Energy Efficiency Measures to Consider

The following list is a reference resource of energy efficiency measures (EEMs) to consider when performing an energy audit. The list is organized by end use and building component and includes some water efficiency measures.

The list was developed by ASHRAE Standard Project Committee 100 in 2011 as part of the committee's rewrite of ANSI/ASHRAE Standard 100-2006. The list was developed as a reference guide to address commercial and residential occupancies, though much of the content pertains primarily to commercial and institutional buildings. Although the list covers most typical EEMs, it is by no means all inclusive. It is intended as a starting point to aid in the development of energy efficiency projects. Since Standard 100 was still in review at the time of publication of *Procedures for Commercial Building Energy Audits*, Second Edition, the reader may wish to check the published edition of Standard 100 for the most up-to-date copy of this list.

Building Envelope

- **Walls**
  - Insulate walls. Retrofit insulation can be external and internal.
    - External post insulation makes large savings possible, as this type of insulation not only contributes to a reduction of the heat loss through large wall surfaces but also eliminates the traditional thermal bridges where floor and internal wall are anchored in the exterior wall.
    - Internal insulation is typically done when external insulation is not allowed (e.g., for historical buildings). Design location and selection of insulation and vapor barrier to avoid condensation.
    - Insulate cavity walls using spray-in insulation. Design location and selection of insulation and vapor barrier to avoid condensation.
  - Consider converting an internal courtyard into an atrium to reduce external wall surfaces.
- **Roofs**
  - Use cool roofs (high-reflectance roofing material) with reroofing projects.
  - Determine roof insulation values and recommend roof insulation as appropriate.
  - Insulate ceilings and roofs using spray-on insulation.
  - Where appropriate, exhaust hot air from attics.
- **Floors**
  - Insulate floors.
  - Insulate floors using spray-on insulation.
  - Insulate basement walls with a slab over an unheated basement.
- **Windows**
  - Replace single-pane and leaky windows with thermal/operable windows to minimize cooling and heating losses.
  - Install exterior shading such as blinds or awnings to cut down on heat loss and to reduce heat gain.
  - Install storm windows and multiple-glazed windows.
  - Use tinted or reflective glazing or solar films.
  - Adopt weatherization/fenestration improvements.

- Consider replacing exterior windows with insulated glass blocks when visibility is not required but light is required.
- Landscape/plant trees to create shade and reduce air-conditioning loads.

- **Doors**
  - Prevent heat loss through doors by draft sealing and thermal insulation.
  - Install automatic doors, air curtains, or strip doors at high-traffic passages between conditioned and unconditioned spaces.
  - Use self-closing or revolving doors and vestibules if possible.
  - Install high-speed doors between heated/cooled building spaces and unconditioned spaces in areas with high-traffic passages.
- **Access**
  - Install separate smaller doors near large vehicle doors.
- **Air Leakage**
  - Seal top and bottom of building.
  - Seal vertical shafts, stairways, and outside walls and openings.
  - Compartmentalize garage doors as well as mechanical and vented internal and special-purpose rooms.
- **Moisture Penetration**
  - Reduce air leakage.
  - Install vapor and air barriers in walls, ceilings, and roofs.

HVAC Systems

- **Ventilation**
  - Reduce HVAC system outdoor airflow rates when possible. Minimum outdoor airflow rates shall comply with ANSI/ASHRAE Standard 62.1[1] or local code requirements.
  - Reduce minimum flow settings in single-duct and dual-duct variable-air-volume (VAV) terminals as low as is practical to meet ventilation requirements.
  - Minimize exhaust and makeup (ventilation) rates when possible by complying with the most stringent federal, state, and/or local code requirements.
  - Use operable windows for ventilation (natural ventilation) during mild weather when available and when outdoor conditions are optimal. Confirm that the facility has been designed for natural ventilation and that control strategies are available for operating the facility in natural ventilation mode.
  - Eliminate outdoor air ventilation during unoccupied building morning warm-up.
  - Convert the mixing air supply system into a displacement ventilation system to create temperature stratification in spaces with high ceilings and predominant cooling needs.
  - Consider replacement of an all-air HVAC system with a combination of a dedicated outdoor air system (DOAS) coupled with radiant cooling and heating systems.
  - Convert constant-volume central exhaust systems into demand-based controlled central exhaust systems when possible.
  - Convert HVAC systems to provide ventilation in accordance with the Indoor Air Quality (IAQ) Procedure of ASHRAE Standard 62.1.

[1] ASHRAE, ANSI/ASHRAE Standard 62.1-2010, *Ventilation for Acceptable Indoor Air Quality* (Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2010).

- **HVAC Distribution Systems**
  - Convert a constant-air-volume (CAV) system (including dual duct, multizone, and constant-volume reheat systems) into a VAV system with variable-frequency drives (VFDs) on fan motors. A VAV system is designed to deliver only the volume of air needed for conditioning the actual load.
  - Control VAV system VFD speed based on the static pressure needs in the system. Reset the static pressure setpoint dynamically, as low as is practical to meet the zone setpoints.
  - Reset the VAV system supply air temperature setpoint when the system is at minimum speed to provide adequate ventilation.
  - If conversion to VAV is impractical for CAV systems, reset the supply air temperatures in response to load. Dynamically control heating duct temperatures to be as low as possible and cooling duct temperatures to be as high as possible while meeting the load.
  - Use high-efficiency fans and pumps; replace or trim the impellers of existing fans and pumps if they have excessive capacity relative to peak demand.
  - Install higher-efficiency air filters/cleaners in the HVAC system. Size ducts and select filter sizes for low face velocity to reduce pressure drop where available space permits.
  - Insulate HVAC ducts and pipes, particularly where they are outside the conditioned space.
  - Check for air leaks in HVAC duct systems and seal ductwork as indicated.
  - Rebalance ducting and piping systems.
  - Provide cooling effect by creating air movement with fans.
  - Select cooling coils with a face velocity range of 300–350 fpm (1.5–1.75 m/s) to reduce the air pressure drop across the cooling coil and increase the chilled-water system temperature differential across the system.
  - Replace standard fan belts with fan belts designed for minimum energy losses, such as cog belts.
  - Eliminate or downsize existing HVAC equipment when improvements in building envelope, reductions in lighting or plug loads, and other EEMs that reduce cooling or heating loads have been implemented.
  - Eliminate HVAC usage in vestibules and unoccupied spaces.
  - Minimize direct cooling/heating of unoccupied areas by system zone controls or occupancy sensors or by turning off fan-coil units and unit heaters.
  - Replace forced-air heaters with low- or medium-temperature hydronic radiant heaters.
  - Replace inefficient window air conditioners with high-efficiency (i.e., high SEER rating) modular units or central systems.
  - Employ heat recovery from exhaust air and processes for preheating or precooling incoming outdoor air or supply air.
  - Install a transpired air heating collector (solar wall) for ventilation air preheating.
  - Modify controls and/or systems to implement night precooling to reduce cooling energy consumption the following day.
  - Use waste heat (e.g., hot gas, return air heat, return hot water) as an energy source for reheating for humidity control (often air is cooled below the dew-point temperature to remove moisture and then must be reheated to the desired temperature and humidity).
  - Avoid temperature stratification with heating either by proper air supply system design or by using temperature destratifiers (e.g., ceiling fans).
  - In humid climates, supply air with a temperature above the dew point to prevent condensation on cold surfaces.
  - Insulate fan-coil units and avoid their installation in unconditioned spaces.

- Clean heat exchangers (to maintain heat exchange efficiency) in the evaporators and condensers of refrigeration equipment on a seasonal basis.
- Use high-efficiency dehumidification systems based on either DOASs or VAV systems.
- Identify whether there are any "rogue" zones (i.e., zones that determine the cooling or heating demand on the entire system) in a multiple-zone air-handling system and modify them to eliminate their negative impact.
- Modify supply duct systems to eliminate duct configurations that impose high friction losses on the system.
- Retrofit multiple-zone VAV systems with direct digital control (DDC) controllers at the zone level, and implement supply air duct pressure reset to reduce supply air duct pressure until al least one zone damper is nearly wide open.
- Eliminate duplicative zone controls (e.g., multiple thermostats serving a single zone with independent controls).
- Convert three-pipe heating/cooling distribution systems to four-pipe or two-pipe systems. Eliminate simultaneous heating and cooling through mixed returns.
- Convert steam or compressed air humidifiers to ultrasonic or high-pressure humidifiers.
- Replace mechanical dehumidification with desiccant systems using heat-recovery regeneration.
- Consider small unitary systems for small zones with long or continuous occupancy. Avoid running large distribution systems to meet the needs of small, continuously occupied spaces.
- Install thermostatic control valves on uncontrolled or manually controlled radiators.
- Replace unitary systems with newer units with high efficiency and high SEER ratings.
- Install evaporative precooling for direct expansion (DX) systems.
- Install air-side heat recovery for systems using 100% makeup air (e.g., run-around piping or energy exchange wheels).

- **Building Automation and Control Systems**
  - Create building/air-conditioned space zones with separate controls to suit solar exposure and occupancy.
  - Use night setback or turn off HVAC equipment when building is unoccupied.
  - Install occupancy sensors with VAV systems; set back temperatures and shut off boxes.
  - Install system controls to reduce cooling/heating of unoccupied spaces.
  - Lower heating and raise cooling temperature setpoints to match the ANSI/ASHRAE Standard 55[2] comfort range.
  - Install an economizer cycle with enthalpy switchover.
  - Schedule off-hour meetings in a location that does not require HVAC in the entire facility.
  - Adjust hot-water and chilled-water temperatures to develop peak-shaving strategies based on an outdoor air temperature reset schedule.
  - Adjust housekeeping schedule to minimize HVAC use.
  - Install programmable zone thermostats with appropriate dead bands.
  - Use variable-speed drives (VSDs) and DDC on water circulation pumps and fan motors and controls.

[2] ASHRAE, ANSI/ASHRAE Standard 55-2010, *Thermal Environmental Conditions for Human Occupancy* (Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2010).

- Reduce operating hours of complementing heating and cooling systems. Ensure proper location of thermostat to provide balanced space conditioning.
- Implement an energy management system (EMS) designed to optimize and adjust HVAC operations based on environmental conditions, changing uses, and timing.

Refrigeration

- **Reduce Loads**
  - Install strip curtains or automatic fast open and close doors on refrigerated space doorways.
  - Replace open refrigerated cases with reach-in refrigerated cases.
  - Replace old refrigerated cases with new high-efficiency models (with improved glazing, insulation, higher-efficiency motors, reduced antisweat requirements, and higher-efficiency lighting).
  - Replace worn door gaskets.
  - Replace broken or missing automatic door closers.
  - Check defrost schedules and avoid excessive defrost.
  - Repair/install refrigeration piping insulation on suction lines.
  - Install humidity-responsive antisweat heating (ASH) controls on refrigerated case doors.
  - Install refrigerated case, walk-in, or storage space lighting controls (scheduled and/or occupancy sensors).
  - Install night covers to reduce infiltration in open cases.
  - Install low/no ASH refrigerated case doors.
  - Replace lights with light-emitting diode (LED) strip lights with motion sensors in refrigerated cases and spaces.
  - Increase insulation on walk-in boxes and storage spaces that have visible moisture or ice on walls, corners, etc.
- **Improve System Operating Efficiency**
  - Clean condenser coils.
  - Check the refrigerant charge and add refrigerant when needed.
  - Reclaim heat from hot gas line for domestic water heating or space heating.
  - Install floating head pressure controls, adjustable head pressure control valve, and balanced port expansion valves for DX systems.
  - Install floating suction pressure controls on DX systems.
  - Install evaporator fan motor VSDs and controllers in walk-ins and refrigerated storage spaces.
  - Replace single-phase, less than 1 hp evaporator fan motors with electrically commutated motors (ECMs).
  - Replace three-phase evaporator and condenser motors with premium efficiency motors.
  - Replace single compressor systems with multiplex systems and a control system.
  - Install mechanical subcooling.
  - Install mechanical unloaders on appropriate multiplex reciprocating semi-hermetic compressors.
  - Install VFDs on ammonia screw compressors.
  - Install high specific efficiency (Btu/W) condensers.
  - Install hybrid air-cooled/evaporatively cooled condensers.

Water Systems

- **Domestic Hot-Water Systems**
  - Lower domestic water setpoint temperature to 120°F (49°C).
  - Install point-of-use water heaters.
  - Install water heater blankets on water heaters.
  - Install automatic flue dampers on fuel-fired water heaters.
  - Insulate hot-water pipes.
  - Use heat pump water heaters.
  - Reclaim heat from waste water, refrigeration system, cogeneration, or chillers.
  - Install solar heating where applicable.
  - Replace dishwashers by installing low-temperature dishwashers that sanitize primarily through chemical agents rather than high water temperatures.
  - Retrofit dishwashers by installing electric eye or sensor systems in conveyor-type machines so that the presence of dishes moving along the conveyor activates the water flow.
  - Reduce operating hours for water heating systems, including recirculating pumps when applicable.
  - Install gray water heat recovery from showers, dishwashers, and washing machines.
  - Install low-flow dishwashing prewash spray nozzles.
  - Replace outdated laundry equipment with newer low-water-usage models.
  - Reduce recirculation water flow to achieve at least a 5°F (2.8°C) temperature drop based on heat losses in the supply and recirculation piping systems.
- **Water Conservation**
  - Replace faucets with units that have infrared sensors or automatic shutoff.
  - Install water flow restrictors on shower heads and faucets.
  - Install covers on swimming pools and tanks.
  - Install devices to save hot water by pumping water in the distribution lines back to the water heater so hot water is not wasted.
  - Install water, industrial waste, and sewage metering.
  - Install irrigation timers to schedule sprinkler use to off-peak, night, or early morning hours, when water rates are cheaper and water used is less likely to evaporate.
  - Use low-flow sprinkler heads instead of turf sprinklers in areas with plants, trees, and shrubs.
  - Use sprinkler controls employing soil tensiometers or electric moisture/rain sensors to help determine when soil is dry and to gauge the amount of water needed.
  - Use trickle or subsurface drip irrigation systems that provide water directly to turf roots, preventing water loss by evaporation and runoff.
  - Install low-flow toilets and waterless urinals.
  - Use water reclamation techniques.

Energy Generation and Distribution

- **Boiler System**
  - Install air-atomizing and low-nitrogen-oxide (NO_x) burners for oil-fired boiler systems.
  - Install automatic boiler blow-down control.
  - Install flue gas analyzers for boilers.
  - Install an automatic flue damper to close the flue when it is not firing.
  - Install turbulators to improve heat transfer efficiency in older fire tube boilers.
  - Install low-excess air burners.

- Install condensing economizers.
- Install electric ignitions instead of pilot lights.
- Install an automatic combustion control system to monitor the combustion of exit gases and adjust the fuel-air ratio to reduce excess combustion air.
- Install isolation valves to isolate off-line boilers.
- Maintain insulation on the heat distribution system. Replace insulation after system repair, and repair damaged insulation.
- Provide proper water treatment to reduce fouling.
- Replace central plant with distributed satellite systems.
- Downsize boilers with optimum burner size and forced draft (FD) fans.
- Operate boilers at their peak efficiency; shut down large boilers during summer and use smaller boilers.
- Install expansion tanks on hot-water systems that are properly sized for the system.
- Employ heat recovery through desuperheating.
- Preheat combustion air, feed water, or fuel oil with reclaimed waste heat from boiler blowdown and/or flue gases.
- Install automatic controls to treat boiler makeup water.
- Adjust boilers and air-conditioner controls so that boilers do not fire and compressors do not start at the same time but satisfy demand.
- Clean boiler surfaces regularly to reduce scale and deposit, which will improve heat transfer.
- Replace noncondensing boilers with condensing boilers (15%–20% higher efficiency when compared to new noncondensing boilers).
- Prevent dumping steam condensate to drain.
- Survey and fix steam/hot-water/condensate leaks and failed steam traps.
- Convert steam system to low-temperature sliding temperature hot-water system. Install complementing steam boilers where needed.
- Improve boiler insulation. It is possible to use new materials that insulate better and have lower heat capacity.
- Check steam trap sizes to verify they are adequately sized to provide proper condensate removal.
- Consider opportunities for flash steam use in low-temperature processes.
- Consider pressuring atmospheric condensate return systems to minimize flash losses.
- Consider relocation or conversion of remote equipment such as steam-heated storage.
- Evaluate potential for cogeneration in multi-pressure steam systems presently using large pressure-reducing valves.
- Install steam metering and monitoring systems.
- Investigate economics of adding insulation on presently insulated or uninsulated lines.
- Review mechanical standby turbines presently left in the idling mode.
- Review operation of steam systems used only for occasional services, such as winter-only tracing lines.
- Review pressure-level requirements of steam-driven mechanical equipment to consider using lower exhaust pressure levels.
- Survey condensate presently being discharged to waste drains for feasibility of reclaim or heat recovery.
- Reduce boiler operating pressure to minimize heat losses through leakage.

- **Chiller System**
  - Retrofit chillers with equipment that has high efficiency at full and part load.

- Retrofit cooling towers by including high-efficiency fill, VSD fans, fiberglass fans, hyperbolic stack extensions, fan controls, VSD pump drives, and improved distribution nozzles.
- Install economizer cooling systems (heat exchanger between cooling tower loop and chilled-water loop before the chiller).
- Install evaporatively cooled, evaporatively precooled, or water-cooled condensers in place of air-cooled condensers.
- Isolate off-line chillers and cooling towers.
- Reduce overpumping on chilled-water systems.
- Replace single compressors with multiple different-size staged compressors.
- Install two-speed mechanical unloading or VFDs on compressor motors.
- Use absorption chillers when there is a cogeneration system or waste heat or when heat from solar thermal generation is available.
- Install double-bundle chillers for heat recovery.
- Cycle free cooling by piping chilled water to the condenser during cold weather.
- Prevent chilled water or condenser water flowing through the off-line chiller. Chillers can be isolated by turning off pumps and closing valves.
- Control makeup water and reduce blowdown by adding temperature control valves to cooling water discharge lines in equipment such as air compressors and refrigeration systems.
- Install drift eliminators in evaporative cooling systems or repair existing equipment.
- Install softeners in evaporative cooling systems for makeup water, side-stream filtration (including nanofiltration, a form of low-pressure reverse osmosis), and side-stream injection of ozone.
- Install submeters in evaporative cooling systems for makeup water and bleed-off water for equipment such as cooling towers that use large volumes of water.
- Use evaporative cooling systems that control cooling tower bleed-off based on conductivity by allowing bleed-off within a high and narrow conductivity range. This will achieve high cycles of concentration in the cooling system and reduce water use in cooling tower.
- Clean evaporator and condenser surfaces of fouling.
- Optimize plant controls to raise evaporator temperature as high as possible while meeting the loads of the system. Also optimize condenser water temperature control to achieve the best combination of chiller and tower efficiencies.
- Optimize multiple chiller sequencing.
- Control crankcase heaters OFF when not needed.
- Raise evaporator or lower condenser water temperature.
- Optimize multiple chiller sequencing.
- Use two-speed or variable-speed fans instead of water bypass to modulate the cooling tower capacity.
- Balance water flow in the chilled-water system.
- Use VFDs for the primary chilled-water pumps above 5 hp (3.7 kW). Consult chiller and tower manufacturers' specifications to set appropriate minimum flow limits.
- Apply cooling-load–based optimization strategies.
- Install water-source heat pumps (WSHPs) to augment the capacity of the hot-water boiler and to reduce the cooling load on the existing chiller systems when heat is required.
- Trim impellers on all condenser-water and chilled-water pumps that are oversized.
- Replace all pump and fan motors with premium-efficiency motors.

- **Thermal Storage and Heat Pumps**
  - Install cool storage to reduce peak demand and lower electric bills.
  - Install hot-water storage to shave peaks of hot-water usage or to store reclaimed energy from combined heat and power systems or waste heat from chillers for later use.
  - Install add-on heat pumps.
  - Install secondary pumping systems.
  - Install VFDs on secondary pumps and replace most three-way valves with two-way valves.
  - With cool storage and VFDs on fans and pumps, consider use of low-temperature chilled water to reduce fan and pump energy.
  - Replace air-conditioning and heating units with heat pumps. Consider geothermal heat pumps.
  - Replace electric water heaters with heat-pump water heaters.

Nonresidential Lighting

- **General**
  - Check the current Illuminating Engineering Society of North America (IES) recommended light levels[3] for the tasks in the facility; they may be lower than when the original lighting system was designed. Use the current recommended light levels to help shape all future lighting decisions, including those enumerated here.
- **Daylighting**
  - Replace existing fenestration (toplighting and/or sidelighting) with dual-glazed low-e glass wherever possible to reduce thermal gain.
  - Evaluate opportunities for daylight harvesting. Measure light levels on a day with a clear sky with the electric lighting both turned on and turned off. If daylighting provides sufficient light levels, then install dimming controls (and appropriate ballasts if the lighting system is fluorescent or high-Intensity discharge [HID]) to reduce the use of electric lighting. See ANSI/ASHRAE/IES Standard 90.1-2010,[4] Section 3.2, for the definition of "daylighted" areas.
  - Install interior and/or exterior shading as appropriate to reduce solar heat gain and cut down on heat loss.
- **Luminaire Upgrades**
  - Replace incandescent lamps in existing luminaires with more efficacious sources such as halogen, integrally ballasted compact fluorescent, solid-state (LED), or metal halide retrofit lamps. Alternatively, replace incandescent and halogen luminaires with luminaires using these sources.
  - Upgrade T12 fluorescent luminaires with more efficacious sources such as high-performance T8 or T5 systems by i) replacing lamps and ballasts, ii) utilizing luminaire upgrade kits, or iii) installing new luminaires.
  - If the lighting system is already a high-performance fluorescent system, consider replacing the lamps with reduced-wattage lamps (where appropriate).
  - For fluorescent lighting, install high-performance electronic ballasts that are multilevel or continuously dimmable with the appropriate controls.

[3] IES, *The Lighting Handbook*, 10th Edition (New York: Illuminating Engineering Society of North America, 2011).

[4] ASHRAE, ANSI/ASHRAE/IES Standard 90.1-2010, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2010).

- Replace mercury vapor or probe-start metal halide HID luminaires with pulse start metal halide or high-performance T8 or T5 fluorescent luminaires.
- Upgrade task and display lighting, including lighting in refrigeration and freezer cases, to more efficacious sources such as LED sources.

- **Signage**
  - Evaluate upgrading standard fluorescent or neon signage with more efficacious sources such as high-performance T8 or T5 fluorescent systems or solid-state (LED) systems.
  - Upgrade all exit signs to solid-state (LED) exit signs. Supplemental lighting may need to be added if the existing exit sign also provided general lighting.
- **Lighting Controls**
  - Reduce lighting usage through management and controlled systems—in general, consider bringing the lighting control protocols for the building up to ASHRAE/IES Standard 90.1-2010 (Section 9.4.1) standards; this includes the following.
    - Reduce operating hours for lighting systems through the use of controls and building management systems. This includes the use of shutoff controls such as time clocks.
    - Use reduced lighting levels, including OFF, when spaces are unoccupied, during nighttime hours, and for restocking, cleaning, and security. Whenever possible, move restocking and cleaning operations to daytime.
    - Use occupancy, vacancy, or motion sensors. Wherever applicable, these sensors should either be manual ON or turn lighting on to no more than 50% of lighting power.
    - Use controls to allow for multilevel or dimming control of the lighting in appropriate spaces.
  - Recircuit or rezone lighting to allow personnel to only turn on zones based on use rather than operating the entire lighting system.
  - Install personal lighting controls so individual occupants can vary the light levels within their spaces.
  - Consider installation of lighting systems that facilitate load shed requests from the electric utility or energy aggregator.
  - Evaluate turning emergency lighting off or to a lower level—without sacrificing safety requirements—when a building or portion of a building is completely unoccupied.
- **Exterior Lighting**
  - Use automatic controls that can reduce outdoor lighting levels or turn them off either when sufficient daylight is available or when not needed.
  - Reduce power levels or turn exterior signage off when appropriate.
  - When selecting new outdoor luminaires, consider the amount of backlight, uplight, and glare delivered by each luminaire type to improve functionality and minimize the environmental impact. See IES TM-15-11.[5]
- **Luminaire Layout**
  - Consider using lower levels of general illumination overall and then supplement with task lighting where needed.
  - Consider new layouts that may maximize efficiency and reduce the total connected lighting load. Consider plug-and-play systems to provide flexibility as space use changes.
- **Other**

[5] IES, *Luminaire Classification System for Outdoor Luminaires* (New York: Illuminating Engineering Society of North America, 2011).

- Implement a plan to recycle lamps, ballasts, and luminaires removed from the building.

Residential Lighting

- **General**
  - Replace incandescent lamps with halogen, integrally ballasted compact fluorescent, or solid-state (LED) retrofit lamps in existing luminaires.
  - Select lamps that deliver the appropriate color temperature of light. Color temperature indicates the color appearance of the light produced by the lamp. Halogen lamps are a more energy-efficient form of incandescent technology and will deliver light similar to incandescent lamps. Linear fluorescent, compact fluorescent, and solid-state (LED) lamps are available in a variety of color temperatures. Lamps with color temperatures of 2700K and 3000K will deliver the most incandescent-like light. Lamps with a color temperature of 3500K will deliver a neutral, white light. Lamps with color temperatures of 4000K and higher will deliver cooler, white light. The higher the color temperature number, the cooler the light.
  - Select lamps appropriate for use in enclosed luminaires, outdoor applications, cold-temperature applications, and with dimming controls. Check the packaging or manufacturer's Web site for guidance.
  - Utilize energy-efficient technologies such as fluorescent, compact fluorescent, or solid state (LED) in applications with the longest operating times.
  - Use a whole-home lighting control system.
- **Interior**
  - Replace ON/OFF switches with dimming controls appropriate for the light source.
  - Upgrade T12 fluorescent luminaires to high-efficiency T8 or T5 systems by replacing lamps and ballasts or installing new luminaires. Ballasts should be rated for residential use by the Federal Communications Commission.
  - Evaluate replacing incandescent and halogen luminaires with dedicated compact fluorescent or solid-state (LED) luminaires.
  - When replacing fluorescent ballasts or installing new fluorescent luminaires, evaluate using electronic dimming ballasts with the appropriate dimming controls.
  - Evaluate adding daylight-sensing controls for general illumination lighting in rooms with windows or skylights. Use in combination with dimming systems so the electric light level can be adjusted based on the amount of daylight available.
  - Install vacancy sensors to automatically turn off lighting in closets, storage areas, workrooms, garages, and exterior buildings when the space has been vacated for 15 minutes.
  - Add task lighting that utilizes energy-efficient technologies such as fluorescent and solid state (LED) and reduce or eliminate overhead lighting.
- **Exterior**
  - Install time clocks and/or motion sensors to control outdoor lighting.

Electric Systems, Motors

- Install energy-efficient transformers. Use an infrared camera to indentify high-heat-loss transformers.
- Install electrical meters for submetering lighting, elevators, plug loads, and HVAC equipment.
- Reduce demand charges through load shedding, operational changes, and procedural changes.

- Replace oversized electric motors with right-sized or slightly oversized motors.
- Replace existing three-phase, 1 hp and greater electric motors with premium-efficiency motors (often a better choice than rewinding motors).
- Replace existing one-phase, 1 hp and lower motors with ECMs.

Appliances

- Install appliances (clothes washers, dehumidifiers, dishwashers, freezers, refrigerators, room air cleaners and purifiers, office equipment, and televisions) that are certified as ENERGY STAR® compliant.
- Reduce plug loads, using devices to shut off equipment not being used (use occupancy sensors or timers).
- Install vending machine controllers.