Pam Cole: I am Pam Cole with the Pacific Northwest National Laboratory, and I'd like to welcome Reid Hart and it's all yours, Reid, take it away.

Thank you. Well, good morning, everyone. Just want to cover our learning objectives for today. This is gonna be a pretty high-level overview of HVAC systems, so our focus is on what different system types are used for heating, ventilating and air conditioning in buildings. We will touch upon some code items along the way, kind of the high points, but this is not intended to be a comprehensive all HVAC and mechanical system code requirements.

At the end of today, hopefully, you'll be able to identify the common HVAC system types, identify important HVAC controls, including economizers, name high impact energy code items related to HVAC equipment and controls, and list the steps in verifying fan power calculations, one particular code requirement.

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Our outline overall is to just talk about some HVAC systems basics, basic controls that save energy, outside air economizers, fan energy systems. Then we'll move from more simple systems into complex systems where you've got a central plant, secondary HVAC systems and the more complex controls involved with those systems, and hydronic system controls. And we'll also talk about the HVAC high efficiency option in the IECC energy code.

Throughout, I will be referring to some code requirements and these will be based on the 2015 International Energy Conservation Code or IECC. There are usually similar requirements in the 2012 IECC or ASHRAE 90.1-2013, but the section numbers will obviously be different and there are slight variations in requirements. Also note that different states during their adoption process –

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may amend or change the model code so each state may have some different requirements.

So let's talk about HVAC system basics. So what's the basic purpose of an HVAC system? Well, first of all, we have some air conditioning for thermal and humidity comfort and that includes heating, cooling, dehumidification, humidification. If you look at the little chart on the right that's the ASHRAE comfort diagram and you can see that there is two areas of comfort related to clothing, the left band is related to winter clothing, where people might wear a jacket or more heavy clothing. The right area is related to lighter summer wear, where people may wear shorts or a short-sleeved shirt and so we've got a difference there.

And then –

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it also relates to humidity, the curving lines there relate to different humidity levels in the building. But you can see there is a moderately wide range of comfort and this is a band where 80 percent of the people, based on experimentation, would be comfortable in the building.

Another purpose of HVAC systems is ventilation, so the introduction of required outside air, and depending upon the code you're working with, this is specified either in the International Mechanical Code or IMC, or ASHRAE Standard 62.1. Now, those ventilation requirements are very similar typically, they tend to follow each other. There is also, as part of ventilation – and by the way the word ventilation includes movement of recirculated air as well, not just outside air. So when we talk about outside air, that's specifically named outside air in the code. But filtration of recirculated air is included in ventilation, also the exhaust –

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of undesirable air from toilet rooms, kitchens, lab exhausts, that sort of thing. And air movement in the space is considered by some people to be beneficial in people feeling comfortable but obviously not required as there are radiant systems that don't involve that.

Space pressurization may also be part of the HVAC system purpose. In other words, keeping a positive pressure – this is more typical in commercial buildings, so that you keep infiltration out during the occupied hours and also making up exhaust air. So if you have a lot of exhaust air, you need to make sure that you're bringing in outside air in equal volume so that you aren't having the front door get sucked in to, you know, provide makeup air back into say the kitchen.

So let's talk about this idea of heating and cooling, and it's based on heat gain versus heat loss.

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Heat loss occurs in the winter, heat gain occurs in both the winter and summer weather conditions. So heat gain occurs, solar gain is the sun shining through the windows or shining on the walls and eventually that heat makes its way into the building. There is also summer transfer and infiltration. So we've got heat transfer through the walls where heat is coming into the building. We have internal gains, electric use in the building, lighting, equipment, computers. We have body heat, every person walking around in the building is a little 500 BTU per hour heater giving off heat into the building. And so we've got heat gain going on.

In the winter, we've got heat loss going on. The diagram is showing a winter or cold outside condition, where heat is escaping from the building through the insulation or through infiltration, and heat loss occurs through air leaks, through transfer, in other words –

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conduction and radiant transfer through walls, roofs, floors and windows. And there is a balance then between heat gain and heat loss. If we're gaining more heat than we're losing, and that can occur in the winter where there's enough internal load, especially in a commercial building, where we still need to get rid of heat, then we need to provide cooling or air conditioning. The term air conditioning is somewhat broad, including some of the other items we mentioned earlier, but it also can refer to just cooling. Or if we're in the winter and it's really cold outside and there's more heat loss than gain, then we need to provide heating through our HVAC system. So that's the basic temperature maintenance purpose of HVAC.

So there are two different kinds of air conditioning, and here I am referring to the cooling use of that word, it can be refrigerant based, so there is a refrigeration –

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cycle used to move heat from one space, we move the heat from indoors, to another, to outdoors and that refrigerant evaporates and condenses continuously within the cycle. And refrigerant has a low boiling point, in other words, it's – we use it just like you boil water on a stove except that boiling is occurring down at 25 or 30 degrees. So as it boils, it will suck heat out of the air and, you know, that makes it ideal for an HVAC system, and that refrigerant is all contained within a pressurized system. This is similar to your car air conditioning system, where when you turn on the air conditioner there is a little condenser under the hood and it gets right of heat and it's extracting heat from the air coming through your fan.

Non-refrigerant cooling is evaporative cooling, maybe also called a swamp cooler, not typically used but in some buildings they may use evaporative cooling –

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to help with the cooling process or provide all the cooling if they don't have refrigerant-based air conditioning.

Also, our systems can be simple versus complex. Now, that is no longer a code distinction in the 2015 IECC. In 2012 and before, simple systems versus complex were a distinction. In the 90.1, there is still a simple system section for single zone units that refers to different sections in the rest of the code so that you don't have to follow through all the complex things when you've got a simple system.

Simple systems often use direct expansion coils or direct heating, say to a furnace. The refrigerant is used to directly cool the air, direction expansion is also called DX cooling, that's another name for it. In other words, the refrigerant is right in the cooling coil and it's used to extract heat from the air. On the heating side, we might use gas, oil –

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or electricity in a furnace to heat the air. And simple systems usually serve one zone and the unit – and we'll talk about units in a minute, is directly controlled by a thermostat in that zone.

Complex systems have a little bit more of an architecture. They have a central plant with heat generators and cooling generators, and they use chilled water or heating water, hydronically – hydronic just means working with water. There may be glycol in those solutions to prevent freezing but basically we're using a liquid fluid to move heat throughout the building. It goes out to secondary systems where we heat and cool as needed for the zone or zones supplied from the secondary system. So typically a complex system will serve multiple zones.

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So in all cases in buildings, the code requires that someone do an actual load calculation. This can be done with computer software, there's Manual N for commercial load calculations by ACCA, and it's important to make sure that someone has actually done a load calculation and there are cases in design built buildings where someone might come out and just kinda stick their thumb in the air and say, oh yeah, a 5-ton air conditioner, that's fine here and maybe a 3-ton would have been quite adequate.

So why do we care that systems are not dramatically oversized? Well, for simple constant volume equipment, the fan energy use will be significantly higher. So if the system is twice as large as it needs to be, the fan will be twice as large as it needs to be and that fan runs actually more times, sometimes, than the air conditioner and heater, depending upon the climate, –

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and so there is a significant energy use because that fan should be running constantly to provide ventilation.

For larger, multiple zone systems, if they're, again, oversized dramatically, fan and reheat energy use may well be higher because if you've oversized all the zone boxes, you cannot turn them down as far to the minimum settings and as a result, we end up with more minimum airflow and more reheat. So, you know, looking at the sizing, and the sizing requirements do allow for some reasonable safety factors and obviously, you know, if you come up with a size that's 3.2 tons, you'll need to jump up to the next size unit, maybe 4 tons, but, you know, you don't want to, like I say, double or triple the size of the equipment in a building.

Ventilation, there's two types of ventilation, mechanical ventilation –. Again, ventilation deals with both –

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recirculation and bringing outside air into the building and requirements are available for minimum outside air based on occupancy, floor area, number of occupants, and again, those requirements are pretty similar between the International Mechanical Code and ASHRAE standard 62.1.

In natural ventilation you might have no fans. Some more sophisticated buildings, like the one shown there, with the tower stacked effect may be able to accomplish that without fans in a large building. Typically, natural ventilation is used more in smaller buildings, although even residential buildings now require some type of mechanical ventilation in the newer codes.

So let's talk about simple HVAC systems. So we've got what are called package units, and we'll talk about the word package, it has a couple of meanings. Like, a package –

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through the wall air conditioner or packaged terminal air conditional called a PTAC or packaged terminal air heat pump. Those are the units you see, you know, in many hotel rooms just sitting under the window. They have an outside portion where they reject the heat outside or in a heat pump situation, they reject cold outside and heat inside the building. So they produce that transfer of energy.

Unitary air conditioners are typically a little bit bigger in size, and the unitary air conditioner can either be in a single package, so here is another use of the word package, or they can be a split system. So on the right we see a single package on the roof. The fan and coils are in the right half of that unit and you can see there is an outside air intake that will bring in outside air. On the left side of the unit we have the condenser and compressor that provides the refrigerant transfer. We'll talk about that in a minute, but they're all in one box.

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That would be a single package system.

On the left, we see a diagram of a switch system. Here, we have an indoor unit that has the fan and the evaporative coil, and you know, air is blown through the coil and into the space, and then there's refrigerant piping connecting the two units and outside, again, we have the condenser and the fan. So we've split those units apart and connected them with control wires and the refrigerant piping.

Both of these units are considered unitary. The word unitary meaning we connect them directly to the power source, whether it's electricity or natural gas, and they use the power source directly internally. They don't rely on a chiller or a boiler somewhere else to do the heating work.

Here is a look inside either the indoor unit or the fan half of that outdoor unit, and we can see what's going on is the return air –

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that's, say in this case, been warmed up in a room in the cooling mode, comes back to the unit, is drawn in by the fan suction, a little bit of outside air gets mixed in and there is an outside air damper there. That air goes through an air filter to remove particulates and then here is our direct expansion coil or our DX coil, and it is cold, cooling the air down and that cool air is then returned back to the room in the supply air or discharge air.

The room thermostat senses the temperature and it will connect to the unit system board that turns on and off the compressor. So we haven't shown the compressor in this picture, but this coil is connected to the compressor and that's your basic air flow. So we're taking air and we're transferring – we're taking heat out of the air in the cooling mode and putting that cold air back into the room. If this was a heat pump –

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the cycle would be reversed and this coil would be hot. It would be reversed with the outside coil and we would put heat into the air.

So here's the same thing with the split system. This indoor unit is just like the diagram we walked through, and the outdoor unit is where the compressor magic is happening. Let's talk about refrigeration. So if we look at the diagram of just the refrigeration circuit here, we see we've got a compressor, we have got a condenser, we've got an evaporator, and basically what that compressor does is it takes cold refrigerant vapor, a gas, and it compresses it and when it changes the pressure of that refrigerant, it makes that gas hot and that hot gas then moves out to the condenser and it makes the condenser hot. The condenser then – there is a fan –

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blowing air through that condenser that rejects the heat to the outdoors. And then we end up with a liquid that is hot, a hot refrigerant liquid, that liquid comes back here and then it goes through an expansion device, as it does, it boils, literally. Again, we're boiling at a lower temperature 'cause it's a different refrigerant, it's a different chemical than water, and we boil at that low temperature, and as we boil it, we extract the heat out of it. The evaporator coil gets cold and we're able to blow air through that coil and extract heat out of the air and cool down the situation.

Again, in a heat pump there is an additional reversing valve not shown here that switches the function of the indoor and outdoor coil, so the indoor coil becomes the condenser and the outdoor coil becomes the evaporator.

The energy use in this system is in the fan blower indoors and the fan blower outdoors and in the compressor –

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that is moving that refrigerant back and forth. And because this is – well, for example, we used the word heat pump, we are pumping that refrigerant around and it takes much less energy, say, to pump the refrigerant around than if we had a strip resistance heater and that's why we like heat pumps from an efficiency point of view.

There is a more modified or newer type of unit, actually these have been around for quite a while in Asia and Europe, been quite popular because they're easier to retrofit into buildings that are hundreds of years old, and this is variable refrigerant flow. So this is basically the same concept. We've got a compressor out here and it's the heat pump concept, but we've got now multiple indoor units and we've got a smart little switching box here hooked up to the controls for all these units, and it says well, which unit wants to be in cooling and which unit wants to be in heating, and it will –

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distribute either the liquid to expand in cooling to the units that want cooling, or it will distribute that hot gas to the units that want heating.

And so we have a heat pump that actually cycles heat between zones as well as switching this compressor between either being in a heating or cooling mode, depending upon the balance of all these zones. I know that was a pretty quick explanation but these units are becoming more popular and the controls are fairly complicated and typically the manufacturer is involved closely with the contractor in installing these units, and they're up and coming in the marketplace.

So let's talk about things to check relative to these units and the Energy Code. Equipment efficiency is the main thing. There are tables in Section C403.2.3, –

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separate tables for each type of system, heat pumps are separated from air conditioners and there's other units. There are different efficiency ratings depending upon the type of the unit and the size of the unit. So you have to know what the output capacity is for an air conditioner in cooling mode, you can see there is different sizes. And there are different efficiency ratings. So a smaller unit might be rated in SEER or seasonal energy efficiency ratio. A larger unit might be rated in both EER and IEER, energy efficiency ratio and integrated energy efficiency ratio.

And when we have multiple requirements, like, for instance, in this, you know, medium-sized packaged air conditioner, or it could be a split air conditioner for that matter, we have these requirements to meet. We have to meet both the EER and the IEER. And again, with all these requirements, a higher number is better. So if the number on the nameplate –

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or on the documentation for the unit that's installed is bigger than the number shown on the table, you're good with the code.

Now, the importance of equipment efficiency – you know, there is a bit of an interesting situation here because we have multiple regulations covering this equipment. There's federal manufacturing regulations or standards, and if you're interested in those, there is a web link. That web link is not on the currently posted slide but we will get up a slide for that. We had a question about that this morning. And, you know, the equipment must meet those manufacturing requirements.

Now, there have recently been regional requirements in place and again, these federal requirements typically relate especially to single phase, smaller size equipment. And the regional requirements, from my understanding, and I am not an expert in this area, –

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but relate to units rated in SEER and not to other units. Now, one artifact of the fact that our codes get adopted and then they go through an adoption cycle, it may take three years before a new code gets into place in states, or even longer, the tables may not be up to the current federal condition. In fact, there are often states here about new requirements coming into place. So the federal condition may rule. I think pretty much the code person has jurisdiction over these ratings, and some of the ratings in the tables, say for chillers and other things, are not in the federal regulations, they are in ASHRAE Standard 90.1 and then transfer over to IECC. So that is the ruling case there.

There are regional requirements now, where, for instance, there is a higher SEER rating required in the southern United States and actually in the southwest there is also an EER requirement in addition to the SEER requirement.

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And so those apply if, you know, a code official found that something did not meet the federal requirements you could find on this page, they could notify the DOE energy enforcement line on a violation there. However, that inspection is probably not under the jurisdiction of code beyond what's in the tables, which, again, may be out of date.

So that's a little bit of a confusing area from an enforcement point of view but basically there is enforcement on the manufacturing side, and we do have cases where one state may adopt the most recent code and the state next door may have an older code. The federal regulation requirements for the new regional ones are based on date of manufacture, so they could be inventory that's been out there several years that would be legal to install in the state with the older code but not necessarily legal to install in the state with the newer code.

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So I hope that didn't confuse everyone. We talked about variable refrigerant flow a minute ago and that system efficiency is not covered in the 2015 IECC but it is in the ASHRAE standard 90.1-2013. So depending upon which code you're following, there may or may not be VRF requirements, although I believe almost all VRF systems available pretty much are manufactured above the level of what is in those ASHRAE tables.

So let's move on from the actual equipment to controls and basic controls that can save us some energy. Again, we're hitting the high points. There's several pages of control requirements in the code. Now, I'm gonna mention this, it's not indoor HVAC but it is in the mechanical code, snow and ice melt heater control, you know, if we've got some heaters under this walkway to keep it clear in the winter in our northern climates, that is a system that if it is not properly controlled, let's say it stays on all summer long, can use a tremendous amount of energy.

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So not every building has this; a few of them do, but I guess I want to point out that if they do have a system there are some control requirements in the code that you should make sure that they meet. There are some precipitation sensing requirements and temperature requirements so that this unit is not really running when it doesn't need to be.

The other items we'll want to talk about are temperature setback scheduling, thermostat deadband and economizer controls, and we previously mentioned proper equipment sizing, that's another high impact measure and we'll get to the rest of these in a bit.

So temperature setback scheduling. Commercial buildings require that for single zone units you have a thermostat that has a seven-day schedule in it so you can set up a nighttime temperature that's either a setup or a setback. There needs to be some manual override. There's some pretty specific requirements in the code on this.

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Now, one thing I want to address is an energy myth. Some people think setback does not save energy 'cause it takes so long to warm up the building in the morning. Well, this is not true, and the reason it's not true is a building typically has a very large heat loss area, the entire envelope to the building related to the mass in the building, and so that means the building's gonna cool down relatively quickly and it would take a fair amount of energy to keep it warm during unoccupied hours. And consider this, out of 8,760 hours in a year, a building is only occupied 2,000 to 3,000 hours, well, that means there's another 5,000 plus hours that that building is unoccupied. So the unoccupied period is usually twice as long as the occupied period in most buildings, not all buildings, and given that, it's important to get that temperature set back. And occupant sensor is an alternative although not typically used.

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Although now there are requirements for occupancy sensors of some kind in hotel rooms so be aware of that. Actually, that might be in ASHRAE and not in 2015 but it is coming in 2018.

DDC systems. So you could have a bunch of single zone units controlled by a DDC system or you could have a DDC system controlling more complex systems. There's central scheduling of all the units and you might have a schedule on the screen that looks like this, with a start time and a stop time and during this off period the units may cycle to meet that setback temperature. And the other thing you want to look at is optimum start and we'll see an example of that later when we get to complex systems.

Okay. Move it along. Temperature deadband. Now here is an item that's been in code for a long time and for some system types possibly ignored.

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Thermostats out of the factory are typically set up with a temperature deadband, say 70 degrees for heating and 75 degrees for cooling. If the heating is set at 70 degrees, then the cooling is supposed to, according to code, be set up to 75 degrees or higher. Now, obviously, once the occupancy permit's issued, the code, you know, doesn't necessarily apply but at the time of inspection it would be good to look and see if units are set up with those types of deadbands. You know, the code does carry through the inspection and a lot of the language in the code has recently changed from things being capable of to being capable of and configured to, which implies that we want to inspect and understand that things are configured to operate properly, even though they may get changed later.

Why do we want to do this? Well, simple systems can fight each other. So especially if you – say you've got an open office area, you might have an open office area with –

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five or six different control zones in it and if I've got something set with cooling down to 68 degrees and the zone next to it's set with the heating up at 75 degrees, well, all that cool air is gonna be go over and need to be heated up into the adjacent zone. So it's important that we have a good temperature deadband and, you know, it's now required in code but it's also a good idea to have consistent settings in those large, open office areas.

VAV systems also may have excessive reheat if their settings are too tight and we'll talk about that more in a minute when we get to VAV or variable air volume systems. Energy Star recommends factory default setpoints of heating at 70 and cooling at 78. There used to be Energy Star thermostats but I believe those are not necessarily currently in practice, but there is a proposed process –

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they're trying to develop that again.

If you look at a DDC system, rather than in the thermostat settings, you may see that, again, on a screen for what the setpoints are for heating and cooling or in a trend line for heating and cooling setpoints throughout time.

Now, let's talk about outside air economizers. This can be a confusing issue and frankly, many contractors can be confused about how to properly set these up and it's good to make sure they're working properly. What's the idea of an economizer? Well, we've got a little circle of ventilation there going on here, so let's say we have 10 percent outside air coming in and that's mixing with our return air and it goes to the ventilated space and then we exhaust air out of there. Well, that 10 percent or 20 percent is probably great for the minimum ventilation requirements, but we can get some benefit out of increasing that amount during certain time periods.

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So again, commercial buildings have a lot of internal loads, so there may well be a cooling load when the air is 60 degrees outside. So what I can do is increase that to 100 percent outside air when it's 60 degrees out and cool my space off and that means I will be running my refrigeration cooling coil less by bringing in that outside air. So we'll hit that concept again a couple times.

Now, let's go back to our fan unit here. It's a nice, simple situation. We've got the return air coming back, we cool it down, we put it in the space. We've got our minimum amount of outside air coming in, say 10 to 20 percent, and you know, everything's good, it's pretty simple to understand. We set our room thermostat, as we were just talking about a minute ago, and everything runs fine. Well, let's add an economizer. Gee, life just got more complicated, didn't it? We added a lot more controls, we added a lot more equipment.

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We've got a bigger outside air damper. We've got a return air damper now. We've got a damper motor that operates those two automatically. That damper motor is connected to an economizer controller; it'll have at least an outside air temperature sensor. It may have a sensor as well, we'll talk about that in minute. It may have a return air sensor, it may not. There's also a relief damper of some kind, whether it's power damper or barometric relief because when I go to 100 percent outside air and I'm filling that space with outside air, that air needs a place to go. So there should be a relief damper installed that lets the air out of the building. There may also be an optional power relief fan that helps that air get out of there and maintain a pressure inside the building so the front doors are not standing open, if you see that, that's an indication that the space is not balanced as far as pressure and air flow.

But you can see, we've added some complexity to this entire system –

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and that means the contractor has to understand what he's putting in and, you know, if you really want to inspect it in detail – I do an eight-hour basic training and an eight-hour advanced training on these units, and that advanced training includes demand controlled ventilation. But you know, it takes a while to understand these systems and how to make them work.

Now, here is an example of some of the control components in the system. We showed the dampers in the earlier slide, didn't show 'em here but we've got dampers, we've got damper motors or a single motor that's connected to both dampers. We've got mixed air temperature or discharge air temperature sensors, may look like this or like this. Outside air return air sensors may look like this. Those can be dry bulb or include the humidity that gives the total enthalpy reading.

There are some code requirements. The outside air ductwork needs to be large enough.

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There needs to be a relief damper provided so that – somewhere, it may be located right in the unit or it may be located in the return air ductwork if that's up on the roof, so the air can get out of there. It may just be integrated, which means it operates with the compressor and it's coordinated with cooling, and we'll talk about some of the other control requirements on the next slide – well, on a slide in a minute.

First, let's talk about savings and understand that. So why do we put an economizer in? So when the outside air is cool and this dotted line is outside air, when it's cool enough, instead of running the cooling compressor, and this line represents the energy used by the chiller or the cooling compressor, and you can see it turns off and goes back to dull roar afterhours, we can use the outside air. And so when the outside air is open and things are working, –

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we can get rid of this region of energy use. So in other words, without the economizer, this line would have been up here to cool the building off because we would have only had 10 percent outside air. So when the air's cool enough, we can use it to cool the building instead of putting power into our chiller or our refrigerant energy cycle.

So really, the savings occurs in the settings, and this is an area where unfortunately contractors do not always understand the proper settings. So there needs to be a high limit on an economizer; in other words, the economizer only makes sense when the air outside is colder than it is inside, right. So we can do that about three or four different ways. So a fixed dry bulb – and these are in a code table, as far as what climate zone you can use these in –

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and what the settings should be based on climate zone.

So the fixed dry bulb would cut off at 75 in western climate zones, 70 or 65 in more eastern climate zones. So there is a setting and that setting should match, again, at the time of inspection, what is in the code table, and again, the table lists it by climate zone. That's a fixed dry bulb, the single dry bulb sensor.

A differential dry bulb cuts off when the outside air temperature is greater than the return air temperature. So here you have two sensors, one in the outside, one in the return air. That doesn't have a temperature setting because internally it's looking at the difference between those temperatures. Now one thing to understand is the differential dry bulb is no longer allowed in the southeastern climate zones and that's a change in 2015 IECC that came over from the ASHRAE 90.1.

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There also are fixed or differential enthalpy high limits. So those look at also the moisture in the outside air. Those are more appropriate in those southeastern climates, not necessarily helpful in western climates where the air is dryer and it adjusts for humidity with the idea that if the air is humid, even if it's cool, all that water is gonna come out in the cooling coil and increase energy use so it may actually not be helpful to bring in the outside air.

Now, the enthalpy controls now require a paired dry bulb high limit, and again, that was a change in 90.1 that got carried into 2015 IECC, and that relates to the fact that the humidity sensors are not always as accurate as we would like them to be or they fail sometimes and so that dry bulb high limit is kind of in there as a safety, you know, at 75 degrees, saying, hey, it got up to 80 degrees and the enthalpy didn't switch us over, –

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we really want to turn off the economizer. So those are the high limit settings and we'll see in a minute where you find those.

So economizer savings, again, why are we doing this? Theoretically, we could save, in an older building that, you know, the status is somewhat dated, it's when lighting power densities were higher and we might be cooling actually down to 40 degrees outside, but theoretically, we might save 60 percent, maybe say more like 50 percent. If our high limit settings are low, and that's the problem, instead of setting these up in the 70s or 65 degrees, contractor might set that at 55 degrees. Well, at 55 degrees it means we are not gonna use the economizer at all up in this area of the chart. This chart shows us the total kilowatt hours per ton of energy we use in a building related to the outside air temperature. This happened to be Eugene, Oregon, but it's a similar kind of profile.

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We've got a lot of hours at this midrange temperature where an economizer can benefit us, not so many hours when it's really hot outside. And you can see here, we absolutely need mechanical cooling in the dark blue. If we had that power exhaust and some other features, like low leakage return air dampers which are not necessarily required, although some of those requirements are coming into code, we might also save in this region, with just a simple economizer, we would save in this region but that's assuming it's properly set up. If it's set down at 55 degrees we would lose this entire area up here.

So a good code economizer should save both this pink and this green region and possibly some of this light blue region. So a premium economizer, which is the green region plus the pink region, is a code economizer if the settings are correct, if we've got relief air in there, if it's integrated, and most economizers are installed in an integrated fashion these days.

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And if there is a checkout, and we'll talk about fault protection and diagnostics in a minute. But again, that checkout's important that either a commissioning agent or someone inspect that the settings are done properly.

So the economizer, things to check in the energy code. Well, we mentioned the dampers and ductwork. Usually, if the unit's up on the roof, no problem, the outside air damper is big enough to get in a large amount of outside air, but if it's buried down in the building, like a split system, that outside air damper – ductwork, getting to the unit, if it's pretty small, you might not get 100 percent outside air or as much as you can. It may not always be 100 percent even though that's what the code calls for.

There is a relief damper, either it's powered or barometric, again, that's important. To be able to get enough outside air in the building we need to be able to get it out of there. And then that high limit or changeover setting we just talked about is in compliance with our –

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C403 and a lot of 3 section there. The proper setpoint, again, is a mystery to many field technicians, unfortunately, and there is just not enough training out there about this and the settings are typically too low, so that reduces savings if it's set down at 55 degrees.

Now, that relates to, in the older units, which these are still legal under 2012 IECC, you know, there's a little turn screw that could be set A, B, C, D. If it's set down at D, that is equivalent to that 55 degree setting, it really needs to be set up around B or C, somewhere in that range, to really achieve the savings. That setting on the newer direct digital control units, it shows up right on the screen, you can walk through the settings or have the contractor do that and point out, oh yeah, it's set at 75, that's what it's supposed to be. In fact, this right-hand unit, you put in the ZIP Code and it automatically sets it according to the code table, so that's a pretty nifty feature –

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that is automatically keeping the unit in compliance with the code.

Now, there's also some new fault protection and diagnostic requirements in 2015 IECC. These have been around for a while in California Title 24, and you know, it requires that the sensors have a certain accuracy, that faults be detected and enunciated either to an idiot light on the thermostat or sent to a web connection so that some maintenance person will see it, and that they be set up properly and have the controls during set up, when I can push this button and kinda walk through it and kinda see the economizer go through all its paces.

The controller above, this one that's been around for 40 years and it's nice it's inexpensive, and again, still may be used in many units, does not meet the new requirements. So if you're under the 2015 IECC and you see an economizer unit that looks like this –

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that is a no-pass, just so you're aware. It would be one of these – you know, the same manufacturer now makes a more modern unit that does meet the requirements as do other manufacturers, and sometimes all this economizer logic is included in a larger direct digital control system as well.

So we're back to our list of meaningful measures here. Just want to mention – and that's it on economizer controls. I know there's a lot of information in that topic and maybe that's a good item for further training.

Exterior ductwork insulation. Now, this item is important because if it's totally missing, if, you know, you've got a nice ductwork running out on the roof or running in the attic and someone left the insulation out completely that is exposed to either hot condition in the summer or cold conditions in the winter, and in IECC 2015 those requirements went up. For exterior ductwork we need R8 in climate zones 1 to 4.

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R12 in climate zones 5 to 8. So again, that's exposed on the roof or in the attic needs more insulation. If it's just in an unconditioned space inside the building it can get by with a little bit less. So that – just wanted to mention that in passing. But again, most buildings are gonna have the proper insulation, but if they – and not a lot of buildings have ductwork out exposed on the roof. A lot of multifamily do have that ductwork in the attic, however, and if it's outside the building envelope it does have to meet these new requirements.

Fan power needs to be within limits and let's talk about fan power. So fan energy limits. What goes on in a fan? Well, a fan – the purpose of a fan is to move airflow. So we have an air horsepower, actually, we're trying to achieve with this fan related to how many CFM we want to move, what the static pressure is and the ductwork. Static pressure, the higher that is, –

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the more work it takes to move that air through all that ductwork. So the smaller the ductwork is, the more work it's gonna take to move the same amount of air. Well, the fan itself might be 70 percent efficient, it might only be 50 percent efficient, so there's some losses here at the fan.

We go over to the fan belt; most larger fans will have a fan belt to adjust their speed properly, that might have a 6 percent loss. Some fans that might even be up to 20 percent, but there's a belt loss involved. And then we get to the motor and the motor has a certain efficiency, so we have maybe 20 percent, maybe less if we have a high efficiency motor. And there's even losses in this wire going back to the electric meter. So we add all that up and overall this fan efficiency in total might be only 52 percent.

So the energy code manages the overall large fan efficiency by limiting the nameplate motor horsepower or the fan brake horsepower –

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per CFM of airflow supplied. So we just do a simple ratio that way you don't need to get into the detail of all these different stages of efficiency, and let's see how that works. So there is a good old fan power limitation table. Again, this is the reference for 2015 IECC. It either meets the nameplate horsepower or the fan brake horsepower, and we've got a different requirement for constant volume and variable volume.

Now, we have all these fine formulas here and I'll talk about concept in a minute, as far as you can just put in your fan information properly there and it will do all the math for you and figure out whether you meet the code. Now, if you choose to look at the fan system brake horsepower, and again, this applies where the total fan nameplate horsepower is 5 or is greater than 5, I'm sorry. So that meant if I have a 4 horsepower fan motor and a 2 horsepower return fan, –

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so I've got both a supply and return fan in the system, I'm now at 7 horsepower, that's greater than 5 so I fall under these requirements. And then if there is an exhaust fan serving the same areas of the fan that exhaust fan power also needs to be included. So if you add up all the fans serving a particular system, if you're greater than 5 horsepower, you fall under these limitation requirements.

So the simple way to do this is the nameplate horsepower and you get a certain allowance that kind of includes everything, including the motor efficiency, and there you go. Now, for more a complex system an engineer might want to go with the brake horsepower approach and usually should show you these calculations, either as a submittal or on the drawings and that break horsepower needs to be less than that supply CFM. Again, this is based on supply CFM times a factor. The factor is different for constant volume and variable volume fans. And then there is this little A adder, what's that?

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Well, the A adder takes into account the fact that some systems need a little bit more horsepower than other systems, so there is a separate table with the adjustment, and this is basically going down all of these different conditions and they relate to the CFM going through a particular device, whether it's a heat exchanger, exhaust filters, filters, and they get a certain addition of static pressure that goes in there with this little formula and you add them all up. Again, this is all taken care of for you in COMcheck software.

So those are the different steps in understanding fan limit. You need to understand is this fan variable volume or constant volume. It's constant volume if there is no variable speed drive or no two-speed operation; variable volume if it does have a variation in volume that's included.

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And I do want to mention COMcheck. There is a completely separate training that's available on the website for COMcheck. I think Pam will mention later exactly where to find that. But we can determine the fan power limitation compliance for each fan system, either based on, again, the nameplate or the brake horsepower. You can choose which method you're gonna do and all those pressure drop credits can be put into this system. Now, one thing to understand is we need all supply, return and exhaust fans in each system. One question that often comes up on the code help desk is gee, I've got an exhaust fan for the restrooms and there's three supply systems next to it. Well, you have a choice there, you can either assign that exhaust fan to one of the supply systems in particular or you can allocate partial exhaust to each system and allocate that exhaust horsepower to all the systems involved.

And one thing to be aware of in –

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COMcheck is, you don't – if you've got 25 supply fans that are identical, say 25 rooftop units on your building and they're all the same, you don't need to enter the 25 times, you can just say I've got 25 of these, I can enter at once and you can assign it to the different HVAC systems in the building. So that can save some time in using COMcheck to meet the code compliance.

All right, let's talk about variable speed. We mentioned that a little bit, variable speed drives. Now, reducing fan or pump speed saves energy at partial flow. So if I have a fan and I want to reduce the flow or a pump and I want to reduce the GPM, so the fan flow might be in cubic feet per minute, pump flow would be in gallons per minute, if I want to just reduce it by either using a damper or a valve, I would do what's called riding the fan curve, and I would –

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come down this line called normal. So what that means is, is that 40 percent flow, I would still be at 80 percent energy use, okay.

If I put a variable speed drive on that fan with some sort of sensing device, a pressure sensor or a more sophisticated control system that looks at all my valves or dampers and I reduce the speed of the fan relative to the flow that I need, I can see now, at 80 percent flow, I'm using only 50 percent energy. So there is a significant savings in reduction for variable speed drives. So fans in hydronic and multiple zone systems must be variable flow, okay, pretty much. So if it's a direct expansion system above 65,000 BTUs per hour, I need at least a two-speed fan on a DX unit.

If it's chilled water system, a chilled water coil, –

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anything above a quarter horsepower I need either a variable speed drive or a variable speed motor. So under 1 horsepower I might have an electronically commutated motor, an ECM that has speed control built into it. Above that, I am gonna need a variable speed drive. This is what a variable speed drive looks like. So most chilled water system fans, if the cooling is by chilled water, must have variable speed drives, so –. And we talked about the potential savings here. If we can vary the speed, we get a huge savings in energy, and most units don't run or don't need to run at full speed except for those very hot designed days on the cooling days or we do need maybe a little boost in air speed at the peak heating condition.

So variable speed drive should be evident or a multispeed motor, either at the site, you're gonna see something like this connected to the fan, –

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or on the specifications or in the drawings there should be information saying a particular fan is variable speed. So I think that's it on fans for today. Again, we're covering a lot of material and we're covering it pretty quick, so hang in there.

Now let's go into more complex systems, and these systems will have secondary systems and a central plant which, let's tackle the central plant first. So we've got our system out there, the secondary system we'll talk about it in a minute, and it needs cold water to cool and hot water to heat. Well, where is that coming from, and it's coming from the central plant, okay. And let's talk a little bit about categories of HVAC systems when things start to get complicated and everything is not in one box.

So we no longer have a unitary system, we have primary, secondary systems, that sort of thing. So the central plant itself has boilers, chillers and cooling towers. The boilers and chillers generate –

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hot water and cold water to go out to the units. So we've got a few pieces of large equipment we're looking at. There's some distribution systems, pumps, pipe and control valves, ductwork diffusers and registers. So we distribute the air, we distribute the water throughout the system. And then we have secondary and zonal HVAC systems, that would include air handlers with coils and economizers, we might have fan coils that are more zonal systems in larger secondary systems. We might have VAV boxes that work in conjunction with the secondary system at the zone level.

So these are selected based on what are the space temperature and humidity requirements in the building. Again, a load calculation is done for the chiller. Now, chillers, in a large building, may have some redundancy issues if those properly stated in the load calculation. You might have a third, again, as much chiller capacity as is needed.

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It's all based on first cost, operating cost and maintenance cost, how much space do we have. You might have a room in the basement with a chiller or a room on the ground floor, or you might have a chiller up on the roof in a penthouse. And there may, again, be redundancy issues in the design of a system, especially a hospital or a – say a high reliability data center.

So we have heating and cooling primarily that we're trying to satisfy, keep the space temperature in the building reasonable and comfortable for the occupants. On the heating side, our typical fuels are electricity and natural gas. Efficiency matters, so for instance, electricity is theoretically 100 percent efficient as it's measured and delivered to the site, so if I take a 1000 watt hair dryer, it gives me 1000 watts of heat into the room, right. But what's the source efficiency? A coal-fired plant might be down around 35 percent efficient, gas, you know, combined cycle might be more up in the 60 percent range.

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So there is an impact on source fuel efficiency related to using electricity directly. So that's why we like the heat pump, it's much more efficient than resistance heat. And here we have a measurement of COP or HSPF combines both measurements at multiple temperatures, right. And these are all measurements of efficiency. So efficiency might be 330 percent, say at 47 degrees or a COP of 3.3. At a colder temperature, the efficiency of the heat pump goes down, again, if you move the decimal point it's either percent or COP. HSPF is a number that combines both of those and then we throw in the multiplier for electricity there. So it has both seasonal components and a conversion factor. But again, the higher that number, the better, right.

Natural gas typically 80 percent efficient, might be 82.

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Just your straight up furnace of boiler that's gonna be down in this range. That means, for instance, that I might be putting in 100,000 or a therm of gas and I get out 80,000 BTUs per hour of heating into the building into the system. Now, condensing boiler furnaces have much higher efficiency, exceeding 90 percent, maybe even up to 97 percent, and those are getting more popular and you may well see those. Again, they're gonna certainly meet code as a high efficiency item.

Cooling, we have a central chiller. Now, that chiller can be water cooled or air cooled. We'll see a couple of those in a minute. Water cooled requires an additional item called a cooling tower for heat rejection, whereas in an air-cooled chiller we've got fans built in just like on our packaged unit.

So let's look at boilers in the central plant. Again, hot water or steam boilers are typical. Hot water for smaller buildings, although even larger buildings –

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use hot water. It's usually natural gas or sometimes electric. Steam might be more common on a college campus or a very large building like a hospital. Boiler looks like this. It's got, you know, the gas coming into it. You can see that gas pipe painted yellow down at the bottom. There is water coming in and out of it, so we've got hot heating water return, heating water supply that are connected to the boiler. There is flue gas. The air is injected into the boiler and leaves the boiler and heat going up the boiler is why it's not 100 percent efficiency going up the stack.

If we kinda break it down and look at it, we can see we've got burners in there, we've got some sort of heat exchange to heat up the water. Water coming in, water going out. And you know, it's a pretty straightforward device. There are some code requirements I'm not really gonna talk about today, about the burner and how far can it turn down –

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or if I've got multiple boilers what am I able to turn down to related to the capacity.

Central plant chillers, okay. Chillers are using electricity to remove heat from the chilled water loop. This is just like our packaged rooftop unit. We have the same refrigeration cycle going on. We've got a compressor. It could be a compressor of many different types. What we see here is a centrifugal compressor, sort of like a pump, it's moving the refrigerant in a centrifugal fashion. The compressor might be a scroll compressor or a bunch of scroll compressors. It might be a reciprocating compressor, a screw compressor. So there are a lot of different types it could be here and those types are laid out in the tables in the code and there are different efficiency requirements based on the size and type of the chiller.

Again, we've got an evaporator here that gets cold. We have the same refrigeration cycle. We have a condenser here that gets hot.

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The evaporator is connected to the chilled water system and there's pipes going out there and pumps to deliver the chilled water in the building. And the condenser is connected to the cooling tower to get rid of that heat outside the building. And here is sort of the cutaway of the same thing, showing you all the heat exchange tubes that occur inside the chiller.

So here is the cooling tower. Again, if it's a water-cooled chiller, which is more efficient than an air-cooled chiller, typically, we use evaporative cooling. Evaporative cooling means I actually am evaporating water in this device, the water that came from the chiller, the hot water goes in here, some of it evaporates, some of it just gets cooled blowing through an air stream. There's a fan running. And then that water returns back to the chiller, usually about a 10 degree temperature difference. And this fan may be controlled, depending upon the size.

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There may be requirements on a variable speed drive fan control there as well. And the fan motor, you can see, is out here.

Things to check in the code. So again, we've got specific equipment efficiency tables for boilers, for chillers. Again, they're based on the type, are they hot water, are they steam, are they gas-fired, are they oil-fired, what efficiencies do they have. This shows the radiant test procedure, again based on size. We might have different efficiency ratings; thermal efficiency is a little different than the AFUE, smaller units have an AFUE rating. On the chillers, same kind of deal, we have different types of chillers, air-cooled chillers, air-cooled chillers separate from the condenser, water-cooled chillers. The air-cooled chillers are rated in the EER just like our package rooftop unit, and here is a picture of one. It's a lot like the packaged rooftop unit. We've got the condensers, –

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we've got the compressors down in here, we've got a control panel where all the controls are here to control the fans properly. There are control requirements on the fans. I'm not gonna go into detail on that today.

And then we actually may have the pumps for the chilled water system built into the air-cooled chiller or they may be separate and we'll talk about hydronic requirements in a minute. So there is what your air-cooled chiller looks like. It's rated in EER, again, the higher that number, the better. What's more interesting about the chillers, and here we have two different dates, so you can kind of ignore two of these columns here because New Year's Eve on 2015 is already passed and so we're into these pair of columns. Someone can pick, am I meeting by path A or path B. So path A has a higher efficiency requirement at peak load and a lower efficiency requirement at part load, whereas path B has a lower efficiency at peak load but a higher efficiency –

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at part load, and that accounts for the fact that depending upon how the chiller is designed, we can either prioritize it for part load or full load. And there's a benefit to having a part load efficiency that's higher and not such a great efficiency at the peak load.

Remember that diagram we had in the economizer, there aren't that many hours of cooling of peak load, most of our hours of cooling occur at part load. So we care about that efficiency, so full load is marked FL, IPLV is integrated part load, but I can't remember what the V stands for, but it's part load efficiency, basically. And when we have, again, multiple requirements, both requirements have to be met; we have to be higher on the full load and higher on the IPLV requirement and both of those have to be met and you can see we're dealing with different sizes here, so depending upon your size, you've got a pair of requirements to meet.

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Now, we've got the same thing on larger chillers, the water-cooled chillers. Now, these are rated in Kw per ton. So here is a case where the numbers go backwards. EER, the higher the number, more efficient; KW per ton is reverse, the lower the number the more efficient, so just be aware of that when you're checking out the larger chillers. And again, they have, depending upon the size, they have a pair of requirements to meet and depending upon which path the engineer chose to go through, either path A or path B, they need to meet those requirements either one or the other pair of requirements.

So now that we've got our hot water from the boiler and our chilled water from the chiller, we want to go ahead and get those into our system and talk about the secondary systems and how those use energy and how we need to look at those in the building. So you can see in this picture, we've got our chiller and cooling tower up here. We've got our boiler up here. We've got some pumps in there –

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distributing the water out to the coils in our secondary system which blows air through the building and the air returns back and there's some zone controls we'll talk about in a minute and that makes our complete HVAC system in a larger, more complex building.

So these large systems are similar to residential and small commercial HVAC systems but they're bigger and there are more moving parts to them, if you will. They work to maintain the comfort in the space just as the small systems do, they may be more expensive but they're usually more efficient than smaller, simpler systems. That depends, sometimes all those extra pumps and different controls with the reheat systems may not be as efficient as just having a bunch of individual single zone systems. It depends on how efficient a single zone system you get.

Usually, heating and cooling energy comes from the central plant and we use chilled water and heating water piping and we pump it –

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throughout the building to get to the coils. And then some package VAV systems might be unitary, kind of an intermediate, where we would have a compressor built into this unit, this one does not and these coils would be DX coils or have a furnace actually built in. This is a built-up secondary system. We might actually put this up on the roof, bring the air in through the unit, return the air, take it through a fan, have our economizer section, bring it through our coils and bring it back out through filters into the building. So, you know, we've got the fan and coils just like smaller simpler systems. Usually these coils are hydronic, using chilled water and hot water.

We've got, in this case, a heat recovery unit that works in addition to the economizer with the outside air and exhaust air, –

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And we covered some air, we're not gonna cover heat recovery units in detail today but those are required based on total CFM and a percentage of outside air, based on tables in the code, and if they're required, they need to meet certain efficiency requirements as well.

Another air handler example. This one, rather than up on the roof, is in a penthouse or located in the basement or up in the attic of the building, indoors. You can see, we've got those chilled water and heating water pipes coming in. There's some coils hidden inside there. We've got a door, we can walk in here to inspect the filtration systems, look at the fan. We've got actually multiple doors. We have got a control cabinet, probably a variable speed drive in here for the fan.

And this unit, again, we've got the return air coming back. Usually there is a return fan on these larger units. We go through a mixing section for that economizer where we can mix the outside air and the return air –

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to get the temperature air we want based on the conditions and the conditions outside. We go through a heating coil and a cooling coil, out through our supply fan and then out either to a large single zone or out to multiple zone secondary zonal units. So this is the primary – well, it's the secondary unit that provides primary air out to individual zone units.

And then we've got distribution. So we've got all those coils we were talking about in the units, right. And so we have hydronic distribution, water is steamed, heated by the boilers on the heating side, delivered out here to the coils. We have various types of heat exchangers, heating coils from the air stream look like this. We might also have radiant heat in the building, baseboard heaters or convectors they're sometimes called or we may have radiant floor heating where there's hot water piping in the floor that heats up the floor. Even radiant cooling is used in some buildings these days.

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We'll talk about the controls for the hydronic side of things in a bit. Chilled water distribution is similar. We've got the chilled water coming from the chiller, it goes out to the cooling coils, it goes through those coils, gets heated up by the air, cools the air down. The warm air goes back to the chiller, gets cooled down again and the cycle keeps going on. We can see that the hot or cold water flows through the tubes, air flows across those tubes, it looks like this, little plates on the tubes, and we the heat transfer. Now, the ductwork is also used to distributed heated or cooled air and return or exhaust air throughout the building, so there is another distribution system. So we have water distribution systems and air distribution systems in the building.

So let's talk about variable air volume, which is one of the more popular types of systems in larger –

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buildings, especially office buildings. So again, we've got our secondary unit up on the roof, we've talked about that. It's got the mixing section, it might heat the air if it's really cold outside. It would cool it down when it needs to. So let's say I've got 60 degree air coming out of this unit and I've got the same primary air going to all of my zones, and then for each zone, a zone typically being a room, although I could have multiple zones in one large open office area, each zone box or zone unit is gonna respond to the thermostat in that zone to provide the temperature it needs.

So one zone might be that – need that 60 degree air to provide full cooling. That could be 55 degrees in the heat of summer in a perimeter zone might be needed for full cooling. Another zone might close down the damper –

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actually that's not shown in this example, or might close down the minimum and then use a little bit of reheat, say it's gonna provide 70 degree air to this zone to keep it happy. Another zone might have the reheat really cranked up, say 110 degree air if this was – had a bunch of glass area and it's say 10 degrees outside so there's a lot of heating load required in this zone.

So we can see that with one large central air handling unit, we can provide this primary air to multiple zones and we have these boxes in each zone and they – the box has the function of modulating air flow based on cooling load, then maintaining the minimum air, so there's also ventilation there. Even when it's really hot or cold outside and we are no longer using the economizer, we might be bringing ventilation – we will always be bringing some ventilation air in here. So these boxes need to be stayed open to minimum is that is the only source of ventilation to the space.

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And then, again, if we need heating in that air, if that 60 degree air is too cold at the minimum ventilation, we're gonna need to add some heat to each zone.

So the boxes look like this. Here is one of the individual zone boxes. We have the air inlet, it's coming from the air handler. Again, that air handler provides the primary air temperature that all the zones will see at their box. Then we have a damper actuator that adjusts the air flow for this particular zone. So if it needs full cooling, it gives it 100 percent of its supply air designated for that zone. If it only needs half cooling, it can cut that air flow back to 50 percent and give it less air volume but at the same temperature and cool down the space. So that's more efficient than reheating the air in the old constant volume reheat systems.

Then we have a heating coil, so if we take this all the way down to minimum, let's say our minimum is 30 percent for ventilation –

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then we might need to reheat this air if this is a perimeter zone and we have a big heating load on it and there is a heating coil up there heating – I'm sorry, control valve that controls the flow of heat into the heating coil so we can adjust that air as needed.

And then the air comes out of here at the right temperature to serve the zones and there might be multiple diffusers in that zone or even multiple rooms sometimes. You might have three private offices on one zone control, that always ends up with a nice interesting thermostat war, but anyway. We've got the air coming out and getting distributed then in the ductwork distribution system out to the zones.

So let's tie it all together, right. Again, we've got our cold water, hot water coming from the central plant. If we've got a water-cooled chiller, we've got this cooling tower. If we have an air-cooled chiller, the chiller is up on the roof and it doesn't need a cooling tower.

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But we distribute – we have pumps distributing that hot and cold water throughout the building. This only shows one air handler. Usually a building probably has two or three air handlers, it might have one on the east side, one on the west side, one on the north and one on the south, something like that, or it might have one on the top floors and one down in the basement. Or maybe you've got a mechanical room like this every five floors, so that these duct runs don't need to be too long, that's one way to improve the fan performance we were talking about earlier, by not having these ductworks go 20 floors in the building.

Then we've got that VAV terminal unit we were just looking at, where we can either reduce the air flow or add heat so that the right volume and temperature of air is coming out into the space. And then it gets returned back to the unit. We do our economizer, if appropriate, or minimum outside air if it's not appropriate, and the cycle just keeps on going. So again, the central plant –

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has the boiler, cooling tower chiller, distribution is by pumps, pipes, control valves. Also we've got distribution of the air, and the secondary system has an air handler, and then we've got some VAV terminal units out here at the zone level.

So let's talk about controls for these systems. There are a lot of control requirements. This may be one of the more confusing parts of the code, hopefully we'll shed a little light on this, although, again, we're working at a pretty high level here as we go through. So let us get into controls. Well, first of all, controls can be complicated, so that's a warning, and actually, this picture is of an actual control system where, you know – an earlier style one before we had everything put together with electronic networks, where all these little wires had to patch into the right place to control things. So sometimes that level of control complexity –

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is inside the DDC system in the way things are latched together in there.

So let's again hit our high impact measures that are listed in the code. We'll come back to the 5 degree deadband again and talk about how that applies in VAV systems. We'll talk about limitations of simultaneous heating and cooling, VAV ventilation optimization and supply air temperature and fan static reset controls, okay. Those are all requirements in the code relating to this VAV reheat system, which again, is one of the more popular systems in modern building construction.

So the deadband requirement. Hey, guys, the deadband requirement applies to VAV boxes too, okay, and I think many people ignore that. Just because the lease specification says temperature shall be maintained at 2 degrees Fahrenheit does not allow a 1 degree deadband, sorry.

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A 5 degree temperature deadband is still required, okay. So that means that the VAV box controls must have separate heating and cooling setpoints. So here we're looking at a diagram that shows maximum heating out of that box, maximum cooling over here out of that box. So you might think of this is when the room is warm, this is when the room is cold and we need lots of heat, warm, we need lots of cooling. I need a deadband here, so I need my cooling setpoint say around 75 degrees and I need my heating setpoint say around 70 degrees. And those can vary, we don't care if you want to shift those seasonally, that's fine, but we want a deadband at any particular time, and during that deadband, I don't want anything more than what's called the minimum boxed amount of air going into the space and I do not what the heating coil on. So that's what we're looking for.

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And frankly, again, there are still say state lease requirements or call for plus or minus 2 degrees, which you cannot meet with a 5 degree deadband, but I believe the energy code takes precedence over those requirements.

So the deadband occurs between heating and cooling operation, as we said. The minimum damper positions are maintained. We still need that minimum amount of ventilation there, so this vertical scale shows either percent of air, maximum supply air down to minimum supply air, that's this line, and our dotted line shows us what's going on with our supply air temperature related to our heating coil in the box.

so we want the reheat valve closed during the deadband, okay. Now, you can find this out in the specifications, what the temperature settings are, and in the control sequences. This could be mentioned in the commissioning report, potentially.

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We'll see later a little diagram you can call up possibly on the DDC system that shows you what those setpoints are over time, and I'll discuss that when we get to that diagram. But it can be inspected.

Minimum ventilation reduces the reheat of cooled air, so that's important. So when we get in this heating mode, we pretty much want, and most of the time that minimum ventilation will be adequate to meet the heating requirements, especially as insulation requirements are getting more strong. And so we sit at minimum ventilation and we bring up the supply air temperature to the maximum, and then once we reach the maximum if we have a really cold situation or a really high heating mode, we might actually have to increase the ventilation air from the minimum to say 50 percent, and that increase to –

[1:20:00]

50 percent is allowed. This is a dual maximum setpoint. I believe that's a new requirement in 2015 or new allowance. In 2012, actually you needed to stay at this minimum position, but there's some benefits to that 'cause we don't want to increase our heating temperature so high that we end up with all the hot air up at the ceiling and not circulating down into the space.

Now, that minimum ventilation setpoint can vary. The code calls for it to either be 30 percent of the design airflow or a higher percentage of it saves energy, I'll talk about that in a second, or the required ventilation amount needed in that space. And if you do the multi-space equation in the International Mechanical Code or Standard 62, it'll tell you for critical spaces on a ventilation point of view what that minimum needs to be. Sometimes it is higher than 30 percent. In this higher percent if it saves energy, again, I believe that was added in 2015 to the IECC. It's been in ASHRAE –

[1:21:00]

for several code cycles.

In the case of a school that has a very high population in a classroom, if we're stuck down at this 30 percent level we might not be able to meet the ventilation requirement even if the supply fan is 100 percent outside air. So it might be better off to put this minimum ventilation in the school up at 60 percent and that way we can throttle back the ventilation rate at the central fan. So it's a tradeoff, if a higher percentage say is energy, and there should be some substantiation for that from the mechanical engineer, to go above the 30 percent.

Now, there's also a new requirement, again, it's been in ASHRAE and got moved over into 2015 IECC this last cycle, for VAV system ventilation optimization. Now, frankly, this is a pretty sophisticated control algorithm.

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Modern DDC systems can handle it. Basically, what we're doing is the ventilation design is based on VAV boxes all at their minimum setting, right, so my critical zone is – you know, I'm setting my outside air back at the central unit, at the secondary main unit there, supplying the air to all the zones based on this minimum setting. Well, if the VAV box isn't cooling, and it's often the case, like if I fill a conference room full of people, that might be my critical zone and the VAV box opens say up to 100 percent 'cause there's all those bodies in there we gotta cool off, well, I am now giving more ventilation air as a percentage in the system, which means I might well be able to throttle back my ventilation air at the central fan.

So again, it's related to the multi-space equation and actually dynamically looks at that calculation –

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in real-time in the DDC system and makes adjustments. This can usually be verified only through commissioning or if this ventilation optimization is stated in the sequence of operations, it's a little bit difficult just to simply inspect out on the job. But you can look for it in the sequence of operations or you can look at the commissioning report to see if it has been implemented. And that, again, is a new requirement in 2015.

A couple of requirements that have been around for a while are VAV primary supplier temperature and static pressure reset. These things both save energy. So the supply air temperature reset, again, at design, I might need 55 degrees cooling air going to all the zones that need to meet peak cooling load, that means their lights are all on, the room is full of people, the sun is shining in through the windows, it's a warm day outside, I'm getting heat transfer through the walls –

[1:24:00]

even though they're insulated, and so I need the 55 degrees air. But if there are other zones that don't need the full amount, they might be in heating. And so if I'm running that 55 degree air in the winter when I'm not at peak cooling load, it means that I am gonna have to reheat that 55 degree air maybe up high to meet the heating load in the space.

So there's a tradeoff here with fan energy control and there's actually a thermal comfort – well, a comfort improvement because we reduce the terminal gain. In other words, if I don't need that 55 degree air, or 60 degree air will do for my zone with the biggest cooling load or even 65 degree air, I can do better with that. I can, you know, actually improve the way the controls work. So, you know, this looks a little complicated, it's actually out of the control block diagram that I was involved with, –

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but you can see the idea here is when I have a large cooling load, I do want my discharge air temperature to be 55 degrees, and then through a range, when I go to a moderate cooling load, I might let that float up to a higher setpoint and that setpoint might be 55 degrees, it might be 65 degrees. It needs to be 25 percent of the difference between your design supply air and temperature but it can often be more than that.

And then I might also reset my static pressure reset. Now, what does that do? That saves us fan energy. So if I've got a high degree of static pressure, say three inches of static pressure in my ductwork, and I've got every damper in the building on those terminal units –

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closed halfway 'cause I don't need that much air, even though I have got a variable speed drive, I'm pushing more static pressure into the system than I need, so if I look at all those dampers and I keep lowering that static pressure until one of the dampers is all the way open, then I'm gonna have a reduced fan energy use. Again, these things usually require commissioning to verify and when we get to the hydronic system, we might see how we would see what's required there.

So let's talk about the hydronic system. What's its purpose? Well, we've got this great central plant down here making hot and cold water, we've got our secondary system that has coils in it that need hot and cold water, so we got to get it from point A to point B and that's what the hydronic system does for us. So it connects the central plant and the sources of chilled and heated water to the cooling and heating coils in the secondary and zonal HVAC system.

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So it also would run hot water out to all those reheat boxes as well. The system includes pumps, piping, control valves, and the heat exchangers are part of the system or connected to the system although they're really in that secondary HVAC system or the zonal control systems.

So most hydronic systems are required to have variable flow. In other words, we want to vary the flow so the pump isn't doing the same work it needs to do at design. In fact, there's two main flow requirements. We need variable flow when the total pumping is greater than or equal to 10 horsepower. So if all the heating water pumps in the system total more than 10 horsepower, then yes, I need to do it. And if my capacity either on the cooling or heating side is greater than 500 pounds or BTUs per hour, and those requirements are separate for heating and cooling. So I might require a variable flow on the cooling but not on the heating, –

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depending upon the load and the pumping horsepower.

What that means is, mostly we're gonna see two-way valves in that system. So what's the difference, we've got three-way valves and we've got two-way valves, good and bad, right. Now, you might see some three-way valves and we'll talk about that, but in the three-way valve system, in the left part of this diagram is a constant flow system. What that means is out in the system I have a pump, it might even be the primary pump. I might only have one pump in my system. And that is a constant flow based on what I need at maximum design, whether it's maximum heating or cooling.

And the water shows up at this three-way valve and then it adjusts the amount going through that cooling or heating coil based on the load, based on the control system, but all the rest of the water is just gonna bypass around the coil and come back. So my total flow is constant and I do not save any pumping energy at part load, and remember, we're at part load most of the time.

[1:29:00]

In a two-way valve system what we do is we pump out here based on what flow do all the coils require. So we throttle back the valves based on what flow is required and we bring that water back. And in fact, we can even look out, whether we have a pressure sensor out here or a – you know, we're looking at all these valve positions, and we can slow that pump down until one of those valves is almost fully open or the pressure comes down to what we know will work for all these valves. And you know, that's part of the VSD requirement on the pump, but even without that, even if the VS, variable speed drive was not required on the pump, if we use these valves –

[1:30:00]

To throttle that pump will ride the pump curve and we will get some significant savings.

Now, we do have one three-way valve in this system, you might see that. That is to provide the temperature, and we'll talk about temperature reset in a minute, going out to the system, 'cause maybe our boiler needs to operate at a high temperature but we don't need high temperature out in the system itself. So that's what's going on. We can kinda look at a graph through time with these units. So there is a requirement to –.

Oh, let's see, one thing I did want to mention here as well, now, we might have say one three-way valve at the end of this system, so we might have 75 percent two-way valve and then one three-way valve out here at the end of each long pipe run so that the water gets out there, and so that when we get to a really low, low condition, we still have a minimum flow that our pump needs to have to not go into a high head condition.

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So even though it's a variable flow system, we may have a small proportion of three-way valves, but it certainly shouldn't be more than half three-way valves based on our code requirements. So you should see mostly two-way valves in the system, either on the plans or out there in the field.

Okay, let's talk about the hydronic temperature requirements for chillers and boilers. So we're required to automatically reset the supply temperature and that's, you know, in the code section 403.4.2.4. We need to reset by at least 25 percent of the difference between design, supply and return, and that reset could be based on a number of things, outside air, return temperature zone demand. There are a number of ways to do it as long as it gets reset.

The chilled water reset allows our chiller to operate more efficiently, and in fact, operating that chiller at a higher chill water supply temperature, remember that refrigeration discussion we had, that compressor has to move the pressure from the pressure –

[1:32:00]

of whatever temperature our chiller is supplying, up to the condenser temperature we can get out to our cooling tower. If we can raise that chilled water supply temperature it means the compressor is doing less work. It reduces the lift done by the compressor, less work, and we save significant energy on the chiller. So just keep that in mind. That's why we're doing this.

Heating water reset provides a couple of benefits. On a condensing boiler, at a high return water temperature a condensing boiler does not do as much good as far as condensing. So we want to reduce the distribution temperature. So we only need the hottest heating water temperature at peak design when it's really cold outside. So we can also reduce distribution losses, all that heating water going throughout the building, even though the pipe is insulated, it's losing heat wherever the pipe goes.

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And we can verify this in the construction controls and sequences, the commissioning reports to tell you whether you've got temperature reset, again section C408 talks about the commissioning report. Or we can see the trend plot on a DDC system. So here would be a trend plot, typical, you know, from 4:00 in the morning 'til 9:00 in the evening, and we're going along here. Say at 6:00 in the morning our chiller starts up. We're looking at chiller reset here. And when we start up, we don't need 44 degrees chilled water because it's – you know, we're still using the economizer, it's still cold outside. The orange line is our outside air temperature, so I've still got the economizer going pretty good, although I may need to use a little bit of chilled water. So I start my chilled water flow but I can use a higher temperature, frankly, I might even be able to go up to 55, but 50 is a pretty aggressive reset.

And so I can see if I was to plot this on a trend plot of a DDC system, that the chilled water temperature starts up high –

[1:34:00]

and as the outside – sorry about that, as the outside air gets warmer that temperature comes down, and it might come down to our design temperature during the middle of the day when we've got a significant cooling load or it might never get there. Now, that would be resetting on outside air, right, where I'm just looking at this outside air temperature and resetting the chiller supply temperature based on that.

During the course of the day we can also verify is our pump operating at a variable flow? We could look at the variable speed drive setting as a percentage of pump flow, and we can see that, yeah, it kinda ramps up and then as the chilled water temperature comes down it kinda ramps down a bit and then it goes back up as our zone boxes require more – I'm sorry, our secondary systems require more and more chilled water to meet the load and then it comes back down. And then at some point the chiller shuts off because we don't need cooling anymore.

And in the background here we see a couple of lines.

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This gets back to this idea of a deadband. So here is our cooling setpoint, here is our heating setpoint. You can see they're constant throughout the day with our good 5 degree deadband. We can see at the end of the day we have our setback so the heating sets back to a lower temperature, maybe around 58 degrees, 60 degrees, something like that. The chilled cooling setpoint goes up maybe to 80, 85 degrees, and because of that we should have very little operation of our systems during the night, but if for some reason we got too warm or we got too cold, the systems can turn on automatically and just keep things from getting too out of hand for the morning.

Then depending upon how hot or cold it is outside, we would start to bring the setpoints down and that's called optimum start. We would bring them down so that at some point the actual space temperature would kick in and we would turn our systems on and start meeting our load.

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So this is an example of how you can use a DDC trend chart. Again, the commissioning agent may be doing this and reporting in their report what they see on the trend chart that verifies that things are actually set to meet those control requirements in the code.

One other example of hydronic systems is water source heat pumps and there are a couple of different types of those. We've got geothermal heat pumps that have a bunch of boreholes out there that exchange heat with the earth, or we might have, not shown here, a boiler and a little fluid cooler or a cooling tower that would either put heat into the heat pump fluid system or reject it outside. We've got a loop pump here and that loop pump gets that kind of neutral temperature water out to all the heat pumps and they convert that energy, and if they're heating, they're gonna cool down the loop water. If they're cooling, they're gonna warm up the loop water. So they kinda help recover heat from one to the other –

[1:37:00]

and that water keeps going around the loop.

And this loop pump energy is what we're concerned about. It turns out that in a loop heat pump system, if we have full flow going through every heat pump, and there could be several hundreds of these heat pumps in the building, all the time when it's not necessary, that pump energy could be way more than the total of all the heat pumps and we've actually seen this in some situations, back 20 years ago before we had these code requirements.

So there is a requirement, if the total loop pumps, and you might have more than one pump, is more than 10 horsepower, you need a control valve for each one of these heat pumps. The idea is these units are switching on and off, right, based on the thermostat in the zone, and so when the cooling is on or the heating is on, they do need water flowing through them and when the heating or cooling is off and they're just circulating air for ventilation, that valve should close. It reduces the flow in the whole system.

[1:38:00]

It reduces the load on this pump. And then at a certain size, where the code calls for it, we will get a variable speed drive on that pump to get even more savings.

So again, the pumping power can be very large. We should see a little control valve on each unit. Another application might have a little, tiny pump on each unit, that's fine too, with a check valve. That achieves the same result, but usually it's a central pump like this or there may be a separate pump through the well and those might be controlled differently.

Also not so important for a geothermal but for the standard unit with a boiler and tower, we need to control this system so we have at least a 20 degree deadband between the loop heating and cooling setpoints, because these heat pumps can operate over a pretty wide range of loop water temperatures, so we don't want that too tight so that we can allow this recovery from one zone to the other to occur. And that's it on heat pumps. There's more information in the code about that.

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We covered that one pretty quickly.

So let's wrap up here with the HVAC high energy option and get on to some questions before we wrap up. So one example of a high energy option is a condensing furnace. You know, not always so available residentially, but we'll talk about that. So there is an HVAC high energy option that's been in the code on IECC for a while, it is not in 90.1, but basically, if you choose that in – there used to be tables in the code that were separate efficiency requirements, now it just says all equipment must exceed the efficiency requirements listed in the table by 10 percent. And the equipment not listed in those tables is limited to 10 percent of total capacity. Now, VRF is not listed, however there is a reference to the VRF tables in 90.1, so VRF can be used to meet this requirement.

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Even though they are not – don't have a table in the IECC, that reference to 90.1 brings them into the picture.

So the idea here is we want to increase the heat pump efficiency or the chiller and boiler efficiency or even the furnace efficiency, although typically that would require a split system in a more residential type furnace within the building. Although, you know, it's difficult for packaged units with furnaces to meet the extra efficiency requirements, although you could do the split system with indoor condensing furnace, or there are some gas ducted heaters that do meet the condenser requirements. You could have an air conditioning only unit with a separate rooftop gas ducted heater or inside the building gas ducted heater that met the higher efficiency requirement, 10 percent above the furnace requirement.

So let's look at how you deal with this. So depending upon the equipment you've got, let's say I had air source heat pumps, –

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I would have multiple metrics to meet. Again, I have to meet both cooling metrics, EER and IEER, and I need to meet the HSPF for the heat pump or the COP for a larger heat pump. So I pull out for, again, this 5 to 11-ton unit, my code table says 11, 12, and 8. I would basically multiply those by 1.1, or add a 10 percent efficiency improvement. So I have got to meet 12.1 or better, 13.2 or better on IEER and 8.8 or better on HSPF. So again, the higher the number here the better you are. The only exception to that would be larger chillers where the KW per ton would go down by 10 percent.

If I am an air-cooled chiller, again, I've got two requirements, the full load and the IPLV requirement, and I would increase those again by 10 percent and I would have to be –

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better or higher than those numbers, both numbers, to meet the requirement. And then if I had a boiler, if it – 80 percent is the requirement, 88 percent would be 10 percent above. A condensing boiler would certainly meet that. So if had a boiler in here I would have to meet it. Now, I'm gonna have to meet it on both the cooling and the heating sides to meet this extra efficiency requirement.

So let's just summarize. We had all these individual items that I would call my top of the chart items, high impact code items. Certainly every code item ought to be enforced but, you know, these are items that have a particular high energy impact. The snow and ice melt control where those apply, temperature setback on simple systems, 5 degree deadband, economizer controls, having that high limit set properly. On the more complex systems, again, the –

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5 degree deadband does apply, it needs to be in there, in your zone box controls, and there are limits on simultaneous heating and cooling, those are mostly met by those minimum ventilations being in place, minimum damper settings for the zone boxes. That ventilation optimization needs to be there, again, in the sequence of operations or in the commissioning report. Supply air temperature and fan static reset controls need to be there on these supply systems. And we've also got those hydronic reset controls that we talked about.

Other impactful measures, exterior ductwork insulation requirements have gone up and make sure they do have insulation if they're uninsulated it could be a very large energy loss. The fan power needs to be within the limits, including all the fans in the system, and the equipment should be properly sized to not be oversized in the building.

So in conclusion, HVAC systems –

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provide the following: comfort, heating and cooling, sometimes humidity control. They provide ventilation, filtration and air movement. We have multiple system configurations, either unitary, split or packaged, where the power from the meter goes direct to the unit or the small PTACs, little single zone systems, those are typically single zone systems. We've got kind of an intermediate package, DX VAV unitary system that might also serve multiple zones, so here we've got a unitary system that does serve multiple zones. And then we've got our central units where we have central plants with secondary and zonal HVAC systems.

And again, our important energy factors are those controls we went through, setback, deadband, economizer and resets, and the fan energy limits, duct insulation and snow melt controls. And the energy codes provide valuable requirements for energy savings in our buildings and are an important part of our national –

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infrastructure in meeting energy challenges in the future. And I'll turn it back to Pam to wrap us up here.

Pam Cole: Thank you, Reid, for such an informative webinar. That was a lot of information that you covered. As you had mentioned, mechanical trainings could be one to two days long and maybe just on one to two topics. So a couple of resources. If you went back out to the Energy Code's website, which is up on the screen, there is compliance software that Reid mentioned, the COMcheck software, it's a great tool. It'll provide a way to enter your complex or simple systems, run some of your takeoffs for your fans, for your economizer requirements, so forth. It'll actually customize requirements in a requirements checklist form. So it's great for a plan reviewer. It's a really good resource for designers to use to create a really good report that can be used to plan review and to inspect to.

There is also a technical support. We have a help desk, so if you have questions –

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after this webinar, you could submit 'em through our help desk and we'll provide a link to you. There are some code notes out there, ones on mechanical piping and hot water piping, so you might want to go take a look at some of those. There's lots of publications, lots of reports on analysis that's been done. Reid's done a lot of research and analysis at the state level, national level and so forth, on energy savings and so forth. You might – that might be of an interest to you. There are some resource guides.

And then we have the full set of training materials on the last three codes. So we have it from 2009 up to 2015, and it's broken out by envelope, lighting and mechanical, and then we have the ASHRAE Standard 90.1. So that might be something of interest to you as well. And those are full sets of training materials. Again, that's out on energycodes.gov.

So again, I'd like to thank everyone for participating in our webinar today. We're gonna start into the questions part of this and we don't have a lot of time left but we do have a lot of questions but I think Reid's is gonna be able to get through a lot of these.

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All right, so Reid, let me give you a couple of these questions. So what do you see more of, and this could come through the help desk as well as, do you see HVAC compliance coming in using 90.1 or IECC, and would a designer choose 90.1 over IECC or vice versa?

Reid Hart: Well, both options are available in most states who have adopted IECC as a code. One thing that's important there is when you go to the 90.1 route, you gotta take the whole enchilada. You need to do the envelope and the lighting and the HVAC all under 90.1. I think in some buildings, engineers are more comfortable with 90.1, it's kind of written in more engineering language, but it really depends on the building. I think it's a mix. We're starting to track that now through COMcheck submissions and down the road we'll have more information, –

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but I've seen I think both come through.

Pam Cole: Okay. So for ventilation code requirements is it mandated to measure outside air into a building with an airflow measuring station continuously or using a carbon dioxide sensing?

Reid Hart: Yeah, we're talking a little bit about demand controlled ventilation and I didn't get into that today. There is not a requirement that the ventilation air be measured continuously. Some engineers may choose to take that route, there is a requirement that things be tested and balances. So when they set up the system, you know, a balancer can go out and set the damper to a certain position and verify that at a certain airflow you've got the amount of outside air ventilation you need.

Inside the building, in areas with demand controlled ventilation, which again we didn't get into, usually a CO2 sensor –

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is perfectly adequate to understand whether a room or area of the building is highly populated versus low populated and that's a perfectly adequate way to provide the ventilation adjustment.

Pam Cole: So for VAV systems that can only reheat 30 percent of the air, what about the difference or what about for a constant volume unit?

Reid Hart: Well, constant volume units are gonna become less and less allowable. There are still some cases in hospitals, in certain areas where they are required, although even hospitals are getting to the point where they can manage pressures between isolation zones with VAV systems. And even the package units, there are some new requirements that went in, in 2015 –

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that require at least a multispeed control over 5 tons. If you're over 5 tons you need that multispeed control on a package unitary rooftop unit on the fan. So it's not full VAV but it's – you can go down to a lower speed when you aren't heating or cooling, when you're just ventilating.

Pam Cole: Okay. So addressing latent and sensible carryover, where if you have excess latent capacity in a system can be used to satisfy a sensible load, what is a reasonable percentage to include?

Reid Hart: Well, that kinda depends on the individual design and that's a humidity control question. I think the relation of the energy code of that question – and again, this is a topic I didn't talk about, but some people – we did talk about the supply air reset being required on VAV.

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Now, some people would use the primary air for humidity control and just set it at 55 degrees forever because they want the air to be that dry. Well, you only need to take it down to 55 degrees when the air is humid outside. So if you're doing that, there are requirements. If you're doing dehumidification control, you have either a space sensor or an outside air sensor on the humidity side that only takes that action or that override when it's necessary for humidity control, not 24/7 all the time.

Pam Cole: So here's a question that's come up mostly – I see it in residential but there's a commercial as well. Why are geothermal systems not listed, both in the package and unitary options? And the comment was, there's geothermal systems that are used in thousands of commercial applications, like a geo split system.

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Reid Hart: Well, I actually – I'm flipping open my code book right now. I think we do have some listings for water source heat pumps and so those – you know, water to air, water loop heat pumps would apply, and actually there is a separate listing in Table 403.2.3 for groundwater loop heat points and requirements in both the heating and cooling mode. So there is actually a separate listing in the table for ground source heat pumps, and maybe I'm not understanding the question as far as the distinction.

Pam Cole: Yeah. They are listed in the code. So maybe he's – that person is referencing over to their residential code, I am not sure.

Reid Hart: Yeah, it may not be in the residential. It is in the commercial.

Pam Cole: It's not. It's not residential.

Reid Hart: Okay.

Pam Cole: So are all VRF systems heat pumps or can they be DX as well?

Reid Hart: Well, they are DX, they're using direct expansion. That just means the coil has refrigerant in it.

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But pretty much – you could have a mini split serving a single zone that is only an air conditioning system. Once you get into multiple zones you pretty much have to – well, actually, they do have ones that'll either go heating or cooling but not both at the same time. But you usually need the heat source in the building and so usually they are heat pump systems. They could install a system that just provided cooling and then had an electric resistance heater in the indoor cabinet but that's pretty rare.

Pam Cole: What is the difference between heat exchange and heat recovery?

Reid Hart: Well, the term heat exchange just refers to exchanging heat like in a cooling coil, a chilled water cooling coil. Heat recovery refers more to when we are using two different air streams or two different water streams, in some cases, –

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but typically two different air streams and we're recovering heat from one to put into the other. So for instance, a heat recovery system, when it's really cold outside, would take the exhaust air going out, it would extract the heat from that and it would warm up that incoming ventilation air and that's heat recovery.

Pam Cole: Okay. Considering occupant comfort, which system is more effective air distribution or radiant systems? Which is more energy efficient?

Reid Hart: You know, there's people a debate on that. Most of our systems are typically air distribution systems. There are some people who would advocate for radiant systems and if they're properly installed, a radiant system can improve comfort. Part of the advantage of a radiant system is actually I can be comfortable say in the heating mode when the space temperature is as –

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low as 65 degrees because I am receiving radiant heat directly on my body. Now, do people run the systems down at 65 degrees, you know, that may be questionable 'cause everyone's used to seeing 70 on their thermostat.

So they can be more efficient, especially when you only provide the ventilation air into the zone that you need, this outside air. You aren't using a lot of recirculation air. So in VAV systems, it's really a question of separating the ventilation air out, I think, that you get the savings and you could combine a direct DOAS or dedicated outdoor air system with a VAV system and then shut off the heating and cooling completely from the VAV system because your ventilation is in a separate system. That's probably where you would get similar savings to a radiant system but they can both work.

Pam Cole: Okay. For an air-cooled chiller without a condenser, and this would be in 90.1, –

[1:56:00]

what happens if the manufacturer doesn't know the matching condenser? How does he rate them without knowing the matching condenser?

Reid Hart: Well, I think in that case you are gonna have – you know, someone maybe at the application engineer level is gonna have to pull the information together and get a rating because there is a rating requirement. So even though the rating is without the built-in condenser, they're gonna have to look at what equipment are you putting together and come up with a rating for that. And I think they have software that'll do that.

Pam Cole: Here's another generic one and then we're gonna take two more and then we're gonna have to tie it up. We're not gonna be able to address all these questions. There are quite a few. And as I mentioned, if you still want to, you could submit your question through the help desk and we will get 'em answered that way through that avenue. So commissioning, is commissioning required –

[1:57:00]

on both simple and complex systems? When is commissioning required?

Reid Hart: Yeah, there are some capacity limits, and I don't know them off the top of my head, but if you look in Section 408 in IECC and in 90.1 it's based on square footage of the building, but once you get to a certain capacity of either heating or cooling then you're required to commission the mechanical systems in the building.

Pam Cole: Okay. You talked a little bit about brake horsepower, and one of the questions came in as far as how is it calculated, and it might be easy to answer that one to say just use COMcheck. It does the calculations for you. But there was –. Go ahead.

Reid Hart: Well, actually, in COMcheck you need to input the brake horsepower. So that is calculated usually using software from a fan manufacturer. So based on a certain –.

Pam Cole: Right.

Reid Hart: Static pressure and a certain airflow –

[1:58:00]

a fan has a certain brake horsepower and that's the horsepower measured at the fan shaft before the motor and before that pulley drive. So it's usually the fan manufacturer's software will calculate that.

Pam Cole: Right. Okay. We are at a little passed the top of the hour and we do appreciate you taking the time to listen to Reid today. He was a great presenter. He had a lot of good information. And we hope you join us again. We will have one of these webinars next month at the same time and same day on the second Thursday of the month. And thank you for attending. You all can disconnect.

[End of Audio]