Eli Levine: Hello, everyone, and welcome. I'm just going to give everyone a minute or two to join us and then we'll get started today.

All right, well, welcome. Thank you, everyone, for joining us, and we are very excited for today's webinar. This is Webinar #12, so it's great to have everyone here. The topic today is Process Cooling Systems.

There's me. I guess I've moved from a square to a circle this time. Thank you all. This is Eli Levine.

And here we are. It's been a wonderful journey over the course of this online webinar series. This is the 13th and final for right now webinars. We should be coming back with more in the upcoming weeks and months, probably closer to months, but we'll see. But as a reminder, if you missed any of these or if you missed any of the original six that we put on, we've recorded all of them and we've transcribed all of them, so I encourage you to go back or, hey, maybe it's been a couple weeks and you missed joining us on Thursday afternoons and you just want to relive the memories. They're all saved online and you can go back and watch them.

This is the other really big exciting news that we have for today. We released our 2020 Better Plants Annual Report Progress Update, so this is the updated numbers for us. We're up to over 235 partners. I believe the number is 239 at the moment. Cumulatively, our Better Plants partners have saved over $8 billion in cumulative cost savings, and that's 1.7 quadrillion BTU of energy with an average annual improvement in energy intensity of 2.5 percent. So it is really a nice report. I know our team put a lot of effort into it. It's 24 pages or so, so I encourage you to go online and check it out, and I'm sure we've sent you e-mails as well. Share it. Share it on social media. Let's get the word out about the program and everything that you guys have done to make this program a success.

So with that, as you've done for all of our other webinars as well, could you go to slido.com, and that is where we will be doing polls and asking – that is the venue by which you ask any questions. So again, it's www.slido.com #DOE. So yeah, this just explains what we're doing and how you can let us know how you're feeling and what we can do to cater to your needs. So just as a help for this, if you could also use the Slido app to just chime in for us with other topics that you would like to see for future webinars during the course of this webinar, it doesn't have to be right at this moment, please just let us know in that poll section for what topics you're interested in. that would be really helpful for us. So take a moment or two now and enter that, or if you're still thinking and there's other topics that you'd like to see, just let us know. Marissa's pulled that up, so if you have any ideas for future webinars, let us know. Send in your feedback. That would be great.

We're up to two. Energy storage is a great topic. We'll keep this up and maybe, Marissa, we can – there we go. As more come in, keep sending in your topics and maybe we can revisit this at the end when we've seen everyone's answers if that works for you guys. So with that, let me introduce our presenter for today, Wei Guo.

Wei has been with Oak Ridge for a number of years now. He comes to us from the University of Arkansas and has done really wonderful things with all of his partners and has really been a driving force to move us forward and challenge what we can – how we can really work with partners and how dynamic you can make the relationship and the limits of – testing the limits of how much _____ can do to really help their partners. It's really been great to see. He is an expert in process cooling as well, so I'm excited to turn this over to Wei. Wei, take it from here. Thank you for lending us your time today.

Dr. Wei Guo: All right, yeah. Thank you for the opening and introduction. Again, my name's Wei, and I work with Oak Ridge National Laboratory. I have been with Better Plants Program for about five years. Thank you all for joining us today for the training session. To avoid, like you know, we all work from home. To avoid technical glitches and the noise of my kids running around, I have recorded today's training session beforehand. The slide that I'm going to use today and the recorded video will be posted at the Solution Center of Building Better Plants program and the YouTube. Please feel free to get the word out so more of your colleagues can use these training materials.

This training session is about process cooling systems, which is also my favorite topic. The weather is getting really nice and cool now. Our workers, products and the machines need cool air as well. You know, let us learn something about process cooling system today while watching the video. Like Eli said, please use Slido to ask questions, and we will address your questions at the Q&A session. Without further ado, Marissa, let us get the ball rolling. Thank you.

Good afternoon. This is Wei with Oak Ridge National Laboratory. Thank you for joining us today for the training session on process cooling systems. First of all, I would like to give you an overview of the system. Why do we need process cooling systems? Well, we need process cooling systems to make cool and dry air to _____ the temperature and the humidity required by manufacturing processes and it's more comfortable for our workers. Sometimes we also need chilled water to directly cool some manufacturing processes such as the quenching processes and some chemical reactions.

Why do we care about process cooling systems? Why do we have training sessions on process cooling systems? The first reason is that cool and dry air and chilled water are not free. Actually sometimes it can be pretty expensive. It depends on your electricity rate. The second reason is that process cooling systems have many components. They have a lot of moving parts. The controls of these moving parts can be tricky sometimes. The third reason is that there are many energy conservation opportunities for process cooling systems. Most of these opportunities have very quick payback and very easy to replicate.

What are process cooling systems? Just like I said, process cooling systems have many components and a lot of moving parts. We typically categorize these components into two groups: the air side and the water side. Both sides have three major types of equipment. On the air side, we have air handling units, make-up air units and exhaust fans. On the water side, we have chillers, cooling towers and some pumps.

Air handling units. The job of air handling units is to provide cool and dry air so we can get the needed temperature and humidity. We have supply fans inside the air handling units. The purpose of supply fan is to overcome the pressure loss across coils, filters and along the ductwork so we can deliver cool and dry air to our spaces. Sometimes we also have some return fans, but return fans are optional. If we do have return fans, we can select smaller motors for the supply fans. We would like to recommend to have VFDs on the supply fans. This way we can provide just the right amount of cool air to our spaces and we can avoid overcooling spaces. If we provide too much cool air to spaces, we might need to reheat the air temperature up again. That's a waste of energy.

We also have dampers: return air dampers and outdoor air dampers. The job of these dampers is to make sure that we get the right amount of outdoor air for ventilation purpose. You probably want to check the operation of the outdoor air dampers regularly. Make sure that they are not stuck open or stuck closed. If they are stuck closed all the time, you thought you got needed outdoor air, but you didn't. if outdoor air dampers are stuck open all the time, you thought you were modulating the outdoor air dampers to match whatever the demand is, but in reality, you got a lot more outdoor air than needed.

We also have three coils inside air handling units. We have preheat coils, chilled water coils and reheat coils. The purpose of preheat coils is to warm up the air a few degrees above freezing point. This way, the cold air will not freeze and damage our chilled water coil in winter. The chilled water coil is our main coil. The chilled water coils make cool and dry air. Sometimes we also have a reheat coil. The job of a reheat coil is to add heat to the air stream so we can satisfy the heat _____ of our spaces.

For some coils, we – for these coils, we have some control valves. We have preheat control valves, chilled water control valves and reheat control valves. For chilled water control valves, there are two major types: three-way control valves and two-way control valves. For three-way control valves, when the cooling _____ _____ the flow inside of the main pipe does not change. It is constant flow, the same flow all the time. We use the three-way valve to bypass some flow from the coil. The way, the coil will have less flow to match the cooling load, but the main pipe will have the same amount of flow all the time. Therefore, three-way control valves, when the cooling load _____, we will not have any pump energy savings. However, for two-way control valves, when the cooling load _____, we can simply close off the two-way valves a little bit. This way, we will have less chilled water flow both inside the main pipe and through the coils. We can save a lot of pump energy from using two-way chilled water control valves.

Air filters. We need air filters to clean and purify the air. We typically use minimum efficiency reporting value, also known as MERV, to indicate the efficiency of filters. MERV is designed by ASHRAE in 1987. The value of MERV ranges from 1 to 16. The higher the MERV value is, the cleaner air we will get. However, it also means more pressure loss across the filters. We will need to use more fan energy. We definitely do not want to underpurify the air because it might compromise the quality of our products, but on the other hand, we do not want to overpurify the air either because that means energy penalty. No more, no less, just right.

Make-up air units. Make-up units are very similar to air handling units. The only difference between these two types of equipment is that make-up air units do not take any return air from the spaces.

All the air comes from outside. Essentially, they are 100 percent outdoor air handling units. Apparently, if we take more outdoor air, we will need more energy to cool and dry the air, very similar to air cleaning. We do not want to under-ventilate our spaces because it might compromise the quality of our products and the health of our workers. But on the other hand, we do not want to over-ventilate our spaces either because it could mean energy penalty. You might wonder how much the energy penalty is for more outdoor air. This table shows you the annual cooling load per CFM of outdoor air for various locations. For example, at Miami, Florida, the total cooling load per CFM is about 20.5 _____ hours. That includes both sensible and latent heat. For Oklahoma City, Oklahoma, the total cooling load is less, which is about 6.6 _____ hours per CFM per year. Bot for Boston, Massachusetts, the cooling load is even less, which is only 2.3 _____ hours per CFM per year. This table also shows the sensible and the latent cooling loads separately for these locations.

Exhaust fans. All right, we take a lot of outdoor air into our spaces, either through air handling units or make-up air units. We need to exhaust some air out, otherwise, our buildings will be overpressurized and we might have some problems to close our doors or windows. Sometimes we also use exhaust fans to maintain space temperature. For example, for some mechanical rooms, we typically do not have air handling units to directly deliver cool air to our mechanical rooms. Instead, what we do is that we exhaust the hot air out. Hopefully we can get some cool air from the _____ spaces.

The controls of our exhaust fans, there are two main types: manual controls and automatic controls. For manual controls, it is very simple. There's a switch that you can turn on or turn off. For automatic controls, it can be either based on temperature or based on the status of make-up air units. Here we have a number of $500 per horsepower per year. This number means that the annual energy cost for a 1-horsepower motor with 90 percent load factor and 10 cents per KWH electricity price, the annual energy cost is about $500. That means if we can reduce the operating hours by 10 percent, we can save $50 a year. This number is very handy when you are trying to estimate the energy savings from reducing operating hours of motors.

We just talked about the equipment on the air side. Now let's talk about the water side. On the water side, we have some equipment for chilled water generation and some for chilled water distribution. For chilled water generation, we have chillers, cooling towers, chilled water primary pumps, and condensing water pumps. For chilled water distribution, we have chilled water secondary pumps and the whole piping network.

Chillers. The purpose of chillers is very simple. They provide chilled water at a desired temperature, either required by the manufacturing processes or by our spaces. There are two main types of chillers. The first one is vapor compression cycle based, and the other one is absorption cycle based. The vapor compression cycle-based chillers use electricity, but absorption cycle-based chillers use heat. In this training session, we will mainly focus on the vapor compression cycle-based chillers.

The vapor compression cycle-based chillers is very similar to the air conditioner that we have at our home. The condenser – we have a condenser to reject the heat, evaporator to make cold water, and a compressed _____ refrigerant around, and an expansion valve. There are three factors that affect the efficiency of chillers: condensing water temperature, chilled water temperature, and a partial load ratio of chillers. If we gave chillers cooler condensing water, chillers will be happier, more efficient and also use less energy. If we ask chillers to make colder chilled water, the chillers need to work harder and the chillers will be less efficient and use more energy. Part load ratio, which means that chillers and efficiency depends on how much those chillers are loaded – 80 percent, 60 percent or 40 percent loaded, something like that. We typically use KW per ton to measure the efficiency of chillers. The higher the numbers are, the less efficient the chillers are.

We also have primary pumps. The job of primary pumps is to overcome the pressure loss across evaporators of chillers and to circulate water through evaporators so we can get chilled water.

Cooling towers. The job of cooling towers is to cool the condensing water so we can reject heat from chillers. The working principle is very simple. It works by evaporating water. Since we are losing water all the time, we need to regularly add make-up water to our cooling towers. Similar to chillers, we also have three driving factors that affect the efficiency of cooling towers: outdoor air wet-bulb temperature, draft air flow rate, and the design of cooling towers. When the outdoor air wet bulb temperature is low, our cooling tower fans do not need to work as hard to make cool condensing water, so our cooling towers will be more efficient. If we can draw more air flow rate through cooling towers, we can make cooler condensing water.

The efficiency of cooling towers also depends on the configuration of cooling towers, either crossflows or counterflow. It also depends on the manufacturers. We typically use GPM per horsepower to measure the energy efficiency of cooling towers. Similar to chiller primary pumps, we have condensing water pumps to overcome the elevation of cooling towers and circulate condensing water through the cooling towers and reject the heat for chillers.

There are two major configurations on the water side. One is primary and secondary configuration, and the other one is a primary only configuration. _____ times, chillers cannot handle variable water flow through the evaporators, so we have primary pump to circulate the same amount of water all the time to make sure that our chillers will work properly. However, when cooling load drops, when we use our secondary pumps with the help of VFDs to modulate the pump speed and chilled water flow to match the cooling load. So in other words, the secondary pumps will overcome the pressure loss across the _____, across the cooling coils, and make sure that we will get chilled water to those cooling coils.

But for primary pumps, their job is very simple, only overcome the pressure loss across the evaporators of chillers. Here you can see that we have a small common pipe between the primary water loop and a secondary water loop. When the chilled water flow rate in the secondary loop is less than the primary loop, the excessive chilled water flow will go through the common pipe and go back to primary pumps to make sure that our chillers will have the same amount of water flow all the time.

Primary only configuration. When _____ the development of technologies now, most newer chillers can handle variable flow rate through evaporators. This way, we can get rid of the secondary pumps and make the primary pumps to do all the work and we will overcome the pressure loss across the evaporators of chillers, along the pipelines and across the coils. Then we can put VFDs on our primary pumps. This way, we can modulate the pump speed and the chilled water flow rate to match the cooling load. But as you know, though _____ chillers can have variable flow rate through evaporators, they still have a minimum flow requirement. Typically the minimum flow requirement is about 20 percent of design flow rate. In winter or when the _____ loads are very low, the needed chilled water flow is less than the minimum flow required by chillers. For that case, excessive flow will go through that small bypass line and go back to the end of the primary pumps. This way we can make sure that our chillers will have enough chilled water flow through the evaporators and they will work properly. Basically we would like to make sure that the water flow rate through the evaporators will not drop below the minimum flow requirement.

We just gave an overview of the process cooling systems. Now let's talk about energy conservation measures. There are two ways to reduce the energy cost for process cooling systems, to educe cooling loads and to improve the energy efficiency of the system. How to reduce the cooling loads? When you are doing energy assessments, you can ask these three questions. The first question is are there any damage on your piping insulation? If the answer is yes, please go ahead and get the damage fixed because better insulation helps us to reduce the thermal loss from chilled water. Second question to ask is are there any heat sources inside our conditioned spaces? If the answer is yes, okay, can we remove all those heat sources? If we cannot remove them all, can we reduce the heat from those heat sources? The third question to ask is are there any filtration of hot and humid air into our conditioned spaces? If the answer is yes, can we do something to make our spaces sealed better? Less infiltration means less cooling load.

Energy conservation measures for air handling units and make-up air units. Can we turn off our air handling units and make-up air units completely during plant shutdowns for both weekend and off shift shutdowns? If we cannot, all right. Can we reset temperature and humidity set points a little bit higher? This way, our air handling units and make-up air units will not have to work as hard. Avoid overventilation for spaces. We probably want to do some measurements and make sure that we are not over-ventilating ours paces. Of course we do not want to under-ventilate our spaces because it might compromise the quality of our products and the health of our workers, but at the same time, we do not want to provide more than needed outdoor air because that means energy penalty. The same idea for filters. Are we using the correct type of filters? Do we really need _____ for our applications? Can _____ do the job? The idea is that we would like to avoid overcleaning the air if we can. We also recommend to replace filters regularly to make sure that we are not getting too much pressure loss across filters.

Install VFDs to supply fans. If we have VFDs on our supply fans, we can modulate the fan speed and air flow rate to match the cooling load. If we – we do not want to provide too much cool air to spaces because we might make space temperature too low. This way, we might need to reheat the air temperature up. That means we are doing heating and cooling simultaneously. That is definitely some energy waste.

Proper controls of the preheat coil. We would like to make sure that we have appropriate temperature set point for preheat coils. Typically we only want to warm the air up three to five degrees above freezing point. We do not want to warm the air up too much, otherwise we're adding heat to the air stream, adding more cooler load to the main chiller water coil. We recommend to check preheat coil control valves regularly and make sure that there's no leaks through the coils because leaking hot water through preheat coils will add a lot of heat to the air stream.

Reset supply air temperature set point. We can reset the supply air temperature based on outdoor air temperature. When it is hot and humid outside, we can make the supply air a little bit cooler. When it is cool and dry outside, we can make the supply air a little bit warmer. This way, we can avoid overcooling the spaces and we can have a better balance between air energy and chiller energy.

All right, here we have a few more energy conservation measures for air handling units and make-up air units. The first one is air side economizers. When it is cool and dry outside, it takes less energy to cool outdoor air than return air, so it makes sense to take 100 percent outdoor air and exhaust all return air out. This is the idea of air side economizer. It exhaust all the return air and take all the air from outside.

Energy recovery units. When it is hot and humid outside, we are taking the hot and humid air into our spaces, but at same time, we are exhausting dry and cool air out. Other _____ technology that we can use to recover some of the coolness and dryness from the exhaust air? Of course there are. That technology is called energy recovery units, or ERUs. There are three _____ types of ERUs we can use: enthalpy wheels, heat pipes, or coil energy recovery loops. Enthalpy wheels are the most energy efficient because they can recover both sensible and latent energy. But they do have drawbacks. They have some risks of air cross contamination. If you have a really high requirement on your air quality, you probably want to avoid enthalpy wheels. For that application, you can consider heat pipes ERUs. Heat pipes ERUs are not as efficient as enthalpy wheels because they can only recover sensible heat, but they have almost no risk of air cross contamination. The third option is coil energy recovery loops. This technology is a very useful way your intake air ductwork is pretty far away from your exhaust air ductwork, but you do need to build a new loop, buy a pump and some fluid to transfer the heat around.

The final energy conservation measure for air side equipment is about dehumidification. Typically from a modest dew point applications, our chiller water system should be sufficient, but if you need a very low dew point, you will have two choices to install a separate low-temperature _____ system or to install desiccant wheels into your air handling units. I would recommend desiccant wheels because you do not have to maintain another set of chillers and pumps. Desiccant wheels can help you to achieve very low dew point with a modest chilled water temperature. But they do have some energy penalty because desiccant wheels need some heat for the reactivation process. Do you see the air heater on the right? When talking about dehumidification, we always would like to make sure that we are not over-dehumidifying the air because even though desiccant wheels are pretty efficient in terms of dehumidification and have very low maintenance, but they do have some energy penalties.

Energy conservation measures for exhaust fans. We just talk about this number before. $500 per horsepower per year. This is the annual energy cost for a one-horsepower motor with 90 percent load factor and 10 cents per KWH electricity rate. That means if we can reduce operating hours of that one-horsepower motor by 10 percent, we can save $50 per year. So the main idea for exhaust fans is to reduce operating hours. Can we turn off our exhaust fans during plant shutdowns for both weekends and off-shift shutdowns? Can we change the controls from manual controls to automatic controls, either based on temperature or the status of make-up air units? If your exhaust fans are driven by standard V-belts, you can change them to cogged V-belts. Typically, cogged V-belts can give us more energy efficiency. So that is energy conservation measures for air side equipment: air handling units, make-up air units, and exhaust fans.

Now let's talk about the water side equipment. The water side is a little bit more complex because there's no settings that can make all components work as efficiently as possible at the same time. For example, if we make colder chilled water, that means our chillers need to work harder and more chiller energy. But at the same time, we do not need as much chilled water. That means our pumps will be happier and use less energy. Now you can see the tradeoffs between chiller energy and pump energy.

All right, if we make cooler condensing water, our cooling tower fans need to work harder. That means more cooling tower fan energy. But on the other hand, the chillers will be happier, more efficient, and less chiller energy. That is some tradeoffs between chiller energy and cooling tower fan energy. How about less condensing water flow? Less condensing water flow definitely will give us some pump energy savings, but on the other hand, the cooling tower fans might need to work harder to achieve the same condensing water temperature. So you can see there are a lot of tradeoffs going on on the water side. If you really want to optimize the energy performance of the whole system, we might need to perform very complex, very sophisticated simulation work.

Luckily, we have some simple energy conservation measure to help you to achieve near optimum energy performance. For example, we can reset chiller water supply temperature set point based on outdoor air temperature. When the outdoor air temperature is 70 degrees or higher, we can make the chilled water temperature to be 42 degrees. When the outdoor air temperature is 50 degrees or lower, we can make the chilled water temperature to be 46 degrees, and we can do linear regression in-between. This way, we can have a good balance between chiller energy and pump energy. If you need more chiller capacity and are in a position of purchasing new chillers, we would recommend you to select the VFD chillers and chillers with magnetic barriers. These two types of chillers can give you better efficiency at very low _____ ratio. For example, when those chillers are only 40 percent or 30 percent loaded, they can still give you very good efficiency.

Primary pumps. If your system is a primary and a secondary setup, we will recommend you to change that to be primary only configuration. This way, we would have fewer pumps to maintain and you will have a lot of pump energy savings. Remove all your triple-duty valves. Triple-duty valves can do three things: balancing, check valves and shutoff valves, but typically we use triple-duty valves only for balancing _____. If we have VFDs on our pumps, we do not need triple-duty valves to do the balancing ob. We can just use the VFDs to do the system balancing. By removing those triple-duty valves, we can save a lot of pump energy because triple-duty valves have a lot of pressure loss.

Cooling towers. We can reset condensing water supply temperature based on outdoor air wet bulb temperature. When the outdoor air wet bulb temperature is low, we would like to take advantage of that. We would like to make cooler condensing water so we can make our chillers happy and give us a better chiller efficiency, less chiller energy. But at the same time, we do not want to set the condensing water temperature too low and make our fans to run at 100 percent speed all the time, trying to achieve something that is not even physically possible. Here you can see that we actually increased the approach, the difference between condensing water temperature and the wet bulb temperature. When the wet bulb temperature is 68 degrees, the approach is 70 degrees. But when the wet bulb temperature is 47 degrees, we have increased the approach to 13 degrees. If you have one-speed or two-speed controls on your cooling tower fans, change them to be VFD controls. You would definitely save a lot of energy.

Condensing water pumps. You can consider installing VFDs on your condensing water pumps if your cooling tower fans can handle variable flow rate for sure. You can modulate the pump speed and wall flow rate to maintain 12 degrees or 10 degrees pressure drop across the cooling towers. This way, you can have a good balance between condensing water pump energy and cooling tower fan energy. You definitely want to check the operation manuals and consult the manufacturers to make sure that your cooling towers can really handle variable flow and how low the flow rate can be.

Distribution system. Install VFDs on your secondary pumps and reset your DP set point based on the most open valve position. This way, we can provide just the right amount of pressure to the system so that all cooling towers will have enough chilled water flow. Change all three-way cooling tower control valves to two-way control valves. This way, we will convert the system from a constant flow system to a variable flow system and save a lot of pump energy. Remove all triple-duty valves, identify the bottlenecks, loop piping network. What I mean here is that if you are thinking about decentralizing your chilled water plants, you can try to strategically locate your plats to minimize the total distance between your chillers and cooling loads. You can consider booster pumps for very remote loads. By doing this, your secondary pumps do not need to overpressurize all other cooling coils just to make the remote cooling loads get enough chilled water.

We just talked about some low-cost energy conservation measures. Here we have some more capital-intensive technologies for you to consider. The first one is absorption chillers. If there is a lot of waste heat in your plant, you can consider installing absorption chillers. They can now make a benefit of doing this really depends on how much wasted heat you have in the plant, electricity rates and the cost of the project.

The second technology is heat pump chillers. Sometimes they are also called heat delivery chillers. For conventional chillers, we simply reject the heat through cooling towers, but for heat pump chillers, we recover that heat to preheat our heating water or to supplement our boilers. But the drawback is that the cooling energy efficiency of heat pump chillers isn't as high as conventional chillers. So the economic benefit of this technology depends on the natural gas price, electricity price and the project cost.

Another technology is water side economizer. Basically, the idea is that when the outdoor air wet bulb temperature is very low, probably the water temperature from the cooling tower is cold enough to make chilled water or precool chilled water using plate and frame heat exchangers. Some chillers are starting to have this feature built in and you do not have to buy and install a plate and a frame heat exchanger.

Thermal storage. The idea of this technology is that at night typically the outdoor air wet bulb temperature is lower, so our chillers will be more efficient. Typically the demand chart is also low at night, so it will cost less to make chilled water at night. We will make a lot of chilled water _____ during the night. When the outdoor air wet bulb temperature and demand chart are high during the day, we will turn off chillers and release the stored chilled water and ice to satisfy cooling levels and save energy cost. We would like to take advantage of the low wet bulb temperature and demand charge at night. That is the basic idea.

So we just talk about some low-cost energy conservation measures and some capital-intensive technologies. For any of those measures and technologies, before you proceed to implement, you need to do some homework, some engineering analysis work and some diagnosis. To do analysis and diagnosis, we need data on temperature, pressure and flow rates. You can find those temperature and pressure ports around your pumps and chillers. We call it PT ports. With those pressure and PT ports or pressure temperature ports, you can use temperature probes and hydraulic manometers to measure the temperature and pressure. For flow rates, you can either use ultrasonic flow meters or you can use the relationship between flow drops and flow rate to derive flow rates for you.

Right here, I would like to summarize the energy conservation measures that we just talked about for the air side. Can we turn off air handling units, make-up units and exhaust fans during plant shutdowns? Can we – if we cannot turn them off, can we reset temperature and humidity set points? This way, our equipment will not have to work as hard. Regularly replace the filters and avoid overventilation for our spaces to save energy. Upgrade all manual controls to automatic controls for exhaust fans.

Water side. Convert your chilled water system from constant flow to variable flow system by replacing three-way control valves to two-way control valves and installing VFDs on your secondary pumps. Change all your cooling tower fans from one-speed or two-speed controls to VFD controls. Reset your water supply temperature based on the process load or outdoor air temperature. Reset condensing water temperature based on outdoor air wet bulb temperature. Convert your condensing water system from constant flow to variable flow.

Here we have some rules of thumb and unit conversions. For example, for every degree increase of chilled water temperature, you can get chiller energy efficiency improvement by about 1.5 percent. For every 1 degree decrease of condensing water temperature, you can get roughly 1.5 percent chiller energy efficiency improvement as well. A rule of thumb for pump sizing 2.0 to 2.4 GPM per ton for chilled water pumps and 2.5 to 3.0 GPM per ton for condensing water pumps. Distribution pipe sizing. We typically try to make the water velocity to be no more than 10 feet per second and to make the pressure loss no more than 4 feet of water column pressure loss for 100 feet of pipes. One refrigeration ton is about 12,000 BTUs per hour. When cooling tower time is 15,000 BTUs per hour.

We just gave an overview of process cooling systems and we also talk about energy conservation measures. The Department of Energy has developed many technical resources to help people understand the system and to identify energy conservation measures and to quantify savings. You can go to the web site of DOE's _____ Manufacture Office to download info cards and cheat sheets for process cooling systems. We also have developed some Excel tools for process cooling systems. DOE's Better Plants Program is looking into providing in-plant trainings for process cooling systems as well. Right now, we are developing process cooling system module and some calculators for the measure tool suite.

Right now, we have three process cooling system related calculators in our measure tool suite. the first one is psychometric calculator. If you have dry bulb temperature, wet bulb temperature, or relative humidity or dew point, this calculator can calculate all other properties of the air for you. For example, you can get enthalpy, air ____ specific volume, degree of saturation and humidity ratio.

The second calculator is the weather binning calculator. This calculator is very handy when you are trying to determine how many operating hours you can save from implementing weather-based controls. For example, if your _____ heaters are controlled based on the outdoor air dry bulb temperature, right now the triggering temperature is set at 70 degrees and you are thinking about changing that from 70 degrees to 50 degrees, you probably want to know how many operating hours you can save from doing that. Well, these calculators can help you out on that for sure. You only need to upload the weather file and it will tell the calculator which weather range you are interested in. This calculator will tell you for how many hours a year the temperature is within that range. That number will be your operating hours savings.

The third calculator is cooling tower make-up water calculator. This calculator can help you to quantify the water savings from installing _____ eliminators and changing the cycles of concentration. You will need a water flow rate and cooling loads to do the calculation. The make-up water savings is shown on the right-hand side, both absolute savings and a percentage saving numbers.

This is everything that I would like to share with everyone today. Thank you so much for the time and attention.

Eli Levine: Well, thank you so much, Wei. I appreciate you taking time there. Should energy management not work out, you have a voice that's perfect for one of the soothing apps that's helping you fall asleep at night, and I apologize for everyone who had technical difficulties and couldn't quite hear them. I know we had some trouble with the audio. Hopefully some of you were able to just turn your volume up as loud as possible and be able to hear that. But if you had trouble with that, we will be trying to fix that for the recording so it'll be louder if you missed anything and want to watch it again.

So with that, I encourage everyone now, so let's first, let's go back to Slido.com, www.slido.com. I encourage everyone that if you haven't had a chance yet, to put your entry in now for future topics for future webinars. Let us know your feedback there. That can be really helpful for us. And also in the question and answer section, if there are any questions that you have for Wei, we can fire them off here and Wei's volume, now that he's not recorded, will be much louder and everyone should be able to hear. So Wei, one – we had – I guess one question we had here was, Wei, for chillers that are used for facility cooling during the summer, can they be reversed and used as heat pumps during the winter?

Dr. Wei Guo: Yeah, I guess it is theoretical question. We mentioned about heat pump chillers. Heat pump chillers definitely is getting a lot of attention recently because you can recover the _____ on the condenser side, but the answer for this question is no for conventional chillers, for the chillers that right now you have in your facilities which has a cooling tower attached to. We cannot simply reverse that and use it as a heat pump because for heat pump chillers, on the condenser side, the temperature is a lot warmer, which is a lot warmer than the water you will get from cooling tower. So that means the head for the heat pump chillers is very high. The compressors need to be designed to handle the big head. Typically for heat pump chillers, we use the school compressors to handle the big lift, but for the chillers with it would have in our facilities, we have both school chillers and _____ chillers. So yeah, the answer is no, we need to buy those chillers. They are designed to run as a heat pump chiller.

Eli Levine: Great. Thank you so much, Wei. Another question we had, and questions are rolling in now, is there a benefit to installing an enthalpy wheel over the heat pipes?

Dr. Wei Guo: Yes. So enthalpy wheels can recover both sensible and latent heat. So basically they can cover the – they can do the temperature and the moisture transfer, right. So the efficiencies is a lot higher than heat pipes. But for enthalpy wheels, the air streams basic – the air streams will – the air – the intake air stream and the exhaust air stream will go through the same channels of time. So you know, if you are concerned about air quality, enthalpy wheels might give you some cross contamination for your air. But for heat pipes, that problem does not exist because the intake air stream and exhaust air stream do not – never go through the same channel. So the cross contamination for heat pipe ERUs is very, very rarely _____. So yeah, if you want high efficiency and your application does not really have a high requirement on air quality, you can use enthalpy wheels. Otherwise, you can choose heat pumps.

Eli Levine: Fantastic. Thanks, Wei. A few more questions that we got here. One second. Is the weather data in the tool – the weather data in the tool is downloaded and updated separately or does the tool have that capability?

Dr. Wei Guo: The weather – I guess for the weather data, I think _____ has some TMY3 data, and you can Google it and go to _____ web site or download the data. And for the calculators within the ______ suite, right now we are trying to integrate those three calculators into our latest _____. So in the future we might incorporate the weather data into our _____ tool suite as well, but it's kind of a project in progress, so we're still working on it. Right now, no, we have to download the weather – the data separately.

Eli Levine: Fantastic. How far south can I use free cooling or does that only work in the northern facilities?

Dr. Wei Guo: Well, I guess it depends on the weather, right, _____ the free cooling. It is more – I guess, okay, let me clarify this one. This free cooling can also mean I guess free cooling on the – I guess do we mean the air side economizer, and the other one is free cooling on the water side, right. Let's talk about the air side first. So I guess even in south, you know, I guess in Tennessee, I think probably we should have some free cooling hours as well, probably not as many as some northern facilities, not as many as Minnesota or Michigan, something like that. But for the water side free cooling, which is more about weather, it's not only about how hot the temperature is. It's all about how dry the air is. If it's really dry, you know, our cooling towers still can give us very cool water and we can use that to cool our facilities as well. So I guess for this question, no, it will also work with some southern facilities and some western facilities as well.

Eli Levine: Fantastic. One or two more questions, Wei. What is a good kilowatt per ton for chillers?

Dr. Wei Guo: So actually 90.1 has a kind of the – we kind of, I don't know, it's standard. You know, that's the number that we can use. For KW per ton, you know, that we have that design KW per ton, you know, for the design conditions, and we typically I would think probably 0.7, 0.6 should be pretty good. But, you know, for our chillers in our facilities, we are running that all year round for winter and fall when the wet bulb is pretty good, and our actual KW per ton will be a lot less than that. So the annual average of KW per ton I think for your facility, if we can get it somewhere around 0.3, 0.4, I think that's going to be good.

Eli Levine: Perfect. Thanks, Wei. Last question. Is it possible to retrofit older chillers with a variable frequency drive control or do I need to completely replace my chiller?

Dr. Wei Guo: I guess, you know, here we have older chillers. I think for very old chillers, probably we cannot. I guess there's some internal oil return mechanisms. Just to put a VFD on it probably won't work, and if you put a lot of new small parts into the chillers, probably the cost will be more than buying a new chiller, right. So I guess for this one, it is better to consult your chiller manufacturers and get some quotes from them to see if it makes economic sense or not for you guys to do the retrofit or buy a new one.

Eli Levine: Fantastic. Thank you, Wei. We threw a lot of questions at you, and I really appreciate it. So with that, we should have everyone's – I guess we can turn to the next slide. Next slide here is our Better Building Solution Center. You can find all of our solutions and case studies and the links to the recordings of all of these webinars there.

As you can see, here's all of the online learning series that we've done right now, and we hope that you enjoyed all of them and go back and watch the recordings.

More information, you have my contact information and Wei's contact information. So with that, I will thank everyone for being a part of these, and go forth and enjoy our annual progress report, and we will hopefully talk with you all soon. Thank you so much.

Dr. Wei Guo: Thank you guys for the time.

[End of Audio]