



# Top Ten Checklist

## Energy-Efficient Buildings *for the* Southern United States

Jim Cummings and Chuck Withers



Southern Energy-Efficiency Center  
*Building Energy Solutions for the South*



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Jim Cummings and Chuck Withers  
Florida Solar Energy Center

**The following Top Ten Checklist provides recommendations for creating energy efficient commercial buildings in areas with hot and humid summers.**

- 1.** Create a high performance building envelope through effective air, thermal, and vapor barriers, and limiting heat entry through window and roof systems.
- 2.** Optimize lighting systems through high-efficiency lamps, use of daylighting, and shutting off lights during unoccupied periods.
- 3.** Control ventilation through occupancy-based modulation and use of a dedicated outdoor air system.
- 4.** Manage humidity effectively and efficiently by controlling bulk water, stopping water vapor entry, and use of AC systems that dehumidify effectively.
- 5.** Install high efficiency DX or chilled water AC systems with high efficiency fans.
- 6.** Reduce fan and pump energy use by means of VFDs and static pressure reset.
- 7.** Manage building and HVAC system air flows, including avoiding uncontrolled air flows, locating the air distribution system inside the air and thermal envelope, and operating the building at positive pressure during hot and humid weather.
- 8.** Optimize the scheduling of energy consuming systems, including shutting down energy consuming systems or relaxing setpoints during unoccupied periods.
- 9.** Perform commissioning on new buildings and recommissioning on existing buildings to achieve and maintain optimum system and building performance.
- 10.** Analyze building energy use by means of an energy information system.

The Southern Energy Efficiency Center (SEEC) is a pilot, high-performance buildings technology application center serving the southern United States. Its overall mission is to leverage the existing interactions and outreach activities of the SEEC principals and partners to substantially increase the deployment of high-performance, beyond-code buildings across the southern region of the U.S. Primary funding is from the U.S. Department of Energy Building Technologies Program, administered by the National Energy Technology Laboratory.

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# Top Ten Checklist

## for Energy-Efficient Buildings for the Southern United States

Commercial and institutional buildings vary greatly, from one to another, in size, use, and type of construction. For purposes of this Top Ten Checklist we are assuming a medium-sized (20,000 to 50,000 ft<sup>2</sup>) office building located in areas with hot and humid summers. The issues that are raised here may equally apply to schools, churches, theatres, and some retail buildings. Because of space limitation, we have included references [placed in brackets] within the text to direct the reader to additional information sources.

### Building Design and Heating/Cooling Load Management

#### 1. Create a high performance building envelope

- During design, specify that the building envelope should be airtight. Consider setting a specific airtightness objective, and then test the building for compliance.
- Locate the air and thermal (insulation) boundaries in the same plane, and maintain continuity from one plane to another. In most commercial buildings this would be implemented by locating the insulation at the roof deck and not venting the space above the ceiling. As a result, the ceiling space is located inside the air and thermal boundaries of the building. This approach creates a more energy-forgiving environment, so that if duct leakage or unbalanced return air occurs, the unintended air that flows to and from the ceiling space, introduces little water vapor to the building and creates little energy waste. This also reduces the moisture condensation potential as the ceiling space dew point temperature will generally remain below the exterior temperature of ducts and chilled water piping.
- Take care in the placement of intentional and unintentional vapor barriers in wall assemblies [Lstiburek, 2005, 2008]. Vapor barriers should be located on the warm side of the assembly. Avoid multiple vapor barriers within building cavities. If moisture gets trapped between two vapor barriers, it is difficult for this moisture to dry either to indoors or to outdoors. Consider use of vapor impermeable rigid insulation board in wall assemblies, which always has a warm side, thus eliminating an unwanted condensing plane.
- Reduce solar radiation through windows, which can add considerably to cooling energy use, peak electrical demand, and time-of-day glare and comfort problems.
  - Limit window area to that needed for daylighting and outdoor views since window thermal resistance is typically 5-10 times less than opaque walls.
  - Orient the building so that fewer windows face east or west.
  - Provide latitude-appropriate overhangs for south-facing windows. Provide maximum shading of east and west facing windows.
  - Install windows with Solar Heat Gain Coefficients (SHGC) below 0.3 on unshaded east, south, or west portions of the building.
  - Install white or otherwise highly reflective window blinds to reflect solar radiation back through glazing to outdoors.



- Install a heat shedding or heat blocking roof system. This could be achieved by means of highly reflective surfaces (bright white surfaces), a green roof (vegetation), or by means of tile, gravel, or high mass roof systems. If one of the preceding cooler roof systems is not installed, then block the heat from entering through the roof by means of more robust insulation and/or radiant barriers.



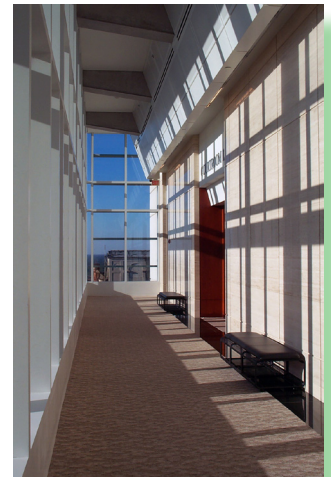
## 2. Optimize lighting systems

- Select high efficiency lighting equipment [*Commercial Lighting Retrofits: A Briefing Report for Program Implementers*, <http://aceee.org/pubs/a032fullpdf?CFID=314590&CFTOKEN=88430439> for lighting overview]. Avoid incandescent lights, which, provide illumination efficacy in the range of 10 to 20 lumens/watt and shorter lamp life. Use fluorescent lamps such as T-8 or T-5 (or compact fluorescent lamps for task lighting) which yield 40 to 100 lumens/watt.
- Design to the guidance provided by the Illuminating Engineering Society of North America, by type of space and task to avoid energy waste.
- Use occupancy sensors to shut off lights in empty rooms.
- Consider implementing daylighting, since this has the capacity to improve the quality of indoor illumination. Use lighting controls that sense daylight levels and reduce electric lighting when possible [US DOE Commercial Lighting Solutions Tool at <http://www.newbuildings.org/lighting.htm>].



## 3. Control ventilation

- Control ventilation based on occupancy. If a space is occupied only intermittently (such as churches, theaters, or convention centers), then the majority of the outdoor air (OA) can be shut down based on a time-clock. In other buildings, ventilation can be controlled based on occupancy sensors. CO<sub>2</sub> control is one of the most effective approaches to OA modulation. The accuracy of CO<sub>2</sub> controllers, however, should be verified approximately every 12 to 24 months.
- *Dry the ventilation air.* Condition OA as it enters the building. By removing the moisture from the OA, the entire ventilation latent load is met. Consider two types of systems:
  - 1) A dual path AHUs can provide continuous conditioning of the ventilation air. This unit has two air streams and two cooling coils. One coil serves the return air stream while the other serves the OA stream. The coil serving the OA can remain cold all of the time resulting in effective drying of the ventilation air.
  - 2) Use of a dedicated outdoor air system (DOAS) with a dedicated OA air distribution system provides flexibility and fan energy savings, allowing variable air volume (VAV) boxes to slow air flow to near zero. This in turn reduces main AHU fan energy use, overcooling potential, and the need for reheat. Furthermore, demand-controlled ventilation can be optimized by using VAV DOAS, static pressure control, and CO<sub>2</sub> controlled dampers to specific rooms.
- *Super-dry the ventilation air.* Provide very low-temperature OA to the building. Air that has been cooled to 45°F, for example, might have a dew point temperature of 42°F. Ventilation air that is this dry can meet the latent cooling load of the ventilation air plus most or all of the latent cooling load of the building. Consider heat pipes on the OA air stream to enhance moisture removal and reduce the overcooling of the space during low cooling load periods.





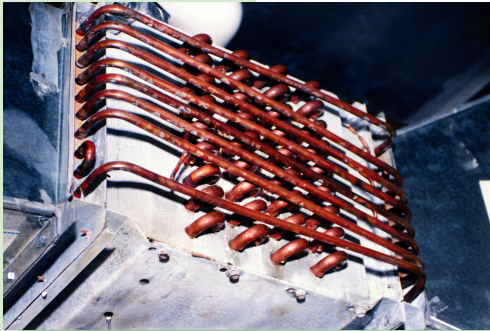


## 4. Manage humidity in an energy-efficient manner

- Prevent bulk water from entering the building, such as from rain, plumbing leaks, and irrigation systems spray. To that end, design roofs with sufficient slope to avoid ponding. Drain water away from the foundation, and for more sustainable practice, consider a cistern to collect rainwater that can be used for irrigation. Maintain irrigation sprinkler systems to keep spray off of building surfaces and away from the foundation.
- Control water vapor entry into the building by three methods.
  - 1) A tight building envelope will help reduce water vapor entry into the building from natural infiltration. This is especially useful during unoccupied hours, allowing the AC system to remain off for all or most of the overnight period, or even for an entire weekend, while keeping indoor relative humidity (RH) below a critical level, such as 65%.
  - 2) Intercept and remove water vapor from the OA stream where it enters the building. On the order of 70-80% of the total latent cooling load of a building originates from the water vapor contained in ventilation air (when outdoor dew point temperatures are high). Effective removal of ventilation water vapor can be achieved by means of dual path AC systems or by using a DOAS.
  - 3) Use an enthalpy recovery ventilator (ERV) to reduce the latent load of ventilation by about 2/3<sup>rd</sup>. This approach can be very cost-effective if there are significant air flow rates of both clean (i.e., free of grease or dangerous contaminants) exhaust air and OA. The ERV captures dryness from an exhaust air stream and transfers it into an incoming OA stream, yielding a large reduction in latent cooling load and reducing ventilation-related energy use by about 60%.
- Select and design AC systems that dehumidify effectively, and avoid those that dehumidify poorly. There are at least a dozen different types of AC systems. One of the chief characteristics that differentiates one AC system from one another is the means by which cooling capacity is modulated. All AC systems dehumidify effectively under full-load operation, because the coil remains cold all of the time. Many types, however, dehumidify poorly under part-load, because they either modulate the temperature of the cooling coil (a warm coil does not remove moisture) or cycle the compressor while running air across the coil continuously (moisture on the coil evaporates when the compressor shuts down). Additionally, an AC system will dehumidify more efficiently with lower air flow rates (say 320 cfm/ton versus 400 cfm/ton) with little energy penalty. This is very true for DX systems and somewhat true for chilled water (CW) systems.
- Use advanced technologies that enhance the moisture removal capabilities of the AC system. This could include installation of heat pipes or runaround coils in the AC system, purchase of AC systems that employ subcool/reheat, or use of enthalpy exchange enhanced AC system designs.
- There is a CATCH 22, however, related to ventilation and RH control. On one hand, we want ventilation to be reliable so that occupants receive sufficient “fresh air” and we want the building to operate at positive air pressure during hot and humid weather (to help dry building cavities). Fan ON control will provide reliable ventilation but fan AUTO will not. On the other hand, we want good humidity-control. Fan ON control causes evaporation of water from the cooling coil (after the compressor shuts off) which causes elevated RH. Fan AUTO will produce good RH control but fan ON will not. In summary, fan ON control yields reliable ventilation



but ineffective humidity control. Fan AUTO control yields better RH control but does not provide reliable ventilation. **Solution:** install a system which separately conditions ventilation air. We recommend that a DOAS with dedicated OA distribution provide the necessary ventilation while also effectively stripping water vapor from the OA. A DOAS with dedicated air distribution also reduces the potential for overcooling and the need for reheat.



- Dehumidifiers can be used for temporary moisture removal circumstances. For longer-term humidity control, however, dehumidifiers should be considered a choice of last resort because they are a very energy-inefficient means of providing latent cooling. All of the waste heat from the fan and compressor motors, plus the heat from water vapor condensation, is delivered back into the conditioned space, thus providing negative sensible cooling. If choosing to use dehumidifiers for a sustained period, at least select high efficiency units (e.g., Energy Factor of 2.2 liters/kWh or better) [[http://www.energystar.gov/ia/products/prod\\_lists/dehumid\\_prod\\_list.pdf](http://www.energystar.gov/ia/products/prod_lists/dehumid_prod_list.pdf)].

## HVAC Design and Selection



### 5. Install high efficiency AC systems

- If installing direct expansion (DX) AC systems, select 15 SEER (12.5 SEER) or better equipment. Use air handler units (AHUs) with high efficiency fans, preferably 0.2 W/cfm or lower, using electronically commutated motors.
- If installing a CW system, install high efficiency chillers and use VAV air handlers. Consider chillers with direct-drive, magnetic bearings with part-load use as low as 0.30 kW/ton.



### 6. Reduce fan and pump energy use

- For VAV systems, employ static pressure reset based on VAV box damper positions. During periods of low load, AHU fan speeds can therefore be reduced, saving fan energy and reducing the potential for overcooling. Slowing the fan speed by 30%, for example, can yield a 60% decrease in fan energy consumption.
- For constant volume (CV) CW systems, use variable frequency drives (VFDs) to reduce fan speed when full capacity is not required, such as during unoccupied periods (nights, weekends, etc.) and during mild weather. This will reduce fan power and improve dehumidification effectiveness.
- Switch CV systems to cycled AHU fan control (fan AUTO) during unoccupied hours. This will save fan energy and improve RH control.
- For CV systems that have a DOAS with dedicated air distribution, cycle the AHU fan during both unoccupied and occupied hours.
- For secondary or tertiary CW pumps, employ static pressure reset based on the control status of the maximum open CW valve serving AHUs served by that pump. This can save resources by significantly reducing pump energy use and reduce wear and tear on the equipment.



### 7. Manage building and HVAC system air flows

- Avoid uncontrolled air flows, such as duct leakage, unbalanced return air, and unbalanced exhaust air [Withers et al. 1996, Withers and Cummings 2006, Cummings et al. 1996a, Cummings et al., 1996b]. Specify duct materials and fabrication methods that produce an airtight system. Require duct airtightness testing. During design, provide for ducted return air or for sufficiently large return transfers so that pressure drop across partitions is no greater than 1 pascal. Alternatively,

consider using the ceiling space as a return plenum, but only if the ceiling space plenum is fully insulated and sealed at wall and roof deck surfaces and operates at positive pressure with respect to outdoors.

- Place the air distribution system (ADS) inside the air and thermal boundaries of the building. Therefore, even if there is duct leakage or unbalanced return air, the energy penalties will be small or negligible, because the uncontrolled air exchange will be from one conditioned space to another.
- Duct leakage can, however, cause energy waste even if it occurs inside the air and thermal boundaries of the building. If, for example, a VAV system has duct leakage, and the AHU fan speed is controlled based on a fixed static pressure, then the fan speed will be greater than needed, the amount of cold supply air delivered directly or indirectly to the space may exceed that required to maintain temperature, over-cooling may occur, and the need for re-heat may be increased.
- Operate the building with positive pressure (compared to outdoors) for the majority of hours during hot and humid weather (when outdoor dew point temperature is say 70°F or higher). Size exhaust air (EA) flow rates as small as possible while still meeting code and performance criteria. In many commercial buildings, EA is the “tail that wags the dog.” For each cubic foot of air removed from the building another cubic foot of air has to be brought back into the building, and conditioned. During high dew point weather, for example, 1000 cfm of continuous ventilation can require moisture removal of 100 gallons/day from the building. Provide unconditioned make-up air (MA) to the space to the extent practicable. In a commercial kitchen, for example, consider providing unconditioned MA in proximity to the exhaust hood, at about 80 % of the EA flow rate, and then provide the 20 % + balance in the form of conditioned OA.



## Operations



### 8. Optimize the scheduling of energy consuming systems.

- Only operate energy consuming systems and equipment when they are needed.
- Reduce heating and cooling system operation for overnight, weekends, and holidays when those systems are not required, by turning off those systems or altering thermostat setpoints. If RH control is required, operate the AC intermittently during the weekends. If the AHU fans are designed to run continuously during occupied hours, switch to fan AUTO control during unoccupied hours.
- Close OA dampers and shut off EA during unoccupied hours. This will save fan power, reduce cooling/heating loads, and yield better humid weather RH control.
- Shut down lighting when spaces are not occupied.
- Shut down computers and/or monitors, printers, copy machines, etc. after hours.
- Reductions in HVAC fan, lighting, and equipment operation will also reduce AC cooling loads, so the AC systems will in turn run less.



### 9. Perform commissioning and recommissioning

- Commissioning (Cx) is a planning and implementation oversight process designed to verify that design intent is accurately embodied in the building design and the constructed building's specifications and performance conforms to the building design. Cx is a critical step toward achieving a high-performance and low energy use building [ASHRAE Commissioning Guideline 0-2005].



- Recommissioning (RCx) – recurring commissioning of existing buildings – helps assure that equipment and systems continue to perform per design. RCx periodically checks control sequences, setpoints, sensor calibrations, and equipment, and implements necessary maintenance and repairs in order to maintain optimum system operation. RCx is typically very cost-effective because it reduces operating costs and unexpected equipment downtime, and helps ensure better indoor environmental quality.



## 10. Analyze building energy use

- One of the best tools for achieving energy efficiency is implementation of an energy information system (EIS) which has the capability to record building energy use (electricity, natural gas, chilled water, etc.). At the simplest level, one can record total building energy use on a daily basis. At a higher level, energy use can be recorded in time-of-day format. For further analysis effectiveness, consider submetering specific energy end uses such as HVAC equipment, reheat, lighting systems, or others, which can help to disaggregate failures or dysfunction for specific equipment or subgroups of equipment.
- The ability to track daily or time-of-day energy use helps the building manager understand normal use patterns, identify anomalies, and document savings from recommissioning, retrofit, or performance contracting activities. Ideally changes in energy use would be normalized to weather and changes in occupancy, if applicable.



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