

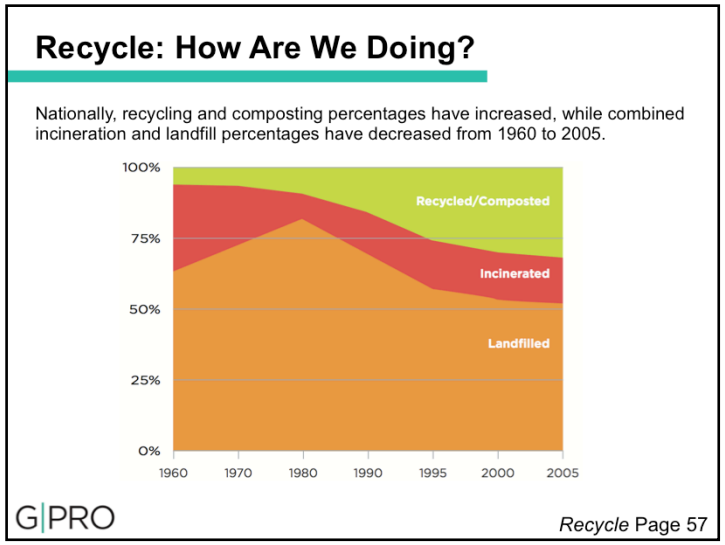
G|PRO *Recycle* Page 57

After you have reduced your material use as much as possible, and reused all the items you can, there is still one more step to reduce your environmental footprint: Recycling.

Recycling turns some materials that would otherwise become waste into resources. For the building operator, collecting used metal, plastic, glass, and paper products and delivering them to the local recycling program is a significant step toward generating financial, environmental, and social benefits.

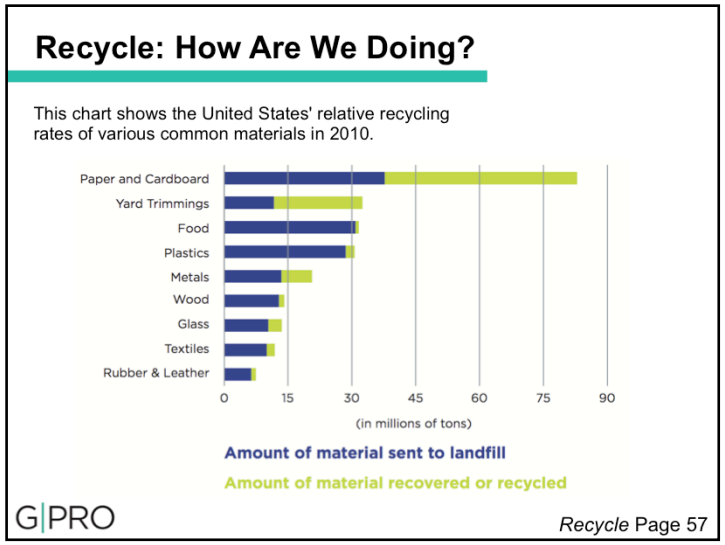
Some of these benefits include:

- Protecting and expanding U.S. manufacturing jobs and increasing U.S. competitiveness
- Reducing the need for land-filling and incineration
- Preventing pollution cause by the manufacturing of products from virgin materials
- Saving energy
- Decreasing emissions of greenhouse gases that contribute to global climate change
- Conserving natural resources such as timber, water, and minerals
- Helping sustain the environment for future generations



As consumer awareness grows and recycling programs and industries become more proficient at managing our waste stream, the percentage of materials that are recycled continues to grow.

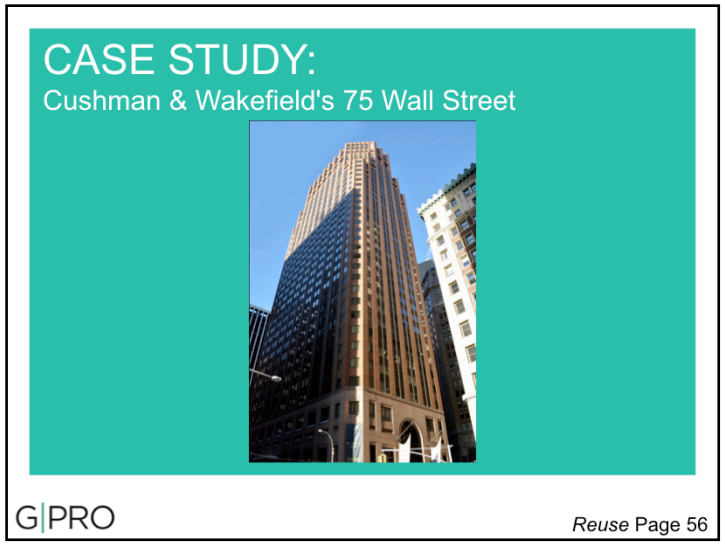
This chart shows how recycling and composting have increased from 1960 to 2005, while combined incineration and landfill usage have decreased.



This chart shows the United States' relative recycling rates of various common materials in 2010.

For example, over half of paper and paperboard are recycled vs. a relatively small amount of plastics.

Increasingly though, more municipalities are collecting plastics and more products are made from this recycled material.



Located in Manhattan's Financial District and managed by Cushman & Wakefield, 75 Wall Street contains 36 floors, 650,000 sq ft of office space, and houses three tenants. In the mid-1990s, the building reduced its carting costs to approximately $2,800 a month by segregating and recycling white paper and cardboard.

Cushman & Wakefield informed tenants of the change through memos and meetings with facilities management and cleaning staff. Management also posted signs describing the program in tenant spaces and on loading docks. The management company communicates nightly with the cleaning supervisor, allowing recycling problems that arise to be addressed immediately.

During the second half of 2003, the building reduced its carting costs to $1,600 per month through re-bidding its carting contract and switching to a comingled, rather than a segregated, paper recycling program. All types of paper, including white, mixed newspaper, and cardboard, are now collected together.

In addition to the disposal savings, the building receives a credit for the mixed paper tenants generate. The monthly credit is based on the market rate for mixed paper and how contaminant-free the material is when it comes out of the building.

Step 1. Collection and Processing

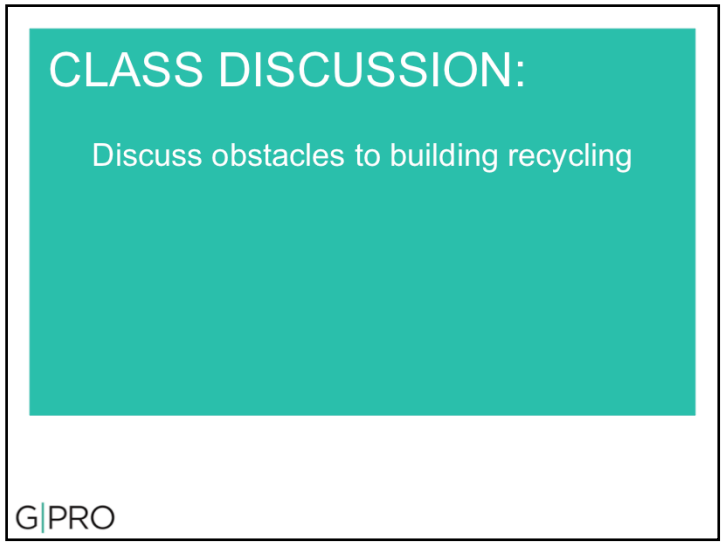
Collecting recyclables varies from community to community, but there are four primary methods: curbside, drop-off centers, buy-back centers, and deposit/refund programs. Regardless of the method used, in this leg of their journey recyclables are sent to a materials recovery facility to be sorted and prepared for new use in manufacturing. Recyclables are bought and sold just like any other commodity, and prices for the materials change and fluctuate with the market.

Step 2. Manufacturing

Once cleaned and separated, the recyclables are ready to undergo the second part of the recycling loop. More and more of today's products are being manufactured with total or partial recycled content. Common household items that contain recycled materials include newspapers and paper towels; aluminum, plastic, and glass soft drink containers; steel cans; and plastic laundry detergent bottles. Recycled materials also are used in innovative applications such as recovered glass in roadway asphalt (glassphalt) or recovered plastic in carpeting, park benches, and pedestrian bridges.

Step 3. Purchasing Recycled Products

Purchasing recycled products completes the recycling loop. By "buying recycled," governments, as well as businesses and individual consumers, play an important role in making the recycling process a success. As consumers demand more environmentally sound products, manufacturers will continue to meet demand by producing high-quality recycled products.



No one is responsible: Designate one person to find out all regulations and confirm that the building occupants are following them.

Occupants don't follow recycling rules: Set up an education program:

- Why they should reach
- What they should reach
- Where they should reach
- How they should reach

Improve signage, and show how much has already been diverted from the waste stream and set goals you are trying to reach.

Too messy: Maintain a clean, well-lit space with clearly marked containers and provide appropriate plastic liners for the bins.

TEST YOURSELF:

1. Describe three strategies for good waste management.
2. List three or more ways recycling reduces environmental impact.
3. What are some ways to communicate your waste program to building tenants?
4. How can reuse of waste be incorporated in a construction job?
5. How is recycling good for the economy?

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[OPTIONAL]

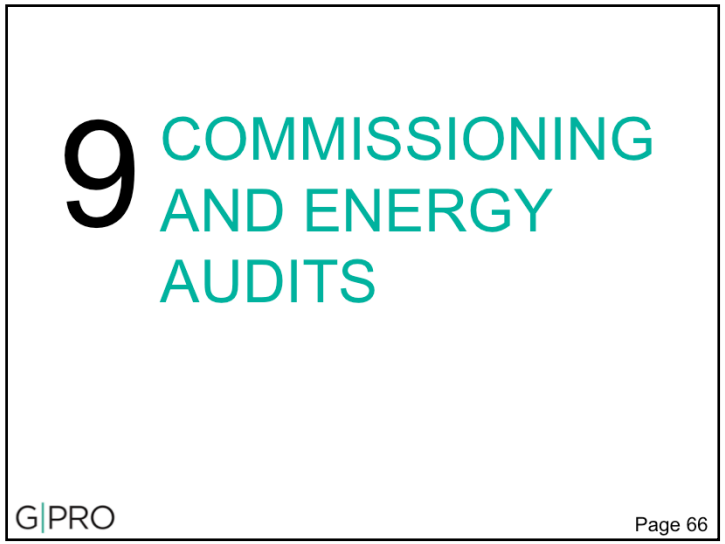
1. Purchase concentrated cleaning supplies in bulk, use reusable cleaning cloths, eliminate bottled water.

2. Recycling reduces environmental impact by reducing the need for land filling and incineration, preventing pollution caused by the manufacturing of products from virgin materials, decreasing emissions of greenhouse gases that contribute to global climate change, conserving natural resources

3. Communicate with tenants through memos and meetings with facilities management and cleaning staff. Management can also post signs descripting the waste management program in tenant spaces and on loading docks

4. Reuse refers to deconstructing some object (a building, apartment components, etc.) and then using salvaged material over again rather than tossing it in the dumpster. Items that can be reused include lumber, carpeting, old gypsum wallboard, and other material that can be used again.

5. Recycling is good for the economy because it protects and expands U.S. manufacturing jobs and increases U.S. competitiveness



The first part of this chapter discusses the commissioning (Cx) processes for both new and existing buildings.

The second part of this chapter focuses on the key role that energy audits play in sustainable building operation.

If you are a building manager or operator for a new property, you may have been included in the initial commissioning process to learn how the equipment works as you took over operation of your building. If you manage or operate an older building, you may engage in the process of continuous or retro-commissioning, where your role will be central to the process.

The Commissioning Process for New Buildings

- Commissioning (Cx) is the process of verifying building system performance
- Cx ensures correct operation and interaction of complex building systems and equipment
- For larger building projects, the owner usually hires a commissioning agent (CxA) to lead the review and verification process based on the Owner's Project Requirements (OPR)
- Full participation from the building manager and operator in the commissioning process is essential

G|PRO *The Commissioning Process for New Buildings* Page 66-67

For new construction, commissioning is a formal process to verify that building systems perform the way they were meant to, based on construction documents called the Owner's Project Requirements (OPR) and the Basis of Design (BOD).

During the design and construction of a larger building (generally greater than 50,000 sf), the owner hires an independent third-party commissioning agent, also referred to as the commissioning authority (CxA), to review building systems and to verify their performance based on the OPR.

Full participation from the building manager and operator in the commissioning process is essential.

This team will be involved with the CxA, designers, and contractors in decision making as issues surface and alterations in system specifications or installations are considered.

One of the important contributions of the commissioning agent is the development of operation protocols through the creation of commissioning manuals.

In the past, Cx was done only on new construction and concluded when the owner accepted responsibility for operations at project turnover. Today, Cx practices are changing to meet new green building standards and is becoming a continuous, rather than one-time, practice.

Retro-Cx and Recommissioning for Existing Buildings

Over time, buildings' systems may no longer function as originally intended, resulting in wasted energy and failing performance.

Retro-commissioning and recommissioning are two ways to ensure systems continue to perform appropriately.

Retro-Commissioning

- A process for buildings that were never commissioned
- CxA reviews building and systems to determine a strategy to optimize performance

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Retro-Commissioning and Recommissioning for Existing Buildings Page 67

As a building's systems age and are changed by alterations, they no longer function as originally intended, resulting in wasted energy and failing performance.

Retro-commissioning (retro-Cx) is a process meant for buildings that were never commissioned.

Retro-commissioning is a retuning process in which the CxA uses a whole-building approach to review all systems so that he or she can identify new operations strategies that will help the equipment and systems function at optimal levels.

The retro-commissioning process should be an interactive one, giving the building manager an opportunity to take the equipment through different functions, to learn from the commissioning agent, and to understand the benefits of operating the building systems as intended.

Retro-Cx can be thought of as a restoration of systems to their best possible performance. This is an opportunity for the building owner and operators to establish a baseline of system performance and have the CxA draw up systems procedures to ensure consistent maintenance protocols for the future.

Retro-Cx and Recommissioning for Existing Buildings

Recommissioning

- For buildings that have been previously commissioned
- A regular, recurring process to tune-up equipment
- Occurs because of a change in ownership or problems with building system performance

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Retro-Commissioning and Recommissioning for Existing Buildings Page 67-68

If a building has been previously commissioned, recommissioning occurs to ensure that a building's systems are still operating as they were designed to. It is a regular, recurring process to tune-up equipment, with a recommissioning plan ideally established during the initial Cx or retro-Cx process.

Recommissioning generally happens because of a change in building ownership, operational problems, or issues with building system performance.

Retro-Cx and Recommissioning for Existing Buildings

Continuous Commissioning®

- A form of recommissioning developed by Texas A&M University
- An ongoing process for the life-cycle management of the building
- CxA will return on a regular schedule to verify system performance

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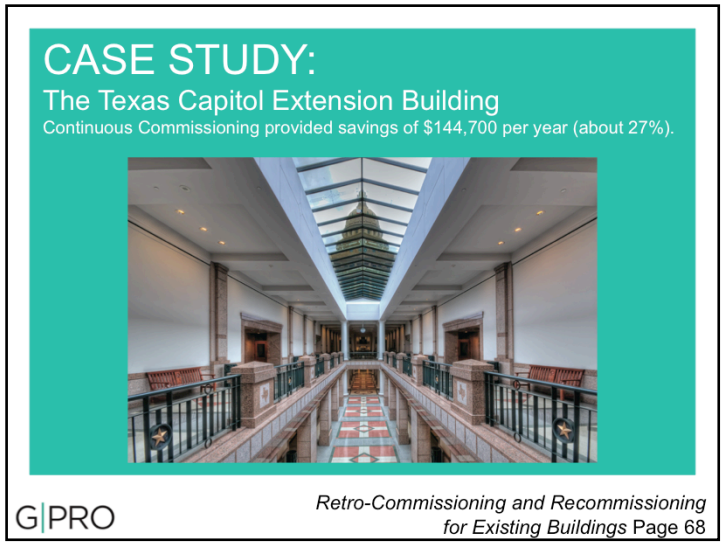
Retro-Commissioning and Recommissioning for Existing Buildings Page 67-68

Continuous Commissioning is an ongoing process for the life-cycle management of the building.

It was developed by Texas A&M, and is implemented by licensed providers.

In this process, a CxA returns on a regular schedule (typically on a three-year cycle) to systematically review, measure, and verify system performance.



CASE STUDY

To see the benefits of continuous commissioning let's look at a 10-year study conducted in Austin, Texas as shown in your manual.

The savings realized with a Continuous Commissioning program substantially exceed that of basic monitoring and dramatically surpass conditions of poor monitoring.

The Texas Capitol Extension Building was built in 1992 as an efficient building and commissioned to design specifications by the contractor.

Prior to the implementation of Continuous Commissioning, energy consumption costs totaled $539,000 per year for electricity, chilled water, and hot water. This new, relatively efficient building was well controlled overall, but persistent cooling problems in certain rooms prompted the building operators to begin implementing CC measures to improve occupant comfort and building efficiency.

The savings achieved by these measures ultimately corresponded to approximately $144,700 annually, or 27% savings.

http://www-esl.tamu.edu/continuous-commissioning

Retro-Commissioning Process

Typical items addressed on retro-Cx projects:

- Heating, cooling and distribution systems
- Equipment
- Damper operation
- Ventilation rates
- Schedules
- Sensors and setpoints
- Controls
- Lighting
- Hot water
- Safety concerns

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Retro-Commissioning and Recommissioning for Existing Buildings Page 68

Retro-Cx is a comprehensive facility returning to determine what is already working at optimal efficiency and what energy-saving adjustments can be made.

During this process, various inspections and tests will be performed, and a new systems manual may be created for the building.

Example items addressed on most retro-Cx projects:

- Systems: Are systems operating at optimal efficiency?
- Distribution system: Is the system balanced?
- Equipment: Can VFDs increase pump or fan efficiency?
- Damper operation: Is the economizer mode working?
- Ventilation rates: appropriate for the needs of the space?
- Schedules: appropriate or do they need to be reset?
- Sensors and setpoints: calibrated and coordinated?
- Controls: set properly and not being manually overridden?
- Lighting: spaces overlit or underlit; efficient bulbs installed?
- Hot water: domestic hot water delivery temperature optimal?
- Safety: fire safety/ smoke purge aspects of HVAC system operational?

Retro-Commissioning Process

Some typical retro-CxA responsibilities:

- Interview the owner
- Review original plans and specifications
- Identify and test the HVAC system
- Check for records of building envelope and systems maintenance
- Test building envelope integrity
- Check for air and water leaks
- Create an equipment list
- Evaluate IAQ
- Review cleaning protocols
- Document proper operation sequences for all systems/equipment
- Train building personnel

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Retro-Commissioning and Recommissioning for Existing Buildings Page 69

The retro-commissioning agent should:

- Interview the owner to determine the current uses of the building.
- Review the original plans, specifications, and control sequences for MEP systems.
- Evaluate occupancy schedules to ensure warm-up and cool-down periods are correct.
- Identify the type of HVAC system in place and what type of reheat is used (hydronic or electric), and test appropriately.
- Identify what types of control systems are used
- Check to see whether the building operator has a good record of building envelope and MEP systems' maintenance, including control systems.
- Test the building envelope integrity for air control and vapor control.
- Create an equipment list for the building if one does not already exist.
- Evaluate indoor air quality for humidity, musty smells, or other issues that could indicate bigger problems with building systems.
- Review cleaning protocols for heat exchanging surfaces (heat exchanger, coils, and tube bundles), and confirm they are in good condition
- Document proper sequences of operation for all systems and equipment.
- Train building personnel on proper energy-efficient maintenance and operations procedures.

Staging and Sequencing

Optimize system controls and improve efficiencies with staging and sequencing strategies.

Sequencing

- Activating and deactivating parallel units in a system when appropriate

Staging

- Starting boilers and chillers in a staggered manner

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Retro-Commissioning and Recommissioning for Existing Buildings Page 69-70

One important task that a retro-commissioning agent can perform is optimizing control strategies such as staging and *sequencing* to improve efficiency in the central plant.

HVAC systems account for more than 32% of a building's electricity consumption, making techniques such as staging and sequencing equipment for part loads an attractive energy- and money-saving option.

The term **sequencing** refers to activating or bringing online parallel units in a system and, conversely, deactivating or taking parallel units offline when appropriate.

Sequencing is the control strategy, while **staging** refers to the practice of starting the boilers or chillers in a staggered manner. For example, when you have a series of boilers, one runs at a set capacity until the load increases, then another one kicks in.

With this process, when the first-stage equipment has sufficient excess capacity, one or more second-stage pieces of equipment can go offline while still meeting the energy needs or load of the building.

The Operator's Involvement:
Primary Documents and Tools of Cx

- The Commissioning Plan
- Pre-functional Inspection Checklists
- Functional Testing Procedures

G|PRO *The Operator's Involvement in Commissioning* Page 70

For both new and existing buildings, the commissioning authority and the building operator should work closely on critical aspects that affect the ongoing operations of a building.

First, we will review the tools of a commissioning process and then look at how roles interact.

Primary Documents and Tools of Commissioning:

The Commissioning Plan: Document developed by the CxA and details the key players, roles, responsibilities, and protocols that will be used throughout the commissioning process including:

- The required inspections
- Handling and installation procedures
- Minimum report requirements for ongoing maintenance and testing baselines
- Requirements for repair and retesting if certain checks and tests produce unsatisfactory results.

Pre-functional inspection checklists: Developed by the CxA and used to provide the basis for the inspections of all equipment. Used to verify that the equipment is in the proper condition, that it is installed in accordance with the contract documents, and has been done so with good engineering practices and workmanship.

Functional testing procedures: Developed by the CxA to define the tests that will be performed by the contractors or equipment manufacturers with oversight by the commissioning authority.

How the CxA and Operator Interact

- CxA trains operators on systems' use and performance
- Operators become familiar with systems during testing phase
- Operators get a head start on systems' functionality and troubleshooting

G|PRO *The Operator's Involvement in Commissioning* Page 70-71

For a new building or one that is undergoing substantial renovations, the initial plans are often developed before the building operator is involved.

If so, when the operating engineers and managers become involved, they should get a copy of the plans and offer suggestions that can help with long-term building operations.

Operators should also become familiar with the project's Basis of Design (BOD) document to learn how the systems are intended to perform so they can maximize performance after the turnover.

The CxA may also structure the operators' training program.

The functional testing period is an ideal time for the engineers and building operators to work closely with the CxA to observe and participate in some of the testing.

If the building has a building management system (BMS), the CxA will exhaustively test the controls to verify that what is being displayed on the BMS is actually happening to the equipment. The CxA will also start, stop, and fail a lot of the equipment. This is an ideal time for the operator to learn how to restore the equipment to normal operation

The CxA will "beat the heck out of the building systems," and operators can learn where any problems may exist as well as any limitations in the systems' performance. Understanding and being involved in this process will give any operator a head start before operation of the building occurs.

Energy Audits

An energy audit allows you to assess how energy is used in your building and to identify opportunities for increased efficiency.

A good audit will address the following:

- Current energy consumption and system performance (benchmarking)
- Proposed energy conservation measures
- Potential cost/benefit evaluation
- Health and safety concerns and improvements
- Required maintenance practices
- Staff and resident education on occupant behavior

Audit building systems equipment to improve efficiency

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Energy Audits Page 71

Once a building has been occupied for a while, an important tool available to building owners to understand and ensure energy efficiency in the building is an energy audit. An energy audit allows a building owner to assess how energy is used in the building and to identify strategies for increased efficiency.

These opportunities may involve changing operating practices to reduce energy consumption or retrofitting the building to make it more energy efficient. An audit shows how to correct problems, update equipment, and manage systems so you save money over time.

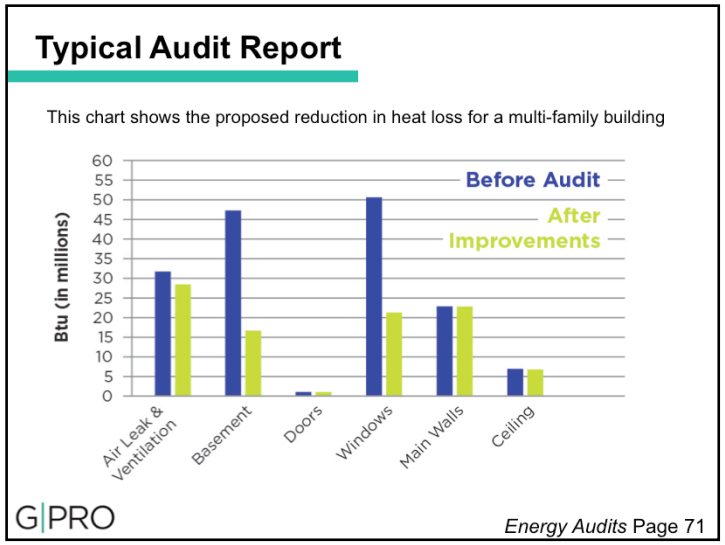
Energy engineers who are trained and certified in this area typically conduct the energy audit.

An energy audit is not something that building staff will normally be expected to do. However, the cooperation of building staff in carrying out the audit is critical.

A good audit of any building type will address the following:

- Current energy consumption and potential strategies for reduction in energy and water use
- Savings to investment ratio or other cost/benefit evaluation of these potential measures
- Health and safety concerns and improvements
- Required maintenance practices
- Staff and resident education on occupant behaviors that help efficient operations

Work with the auditor, he or she is your ally!



The first step for any audit is to develop the energy use intensity (EUI) of the building from fuel, electric, and water bills.

This number is the total energy (in Btu) used on-site per square foot of the building, and it allows the analyst to compare your building to similar buildings and determine whether it is an "energy hog" or whether it is already fairly efficient.

Energy Audits
Level 1: Preliminary Audits (Walkthrough)

- Walking tour of facility
- Limited measurements may be taken
- A report indicating simple energy conservation measures (ECMs), or energy-management opportunities (EMOs), is produced
- Identify measures that need further analysis
- Satisfies USGBC LEED EB:O&M prerequisite

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Energy Audits Page 72

A Level I audit is basically a walking tour of the facility. Some limited measurements might be taken during the audit. The end result is a simple report, focused on the energy conservation measures (ECMs), also called energy-management opportunities (EMOs), easily identified during the audit and will often identify measures that need further analysis.

This approach is typically used for prescriptive replacement programs, such as standard commercial lighting upgrades.

An ASHRAE Level I audit also satisfies one of the pre-requisite requirements for the USGBC's LEED for Existing Buildings: Operations and Maintenance.

Energy Audits
Level 2: General (Intermediate) Audits

- A more sophisticated audit
- Reviews energy use records from previous years to prepare an energy model
- Systems testing and short term systems monitoring may be performed
- Energy simulations are used to calculate potential energy and fuel savings
- Used to develop more complex multi-system conservation plans

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Energy Audits Page 72

This is a more sophisticated audit. It involves looking at a two- to three- year history of utility bills. Some system testing and short-term monitoring may also be performed at this stage.

Computerized energy simulations are created to evaluate the current behavior of both individual systems and the entire building.

Modeling of proposed measures can then be used to estimate potential energy and fuel savings. This type of audit is often used to develop more complex multi-system conservation plans.

Measures are evaluated based on both client interest and financial analysis.

The financial analysis or Life Cycle Analysis allows the facility owner to truly understand the financial benefits of installing energy efficient measures.

An ASHRAE Level II audit can also earn additional points for LEED for Existing Buildings: O&M.

Energy Audits
Level 3: Investment Grade Audits

- Long term monitoring of systems and equipment
- Engineering of detailed ECMs
- Used in larger commercial projects where long-term savings are a major concern
- Guarantees savings over time

G|PRO

Energy Audits Page 72

Very similar to the general audit, the investment-grade audit goes beyond the typical financial analysis. It may involve installation of meters for long-term (several months or years) monitoring of equipment and actual engineering of detailed measures in order to evaluate the recommended solutions more accurately. This type of audit is usually reserved for more capital-intensive measures in larger commercial projects where guaranteed savings are a major concern.

Incentives and Performance Standards

Energy audits are usually required when a building owner wants to participate in a local, state, or utility financial incentive program for energy efficiency improvements.

There are low-interest loans, tax rebates, and other incentives that may apply to your situation.

Consult your local utility or state energy office to find out more.

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Energy Audits Page 72

Energy audits are usually required when a building owner wishes to participate in any sort of local, state, or utility financial incentive program for energy efficiency improvements.

The details of these vary significantly by region, but in many locations there are low-interest loans, tax rebates, and other incentives that may apply to your situation.

For the most current information for your location, you should consult your local utility or state energy office.

Personnel Certifications

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Energy Audits Page 72-73

If you are planning on participating in an incentive program, the energy auditor who conducts the audits and gathers the results for the report will normally be required by the program to be properly certified for the task.

If your auditor is certified, the program will accept his or her report as valid in most circumstances.

The following organizations offer training and certifications for energy auditors for a variety of building types:

- AEE (Association of Energy Engineers): AEE offers certificates for professionals in a variety of specialized areas, such as energy, power, green facilities, an industry.
- BPI (The Building Performance Institute, Inc.) offers the following:
    - Certification of individuals in evaluation, mechanical, envelope, and multi-family designations
    - Accreditation of organizations committed to using a quality management system
    - Quality assurance to verify conformance and provide feedback
    - Affiliation of organizations providing BPI services
    - Technical standards based on sound building science

Standards for Audits

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Energy Audits Page 71-72

The standards that are used for measuring building systems and equipment performance have been commonly agreed upon, so that there are consistent measurements for establishing proper function. The primary standards are those established by ASHRAE (American Society of Heating Refrigerating, and Air-Conditioning Engineers).

ASHRAE has enhanced the industry's understanding of how to make buildings and building systems work more efficiently, while maintaining the health and safety of the human occupants. Many ASHRAE standards have been adopted as the foundation for building codes and construction standards all over the world. The definitions of the Level 1, 2, and 3 audits were developed by ASHRAE and are available in detail at www.ashrae.org.

See page 72 of your manual for a list of ASHRAE standards that have a direct value in building management.

Implementing Audit Recommendations

- Weigh options thoroughly
- When implementing recommendations, think about the whole building approach: remember that all systems affect one another
- Recognize the interactions between all proposed improvements

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As a building manager or operator, you will probably be responsible for working with the building owner to implement the recommendations offered in the audit report; operators should confirm assumptions. It is very unlikely that they will choose to do all of them, so the discussion will be around which recommendations make the most sense to implement.

When implementing recommendations, it's essential to continue thinking about buildings as whole systems. All systems affect one another and, if not scrutinized carefully, can result in lower-than-expected energy savings.

In general, it doesn't typically make sense to upgrade just one system. Rather, one should recognize the interaction of the measures, estimate the savings accurately, and package them in the most effective manner.

An audit report will conclude with recommendations for energy-saving measures, all of which require decision-making from the building owner and operator. Some of the recommendations will be simple and inexpensive, while others will require professional installation and a large capital investment.

CLASSROOM EXERCISE:

Practice reading an audit report.

Find a sample report online at www.gpro.org.

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TEST YOURSELF:

1. What is a commissioning manual and how is it different from standard equipment manuals?
2. What are retro-commissioning and recommissioning, and why are they important for building systems' efficiency?
3. Explain how managing staging, and sequencing of combustion and chilling equipment can increase efficiency.
4. How do energy audits lead to better building efficiency?
5. Why is it important to use a whole-building approach when implementing energy audit recommendations?

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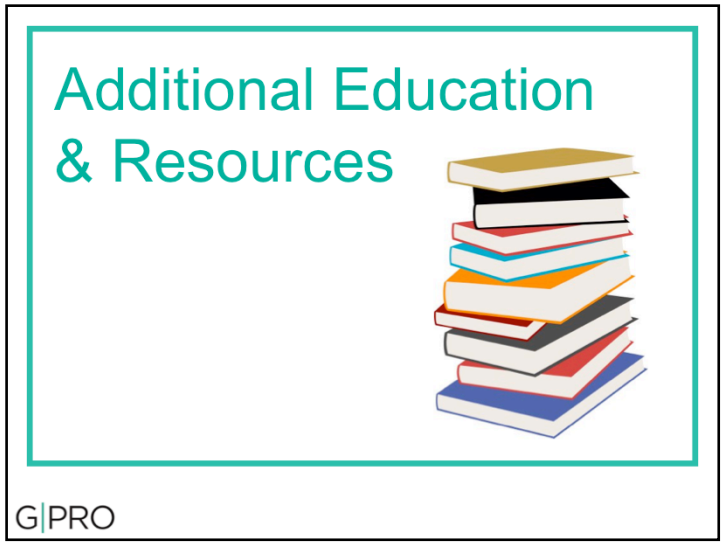
1. A Cx manual contains the required operation protocols. It is different from standard equipment manuals because equipment manuals deal with specific systems, not a whole-building approach, and result in fragmented facilities management practices. Operating manuals have detailed best practices tailored to the building and its systems.

2. **Retro-Cx** is a process meant for buildings that were never commissioned. The CxA uses a whole-building approach to review all systems and identify new operation strategies that will help the equipment and systems function at optimal levels. If a building has been previously commissioned, **recommissioning** occurs to ensure that its systems are still operating as they were designed.

3. Sequencing refers to activating parallel units in a system and, conversely, deactivating parallel units when appropriate. Sequencing is the control strategy. Staging refers to the practice of starting the boilers or chillers in a staggered manner. In this way, when the first-stage equipment has sufficient excess capacity, one or more second-stage pieces of equipment can go offline while still meeting the energy needs or load of the building.

4. Energy audits allow you to assess how energy is used in your building and to identify opportunities for increased efficiency. These opportunities may involve changing operating practices to reduce energy consumption or retrofitting the building to make the building more energy efficient.

5. It is important to use a "whole-building" approach when implementing energy audit recommendations because all systems affect one another, and if not scrutinized carefully, can result in lower-than-expected energy savings.



This course has provided an overview of sustainability in facility operations and management and an introduction to the knowledge needed to maximize building efficiency.

Continuing your "green" education will be essential to fully integrating sustainability into the way you operate and manage your buildings. Similarly, because the world of building operations and management is changing rapidly, continuing your education will keep you at the forefront of this field.

Other Training and Programs to Enhance your Skills

GPRO is a starting point!

- The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)
- Association of Energy Engineers (AEE)
- Building Operators and Managers Institute (BOMI)
- Building Operator Certification (BOC)
- Building Performance Institute (BPI)
- Union Programs
- U.S. Green Building Council: LEED Green Associate and LEED Accredited Professional

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Green Professional Building Skills Training Program