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7 Advanced Modeling Tips

7.1 Challenging Building Types

Modeling tips and advice is offered in this section for laboratories, healthcare and data centers. Each of these building types presents unique challenges to energy modelers. The guidance here supplements the information in Chapter 6. Information provided in this chapter supersedes information in Chapter 6 when there is a conflict.

7.1.1 Laboratories

Many aspects of laboratory energy usage are not directly regulated by the baseline standards. However, these energy uses must be accounted for in order to obtain an accurate simulation of the building energy usage and properly calculate percent savings for green building ratings (tax deduction calculations only require consideration of regulated energy use, e.g. heating, cooling, fans, hot water and interior lighting). In addition, it is also important to note that the non-regulated energy components of the laboratory will impose loads on the regulated portions, such as chillers and boilers, increasing the importance of capturing this energy usage.

Laboratory HVAC Systems

Laboratories tend to be large buildings so the basic HVAC mapping rules presented in Chapter 6 will typically map to baseline building systems 5 through 8, which are variable air volume systems with one air handler per floor. There are three exceptions to this rule, however, that could affect the baseline building systems for laboratories:

- The first exception is specific for laboratories. This exception applies when a laboratory or group of laboratories have an exhaust system designed for 5,000 cfm or more of air movement. The baseline building system serving the laboratory spaces shall be either system 5 (PVAV with hot water reheat) or system 6 (PVAV with parallel fan-powered boxes and electric reheat), depending on the heating source in the building. The PVAV system must be capable of reducing the exhaust and makeup air volume to 50% of design values during unoccupied periods. This exception essentially requires VAV for both the supply fan and the exhaust system. (See the PRM, G3.1.1, Exception c.)
- When the above exception for laboratories does not apply, a separate laboratory system may still be required to be modeled in the baseline building. Either system 3 (PSZ-AC) or system 4 (PSZ-HP) shall serve laboratories in the baseline building (depending on the heating source for the building) when one of the following conditions apply:
  - Spaces on a floor have significantly different schedules or internal heat loads: heat gain differences of more than 10 Btu/h or operation schedule differences of more than 40 hours/week. (See the PRM, G3.1.1, Exception b.)
  - Spaces on a floor have "special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates." Many laboratory spaces with fume hoods would likely trigger this exception. (See the PRM, G3.1.1, Exception c.)

These special systems apply to the spaces that trigger one or more of the exceptions. The rest of the building/floor would be served by the baseline building HVAC system and air handlers.

Equipment Loads

The amount of internal load in a laboratory from equipment will vary greatly based upon function, and also will vary based upon time, with night-time loads typically much lower. The topic of diversity is addressed under the topic of schedules; however the peak load should be input based upon the actual equipment selection. In most cases, the equipment power will be the same for both the baseline and proposed design, except when the proposed design employs explicit strategies to reduce energy use and reduce internal loads, in which case, more efficient equipment or lower internal loads may be assumed in the proposed design. As an example, localized refrigeration equipment in the lab space might be replaced by a central chilled water system, thus reducing the heat rejection load that occurs in the space and increasing the efficiency of cooling the equipment. In this case, it would be acceptable to have different
internal loads in the baseline and proposed buildings. When equipment power or internal loads are different between the proposed design and the baseline building, special documentation shall be provided. Some common laboratory equipment is discussed in greater detail in subsequent sections.

Redundancy

In some cases it is standard practice to provide redundant equipment in laboratories because of the risk involved in equipment failure. If additional equipment is installed for pure redundancy, then this equipment shall be ignored in the modeling of the proposed design and the baseline building equipment is installed for pure redundancy, then this equipment shall be ignored in the modeling of the proposed design and the baseline building. For a more complex situation, a laboratory with a 100 ton load might be designed with two 75 ton chillers with the idea that should one chiller fail, the remaining chiller will be able to satisfy the critical load. If this design intent can be documented, then it is acceptable to model the proposed design in this fashion. The baseline building equipment will be autosized according to the rules in Chapter 2 and Chapter 6 and the number of chillers or boilers will be determined based on the rules in Chapter 6.

Design Conditions

Space dry-bulb temperature setpoints should generally be based upon actual design requirements, but for laboratories will generally be around 70°F for heating, 72°F for cooling. Humidification to at least 30% RH is common in most areas of the country. Dehumidification, when required, is accomplished by keeping coil leaving air temperatures around 53 F during humid ambient conditions.

Air Delivery

For systems serving laboratory spaces, use a supply-air-to-room-air temperature difference of 17°F for the baseline building and the proposed design (Chapter 6 specifies 20°F for other building types). If return or relief fans are specified in the proposed design, the baseline building design shall also be modeled with fans serving the same functions (this is the general Chapter 6 modeling rule). The baseline building return/relief fans shall be sized for the baseline system supply fan air quantity less the minimum outdoor air, or 90% of the supply fan air quantity, whichever is larger. See the discussion above on laboratory HVAC systems for more detail on exhaust systems serving fume hoods.

Outside Air

Due to the presence of hazardous materials in laboratory environments, it is common practice to use 100% outside air. The codes do not explicitly forbid lab air recirculation within individual lab zones, but code requirements are most easily met by a 100% outside air system. The Chapter 6 modeling rules apply in this case, as the outside air for the baseline building is the same as the outside air for the proposed design.

In some cases, labs are part of a mixed-use building that includes both office spaces as well as laboratories served by the same air handling system. In most cases, the baseline building system serving laboratories will be separate from the main building system (see laboratory HVAC systems above).

Outside air delivered by these dedicated systems would be the same as the air delivered by the proposed design systems, unless the assignment of thermal blocks to systems is modified.

Schedules

Appendix C has schedules for laboratories that shall be used as a default. The schedules assume heavier loads during more typical working hours. Fans are assumed to be on 24 hours throughout the day. If the laboratory operates on a seasonal schedule, such as a school schedule, and has lower usage during one season, adjust the schedules as needed.

Animal Cages

Open animal cages that do not include their own dedicated ventilation system are commonly used in laboratories. These shall be the same in the proposed design and the baseline building.

Autoclaves

These systems use high pressure steam for sterilization. Typically efficiency measures accounted for here would be on the steam side.

Compressed Dry Air

Some laboratories require a supply of compressed dry air for drying and other purposes. When these systems exist in the proposed design, they shall also exist in the baseline building. In the baseline building, the supply air pressure setpoint is constant and the systems do not employ heat recovery. The air dryers are regenerated with compressed air, on a regular time-based interval. Energy efficiency measures may be documented for the proposed design with proper documentation.

De-Ionized Water

These systems remove minerals and ions from the water to reduce the electrical conductivity of the water and would typically be the same in the baseline and proposed buildings.

Environmental Chambers

Heat pumps typically heat or cool the interior of the chamber to provide a controlled test environment. For the baseline building, heat rejection (or absorption) from the heat pumps is assumed to occur directly into the space in which the heat pump is installed. The proposed design may employ energy efficiency measures, including high efficiency heat pump units, as well as remote heat rejection through a condenser water system.

Fume Hoods

Fume hoods generally do not contain local fans, but rather have an exhaust system serving multiple hoods. The energy use of a fume hood is reflected in the amount of air moving through the hood and the efficiency of the exhaust system that serves it. Fume hood exhaust systems in the proposed design can be operated as constant air volume (CAV) or variable air volume (VAV). The baseline building exhaust system shall be VAV for laboratory exhaust systems that are designed for 5,000 cfm or more. See laboratory HVAC systems above. Otherwise, the baseline building exhaust fan system and operation shall the same as the proposed design. The modeling assumption for the sash opening face velocity is a constant 100 ft/min for both the proposed design and the baseline building, regardless of space occupancy and regardless of whether an occupant is standing in front of the hood. However the baseline hood exhaust schedule assumes the hoods are closed and airflow reduced during unoccupied periods.

Biosafety cabinets can also be operated as CAV or VAV. However, biosafety cabinets have a more demanding tolerance (+/-5%) on variations in air flow than fume hoods. The air flow variation in a typical VAV system is on the order of +/-1for biosafety cabinets is CAV.

Glass Washers

These machines will wash and sterilize lab glassware. The equipment will typically be the same in the baseline and proposed buildings. This equipment has high but intermittent heat and moisture gains to the containing spaces.

Vacuum Systems

Process vacuum pumps create a negative-pressure distribution system needed for certain types of lab equipment. Not to be confused with the “house” vacuum system, used for janitorial purposes. In most cases, the baseline and proposed vacuum pumps will be the same, although more efficient vacuum pumps could be substituted in the proposed design with suitable documentation of what is considered a typical base case condition.

Reverse Osmosis Water

These systems are similar to the de-ionized water systems except that the process involves pumping the water through a semi-permeable membrane. These systems would typically be the same in the baseline and proposed buildings. Average loads should be far below design electrical capacities.

7.1.2 Health Care

Many health care projects are designated as occupancy group "I", which subjects them to specialized code requirements necessary based upon health and safety requirements. Typically, the envelope components of health care projects are not that different from conventional occupancies. However, lighting, HVAC and domestic hot water systems can be significantly different and will present some challenges in the modeling process. In addition, these facilities can have many other energy consuming systems that will require attention.

Lighting

Health care projects typically have a wide range of space uses. A typical hospital could have 50 or 60 different space functions occurring in the facility. In modeling the facility, there are two possible choices for lighting. The easiest choice is to use the *building classification* method for all spaces that occur in the building. The second choice is to break the building out into each space function and use the *space-by-space* method, which will entail a significantly larger amount of work. Choosing the approach can be difficult, as a facility with a large amount of space functions requiring large amounts of light would benefit from the more granular approach of using the space functions. Given the fact that a hospital might require HVAC zoning of several hundred zones, the additional work of layering in space function lighting can result in models with zones numbering 600 to 1000. In either case, the baseline and proposed buildings will have the same thermal blocks, zoning and space functions.

An additional consideration is that many spaces in the proposed design may use task/ambient lighting systems. For example, patient rooms will typically have an ambient lighting system that provides minimal illumination, and a second lighting system that will only be activated by staff during brief examination periods. Other areas, such as surgery rooms, will have surgical lights that are only used during active surgery, so it is important that the lighting systems include appropriate schedules for the task lighting that accounts for the intermittent use. Note that in modeling the baseline building, the baseline lighting power density allowance will be modeled, using the ambient lighting schedule from the proposed design. An alternative schedule may be used for task lighting in the proposed design. For exempt lighting uses, this alternative schedule shall be used for both the baseline building and the proposed design.

HVAC

The basic HVAC system mapping rules described in Chapter 6 apply to health care facilities. Most are large buildings so the baseline building systems will tend to be system 7 (VAV with hydronic reheat) or system 8 (VAV with parallel fan-powered boxes and electric reheat). However, many spaces in healthcare facilities trigger the exceptions to the HVAC mapping rules:

- The laboratory exception applies when a laboratory or group of laboratories have an exhaust system designed for 5,000 cfm or more of air movement. The baseline building system serving the laboratory spaces shall be either system 5 (PVAV with hot water reheat) or system 6 (PVAV with parallel fan- powered boxes and electric reheat), depending on the heating source in the building. The PVAV system must be capable of reducing the exhaust and makeup air volume to 50% of design values during unoccupied periods. This exception essentially requires VAV for both the supply fan and the exhaust system. (See the PRM, G3.1.1, Exception c.)baseline?
- When the above exception for laboratories does not apply, a separate system may still be required to be modeled in the baseline building. Either system 3 (PSZ-AC) or system 4 (PSZ-HP) shall serve healthcare spaces in the baseline building (depending on the heating source for the building) when one of the following conditions apply:
  - Spaces have significantly different schedules or internal heat loads. Heat gain differences or more than 10 Btu/h or operation schedule differences of more than 40 hours/week trigger this exception. (See the PRM, G3.1.1, Exception b.)
  - Spaces on a floor have "special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates". Surgical suites and other healthcare spaces would likely trigger this exception. (See the PRM, G3.1.1, Exception c.)

The HVAC systems in many healthcare facilities are in operation 24 hours per day and consume very large amounts of energy. In many cases, the decision of a certain type of mechanical system in these facilities is made for health and safety code compliance, and in many cases they will be 100% outside air systems. It is not unusual to see very large static pressure requirements due to HEPA filtration and sound attenuators. In the case of 100% outside air systems, exhaust fans are also an important aspect of the design. Given the large diversity of space uses, and the fact that each may have specialized ventilation requirements, it is important to model the building with a sufficient number of zones to account for these uses. In modeling the baseline building, the same zones are used with the same ventilation rates used in the proposed building. These conditions will likely trigger one of the exceptions to the HVAC mapping rules and require that the spaces be served by a separate system.

Some healthcare facilities will have areas that are used continuously, such as patient rooms, mixed in with areas that are only in use during normal daytime hours, such as medical offices. In some cases an entire wing or floor of a facility will be on a normal 8-5 operation and will have a dedicated HVAC system to allow night-time shutdown. In this case, the proposed building modeling should include appropriate HVAC operating schedules to account for the night-time operation. The baseline building will typically have separate systems for spaces with a different schedule (see discussion above).

Most areas of hospitals have relatively high airflow minimums and require continuous operation even when unoccupied. Some areas do not allow VAV operation or require return air VAV valves to assure pressurization. Some areas of the building will have very large air change rates, such as surgical suites. However, in many applications, these suites are only used during daytime hours. One strategy is to have a night setback in these spaces, reducing the air change rate from 20 in the daytime, for example, down to 6 at night. This will require the proposed building to include schedules to account for this, but in the case of the baseline building, operation would be assumed to be at the 20 air change rate for all hours.

Surgical suites may also require low SATs and special dehumidification. Most hospitals require winter humidification, varying among systems and zones.

Domestic Hot Water

Domestic hot water usage will vary greatly depending upon the type of facility, as well as functions that occur in the facility. Some hospitals have on-site laundry facilities, while many others out-source this activity to offsite providers. Facilities such as medical office buildings will have dramatically lower hot water usage than a multi-bed facility with many patient rooms. Once again, accurate schedules that reflect this usage will need to be developed. In most cases, the baseline and proposed buildings will include the same hot water usage and schedules, unless a reduction in hot water usage can be demonstrated due to a proposed design feature that is not required by or typical of the baseline building. An example might be a laundry facility that uses water saving equipment. Other energy savings in the proposed building could come from the boiler efficiency and possibly the recirculation pumping system.

Internal Loads

A wide range of internal loads exist in healthcare facilities, ranging from television sets in patient rooms to radiology equipment in labs, all running during different hours of the day. Most internal loads are reduced to a minimum at night while a facility is fully staffed in the daytime. There will be a need to develop equipment operation schedules to reflect this operation. In addition, given the fact that some equipment will only run a few minutes out of the hour, such as an MRI machine, it is important not to overestimate the loads attributed to the equipment. In most cases, the baseline and proposed building models will include the same equipment loads and operating schedules, unless the modeler can clearly demonstrate a more efficient piece of equipment is being used compared to standard practice or code minimum.

7.1.3 Data Centers

Data centers are spaces specifically designed to accommodate dense arrangements of computer equipment. This currently includes telephone company “central offices” (“telcos”) and computer labs. Any space where dedicated HVAC is installed to handle computing equipment load is likely to be considered a data center.

Data Center HVAC Systems

Data centers in the baseline building will typically be served by a separate system because they trigger the exception to the HVAC mapping requirements having to do with abnormal internal heat gain and schedules of operation. When heat gain differences of more than 10 Btu/h or operation schedule differences of more than 40 hours/week trigger this exception, a separate system is required to serve the data center. Either system 3 (PSZ-AC) or system 4 (PSZ-HP) shall serve the data center (depending on the heating source for the building). See the PRM, G3.1.1, Exception b.

Loads

Loads in a data center could range from anywhere as low as 20 W/ ft^2 up to 400 W/ ft^2 Load densities above 400 W/ ft^2 would not typically be handled by an air based cooling system. As a rule of thumb: the initial actual energy use of a new data center is 50% of the design capacity of the cooling system serving the data center, so the equipment is initially oversized by a significant margin. In many cases, the data center load will increase each year, as additional equipment is added, reaching full load after a five year period. However, if there is more precise information on the expected load, this should be used. In most cases, the load for the baseline and proposed buildings should be the same, unless documentation of equipment that is more efficient than standard practice can be provided.

Redundancy

Given the uptime requirements of data center equipment, redundant equipment is a necessity. Purely redundant equipment is ignored in the modeling of the proposed building and the baseline building. This might simply be additional CRAC (computer room air conditioning) units, or might be more complicated to include additional chillers and supporting pumps.

Ventilation

In mixed-use facilities, ventilation for the data center is often provided by the “house air” system, i.e. the system that serves the office or other commercial space, with a separate system providing cooling. In dedicated data center systems, the ventilation air is typically provided by a dedicated outside air system and should be modeled accordingly. Outside air in the proposed and baseline system will be the same, but the baseline building system will typically be modeled with its own supply of outside air.

Humidity Control Systems

The ASHRAE document “Thermal Guidelines for Data Processing Environments” describes the “Recommended” relative humidity (RH) range for Class 1 and Class 2 computing environments as 40% to 55%, and the “Allowable” range for these same environments as 20% to 80%. These RH values apply to the air entering the computer equipment.

CRAC units with on-board humidity control systems typically have the temperature and humidity sensors factory-mounted in the return air opening of the CRAC. For open aisle data centers, the sensors are typically left in this position, and the humidity of the return air is controlled to the ASHRAE recommended range of 40% to 55%.

For ducted return and fully enclosed data center aisles, the practice is to relocate the CRAC temperature and humidity sensors to a cold aisle, or to install additional temperature and humidity sensors in the cold aisles and disable the original CRAC sensors. The aisle-mounted sensors will control the CRAC humidity system to provide the ASHRAE recommended range of 40% to 55% in the cold aisles.

The baseline building system shall be modeled with the same temperature and humidity conditions as the proposed design.

Uninterruptible Power Supply (UPS)

Data centers typically include some type of battery-based system to address power failures. Depending upon the size, configuration and amount of load, the efficiency of these systems will range from 86% to 93%. In determining the data center power usage, this must be accounted for in the building modeling. In addition, there will be additional cooling requirements for the UPS systems that will need to be modeled. Both the baseline and proposed buildings should be modeled with the same UPS configuration and power, unless supporting documentation of a more efficient technology or arrangement can be documented.

7.2 Design Features

7.2.1 Automatically Controlled Window Shades

Some advanced buildings include either interior or exterior shading systems that include automatic controls to optimize the shade position for energy savings. In some cases, this may be as simple as a time based control system that operates the shades based upon time of day. More sophisticated systems may include sensors designed to detect solar gains on the fenestration, and determine the optimum shade position.

Most simulation programs include a variety of commands to facilitate modeling the various scenarios that will be found in buildings. In the case of the simple time of day based control system, a straightforward hourly/daily/monthly schedule command can be utilized that will adjust the solar gain through the fenestration using a multiplier that is applied to the hourly solar gain.

For the more sophisticated case, a solar gain or glare threshold should be input that will result in the shades being closed. In some software, this

For the more sophisticated case, a solar gain or glare threshold should be input that will result in the shades being closed. In some software, this may include hourly pairs of values that describe the solar gain threshold and corresponding solar gain multiplier resulting from the shade.

7.2.2 Active Chilled Beams

An active chilled beam is a device that is located in or above the conditioned space to provide heating, cooling and ventilation. The system consists of a coil box that is recessed in or hung from the ceiling with chilled water flowing through the coil. Ventilation air is introduced by a remote air handler into the diffuser box through small air jets, which induces room air to flow through the coils. Because the active introduction of ventilation air magnifies the natural induction effect, active chilled beams are commonly referred to as induction diffusers.

Depending upon the modeling software, active chilled beams may be modeled directly in the software or by using the more commonly available induction unit selection. Since each zone in a building will typically have its own chilled beam system (multiple units) with thermostatic control, a decision will need to be made as to how to properly zone the building to account for the individual chilled beam units. In most cases, conventional zoning of the building will be sufficient, such that thermally similar zones would be combined together. In combining zones, however, the source of ventilation air will need to be taken into account. Thus, two thermally similar chilled beam zones that are supplied by different ventilation air handlers would need to be separated out for modeling purposes.

Once the thermal zoning has been determined, each zone will then be modeled with a chilled beam induction system; inputs would include the system cooling capacity and the induction ratio. In addition, the source of heat, whether electric or hot water, would need to be specified. Since one or more dedicated ventilation fan systems will provide the outside air to the chilled beams, this would be modeled in the same fashion as the dedicated outside air system described below, with each chilled beam system coupled to this dedicated outdoor air system.

7.2.3 Dedicated Outside Air Systems (DOAS)

Dedicated outdoor air systems are provided to pre-condition the outside air which is then supplied to the main HVAC systems in the building. In most cases, the purpose of a DOAS is to address the large loads associated with the introduction of outside air, whether due to low ambient conditions, high ambient conditions or high humidity of the outside air. Depending upon the configuration, the DOAS may include heating coils, cooling coils and possibly a heat recovery component, in addition to the supply and optional exhaust fans associated with the unit. The main HVAC system fed by the DOAS could be any number of HVAC system types but typically will be smaller zonal systems such as water source heat pumps, VRF systems or fan coil units. By shifting the outdoor air load over to the DOAS, these systems may be smaller.

The DOAS system is modeled as a conventional HVAC system if that is how it is configured, with inputs for heating and cooling coils as well as fans. The choice of system type will depend upon the type of system being modeled. The DOAS system could be a simple rooftop DX system, or possibly a chilled water air handler with hot water coils fed from a central plant. It is important that the system be specified with 100% outside air, unless a more sophisticated outside air control scheme has been utilized. Optional parameters that could be specified include an exhaust fan and/or a heat recovery component. Heat recovery would require the specification of the heat recovery effectiveness as well as any pumps or fans associated with the heat recovery component. Often DOAS AHUs include precool-reheat loops (wraparound heat pipes or sensible loops) or mixed dual heat recovery systems. If proposed buildings include these systems, software should be chosen that models these systems explicitly. DOAS equipment often delivers warmer air to zones with chilled beams, panels or other local cooling. Where minimum airflows are high, this can lead to significant savings in reheat.

Each HVAC system that receives outside air from the DOAS will be specified as a conventional HVAC system, except that the source of outdoor air will be coupled to the DOAS system associated with this unit. When specifying the ventilation rates for the zones served by the HVAC system, they will be specified as normal. By coupling the HVAC system to the DOAS system, the energy model will utilize that stream of air as the basis of the outdoor air.

If the DOAS only provides outdoor air tempering for other mechanical systems, the baseline building is not modeled with a corresponding DOAS system. However, in the case where the DOAS also provides general space conditioning to a space (such as conditioned air into a hallway, that is then pulled out by other HVAC systems) then that space will be modeled with the HVAC systems defined in Chapter 6.

7.2.4 Displacement ventilation

Displacement Ventilation (DV), a space conditioning technology in use in Europe since the 1970’s, has the ability to reduce energy usage in buildings due to a number of energy saving strategies not found in conventional overhead mixing systems. The fundamental principle involved in a DV system is to supply significantly warmer supply air temperatures during cooling mode, typically 63°F to 68°F. With the use of higher supply air temperatures comes the ability to operate in economizer mode many more hours each year. When producing the higher supply air temperatures, chilled water systems have the ability to operate at much higher chilled water temperatures, thus resulting in a significant increase in the chiller efficiency when producing chilled water. In addition, for systems that will be requiring reheat, additional heating and cooling energy is saved since they will be reheating air that is cooled to only 65°F versus a conventional system that has cooled the air to 55°F.

By not mixing the air in the room, the DV system results in more of a stratification effect. Thus, much of the heat in the space will rise towards the ceiling, where it will be exhausted by the high return air register. A portion of the cooling load in the space, including occupant heat gain, lighting and equipment, never appears as a cooling load.

Some software tools have built-in system types that allow for the direct modeling of DV systems while others will require the user to make approximations of some of the effects associated with DV, in particular, the stratification of room loads. In all cases, the supply air temperature of the system will need to be set to the higher design value of the system, and in most cases the control strategy for the cooling coil will be to reset the leaving temperature based upon the warmest zone requiring cooling.

For modeling the actual zone, the idea is to account for the stratification of air in the zone. One technique is to model the lower 6 feet of the zone as a conventionally conditioned zone and to model the upper portion of the zone as a return air plenum. Loads associated with the wall, roof, lighting and some of the equipment will then be modeled as being part of the return air plenum, rather than part of the space. This has the effect of modeling the stratified, non-mixed air in the zone, placing much of the heat gains into the return air. When the system is operating in economizer mode, these loads will simply be exhausted out of the building, rather than appearing as a cooling load in the space.

Assuming the system is VAV with reheat, each zone will be modeled with a conventional VAV terminal box to account for heating. Note that once modeling has been completed, it is important to verify that the higher supply air temperatures associated with the DV system will in fact meet the loads. Output reports from the software should be checked for unmet load hours. In addition, if working in a humid climate, it is unlikely that the higher temperatures will satisfy the latent loads. One solution is to design the system with a bypass on the cooling coil so that a certain portion of air will be cooled to 55 degrees and dehumidified, with the rest bypassing the coil, resulting in a mixed air temperature of 63°F to 68°F.

Depending upon the strategy used for the coil temperature, the chilled water temperature may also be modeled at a higher temperature. Assuming the bypass strategy is not used, the chilled water temperature should be set based upon the higher design, resulting in additional savings at the chiller.

The baseline building is not modeled with displacement ventilation.

7.2.5 Gas Engine Driven Heat Pumps

These systems typically are conventional DX packaged systems that utilize a natural gas or propane engine in place of an electric motor. During cooling operation, the gas engine will operate the cooling compressor to provide cooling to the DX coil. During heating operation, the same effect will be utilized. In both cases, the manufacturer may include the option for heat recovery from the gas engine for use in building hot water loads, such as domestic hot water or heating coils.

Given the unique nature of these systems, the energy modeling will need to utilize a system selection in the modeling software specific to gas engine driven heat pumps. In addition, user defined operating curves will need to be input to reflect the manufacturer specific operation during heating and cooling modes. Should the system utilize heat recovery, the heat recovery efficiency will need to be determined and assigned to the system. Two possible types of heat recovery include jacket based heat recovery, where heat is extracted from the engine jacket used to cool the engine, and exhaust based heat recovery, where heat is recovered from the engine exhaust. In some cases, heat recovery may come from both sources. The heat recovery energy will then need to be assigned to a hot water or other demand in the building. This might include supplying domestic hot water needs for the occupants or perhaps reheat coils used downstream in the HVAC system.

The baseline building is not modeled with gas engine driven heat pumps.

7.2.6 Ground Source Heat Pumps

Sometimes referred to as geothermal systems, ground source heat pumps (GSHP) couple the condenser water side of the heat pump to a ground source. Possible couplings include vertical wells, horizontal wells or a body of water such as a pond or lake. In closed loop systems, water or an antifreeze solution is circulated through a series of pipes, while in open loop systems, water is pumped through the system and discharged openly.

The temperature of the heat sink available to the GSHP is going to be highly site dependent, and should be based upon the anticipated temperatures that will result after the system has been operational for a reasonable period of time. In some cases, a large lake may have fairly stable temperatures that can be anticipated on a monthly basis based upon historical trends. In other cases, a smaller heat sink such as drilled wells may be subject to localized temperature increases in the areas surrounding the wells, and this will need to be factored in. In addition, sites that have underground aquifers will see different resulting ground temperatures than sites without. As a result, local conditions will need to be factored into the ground temperature assumptions which are key to GSHP modeling.

Modeling of the GSHP systems will begin with the basic zoning of the building. It is common to use fairly small (5 ton and under) systems, so each will typically require a separate zone in the model. In cases where zones have the same GSHP installed and are thermally similar, combining of zones is acceptable. Some large applications of this technology will utilize multiple zone air handlers, in which case conventional zoning procedures will apply. Input descriptions for the GSHP will include heating and cooling capacities, the heating COP and cooling EER, as well as the supply fan and possibly return fan information. On some larger systems, economizers may be included.

The coupling of the GSHP system will occur through the condenser water loop, so the next step is to define this loop. Included in this definition will be information such as the pumping flow rate of the system, type of pumping (variable speed, constant speed), pump motor size as well as whether the GSHP condenser coils include three-way or two-way valves to control flow.

In cold climates, a backup boiler may be included as part of the condenser water system to prevent low water temperatures in the loop. The basic boiler information will need to be specified, as well as a minimum loop temperature which will dictate when the boiler is activated.

The final step is to define the actual ground or pond heat sink. This may include defining a schedule of monthly temperatures to represent a large body of water, although on smaller bodies of water changes in

temperature from the GSHP system will need to be accounted for. In the case of a vertical or horizontal well system,information including the type of well, well spacing and well depth will need to be included.

The baseline building will not have a GSHP.

7.2.7 Ice Storage Air Conditioners

Ice Storage Air Conditioner (ISAC) systems contain ice storage tanks distributed throughout the building, with each tank associated with the air-side component of a single HVAC system. In contrast, traditional thermal energy storage systems centralize the storage, which then serves the load of the entire building. The ISAC system will typically rely on cooling fed from the storage tank to an air handler containing either a chilled water or DX coil. The tank will be charged by a condenser during night-time hours, and discharge will occur during the daytime hours. In modeling the ISAC system, the modeler will typically utilize the Split DX system type available in most analysis software. This system type will most closely approximate the performance of the condensing unit that will be used to charge the ice storage tank. In addition, custom cooling curves will need to be input to account for the system performance during the charging mode, since much lower temperatures will need to be produced by the condensing unit.

Operating schedules for the charging and melting model will depend upon the controls configuration of the ISAC system. Some systems are designed and configured to run in a simple charge/melt mode, where the entire daytime load will be handled by the ISAC system, and then the system will be recharged at night. Others are designed to only address peak period loads, and thus will run only during the peak utility period, with the condenser operating in the mornings during the shoulder peak periods. Another variation is an ISAC system that is designed for peak load shaving, with the ice melt supplementing the condenser cooling. These different strategies will require the use of appropriate operating schedules to control the condenser operating strategy as well as the ice tank charge/melt occurrences.

The baseline building does not have ISAC.

7.2.8 Radiant Heating and/or Cooling

Radiant heating systems rely on the delivery of heat via a system located in the floor, or in some cases, ceiling or wall mounted panels. The delivery can be either via a hydronic system coupled to a boiler (or other source of hot water) or using electric radiant panels. In the case of radiant cooling systems, delivery is typically via a hydronic system that is supplied with chilled water from a chiller or other cooling source. One of the most important factors of a radiant cooling system design is the control of the chilled water temperature that is supplied to the system. If the chilled water temperature supplied results in the radiant delivery system surface temperature falling below the dewpoint in the space, condensation will occur on the surface. The result of this would be moisture on the floor or ceiling, depending upon the location of the delivery system. As such, the chilled water supplied to the radiant system will be maintained at a higher temperature than a conventional chilled water system. This higher chilled water temperature will need to be accounted for in the energy modeling as it will impact both the pumping energy use as well as the chiller energy use. "Radiant" heating or cooling systems that utilize concrete slabs may be very slow to react to load changes. Simulation programs should be chosen that account for this or these systems should only be modeled in spaces that will have very slow load changes.

Since these systems rely upon the radiant delivery of heating and cooling, no fans are associated with the radiant component of the system. However, it is common that a fan is associated with the ventilation system. Modeling of the fan associated with the ventilation will depend upon how the ventilation system is configured. One approach is to utilize a Dedicated Outside Air System (DOAS). The modeling procedures for this type of system are described elsewhere in this chapter. Another approach used with radiant systems is to use a displacement ventilation system, in which case modeling of this component will follow procedures dictated elsewhere in this chapter. In some cases, radiant systems utilize natural ventilation as the source of outside air. These procedures are also addressed in this chapter.

The baseline building does not have radiant heating or cooling.

7.2.9 Switchable glazing

Switchable glazing can change the light transmittance, transparency, or shading of windows in response to an environmental signal such as sunlight, temperature or an electrical control. Technologies such as electrochromic and liquid crystal windows change from transparent to darkened by applying an electrical current to the window. Once the change in tint has been initiated, the glazing does not need constant voltage to maintain the tinting, so electrical usage is negligible for energy modeling. In addition, the film can be tuned to block certain wavelengths of light, such as infrared energy.

In modeling switchable glazing that includes an automatic control such as a heat sensor, a control set-point, usually in Btu/h, will be used in the model. The basic window will be modeled with the U-Factor, SHGC and VT (visible transmittance) of the glazing with no tinting applied. The energy model will then include modifiers to each of these values when the control set-point has been reached. Thus, the energy model will reduce the energy gain through the windows in response to solar gains on the particular window.

Another approach is to apply the same modifiers on an hourly basis using a series of schedules. This approach might be used in a circumstance where the glazing is being controlled with a building energy management system and would be applied at a consistent time of day, or seasonally.

In this case, the hourly schedule would dictate the multiplier to be applied to the U-Factor, SHGC and/or visible transmittance.

This is but one way to model switchable glazing; other engines such as EnergyPlus have more advanced features and the use of alternative approaches is acceptable.

The baseline building does not have switchable glazing.

7.2.10 UFAD

Underfloor Air Distribution (UFAD) systems provide cooling supply air streams at significantly warmer temperatures than conventional systems, typically 60°F to 68°F. With the use of higher supply air temperatures comes the ability to operate in economizer mode many more hours each year. When producing the higher supply air temperatures, chilled water systems have the ability to operate at much higher chilled water temperatures, thus resulting in a significant increase in the chiller efficiency when producing chilled water. In addition, for systems that will be requiring reheat, additional heating and cooling energy is saved since they will be reheating air that is cooled to only 65°F versus a conventional system that has cooled the air to 55°F.

Since UFAD systems deliver air at lower velocities than conventional system, there is more potential for stratification since room air is mixed less. Thus, a certain portion of the heat in the space will rise towards the ceiling, where it will be exhausted by the return air register. The overall result is that (like with Displacement Ventilation) a portion of the cooling load in the space, including occupant heat gain, lighting and equipment, never appears as a cooling load. Given the fact that at any given point in time, at least some portion of the return air will be exhausted due to outside air requirements, this heat gain will also be exhausted.

Modeling of the UFAD system will follow the same general approach as the Displacement Ventilation systems described earlier. In some instances, fan powered terminal units are used in this application, so a fan powered box may need to be included in the zone inputs. The baseline building does not have an UFAD system.

7.2.11 Variable Refrigerant Flow

Commonly referred to as VRF systems, Variable Refrigerant Flow systems are produced by a number of manufacturers and consist of both heat pump and heat recovery units. Similar in nature to a Water Source Heat Pump system, the VRF system consists of an outdoor condenser unit tied to a group of indoor heating and cooling units using a piping loop. Unlike a wate source heat pump system, however, the VRF system uses a refrigerant loop connection between the indoor and outdoor units. In the case of the heat recovery version of the VRF system, indoor units are able to exchange heating and cooling energy via the refrigerant loop.

Given the nature of partial loading on the outdoor unit from the various indoor units, using a simple full load EER to approximate unit performance will result in a gross underestimation of system performance. Accurate hourly loading of each indoor unit is necessary to derive the maximum accuracy. Each indoor unit must be modeled as a zone or thermostatic control element in the software. In situations where a single zone contains a number of indoor units, it is acceptable to group those units as a single zone, provided each area served by the indoor units is thermally similar. Once the thermal zones have been determined, each indoor unit will be modeled based upon actual heating and cooling capacity and fan characteristics. Some VRF systems include optional components that provide outdoor air heat recovery and/or economizer capability, so these features will need to be specified at the zone level inputs of the software.

Once all the indoor units have been defined, each indoor unit will need to be associated with a loop that connects it to an outdoor unit. As part of the specification of the loop, heat recovery may also be included if the unit has this capability. Each outdoor unit will be specified with inputs for capacity and full load efficiency. In addition, operating curves will be input to adjust the full load efficiency for part load conditions and varying outdoor conditions.

Additionally, some VRF systems include the ability to connect all of the outdoor condensing units to a water or glycol based condenser water loop that includes a cooling tower and possibly a boiler. If this is the case, additional parameters will need to be input to define this water loop including the description of the pumps, cooling tower and boiler. This description will be similar to the parameters that are described for a conventional water source heat pump condenser water loop.

A final variation on the water cooled condensers is the inclusion of a ground coupled system. In this case, the condenser water will be pumped through a series of wells that couple the condenser water to the ground temperature. This portion of the modeling should generally follow the procedures specified in the section on ground source heat pumps elsewhere in this chapter.

The baseline building does not have a VRF system.

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