General Air Handling Unit Checklist

- [ ] **Verify Proper Operation of Air Dampers**
Confirm that all AHU dampers are operating correctly. Have an operator send a control signal to open and close all dampers and visually confirm that they are fully opening and closing. Also have the operator open the dampers to about 50% to make sure they are modulating correctly. Repair any actuators or damper banks that are not functioning correctly. In some cases modulating damper actuators will need to be installed to allow for changes in outside airflow rates if the current dampers are open/closed.

- [ ] **Verify Proper Operation of Air-side Economizer**
Check the DDC system control sequence to see if the current control system is using an air-side economizer. Make sure the economizer is working correctly by viewing damper positions and outside airflow rates at different outside air temperatures. If no air-side economizer function is currently used, determine the applicability of enabling one. Outside air temperature sensors are required for dry bulb–based economizers and an additional outside air relative humidity sensor is needed for enthalpy-based economizers. Both of these sensors need to be working correctly for the system to operate as designed.

- [ ] **Verify Proper Operation of Heating and Cooling Valves**
Check all heating and cooling valves for proper operation. Check the heating valve in the winter by shutting off the valve and checking the air handler mixed air and discharge temperatures. If the valve is closed and supply is still heated by the coil, the valve isn't seating correctly and is causing unnecessary simultaneous heating and cooling. The same procedure should be followed for cooling coil analysis.

- [ ] **Check the Condition of Heating and Cooling Coils and AHU Filters**
Visually inspect the condition of the heating and cooling coils and the AHU filters. If the coils are dirty or the filters are clogged, change out the filters and clean the coils. If the current maintenance schedule isn't sufficient, revise the schedule accordingly. If static pressure sensors are used to determine filter dirt loading, make sure the sensors are working correctly. Dirty filters and coils will increase the static pressure across the coil, increasing fan system energy use in addition to reducing the heat transfer coefficient of the coil, forcing the system to move more air over the coil for the same heating/cooling effects.

- [ ] **Eliminate Duct Leakage**
Periodically trace the main heating, ventilating, and air conditioning (HVAC) duct runs and listen for air leaks in the duct system. Confirm that the duct static pressure setpoint is within the pressure class of the installed ductwork before repairing any leaks. If the distribution system is really leaky, consider replacing the ductwork or using a duct sealant system to seal the leaks.

- [ ] **Eliminate 100% of Outside Air Systems if Practicable**
One of the largest energy-wasting systems is 100% outside air ventilation in areas that don't require it. Common areas that require 100% outside air are operating rooms (ORs) and labs. If 100% outside air AHUs are being used for differing space types that don't require outside air, modulating outside air dampers and return air systems should be installed to reduce outside air.

- [ ] **Reduce Outside Airflow Rates to ASHRAE 62.1-2010**
Most buildings are bringing in more outside air than they are required to per ASHRAE 62.1-2010. Outside airflow rates should be reduced to the minimum allowed by ASHRAE for each space. Consider installing CO_2 sensors in return air ductwork and maintaining interior CO_2 levels at <700 ppm above outside air CO_2 levels during occupied hours. Also consider implementing an outside air damper reset schedule based on time of day and occupancy patterns within the building. During unoccupied hours and during morning warm-up cycles, all outside air dampers should be 100% closed.

- [ ] **Implement an HVAC System Night Setback Schedule**
For all HVAC systems that serve non 24/7 areas, make sure that night setback controls have been implemented. Work with site staff to identify operational hours of HVAC equipment. Some areas may contain equipment that have acceptable temperature limits, thus it is important that unoccupied set-points are not outside the acceptable limits of the equipment in the space.

- [ ] **Track HVAC Setback**
Set up trend logs of your HVAC systems to collect data on whether your systems are actually going into night setback mode. If your system is coming on during the night to either warm up or cool down spaces, look at the unoccupied temperature range of the space to see if it can be adjusted. Also check to see if there is something going on in the space causing the temperature to go out of range. In addition, the site can implement an optimum start/stop sequence through the building automation system or advanced programmable thermostat.

- [ ] **Monitor Exhaust Fan Controls**
For HVAC zones that are utilizing night setbacks, make sure the exhaust fans serving that zone are shutting down on a similar schedule. If exhaust fans are left on 24/7 a negative pressure will form within the building that will draw in unconditioned outside air, increasing the amount of time and energy it will take the HVAC system to bring the space temperature back to the occupied setpoints. This will also use additional electrical energy at night to power the fans, which can be reduced or eliminated by turning the fans off or installing variable frequency drives (VFDs) to set back the flow rate at night.

- [ ] **Slow Down Systems During Unoccupied Hours**
If certain parts of the building are occupied after hours, implement the following measures:
  - Reset outside air intake to a lower level (outside air damper 0-5% open)
  - Reset minimum airflow to a lower value (typically 33% to 50% of current flow)
  - Reset supply air static to a lower level or set supply air fan speed to a lower value

Constant Volume Air Handling Unit Checklist

- [ ] **Adjust Total Airflow and Head**
Airflow rates are often significantly higher than required in buildings primarily due to system oversizing. In some large systems, an oversized fan causes over-pressurization in terminal boxes. The excessive airflow can often cause excessive fan energy consumption, excessive heating and cooling energy consumption, humidity control problems, and excessive noise in terminal boxes. Calculate the required airflow rate in heating and cooling mode to determine the correct flow rates. If the airflow rate can be reduced, install a VFD and slow the fan down to the required flow rates. The VFD can also be used to slow down the fan during unoccupied hours if the AHU has to stay on at night. In addition, make sure outside air is reduced accordingly.

- [ ] **Convert the Constant Volume System to a VAV System**
A VAV system can significantly reduce HVAC system energy use. All constant volume AHUs should be identified and considered for retrofit to a VAV system.

- [ ] **Implement a Supply Air Temperature Reset Schedule**
The goal of a supply air temperature reset schedule is to minimize combined fan power and thermal energy consumption or cost. For single duct constant volume systems, maintain the supply air temperature no higher than 57°F if the outside air humidity ratio is higher than 0.009 or the dew point is higher than 55°F. When the outside air humidity ratio is lower than 0.009, the supply air temperature can be reset to a higher temperature over the temperature range of 55°F to 65°F.

Variable Air Volume Air Handling Unit Energy Conservation Measures

- [ ] **Investigate Duct Static Pressure**
For VAV systems, review your duct static pressure setpoints and adjust them as low as possible while keeping all VAV dampers below 90% open. If VAV dampers are 100% open during periods, identify the reasons the space is calling for additional air flow and adjust system loads (i.e., relocate certain internal loads).

- [ ] **Reset the Supply Air Temperature**
Maintain the air temperature no higher than 57°F if the outside air humidity ratio is higher than 0.009 or the dew point is higher than 55°F. Both humidity ratio and dew point can be determined using dry bulb temperature and relative humidity data. Maintain the supply air temperature no higher than 57°F if the fan air flow is higher than 70% of the air flow under the maximum load conditions. This is often significantly smaller than 70% of the design air flow. When the air flow is higher than 70%, increased air flow has a significant impact on fan power. For example, resetting the supply air temperature from 55°F to 57°F can potentially increase the air flow by 10%. This will increase fan power from 34% to 51% of the maximum value. When the outside air humidity ratio is lower than 0.009 and the air flow is lower than 50%, the supply air temperature can be modulated to maintain total airflow at 50% or lower. If the air flow is lower than 50%, the supply air temperature can be increased. However, the supply air temperature must be lower than a high limit, which can be set to 65°F.

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Boiler System Checklist

- [ ] **Install Small Modular Boilers**
Evaluate the opportunity to install multiple small boilers to meet the heating load of a given facility. It is more efficient to operate smaller boilers when the heating load is 25% to 50% of the design capacity than it is to use one large boiler to meet a partial load. Specify minimum boiler efficiency at 89% (annual fuel utilization efficiency [AFUE]).

- [ ] **Install a Condensing Gas Furnace**
For smaller facilities, condensing gas furnaces should be installed that have efficiencies on the order of 92% to 96%. Small condensing gas furnaces are a great application for small facilities and can reduce overall natural gas use at a small facility by 10% to 20%.

- [ ] **Install Condensing Boiler Systems**
Evaluate the opportunity to install multiple condensing gas boilers to meet the heating load of a given facility. Condensing boilers have good part-load efficiencies and can have overall efficiencies as high as 98%. In addition to the condensing boiler installation, 180/120°F heating coils (60 deg delta) should be installed with a supply water temperature reset.

- [ ] **Convert Three-Way Hot Water Valves to Two-Way Valves**
Check the configuration of each hot water valve on each heating coil (includes air handling units, fan coils, etc.). If three-way valves and constant volume pumps are installed, convert the valves to two-way and install variable frequency drives on hot water pumps. Once the valve configuration is confirmed as correct, check that the static pressure setpoint controlling the pump variable frequency drives isn't set artificially high.

- [ ] **Reset Hot Water Supply Temperature and Pressure Based on Heating Coil Valve Position**
Adjust the hot water supply temperature and loop differential pressure based on the heating coil valve position. The hot water supply temperature should be reset based on manufacturer's recommendations for the particular boiler. The control algorithm should be set up such that the coil with the largest cooling load maintains the valve at 90% open.

- [ ] **Perform Combustion Efficiency Analysis and Install Automated O_2 Trim System**
The efficiency of the combustion process is typically measured through the percent oxygen (O_2) in the exhaust gas. The amount of oxygen (or excess air as it is often called) in the exhaust gas is defined as the amount of air above that which is theoretically required for complete combustion. The boiler can be tuned by adjusting the air-to-fuel ratio linkages feeding the boiler burner. Combustion analysis and tuning should be conducted at least twice a year. For larger boilers, greater than 300 hp, a stack gas oxygen analyzer can be installed to continuously monitor excess air and adjust the boiler fuel-to-air ratio for optimum efficiency.

- [ ] **Use Effective Boiler Management Techniques**
Operating on high fire settings or installing small boilers can save more than 7% of a typical facility's total energy use. Doing comprehensive tune-ups and correcting excessive air losses, high stack temperatures, and excessive smoking can result in fuel savings of up to 20%. Installing insulation on all hot water and steam pipes over 120°F will ensure that excessive heat is not lost in transmission.

- ☐ **Set a Maintenance Schedule for the Boiler**
  Periodic maintenance of a boiler should be scheduled to ensure that the boiler is operating at peak efficiency. Peak efficiency can be achieved by optimizing the air-to-fuel ratio by using an oxygen trimming system. It is also important to clean the fire side and water side of the boiler to make sure that there is no buildup of slag and scale to inhibit the transfer of heat. Checking the water quality is also important to limit the buildup of scale.

- ☐ **Install Automatic Steam Trap Monitors**
  Malfunctioning steam traps can waste much energy. An automatic monitor can handle up to 16 steam traps and detect malfunction, allowing the steam traps to be repaired before a large amount of energy is lost.

- ☐ **Consider Using a Solar Ventilation Preheating System for Combustion Air**
  Using solar ventilation preheating will decrease the amount of energy needed to heat combustion air. The solar preheating system requires no maintenance and has a quick payback (6 to 7 years in some cases).

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Building Envelope Checklist

- [ ] **Install Additional Insulation in Exterior Walls**
Adding insulation to exterior walls can reduce the heat gain or loss through the building envelope and save energy on maintaining comfortable conditions inside of the building. An exterior insulation and finish system (EIFS) can be used for exterior insulation. Loose-fill insulation can be used for enclosed existing walls and hard-to-reach places. Rigid fibrous insulation is good for ducts in unconditioned spaces or other places requiring insulation that can withstand high temperatures. Sprayed foam and foamed-in-place insulation can be used in enclosed existing walls.

- [ ] **Seal Areas of Infiltration in Exterior Walls**
Using caulk or weather-stripping to seal areas of infiltration can reduce the amount of unconditioned air that enters the building and save significant amounts of energy.

- [ ] **Fix Rain Leaks in Exterior Walls**
Rain leaks are indications of improper installation of siding material, poor-quality flashing, and faulty weather-stripping or caulking around exterior joints. This can cause a drainage plane within the wall system of the building and significantly damage the building envelope.

- [ ] **Install Solar Shading Features on East-, West-, and South-Facing Facades**
Installing high-quality fenestration and shading features such as landscaping (trees, hedge rows), overhangs or fins, light shelves, and blinds can save heating and cooling energy as well as save on electrical lighting if designed properly. Shading features should be installed on all applicable east-, west-, and south-facing facades.

- [ ] **Replace Old or Single-Pane Windows**
New window technologies can save significant amounts of energy. Old and metal window frames should be replaced with nonmetal insulating frames. Old or single-pane windows should be replaced with double- or triple-pane glass with insulating gas (argon or krypton). Also, the new glass should be specified based on climate and include tints, heat-reflective coatings (low emissivity [low-e]), or laminates.

- [ ] **Add Film to Old or Single-Pane Windows**
New window film technology can significantly save energy by reducing solar heat gain into the building. Old or single-pane windows should be retrofitted with low-e products or blue/green tints that combine a low solar heat gain coefficient (SHGC) with high visible light transmission (VT).

- [ ] **Install Revolving Doors**
Revolving doors reduce the amount of unconditioned air entering the building by a factor of eight when compared with standard swinging doors. This reduction in infiltration will significantly reduce the energy required for heating and cooling loads. Revolving doors should replace swinging doors where applicable.

☐ **Create Entrance Vestibule with Two Doors**
Entrance vestibules reduce the amount of unconditioned air that enters the building, reducing the energy required for heating and cooling loads. Single-door entrances should be replaced with two-door entrance vestibules.

☐ **Install Weather-Stripping Around Loading Dock Doors**
The irregular surfaces and mounting hardware of rolling doors require heavy-duty weather-stripping (vinyl or wood pile, neoprene bulb, or neoprene baffle). All loading dock doors should be insulated to reduce heat transfer through the building envelope and reduce energy demands.

☐ **Increase Roof Insulation**
Increasing the amount of roof insulation will reduce heat transfer through the building envelope and reduce energy demands. Loose-fill, sprayed-foam, or foamed-in-place insulation can be used in unfinished attic floors. Batt or roll insulation can be used in unfinished attic walls and ceilings. Foam board insulation can be applied above flat roof decks.

☐ **Retrofit Existing Roof with Green Roof or Cool Roof**
Retrofitting an old roof with a green roof or cool roof can save significant amounts of energy. The following Web sites can be useful for calculating savings and searching for products:

- DOE Cool Roof Calculator, www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm
- ENERGY STAR® Roof Products, www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products
- ORNL and LBNL Roof Savings Calculator, www.roofcalc.com/RoofCalcBuildingInput.aspx

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Chilled Water System Checklist

- [ ] **Convert Three-Way Chilled Water Valves to Two-Way Valves**
Check the configuration of each chilled water valve on each cooling coil (includes AHUs, fan coils, etc.). If three-way valves and constant volume pumps are installed, convert the valves to two-way and install variable frequency drives (VFDs) on secondary chilled water pumps. The secondary chilled water loop pumps should have VFDs and two-way valves on all cooling coils (the AHU that is the furthest away from the chiller plant can have a three-way valve). Once the valve configuration is confirmed to be correct, check that the static pressure setpoint controlling the pump VFDs isn't set artificially high.

- [ ] **Install More Efficient Cooling Equipment**
Replace inefficient cooling equipment with new high efficiency equipment that has a higher coefficient of performance (COP) than the existing equipment. Refer to ASHRAE Standard 90.1 – 2010 for the most comprehensive set of efficiency standards for cooling equipment.

- [ ] **Replace Large Air Cooled Cooling Equipment with Water Cooled Chillers and Cooling Towers**
All air cooled chillers over 100 tons should be replaced with water cooled chillers. Water cooled chilled water plants have COP ratings that are approximately twice as high as air cooled equipment.

- [ ] **Reset Chilled Water Supply Temperature Based on Cooling Coil Valve Position**
Adjust the chilled water supply temperature based on cooling coil valve position. The chilled water supply temperature should be reset, up to a maximum temperature of 50°F. The control algorithm should be set up such that the coil with the largest cooling load maintains the valve at 90% open.

- [ ] **Reset Condenser Water Based on Outside Air Wet-Bulb and Install VFDs on Cooling Tower Fans**
Reset the condenser water supply temperature to within 3°F to 7°F of the outside air wet-bulb. This reduces the temperature lift between the condenser and evaporator in the chiller and significantly reduces chilled water system energy use. In addition, VFDs should be installed on cooling tower fans and the control sequence should be set up such that the VFDs ramp up to 50% before bringing on a second fan. The control system should operate the maximum number of cooling tower cells.

- [ ] **Convert the Primary/Secondary Chilled Water Plant to Variable Flow Primary**
Evaluate the opportunity to remove the primary chilled water pumps, and use the secondary pump (which can be resized as needed) as the variable flow primary pump with a modified control sequence.

- [ ] **Install a Desiccant Dehumidification System**
Moisture can be removed from conditioned air through the use of desiccants such as lithium bromide (LiBr). Desiccants enable independent control of temperature and humidity, improving heating, ventilating, and air conditioning (HVAC) system efficiency. Desiccant components can be powered by waste heat from a local onsite producer.

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Domestic Hot Water Checklist

- [ ] **Replace Existing DHW System with an On-Demand Water Heater**
  Tankless natural gas or electric water heaters typically result in energy savings on the order of 8% to 25%. Tankless water heaters eliminate standby energy losses associated with hot water storage tanks.

- [ ] **Lower the DHW Temperature Setpoint**
  Reducing the DHW setpoint temperature reduces standby energy losses and the total amount of energy supplied to the DHW system. A lower temperature limit should be set at 120°F to ensure that all waterborne infections are killed.

- [ ] **Replace Existing DHW System with Heat Pump Water Heaters**
  Heat pump water heaters reduce energy use by 40% to 60% compared to a standard electric resistance heater, with payback periods typically less than three years. Heat pump water heaters need to be installed in applications where the cold air discharged from the evaporator can be exhausted from the space or used to cool the facility (well suited for hot climates).

- [ ] **Install Additional Tank Insulation**
  Blanket insulation can sometimes be applied to existing DHW tanks, reducing standby energy losses.

- [ ] **Insulate Hot Water Pipes**
  Pipe insulation reduces heat loss through distribution pipes and increases overall system efficiency. Any heated pipe with exterior temperatures over 120°F should be insulated. Energy savings can be calculated with 3E Plus software (www.pipeinsulation.org)

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Emerging Technologies Checklist

- [ ] **LED Lighting**
Light-emitting diode (LED) lighting is robust (shock resistant), uses little energy, has a long life (50,000 hours), is fully dimmable, turns on instantly, and has no infrared or ultraviolet components. Although LED lights are still relatively expensive, the price is expected to go down. There are many applications where LED lighting is applicable, so consideration should be given to LED lighting.

- [ ] **Plasma Lighting**
Using plasma lighting has many advantages that make it a good fit for a variety of lighting applications. Plasma light bulbs use all benign materials in their construction and offer high efficacy, long life (20,000–60,000 hours), constant light output over the life of the bulb, and excellent color rendering.

- [ ] **Super T-8 Fluorescent Lamps**
Super T-8 fluorescent lamps have the same light output as standard T-8 lamps, but they use less energy, last longer, and have improved color rendering. The only disadvantage of super T-8 lamps over standard T-8 lamps is that they are slightly more expensive.

- [ ] **Scotopic Lighting**
Scotopic lighting uses a slightly more blue light than traditional lights to stimulate the eye's photoreceptors in order to make the pupils contract and increase visual acuity. This allows the light levels in a building to be reduced while allowing people to see better.

- [ ] **Task-Ambient Lighting Design**
Task-ambient lighting uses direct and/or indirect lighting with lower ambient light levels and localized task lights to illuminate a work surface. This method saves energy and also improves occupant comfort. This approach takes experienced designers to be correctly implemented.

- [ ] **Intelligent Lighting Design Scheme**
Intelligent lighting uses a combination of workstation-specific direct-indirect lighting with personal controls where the indirect portion is constant and the direct portion is controlled by the occupant and occupancy sensors.

- [ ] **Variable Refrigerant Flow System**
Variable refrigerant flow systems control the amount of refrigerant flow to multiple evaporators throughout a building. Not only does this system save energy, it also improves occupant comfort and control, is easy to install, and allows for simultaneous heating and cooling. This technology is beneficial in a building with diverse zones that require individual control. Some downsides of the technology include a relatively high initial cost and poor performance in cold climates.

- [ ] **Sensible and Latent Energy Recovery Ventilators**
Sensible and latent energy recovery ventilators use heat exchangers between the exhaust and incoming ventilation air to precondition the sensible and latent portion of the ventilation air. By using both a heat exchanger and desiccants, a large amount of energy can be recovered from exhausting air.

- [ ] **Heat Recovery Chillers**
Heat recovery chillers are water-cooled chillers with condenser water leaving at a temperature in the range of 130°F that can be used for hot water heating applications. This system can be used in any building that has simultaneous hot water heating and cooling.

- [ ] **Liquid Desiccants with Solar Thermal Energy**
This system uses solar thermal energy as the input energy for a liquid desiccant cooling system. The system can be used for both cooling and dehumidification. This system has very low operating costs.

- [ ] **Fuel Cells**
Fuel cells can be highly advantageous for producing electricity that can be used in cases when uninterrupted power is required. With a long life of 40,000 hours, fuels cells are clean, quiet, and reliable. Two drawbacks of fuel cells include high initial cost ($3,000–$4,000/kW) and efficiencies only falling between 40% and 50%.

- [ ] **Power-Spar Concentrating Solar**
A Power-Spar parabolic trough solar concentrator can be used for electricity, heating, cooling, and lighting applications. The main benefit of the system is its versatility. It can be ground mounted, roof mounted, have two axes or use bi-directional tracking.

- [ ] **Power Panel Solar Collector**
The power panel system is a solar collector that has both a photovoltaic (PV) component for producing electricity and a solar thermal component for producing hot water. This is advantageous because the water is used to cool the PV panels, increasing their efficiency while producing hot water. These systems are beneficial to use when there are space constraints on the solar collector area.

- [ ] **Concentrating PV**
Concentrating PV uses optics to concentrate sunlight on a small area of solar cells. Most concentrating PV systems use either single- or dual-axis tracking. These systems are advantageous over traditional solar panels because of higher efficiencies and lower associated costs. The market for concentrating PV is still in the development phase and there are some reliability issues associated with tracking, but these systems have great potential for growth.

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Heating, Ventilating, and Air Conditioning Checklist

- [ ] **Deploy Operation and Maintenance Programs**
Operation and Maintenance (O&M) programs targeting energy efficiency can save between 5% and 20% on energy bills. In these programs, make sure that the system is operating efficiently by calibrating system sensors, replacing air filters, cleaning coils, periodically retro-commissioning equipment, detecting leaks, monitoring oil levels, and verifying the operation of system components.

- [ ] **Install Programmable Thermostats**
Set up the thermostat to adjust the space temperature according to the 7-day occupancy schedule. These thermostats should have manual override settings for uncharacteristic weather conditions and off-schedule occupancy. The thermostats should be checked periodically to verify the correct settings are in place. This is also a good time to revise thermostat setpoints. Just lowering the temperature by a few degrees in the winter and raising it by a few degrees in the summer can have a large impact on energy usage.

- [ ] **Replace Pneumatic Sensors with Electronic Sensors**
All room humidistats and pneumatic thermostats should be replaced with electronic humidistats and thermostats that can be tied into the direct digital control (DDC) system. All variable air volume (VAV) damper actuators should also be tied into the DDC system, rather than being controlled by a pneumatic thermostat. With electronic sensors, all components can be monitored with the DDC system.

- [ ] **Consider Using a Solar Ventilation Preheating System for Combustion Air**
Solar ventilation preheating decreases the amount of energy needed to preheat outside air. The solar preheating system requires no maintenance and has a quick payback (6 to 7 years in some cases).

- [ ] **Install Dedicated Outside Air AHUs**
Dedicated outside air AHUs should be considered in major renovation or retrofit projects and an experienced HVAC designer should be consulted for implementation. Dedicated outside air AHUs can be installed to provide outside air for the facility and all of the air can be dehumidified from a single AHU and allow for incorporation of energy recovery systems. This allows for higher discharge air temperature setpoints on the remaining AHUs and can save significant cooling energy use.

- [ ] **Exhaust Air Energy Recovery**
Enthalpy wheels, energy recovery ventilators, and runaround heat recovery systems should be considered in cold climates and at installations with high utility rates.

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Office Lighting Checklist

- [ ] **Replace T-12 Lamps and Magnetic Ballasts with T-8 Lamps and Electronic Ballasts**
All T-12 lamps and magnetic ballasts should be replaced with tri-phosphor T-8 lamps and low ballast factor electronic ballasts. Tri-phosphor T-8 lamps use less energy and produce better quality light than standard T-12 lighting systems. Electronic ballasts with low ballast factors (BF<0.85) can reduce lighting system energy use by as much as 40%. Specify tri-phosphor T-8 lamps with a color temperature of 4,100 Kelvin.

- [ ] **Replace Standard T-8 Lamps with Low Wattage T-8 Lamps and Low Ballast-Factor Ballasts**
Tri-phosphor low wattage T-8 lamps use less energy than standard 32-W T-8 lamps. Electronic ballasts with low ballast factors (BF<0.85) can reduce lighting system energy use by as much as 30%. If the lighting levels of the current T-8 lighting system are higher than the recommendations provided above, standard T-8 lamps should be considered for replacement with tri-phosphor low wattage T-8 lamps and/or low ballast-factor electronic ballasts should be installed.

- [ ] **Install Perimeter Dimming Ballasts**
Dimming electric lights in locations where daylight is sufficient for working purposes can significantly reduce energy use. All lamps and ballasts within 10 ft to 20 ft of the perimeter envelope should be capable of dimming and connected to a daylight sensor. Typical fluorescent dimming systems provide continuous dimming from 100% to 1%–10% of light output. In addition, it is important to look for opportunities to install light louvers on south facing windows and lower blinds to increase daylight contributions.

- [ ] **Install Low Wattage Screw-In Lamps**
Compact fluorescent lamps (CFLs), light-emitting diodes (LEDs), and low wattage halogen lamps use significantly less energy for similar light outputs compared to standard incandescent lamps. All incandescent and standard halogen lamps should be replaced with CFLs, LEDs, or low wattage halogen lamps.

- [ ] **Optimized Interior Security Lighting**
Interior security lighting should be maintained at a maximum of 1 fc to 5 fc during unoccupied times in hallways, and turned off in traditional office space during normal business hours. Non-security fixtures should be controlled by occupancy sensors.

- [ ] **Replace Exit Signs with LED Exit Signs**
Light-emitting diode (LED) exit signs typically use 5 W or less and can save significant amounts of energy when compared to standard incandescent exit signs. All incandescent and compact fluorescent exit signs should be replaced with LED exit signs that meet building and fire code requirements.

- [ ] **Replace Incandescent Recessed Can Fixtures with LED or CFL Lighting**
LED and CFL lighting use less energy, have dimming capability, and are good retrofit options for recessed can fixtures. All incandescent recessed can fixtures should be replaced with LED or CFL lighting.

- [ ] **Replace Incandescent and Fluorescent Cooler/Freezer Lights with LED Lighting**
LED lighting uses less energy, can be dimmed, and produces more light in cold environments. All incandescent lamps in coolers/freezers should be replaced with LED lighting.

- [ ] **Replace/Install Under-Cabinet and Task Lighting**
Task lighting can reduce the general area lighting requirements and significantly reduce energy consumption. Under-cabinet and task lighting should be installed in conjunction with an appropriate reduction in general area lighting.

- [ ] **Install Occupancy Sensors in Bathrooms, Conference Rooms, and Private Offices**
Occupancy sensors can significantly reduce light usage during unoccupied times. Occupancy sensors should be installed in all bathrooms, conference rooms, private offices, exterior environments with intermittent occupancy, and other appropriate spaces.

- [ ] **Install Central Lighting Controls**
Central lighting controls can significantly reduce the operating time of current lighting circuits. Central lighting controls should be installed and commissioned according to the various occupancy schedules.

- [ ] **Reduce Lighting Levels on Over-Lit Spaces**
Maintain code recommended lighting levels in all spaces. If some areas are over-lit, de-lamp fixtures or install lower ballast-factor ballasts to reduce the lighting levels and conserve energy.

- [ ] **Replace Linear Fluorescent "Milky White" Lens with Clear Acrylic Prismatic Lens**
A clear acrylic prismatic lens allows approximately 90% of the light to pass through with a more even distribution of light. Replace all milky white or yellowed lenses with a clear acrylic prismatic lens. These older lenses can block 20% to 40% of the light output.

- [ ] **Install Metallic Reflectors**
In older fixtures, if the existing metal reflector is severely degraded or missing, installing new metallic reflectors can significantly increase light output. If this is the case, a lamp can typically be removed or a ballast with a lower ballast factor can be installed. When installing metallic reflectors it is important to ensure the reflector isn't causing glare or decreasing uniformity.

- [ ] **Install Bi-Level Switching**
When retrofitting the lighting system within a space, look for opportunities to install bi-level switching. This gives the user the ability to reduce the number of lamps or fixtures turned on to illuminate the space.

- [ ] **Redesign of a Space**
When a building is going to through a major modernization, look for opportunities to redesign the entire lighting system. Try to use an indirect/direct or fully indirect fixture with revised fixture spacing to reduce lighting power densities and provide for more uniform light distribution. Although indirect fixtures can provide for more uniform light distribution, they can also require more fixtures for the same work-plane illuminance. It is important to provide as many small zones that can be individually controlled through occupancy sensors as possible.

High Bay Lighting Checklist

- [ ] **Replace High Pressure Sodium Lamps and Ballasts with Pulse Start Metal Halide**
Replacing standard HPS lamps with pulse start metal halide lamps and ballasts can reduce energy use while improving color rendition. Pulse start metal halide lamps and ballasts can use existing HID fixtures, making the replacement less costly than putting in fluorescent lamps. Specify replacement pulse start metal halide lamps and ballasts that are compatible with existing fixtures.

- [ ] **Replace HID Magnetic Ballasts with Electronic Ballasts**
Electronic HID ballasts offer better lumen and color maintenance than magnetic HID ballasts. Electronic HID ballasts are also dimmable to 50% of max output, allowing for occupancy or daylight controls.

- [ ] **Replace HID Lamps and Fixtures with T5HO Fluorescent Lamps**
By replacing HID lamps and fixtures with more efficient T5HO fluorescent lamps reduces energy use by 25% to 60% while maintaining light levels. This solution is preferred to replacing HID lamps with pulse start metal halide lamps, but is more costly because the fixtures must be replaced in addition to the lamps. Specify 54-W T5HO linear fluorescent lamps. In addition, high bay fluorescents allow for occupancy sensor-based control that isn't possible with HID fixtures.

- [ ] **Replace HID Lamps and Fixtures with High Performance T-8 Fluorescent Lamps**
Replacing HID lamps and fixtures with more efficient T-8 fluorescent lamps reduces energy use by 25% to 60% while maintaining light levels. This solution can be preferred to replacing HID lamps with T5HO lamps, especially for long cycle times (3+ hours) and low-temperature environments. Specify 32-W T-8 high performance linear fluorescent lamps with a lamp efficacy of 90+ nominal lumens/watt and electronic ballasts.

- [ ] **Install Daylighting Apertures or Devices**
By using daylighting and lighting controls together, energy consumption can be reduced by 40% to 60%. Look for opportunities to install skylights with a skylight-to-floor area ratio of 3% to 5%, or install side-lighting panels.

- [ ] **Install Lighting Controls**
Lighting controls that dim or switch electric lights in response to daylight can allow energy savings of 40% to 60%. This can be done with sensors placed locally, inside the space, or globally, with sensors placed outside and tied to a main control system. Specify a five-minute time delay to avoid cycling caused by rapidly changing sky conditions.

☐ **Install Occupancy Sensors**
In spaces with highly intermittent occupancy, occupancy sensors can reduce lighting energy consumption by more than 50%. The sensors can be either infrared or ultrasonic, detecting heat and movement respectively. Using both will provide better coverage and prevent false triggering. Occupancy sensors should be installed on all applicable high bay fluorescent lighting systems.

☐ **Replace HPS/HID Garage Lighting with LED lighting**
LED garage lighting can reduce the energy usage of standard garage lighting up to 50%. All high-pressure sodium (HPS)/high intensity discharge (HID) garage lighting should be replaced with low wattage LED lighting.

☐ **Replace Outdoor Parking and Street Lights**
Current LED technologies can reduce outdoor parking/street light energy consumption by up to 60%. All HPS or HID lamps with magnetic ballasts should be replaced with a low wattage LED lighting system.

☐ **Install LED Exit Signs**
LED exit signs use 80% to 90% less energy than old exit signs. New LED exit signs cost from $20 to $90 per sign. The selected sign should provide the proper luminance to meet all building and fire code requirements.

☐ **Consider Other Emerging Technologies**
- Hybrid solar lighting
- Wireless lighting controls

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Metering System Checklist

- [ ] **Install Natural Gas, and Steam Metering**
Advanced meters are those that have the capability to measure and record interval data (at least hourly for electricity) and communicate the data to a remote location in a format that can be easily integrated into an advanced metering system. For electrical meters, they measure electrical demand (kW) over a predetermined interval—commonly every 15 minutes to match utility billing intervals. This data can be used to measure, verify, and optimize building performance, identify retrofit projects, monitor power quality problems, and develop energy use indices (EUIs).

  Walk through each building or facility and identify the number and type of electrical, natural gas, fuel oil, and steam meters. Identify the meters that need to be retrofit with a solid state meter with automated metering reading and data collection capability.

- [ ] **Install Smart Electricity Metering**
Smart electricity metering (solid state or digital) can provide more accurate and more detailed information about energy use and power quality. This data can be used to measure, verify, and optimize building performance, identify retrofit projects, monitor power quality problems, and develop EUIs.

  Walk through each building or facility and identify the number and type of electrical meters. Identify the electrical meters that need to be retrofit with a solid state meter.

- [ ] **Install Smart Water Metering**
Smart water metering (positive displacement, differential pressure, velocity) can provide more accurate and more detailed information about water use. This data can be used to measure, verify, and optimize building performance, identify retrofit projects, and monitor problems.

- [ ] **Install Communication and Data Storage Technology**
Communication and data storage is vital to building operation. New technologies communicate data from automated metering systems and allows for real-time information processing of building operating conditions. Communication and data storage technology should be installed in buildings to improve information and identify energy saving potentials.

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Motor Assessment Checklist

- [ ] **Replace all Standard Efficiency Motors with NEMA Premium Motors**
National Electrical Manufacturers Association (NEMA) premium motors can reduce energy use by as much as 10%. All standard efficiency motors should be replaced with NEMA premium motors. For motors on centrifugal loads, a NEMA premium motor with the closest full-load revolutions per minute (RPM) rating should be specified. Instead of rewinding older standard-efficiency motors, consider replacing them. Other convenient replacement opportunities include new installations, equipment package purchases, preventive maintenance operations, and energy conservation program implementation. Also consider replacing single-speed motors with dual-speed motors. Consider adding variable frequency drives (VFDs) to any AC motors that could be ramped up or down for different load requirements. If motor speed is reduced to half of full load speed, power usage is reduced to an eighth of full load.

- [ ] **Replace All Standard V-Belts with Cogged V-Belts**
Replacing standard V-belts with cogged V-belts can increase the efficiency of the power transfer by 2% to 5% due to reduced bending resistance and reduced slip. Cogged V-belts can use the same pulleys as standard V-belts. All standard V-belts should be replaced with cogged V-belts.

- [ ] **Install Variable Frequency Drives on HVAC Fans and Pumps**
VFDs efficiently meet varying airflow or water flow requirements by adjusting the frequency and voltage of the power supplied to an AC motor to enable it to operate over a wide range of rotational speeds. External sensors monitor flow, liquid levels, or pressure, and then transmit a signal to a controller that adjusts the frequency and speed to match process requirements. For centrifugal fans or pumps, the fluid or air flow provided varies directly with the pump or fan rotational speed. The input power requirement varies as the cube or third power of the speed ratio. Small decreases in equipment rotating speed or fluid flow yield significant reductions in energy use. For example, reducing speed (flow) by 20% can reduce power requirements by approximately 50%.

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Plug Loads Checklist

- **Computer Power Management**
  Check all computers for proper power management settings. Power management is built into Microsoft Windows and can be accessed through the operating system control panel. Monitors should turn off after 5 to 10 minutes of inactivity and the system should go into standby mode after 5 to 10 minutes of inactivity.

- **Laptops with Docking Stations**
  Laptop computers typically use less than half as much energy compared to desktop computers. Laptops with docking stations should be implemented as an energy saving strategy.

- **Low Energy Desktop Computers**
  A couple of companies have recently introduced a new line of low-energy desktop computers that use less than 50 W when active and can reduce desktop computer energy use by 50%. If desktop computers are going to be replaced, replace them with low energy desktops.

- **LCD Monitors**
  Liquid crystal display (LCD) monitors use less than half as much energy when compared to cathode ray tube (CRT) monitors. All CRT monitors should be replaced with LCD monitors.

- **Install Vending Machine Misers and De-Lamp Machines**
  Vending machine misers can save a significant amount of energy during unoccupied hours. Also, de-lamping the vending machine advertisement lights can reduce electricity costs by approximately $50/year, depending on electricity rates. All vending machines should be de-lamped and have misers installed.

- **Install Occupancy Sensors**
  Occupancy sensors reduce plug load energy during unoccupied hours. Occupancy sensor power strips should be used for all noncritical office equipment (task lights, printers, faxes, scanners, speakers, radios, fans, etc.)

- **ENERGY STAR Appliances**
  ENERGY STAR® appliances, such as refrigerators, dishwashers, clothes dryers, etc., should be implemented as an energy saving strategy. See www.energystar.gov/index.cfm?c=appliances.pr_appliances for ENERGY STAR specifications on various appliances.

- [ ] **Network Printers**
Networking printers reduces the number of personal printers and can save significant amounts of energy. Office spaces should network central printers and reduce or eliminate the use of personal printers.

- [ ] **LED Task Lighting**
Light-emitting diode (LED) task lighting uses significantly less energy than fluorescent lights and lasts longer. All fluorescent and incandescent task lighting should be replaced with LED task lighting.

- [ ] **Replace Office Equipment with ENERGY STAR Models**
ENERGY STAR office equipment uses less energy than standard office equipment. ENERGY STAR models for computers, monitors, printers, copiers, faxes, etc., should replace all models that are not ENERGY STAR rated. Individual printers, scanners, and fax machines should be removed and replaced with a central ENERGY STAR multifunction device (a combination printer, scanner, and fax machine) for a group of people.

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Renewable Energy System Checklist

- **Consider a Photovoltaic (PV) System**
  PV converts the sun's energy into electricity. Implementing a PV system can reduce the amount of energy that is needed from the grid. PV panels can be installed in a variety of places on a property including the roof, the ground, and as a shade structure. There are also applications in which the panels can be building integrated and hardly noticeable. When considering a PV system, evaluate the solar resource available, incentives available, tilt angle of the panel, azimuth angle of the panel, shading on the panel, electrical system interconnection, and the price of electricity.

- **Consider a Solar Domestic Hot Water (SDHW) System**
  Water heating uses a huge amount of energy each year in the United States. By using solar radiation to heat water, much of this energy could be saved. There are several types of systems available, with different types serving different temperature ranges and different climates. SDHW panels can be installed anywhere on a property where there is space available. When considering a SDHW system, evaluate the solar resource available, freeze protection requirements, incentives available, hot water requirements, and annual cost savings.

- **Consider a Wind Project**
  Using wind energy to produce electricity has huge environmental benefits over generation from dirty sources, namely: no SOx or NOx emissions, no particulates, no mercury, no CO_2, and no water usage. System size varies from small residential systems to large utility size systems. When considering a wind project, evaluate the wind resource, zoning restrictions, incentives, building permits, site electricity consumption, and economic factors.

- **Consider Biomass as a Fuel Source**
  Biomass can be used in a variety of ways to produce energy. Being carbon neutral, it is advantageous over traditional fossil fuels in carbon emissions. It can be combusted to produce heat, gasified to produce fuel, or made into an aerosol by pyrolysis. Most commonly it is combusted to produce heat or make steam. It is important to have a reliable and low cost source of biomass close to the site.

- **Consider a Ground Source Heat Pump to Offset Heating and Cooling Loads**
  A ground source heat pump uses the relatively constant ground temperature to provide heating, cooling, and sometimes hot water. Although the initial cost can be higher than conventional systems, the operating costs are very low, there is very little maintenance, and the life cycle cost is low. Site assessment requires training and specialized software in order to correctly size the system ground loops. Incorrectly sized ground loops will not allow a system to operate correctly.

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Water Conservation Checklist

☐ **Retrofit Existing Toilets**
There are several low-cost options for reducing water consumption in toilets. These options include displacement devices, toilet dams, early closure devices, and dual flush adapters. Using these methods, 0.5–2 gallons of water can be saved per flush. Some of these options can be user installed, while others require the assistance of a plumber.

☐ **Replace Toilets**
Replace the existing toilets with low-flow (<1.6 gpf) or high-efficiency toilets (<1.28 gpf). Look for the WaterSense classification.

☐ **Retrofit Existing Urinals**
- **Siphonic jet retrofits**—Fit flushometer valves with water-conserving parts, and use a timer to stop the flow of water when the building is not occupied.
- **Washout/washdown retrofits**—Add infrared or ultrasound sensor-activated controls that automatically flush after the urinal is used.
- **Blowout retrofits**—Install timers or sensors to operate the urinals only when the building is occupied.

☐ **Replace Urinals**
Replace the existing urinals with low-flow (<1.0 gpf), high-efficiency (<0.5 gpf), or waterless urinals. Look for the WaterSense classification.

☐ **Retrofit Existing Showerheads**
Incorporating flow restrictors is the most cost-effective option available. However, this can result in poor water pressure in some showerheads. The addition of a temporary cut-off valve can be used to stop the flow of water during soap application or shampooing. Water is reactivated at the previous temperature.

☐ **Replace Existing Showerheads**
Replace the existing showerheads with low-flow showerheads (<2.2 gpm). This can be achieved with atomizing, pulsating, or aerating showerheads.

☐ **Retrofit Existing Faucets**
Adding flow restrictors or aerators in the form of a disk or head at the faucet head can greatly reduce the flow rate through the faucet. These are good options for faucets primarily used for washing.

☐ **Replace Existing Faucets**
Replace or repair any faucets that leak. Even slow leaks add up to substantial water usage each year. Several new styles of faucets are available to limit the amount of water usage:
- **Metered valves**—deliver a preset amount of water, then shut off
- **Self-closing valves**—are spring loaded to stay on for a short time only
- **Infrared and ultrasonic sensor valves**—contain sensors in the faucet head that turn on the flow of water only when an individual is present.

- [ ] **Employ Water-Efficient Appliances**
Incorporate ENERGY STAR® water-consuming appliances whenever possible. Dishwashers and clothes washers are the appliances that use the most water in many cases. Use a dishwasher that reuses water for multiple stages; this not only saves water, but also detergent and rinse additives. Typically, front-loading clothes washers use less water than standard upright washers.

- [ ] **Eliminate Single-Pass Cooling Systems**
Single-pass cooling systems use water to cool equipment, and the water is circulated only once before being dumped. If possible, modify these systems to be closed loop. If that is not possible, make sure the cooling system is only running during machine operation. Instruct the machine operators on ways to reduce the machine run time, and look for an additional use for the waste water (i.e., landscape irrigation or cooling tower make-up water). When the opportunity arises, replace the water-cooled equipment with air-cooled equipment.

- [ ] **Reduce Water Consumption from Cooling Towers**
Reducing blowdown is the main way to save water with a cooling tower. This can be achieved by installing covers to block sunlight penetration, treating the water with ultraviolet light, doing an acid treatment to control scale build up, filtering the sediments from the water using a sidestream, or using ozonation to control scale, corrosion, and biological growth.

- [ ] **Minimize Irrigation Water Use**
Reducing the amount of water used by irrigation systems can save large quantities of water. This can be done by watering only in the early mornings, watering deeply once a week instead of watering lightly each day, adjusting sprinklers to water only landscape (not sidewalks and parking lots), and use a soil moisture sensor (tensiometer) to avoid over-watering.

- [ ] **Select Proper Landscaping**
In addition to minimizing water use, some foresight when designing the landscape can also help reduce water usage. When landscaping one should select climate-appropriate plants, reduce turf areas, monitor soil quality, incorporate mulching beds, and set up a proper irrigation system maintenance schedule to check for leaks and broken components.

- [ ] **Procure Irrigation Water from Alternate Water Sources**
Instead of using clean drinking-grade water for irrigation, consider getting water from alternative sources such as municipal water reclaim programs, recycled gray water, rainwater harvesting, single-pass cooling, condensate, or reverse osmosis (RO) reject water.

- [ ] **Install Efficient Irrigation Systems**
In addition to the previous methods outlined, there are several water-efficient irrigation systems available that can further reduce the quantity of water consumed. A few of these include the low-volume drip system, sub-surface drip system, and the weather-based irrigation system.

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