Paul Torcellini: Good morning. Hello, and thanks for joining the webinar today. We're going to give folks another moment or so to log in and we'll be starting soon.

Okay, I have that it's one minute after the hour, so let's get started. Hello, everyone, and welcome to the '23-'24 Better Buildings webinar series. This is the first webinar after the new year. So, thank you for joining. We're dedicated to bringing you the latest actionable insights from leading industry experts. This annual series is a chance to explore topics, technologies, and trends that affect your organization as well as efforts to accelerate decarbonization and energy efficiency adoption. Today's webinar is called Winter Heat Pump Reality Check – Is Yours Keeping Up?

But before we dive in, there are a few housekeeping points I would like to cover. Please note today's webinar will be recorded and archived on the Better Buildings Solutions Center. We will follow up when today's recording and slides are made available. Next, attendees are in listen-only mode meaning your microphones are muted. If you experience any audio or visual issues during the webinar, please send a message in the Q&A box located at the bottom of your Zoom panel. My name is Paul Torcellini and I am your moderator for today. I'm a Principal Engineer at the National Renewal Energy Lab and provide a lot of the technical support for the Better Buildings Challenge and Better Buildings, and glad to be here to moderate this session around heat pumps. Let's move to the agenda.

We're going to do some welcome and introductions. We have three great speakers today that will provide presentations and then we'll have an opportunity for questions and answers and some discussion at the end with the panel before we conclude.

So just want to introduce the topic a little bit here and talk generically about heat pumps. Heat pumps are something that move heat from something that is cold to something that is hot. And we use refrigerants to make this happen. The word pump comes from is two areas. First, we're pumping heat from something low to something hot. But we're also using a compressor inside that heat pump to make that refrigerant move. It takes effort to make this happen. You can think of it climbing up a hill. From the bottom of the hill to the top takes effort. So that effort is often electricity. The smaller the temperature difference from low to high, the easier it is to move that heat. So, the colder it gets outside, the harder it is to push that heat to a warm location. But many heat pumps today will still work when temperatures are very low. One of the advantages of a heat pump is that it is typically two to five times more efficient to move the heat than it is to generate it, such as using electric resistance heaters. So go to the next slide.

So just using that same schematic and showing in heating mode, we're pulling heat from the outside air, which actually makes the outside air a little bit cooler. We're putting effort into the heat pump, again usually electricity. We're producing heat at a relatively high temperature, at least high enough that we can use it to heat the building. Many heat pumps are rated down to 17 degrees Fahrenheit. There are definitely heat pumps out there that will operate much colder, down to 20 below or even lower than that today. We also have systems that are what we call dual fuel, so they use a heat pump for some of the more moderate temperatures then switch to some kind of backup mode, could be electric resistance or gas as the backup heating. It's important to get that switchover correct. I see a lot of these heat pumps and we'll hear a little bit about it later where that switchover temperature is really warm, and the heat pump isn't working to its full capabilities. So next slide.

So, where we pull that heat from, whether it be outdoors as shown in the last illustration or this one where perhaps we pull that heat out of the ground, often the ground temperature is closer to the temperature that we want the heat. So again, the less temperature difference we have to move, the less hard that heat pump has to work. So that temperature difference is really an important piece. So sometimes we have a ground supply, or if you're lucky enough, have a water supply that's at a more advantageous temperature, it gives you a higher efficiency on that heat pump. Next slide.

So again, in heating mode, we're heating the building at the upside. We can also reverse the thinking and put the building at the cool side. Well, that's our conventional air conditioning system where we're pulling heat out of the building, putting it through an air conditioning device, and dumping that heat to the outside. But we can also think about, going to the next slide, maybe we can use that at the same time. So, a lot of buildings have in the summertime, reheat where we often are using electric resistance or a gas boiler, and so not only are we pulling heat from the building but maybe we're putting some of that heat back into the building to help with the reheat. So that's a big thing when we're trying to control humidity in the summertime. There may be some other advantageous uses of that heat, such as pool heating, if your facility has a pool that needs some heat with it. So next slide.

Now, I want us to move to some questions – some poll questions here. Today, we're going to be using Slido as the vehicle to do that. So, if you go Slido.com and enter the event code #DOE. And so now it's your opportunity to respond back with some of these polls. If you could put up the first poll, we're ready to go.

So which sector best describes your organization? And we'll give a couple of seconds for you to populate this. It's great to see so many people today on this webinar. It's definitely a topic of a lot of interest, especially getting heat pumps to work in some of these warmer conditions. It looks like we have a really good distribution of folks on the line. So hopefully, you can get some of your questions answered and learn some things about it. It's interesting how even the spread is between our different sectors. So, we'll give this another couple of seconds to even out a little bit, and give everybody a chance to respond.

Okay, so now moving to the next question. Digging in a little bit with heat pumps. I was curious how many of you have used heat pumps in HVAC applications in your buildings. Sometimes you've never used them and we're hoping that this webinar helps you think about what might be needed to use them. During the Q&A, we'd love to hear from you on what some of your roadblocks are to making them feasible. It seems like there's roughly 16 percent of you that use it most of the time. I guess 20 percent most of the time or always. Over half of you have had some experience with them. So that's great to hear. Okay, we'll give this a few more seconds, and then we'll jump to the next question. Okay.

So especially for those of you that use the heat pumps, what is your motivation for using them? So, I'd like to hear from you on what your top reason is for it. I would definitely expect that some of you that answered last time that you haven't had any experience would select the "I don't use heat pumps". So, it looks like a lot of you are using them in terms of decarbonization. Would love to hear some of your stories about how that is going, and just some of the processes you can use to sell those in your facilities. Okay, let's go to the next question.

Then also would like to hear what some of your barriers are to using heat pumps in HVAC system. So, several of you indicated a little hesitancy to use them. Some of them haven't used them at all. About half of you have only used them sometimes. What would it take for you to use them for every building application? What are some of the hurdles that you're facing to do that? I'm hoping that our speakers will address some of that today and give you some ideas on how they've addressed some of these issues in projects that they've worked on. It definitely feels like some more knowledge would be helpful with this, and as well as addressing how to make these work in the business case.

Okay, well thank you for participating in those polls. We're now going to move to the meat of this. We've got three excellent speakers with us today. So today, we've got Kristy Walson from BranchPattern, Shawn Oram from Ecotope, and David Traxler from Burns & McDonell. They're going to provide some case studies. All three of them work with Better Buildings through our Design and Construction Allies effort. So, if you are interested in an active designer in helping address some of the barriers from a designer and implementor practice, feel free to reach out to us about that effort as well. So, with that, let's hand it off to Kristy. Thanks a lot.

Kristy Walson: Thanks, Paul. I appreciate it. Next slide.

So today, I'm going to talk about an existing building electrification case study. I'm Kristy Walson. Like Paul said, I'm a mechanical engineer and LEED fellow and Building Science Practice Lead with BranchPattern. Next slide.

As the first speaker today, I get to set the stage for why do we electrify in the first place? I do think the word electrify or electrification has gained some traction in the industry, but sometimes it's not as obvious how it's directly connected to heat pumps or why we want to electrify. So, I want to set the stage a little here. On this image to the right, all of the dark blue are states and provinces in the U.S. and Canada that use natural gas for their building heating systems. Space heating systems are the largest source of direct greenhouse gas emissions by end use in commercial buildings. Presently, there's no viable renewable energy alternative for natural gas. This is why we want to electrify our heating systems. Because the electrical grid is decarbonizing and our utility partners have goals to decarbonize their grid, over a 25-year life span both electric resistance and heat pump heating systems will yield lower cumulative emissions than their natural gas counterparts. So, as we move forward in decarbonizing the build environment, electrification of our heating systems is a critical component. Because we're talking about both climate heat pumps specifically here today, I did want to share this Cold Climate Heat Pump Challenge if nobody is aware of it. The Department of Energy is – they issued this in 2021. It was really a call to the industry for manufacturers to start developing better heat pump technology that can operate in cold climates. We should be seeing these on the market very soon. But it's important to know that heat pumps continually get better, and their coefficient of performance continually gets better. So, we move closer and closer towards having full cold climate heat pump solutions every day. Next slide.

So, electrification is in the name of decarbonization like we saw with that survey. So, because I'm talking about an existing building electrification study today, you can't miss the part where you need to assess your existing conditions. If you have an existing building, your utility bills and you can use retro commissioning. In the case of the case study that we did, a ASHRAE level one energy audit, so we had the benefit of going onsite and observing actual conditions on site, which is great. But you can't analyze and then jump straight to electrification. You don't want to do that quite yet. The first step is to really look at your load reduction, starting with a passive load reduction in the building because the colder your climate gets, the more forward your building envelope is in the story of the heating load in the building. So, the more of a role your envelope plays. As your conditions outside get colder, and you try to maintain the same set point inside, that delta temperature, delta T across your building envelope gets bigger and that insulation and tightness of the building really play a huge role in reducing the heating loads in the building. Also look at active load reduction. Try to get your loads optimized as much as possible, and only once you've done that can we start looking at electrification in the name of decarbonization. Next slide.

So, what questions should owners be asking about electrification? Well, in my opinion, these five are pretty important.

[audio cuts out]

I think I got kicked out there for a minute. It depends on what your building situation is, but the first question that I would ask is how can we minimize the increased demand resulting from electrification? We want to electrify but the problem with full electrification without looking at reducing your loads of your building is that you don't want to be adding a ton of electrical demand to an already overtaxed grid that's being asked to simultaneously absorb electrified systems and decarbonize at the same time. So how can we minimize the impact from our electrification to the grid that's serving the building? And then can we partially electrify without the need for increased electrical service? You're always going to be adding electrical capacity or electrical demand to a building when you move from natural gas heating systems over to electric heating systems. So how can we minimize or optimize that, or maybe partially electrify? Then some follow up questions you want to ask – will full electrification increase the buildings peak electrical demand? Does the buildings current electrical service support it, or are we already maxing out the electrical demand? Is additional service available from the utility provider in the first place? Next slide.

Here's just another slew of ways to incorporate energy efficiency and optimization. There's a much longer list than this. It really depends on the building, but once you've optimized as much as you can within your constraints, then you start talking about electrified heating systems. Here's just the landscape of heat pumps in this graphic here. Next slide.

I personally – a lot of designers will jump to a particular system, and I personally like to use something like this decision-making matrix. You probably have something similar with maybe a catchier name probably. Always try to evaluate at least two or three systems that could feasibly go into the building. This is similar to life cycle cost analysis that we do for let's say higher ed institutions, but this particular one incorporates more than just cost-based considerations like acoustics and environmental impact. If you don't have a cost of carbon, you don't have costs to associate with the carbon reduction. So, I do like this system for selecting your – this matrix for selecting your system. Next slide.

So, we're going to talk about an electrification case study. This is an industrial commercial real estate building located just outside of Chicago. So pretty cold climate. W. P. Carey is owner and landlord of the building. Next slide.

I know a lot of owners have large portfolios. W. P. Carey is one of them. They have almost 1500 buildings in their portfolio. So how do you even start the process? Well, my approach for portfolio is to start with one building. You can build the poor performer. You can pick the cold climate location. You can pick the high cost but start with one building and use it as a pilot for the rest of your buildings. Next.

So, first thing you do is assess your existing conditions. In this case, our EUI of the building was 163 kBtu per square foot. You'll notice that the fuel mix in terms of kBtu or energy used, the gas for heating is actually 66 percent, but from a cost perspective, the gas is only 33 percent. Next.

That's indicative of electricity just costing more than natural gas. That's very common. We like to benchmark and see how the existing building is doing against the benchmark. In this case, we used CBECS as our benchmark. Next slide.

Because we have the benefit of going on site with the energy audit, we were able to get eyes on the enclosure. When we sat down at the energy model to calibrate the model based on the utility bills, we could not get this model to use as much natural gas as the actual building was using. At the end of the day, we had to speculate that the enclosure had a lot to do with that, including potentially back doors being left open throughout the day or at certain times during the day. Next slide.

So, we looked at a variety of ECMs. It's hard to see here, but what we did was evaluate each of these ECMs. An ECM1 is preventative maintenance because deferred maintenance tends to be the rule not the exception. So, get your building to a baseline first with that preventative maintenance. But we did take a look at a like for like HVAC replacement. We took a look at electrifying the heating equipment with heat pumps. Then of course, we bundled them down at the bottom. First bundle is like for like with optimized loads. Second bundle is electrifying your heating system with those optimized loads. Next.

This is a landscape of how it all played out. You can see that without doing any other ECM and just electrifying the HVAC system, we had a greenhouse gas intensity increase, but once we bundled all the optimized load reduction strategies down at the very bottom, we actually reduced carbon emissions. Next slide.

Next slide.

Let's go to the end, Anna, since I'm low on time. Last thing. One more.

So, I just want to say renewable energy should always be considered or at least evaluated when you're electrifying your building's heating systems. As we electrify, there are still notable industry gaps. We are in a long transition to decarbonizing the electrical grid and our heating systems. We want to make sure we understand this is a journey. We are not at the end of this, so mindful planning and addressing current limitations and charting a course that aligns with the evolving landscape of decarbonization is extremely important as you work toward electrification and decarbonization. I'll kick it back over to Paul.

Paul Torcellini: Hey, thanks, Kristy. I want to remind everybody about Slido and # is DOE. So, continue to put your questions into the chat or into Slido. Make sure you go through them and upvote them. Obviously, we won't have time to address them all. The Design Construction Allies is working on design guidance for Better Buildings in total that should be out this spring, and so we'll take some of these questions back and make sure that our written materials are addressing your comments as we go along. So, with that, I want to pass it over to Shawn. Go for it, Shawn.

Shawn Oram: All right, thanks, Paul. Good morning. My name is Shawn Oram. I am a Principal MEP Designer with Ecotope. Today I want to talk to you about a project called the Sitka Public Library. This is located up in Alaska. I'll show you a map in a second. But here's the summary upfront. The building on the left was the existing building, and the building on the right was the finished building. I'll walk you through some of the details in it. One thing to note is in this retrofit, a major deep green retrofit, we added about 50 percent more square footage. That was a big piece of this overall package and project. Next please.

Okay, so just to place the project here, if folks don't know where Sitka is, it's in southeast Alaska. You can see it on the map there. It's in that little southeast area there. This profiles some of the typical climate out there. There is snow on the ground about three months of the year. Last year, the lowest temp was about 12 degrees, design temp is about 16 degrees. There's not much of a cooling load up there. 66 is design temp, and there's no humidity to deal with up there. Next.

So, this was a public bid project. We worked on it with MRV Architects out of Juneau, and we also worked closely with the city planner, Kelli Cropper, to get this project realized. Some of the key project goals were zero emission building, all electric building. We wanted to do this without doing a transformers upgrade. We were targeting mid-30s EUI. The big impetus on this kind of project from the city's standpoint is the existing library was leaking. The roof, there's a flat section in it and it was leaky and so there was a – the boiler was about 35 years old. So, it was ready for the next round of upgrades. Next.

So, we talked about the existing system. This is some of the old plans from way back, hand-drawn plans. Always pretty cool. It's a very typical system for a library. I won't get into the details, but it's essentially an oil-fired boiler feeding hot water fan coils and outside air is mixed in. So that's a very typical commercial building system. The fan coils were connected to ductwork which was supplying both overhead and slab ductwork. You can see some of the plans if you want to zoom in after. Next.

Some more pictures of the existing. Left is the oil-fired boiler fan coil. This is the fan coil unit. It's got an outside air connection. The right, you can see some of the hydronic as well as the 35-year-old oil-fired boiler. It's about a half a million Btus. Next.

So, we talked about – the effort here was to try to target both electrification and a low EUI. So, a big piece of that is load reduction. We can see summarized here where we took this envelope. We were really pushing this to try to keep the load under what was available on the transformer. But you can see there is four inches of foam on the outside. The slab is fully insulated. It's radiant floor-heated slab. There's triple pane windows. Next.

Here's a little snapshot of the HVAC system. So, it is a heat pump system called the VRF, variable refrigerant flow. They're quite popular these days. Up top is converting the VRF into hot water production and making essentially water hot enough to head a radiant floor. That's the primary heating. Then there's auxiliary fan coils. Just down in the left is a heat recovery ventilation system. This is a key piece of the load. A big portion of the load is ventilation heating the ventilation air. It's pretty much a year heating climate in Alaska, so the energy recovery ventilation is a great measure. Next.

Just a little detail about VRF heat pumps. There's an outdoor unit over on the left. It's connected by refrigerant to essentially a branch controller manifold, and then those distribute to fan coils. Like I mentioned, this project, instead of fan coils, it used a radiant floor. So, there's a refrigerant to water heat exchanger. But there are some zones that are fan coils and I'll talk about that a bit more. Just wanted to show the derate and how the heat pump was selected. Nominal rating is about 38 degrees for this particular heat pump model. As the temperature drops, you get reduced capacity. So, this was sized for that extreme and it's about a 30 percent hit on capacity. Next.

One of the key innovations here was essentially hooking up – there's a computer lab inside of this building. It's the town central computer lab. That was connected via refrigerant to the hot water producing heat pumps for the radiant floor. So essentially, we'd get heat recovery off the computer lab cooling, and we'd dump it into the radiant floor. Next.

I mentioned load reduction. The existing boiler was a 515 MBH output hot water boiler. What got replaced in the heat pump was a heat plan of 168 MBH, so pretty significant reduction. Really attacking the load. It's about 800 square foot a ton, if those that are dialed into sizing on heat pumps or just general load for heating. The 117 listed in the parentheses is the derate condition. The heating load came out to about 125. We sized just a slight bit less than the design heat load, but we haven't had issues. Next.

Here's a little post EUI study. We looked at EUIs for Seattle libraries compared with the Sitka library. Pre and post are shown over to the right. Keep in mind the pre and post separated by about 4000 square feet, meaning we added an additional 4000 square feet. We got the building down to EUI of 32. This was a great example of both load reduction, heavy, deep green investment as well as use of heat pumps and fully decarb'ed. The grid in Sitka is 100 percent renewable. It's a hydrodam. So, this building is a zero emission building. Next.

I'll dive into some more. This is pre-remodel, post. You can see the red is the heating oil. That was eliminated from the load and replaced with the heat pump and with the load reduction, you can see the profile. We've got a bit of a heating spike. We've essentially eliminated a lot of the ventilation air heating in the off season just with the heat recovery ventilation system. So, it's a great measure. Next.

This is again, just summarize both the energy efficiency measure on the left and then the stacked pre and post retrofit. Again, there's 50 percent area increase in that chart. It's not showing apples to apples. But that's intentional. Next.

One key piece is what's called the Change Point Analysis, and this looks at the temperature dependent EUI bins. So, the red lines, the dotted red, shows you the lights and the non-temperature dependent. The sloped red, that's post, and you can see that slope is pretty shallow. That shows you the temperature dependent EUI which are associated with heating. Then the pre-case is the blue and the green. So, you can see both the base load came down green to dot red, as well as the shape and the slope of the temperature dependent bins, i.e. the heating load. This is a pretty interesting reveal on all the efforts that went into this design. Next.

Then just to wrap on some photos. This is the finished product. I showed you there was a flat roof before. The architects did a great job in creating this butterfly roof effect. It solved one of the key problems which was a leaky roof. Next.

Again, here's from the inside. One of the goals was to eliminate any exposed ductwork. We got pretty clever in how we were able to integrate the new HRV ventilation air into the space. There's also ceiling fans which help to destratify the high base spaces. Next.

Again, another view. There's pretty good daylighting in that clearer story. It comes through the framing. You can see that here. There's really nice views which you'll see in the next slide. Next.

That's the showcase. This is the best seat in the house per se, but a really gorgeous view out into the sound there, local sound of Sitka. Again, those are looking through triple pane windows. Very cozy, very warm radiant floor sitting beneath those seats. Next.

Again, you can see some of the daylighting up top, another view. That's good. Next.

So quick lessons learned. Specifying a separate subcontractor in bidding for a data collections system. That was a lesson learned. We had it integrated into the HVAC plans, and I think in a remote location like this, that was pretty difficult. That's one lesson. The other is existing building electrical infrastructure is typically pretty conservative. So, recommend exploring that existing capacity up front and understanding what – start at trying to understand what the electrical needs will be and potentially set goals like we had. We were really trying to stay within the existing transformer even with the expansion, and the aggressive load reduction was offsetting the transformer investment. So, I think that's a really interesting strategy and we've used that at other projects. The final piece is heat pumps do work in cold climates. You've just got to make sure you follow the manufacturer's requirements for colder climates: snow, and condensate, and defrost melt. You've got to manage that among other things. Next.

That's the end. Thank you. I guess I'll hand it over I guess back to Paul.

Paul Torcellini: Yeah, so thanks, Shawn. Just as a reminder to go to Slido.com and enter your questions. The # is DOE. Then look through the questions and upvote them. We will have some time for some Q&A at the end. But also, this is valuable input to us, so we understand where your barriers are and what you're thinking about heat pumps so we can better address these in the future as well. Over to you, David.

David Traxler: Thank you, Paul. My name is David Traxler. I am with Burns & McDonnell, and I specialize in building electrification, campus electrification, decarbonization and geo-exchange, or geothermal heating and cooling systems. This presentation is taking you on a project where we went from a steam boiler system to a geothermal system. Next.

So, the project is called the Madeira School. It's in McLean, Virginia which is northern Virginia on the banks of the Potomac River, just outside of Washington, D.C. These dorms were built around the 1930s with original steam boilers and steam radiators and no cooling in the building. Also, no insulation in the walls, and single pane windows. The problem was the administration wanted to reduce the amount of money they were paying for fuel oil. They also wanted to put cooling in these dormitories so that they could be more of a year-round use for summer camps and so that they could have air conditioning in the early fall, late summer when classes started, and late spring where it can be hot and humid in the D.C. area. So, the options we looked at were a central air-cooled chiller with piping going to the buildings, and central boilers with piping going to the buildings; central air cooled chiller with building installed boilers; and campus geothermal heating and cooling system. So, the owner chose to go with the geothermal heating and cooling system both for aesthetic reasons but also for sustainability reasons. So, I'll talk a little bit more about that. Next slide.

This is an artistic rendering of the Madeira School campus or part of it anyway. The buildings circled in red were the ones that were part of the retrofit project. They were mostly dormitory buildings but building 29 is also the Head Office building. Because the buildings are pretty packed together and the landscaping didn't have a significant amount of open areas, what we did is we put a geothermal field in a remote location in the parking lot. Then we had a vault, and we piped the geothermal water over to each building, and each building was able to have water to water heat pumps in the form of variable refrigerant flow or VRF, to heat and cool the buildings with water heated and cooled VRF system. The fan coils were placed in each dormitory in place of the radiators. It worked out fairly well. It was a one for one swap in most rooms. The outside air was treated with an energy recovery ventilator to the point where it could be heated or cooled with a traditional water source heat pump. These buildings all had very small mechanical rooms. They're basically just small boiler rooms and a small adjacent room where they used to store coal, and now they had fuel oil tanks. So, we were able to do all of this in their existing mechanical rooms with very limited disruption to the floor plate of the building. So, it was something that turned out really nice. Next slide.

This is a snip from one of the design documents showing on the lefthand side, the remote borefield, the valve vault, and the piping that went underground between the valve vault over to one of the dormitory buildings where it was manifolded together and pumped out through the district. That water would come back and would go back out to the borefields. Each building also had energy recovery within the building. So, it would recover the energy in the building first before it used the borefield for additional energy. Next slide.

These are some images of the finished product. The first one is the oval and courtyard in the center of campus. You can see that no one would know, myself included, that there are geothermal pipes running under the ground to these different buildings. The building on the right is the east dorm where the manifolding and the major mechanical equipment for the system was located to distribute out to the network. It was a tight fit, but it all fit inside existing mechanical space. Even the DOAS units fit in the existing mechanical space. It was very creative, but we made it work. In the bottom right is a dorm room showing the fan coil. The fan coil, you can't even hardly tell. It's a boxed in – they've made casings for the fan coils so they would be aesthetically pleasing and blend in well with the rest of the room. One thing we did look at during this retrofit was new windows, which they did. We also looked at insulating the existing building, but they decided against it. The benefit of the new windows was pretty substantial, and they needed to be replaced anyway. They were very old. The benefit of doing a building insulation was not as substantial. It would have been very difficult to do so they decided against it. Bottom left is one of the apartments. Each dorm building had an apartment where a resident would stay to make sure everything was okay. These had ducted air handlers that distributed air throughout the apartments. Next slide.

So, when I designed this project was about 2013, about ten years ago. VRF at the time was far advanced to most other heat pump systems because it had variable speed compressors. It was one of the few heat pumps that had that. They were able to produce higher temperatures. Very similar to why Ecotope chose to do them on their project. Now we have so many more options that have variable speed compressors and have high-rate efficiencies from small residential in the bottom left to the center which is a larger modular style heat pumps for more commercial buildings, or the far right, which looks a lot like an air cold chiller, but now there are air cold heat pumps up to over 200 tons. They're getting them so they can work in colder and colder climates and more and more applications. It's one of the places where the technology is rapidly improving. Next slide.

Water to water heat pumps, there were some questions in the Slido deck about what do we do if we have a large central system. There are now more and more options for water-to-water heat pumps also, from small systems, down to less than 10 tons, all the way up to greater than 2000 tons, and a whole lot in between. So, there are many, many options now for heat recovery and water-to-water heat pumps and air-to-water heat pump systems that people have available at their disposal if they're interested in electrifying their existing buildings or plans. We even do these projects – a lot of what I specialize in now is more of the large campus style or manufacturing facility electrification where they have a building – or campus where it seems nearly impossible to decarbonize it, but we're able to do a significant amount of decarbonization through things such as energy recovery, geothermal systems, and heat pumps. Next slide.

We want to help you create amazing. All of us here on the panel today really desire to help you meet your goals as building owners, as engineers, and as those who are interested in learning more about building electrification and sustainability and saving money. That's it for me. Back to Paul.

Paul Torcellini: Okay, thanks, David. So again, we're going to move to the question-and-answer portion of this. You can go to Slido.com. Enter #DOE. And we will address some of the questions that you've had. Certainly, the most popular question that has been addressed deals with refrigerants. The question is do heat pumps require refrigerant to provide heat and cooling? I would also bring out that this also applies for air conditioning systems in general. So even not thinking about heat pump transitions, most buildings have air conditioning and also get affected by this. The question is really how does EPA's refrigerant phaseout plan affect the viability of heat pump applications? Again, you have to also lump straight air conditioning into this as well. Any comments on that?

Kristy Walson: I'll make a quick comment, Paul. I think we're in a transition phase there too. This journey that we're on toward decarbonization. As you electrify your building, you take care of one greenhouse gas emissions source but add another with refrigerants potentially. So, it's just something to remain mindful of. As low GWP heat pumps do start to gain traction, start making mindful selections as you put heat pump equipment in your building and electrify your heating systems.

David Traxler: I agree, and they are making a big push – the HVAC industry – in moving to low global warming potential refrigerants and even natural refrigerants, which we didn't have available even five or six years ago. Now there are so many low global-warming potential refrigerants that are available today. There are more heat pump options so even if you – say you get a 20-ton package rooftop heat pump and it has a refrigerant that may not be as low as you want it to be with global warming, in 20 years when you replace that unit, you're probably going to have even a better option. So, you're not married to a refrigerant for the rest of your life if you chose to go with one that's a little bit higher today.

Shawn Oram: And I'll add a finishing comment there that some of the replacement refrigerants that are coming out do have different design criteria, so it's definitely something you want to pay attention to. Some of the A2L refrigerants coming out are a bit more flammable. So, the codes deal with those differently. Definitely pay attention to that. Even today when we did the library, this wasn't even a factor, but today, you do want to understand how the codes allow you to run refrigerant to piping specifically throughout the building. I think that's going to be a big somewhat disruption in the current design approach.

Paul Torcellini: Thanks, everybody. So, the next question, and David, I know you touched on it with your presentation, but really speak to the availability of all this equipment. David, even you just mentioned the natural refrigerant piece of it and some of the low GWP refrigerants. Just how available is this equipment, especially the cold weather equipment? Give us a little idea on even the size ranges. My attitude is you can always start somewhere even if you don't get the entire market all at once.

David Traxler: Yeah, it's never been more options. When it comes to domestic hot water, a huge push right now is to go to a CO_2 heat pump. CO_2 may sound scary, like we're trying to decarbonize, but a CO_2 heat pump has a global warming potential of 1. Our 410A has a global warming potential of over 1000. So, you're less than one one-thousandth of what you're currently working with today. That's been a huge progress for the domestic hot water, but even other large chillers now are coming out with heat pumps that range in size, operate in very cold temperatures and a variety of climates. The Department of Energy has been great with their Cold Climate Heat Pump Challenge that Kristy mentioned at the beginning where I just read that four more manufacturers have signed on to that as of recently. Just about every AC manufacturer in the United States is going to have a heat pump that can operate down to -20 degrees Fahrenheit. You're not going to have big concerns in most locations about cold climate heat pumps.

Kristy Walson: Yeah. And –

Paul Torcellini: Sorry. I was just going to mention –

Kristy Walson: It's okay.

Paul Torcellini: – if you want more information on the Cold Climate Heat Pump Challenge, just do that as a search. You will get literature from the manufacturers that are complying as well as the DOE information on that program. So yeah, go ahead, Kristy. Sorry.

Kristy Walson: Yeah, I just wanted to mention the availability of equipment is directly related to the age of your own equipment in a way, because if you have a five-year system, you're not going to want to replace it today with the equipment that's available today. So, you can plan out a roadmap that's like a today, tomorrow, and future scenario that accounts for some of this technology coming online in the next four to five years. So do your envelope upgrades and your optimization now and plan it into your capital budget, and then plan for the equipment replacement when it's ready to be replaced. I think you'll be in a really good spot, and you'll be at the right spot in technology too. So just wanted to mention that.

Paul Torcellini: Okay, so the next question that has come up, and it comes up several times in the questions, but really has to do with affordability and in this case, the question was specifically affordable to low-income residents. So that was more residential, but I think affordability across the board is a big deal. That's both in terms of the installation or a switchover cost, or maybe even a new construction. Does it cost more? But also, in terms of operation and ongoing costs. So, would the panel like to address that?

David Traxler: I'll address it, but I know everybody else has something to say about this also. Affordability sometimes is a mind shift. You really have to think about designing things in a different way than you used to. What I mean is like this. Say you have a bigger building, and it has a boiler chiller system with advanced control system. You have all the money for your chillers. You have your money for your boilers. You have your money for your ductwork, your controls and everything throughout the building, and all the piping also. So, if you're saying, "Oh, I just want to do a heat recovery chiller instead of a regular chiller." Well, the heat recovery chiller is probably going to cost you twice as much. So, you have to have a lot of usage out of that to be able to get it to pay back. So that's a pretty significant upfront cost, your capital costs. But if you're going into a brand-new building and you could design anything, maybe you just design it totally differently. You design it with distributed heat pumps or a water-to-water heat pump on every floor, or an air-to-water heat pump, or water source heat pumps on every floor. You minimize your control systems. You save money there. You distribute differently. You just have one water loop through your building instead of multiple hot and chilled waters, you just have a condensed water loop. So, you try to think of it holistically and differently. Now, say you have an apartment building and you used to have gas-fired split systems, heat pumps now, they can be almost a one for one swap. Especially with cold climate heat pumps where there's not going to be any additional electrical or very little. It's not going to be a big lift to be able to swap that out, or a significant cost impact. Now I'm sure the other people have stuff to say also, so I'll turn the time over to them.

Shawn Oram: I guess I'll add a plug. I think that affordability is a really important topic. This is a really important concept. Another perspective on this is you've got an existing gas-fired boiler in a building. The load reduction combined with the heat pump is definitely something that you'll want to explore. The idea is you're looking at end of life on your existing equipment and then you're looking at what's going to replace it. If you can do that end of life and also reduce the load, there's a tradeoff that happens in poorly insulated buildings where you're putting the money into conservation and then you're buying a much smaller heat pump and then you start to get closer to that affordability number. Then you get improvements in overall energy. That's been really successful in a lot of the existing building retrofits that we've done.

Paul Torcellini: I think there's some other pieces to it too in terms of even the level of service you're providing. If your comparison is that you're going to replace your gas system with a heat pump but you're also getting air conditioning and dehumidification that you didn't have before, that's an added level of service. How do you value that in the same calculation? Now you've got a piece of equipment that's doing multiple roles. How does the dehumidification help with mold mitigation and other health quality issues that that building may not have had before as well? I think there's a lot of pieces to that. The other one that I have seen, especially going away from old steam systems to heat pump systems, is a much higher level of comfort in the spaces. Instead of using your windows, opening your windows to control your comfort in the space, which often happens in a lot of these older steam buildings that you've actually done something that you can now maintain comfort in. I've seen that especially in schools where we've really improved the learning environment of those schools by controlling the temperatures properly compared to the temperature is somewhere between 70 and 95 degrees, and we don't really know what it's going to be. There's definitely other values that play into part here when we do this kind of work. Okay, I think we've got time for maybe one more question here. I just touched on the idea of steam, but the next question really has to do with your infrastructure is set up for 180-degree water. I could add steam to that list, and a lot of these heat pumps really are designed in the 140-degree range. Replacing all the coils is cost prohibitive. What do you do? How do you actually make that transition from either a steam or a hot water system?

Shawn Oram: I'll take a stab at that. This is a very common problem out there. I'll report on that. I think this is – we're at the crux of this being a major issue. There's a couple ways to think about it. Again, I'll bring up the load reduction. You essentially reduce the load to drive a cooler water temp, meaning the new heating load. That's one. That's one path to explore. Then the other side is to wait for technology. When I say wait for technology, I saw the CO_2 space heating heat pumps that are currently in play in Europe right now will be, I think, that next piece. The CO_2 stuff can make 170 – 180 degrees in big heat pumps. They are picky because they want cooler return water, so you have to set them up to cascade and get rid of all your heat, but that's again, another challenge.

David Traxler: To piggyback on what Shawn said, and I completely agree. Part of it also is sometimes buildings that had 180-degree water but they've never tried doing anything less than 180 degree water. So, testing to see how low the water temperature can go and still maintain temperature comfort in the building is a big part of it. It also is a function of how are you heating your building. If you're using hot water radiators, it's going to be tough. You're going to need hotter water, that 180-degree water. If you're using fan coils, you have a little bit more flexibility. But if you have large air handlers in your building with coils in your air handlers, sometimes buildings what they'll do, is they'll repurpose their chilled water coil into a dual temperature coil. At that point, you can get much more heat transfer out of a chilled water coil because it's much larger than a traditional hot water coil. So, each building is going to be a little bit different and should be investigated.

Paul Torcellini: I think one of the messages here is plan for it as you go along. If you're replacing a VAV box that's running at 180 degrees, and it needs replacing, it leaks or has failed in some way, replace it such that it could operate at that lower temperature. We did that with a school that was on steam, and gradually replaced the radiators. Designed the new radiators at 130, and eventually was able to convert the whole school over. Again, it took four years of planning and watching things fail to get to that point. So, some of it as you look at your building, what do you want your building to look like when it grows up? How do you make smart investments along the way, even if you're just repairing what's there to plan for some of that future discussion?

So, I think with that, we will wrap up the questions. Thank you everybody for your questions, and the panelists for your insight. This webinar is part of the '23-'24 Better Buildings Webinar Series, and as you can see, we have a great lineup of presentations through March. Visit the Better Buildings Solutions Center to learn more and register. Next up is on Tuesday, January 23rd. The webinar is the not so shocking shift towards industrial electrification. Join this webinar to learn from industry leaders about successful electrification strategies. Notice some similar themes here. Explore new tools that are available like the electrification assessment framework. We're also pleased to announce registration for the '24 Better Buildings, Better Plants Summit is now open. The Summit will be in Washington, D.C. from the 2nd through the 4th of April. In addition to engaging and interactive sessions, you can look for plenty of opportunities to network both with industry experts, peers, as well as a lot of the Better Buildings staff. So, you can explore the session tracks and book your accommodations on the Better Buildings Solutions Center. Next, the Better Buildings Climate Challenge Road Show. The Cleveland edition is here. So, watch it now and watch the

DOE energy experts visit several of our Better Buildings, Better Plants partners to see how these organizations are doing decarbonization, putting it into action. Cleveland Cliffs to the City of Cleveland, Cleveland Clinic, these industry leaders are making major headway in emissions reduction. So, I would encourage you to watch that.

With that, I'd like to again thank our panelists very much for taking the time to be with us today. Feel free to contact our presenters directly with additional questions or if we didn't get to your question during the question-and-answer period. I would encourage you to follow the Better Buildings Initiative on LinkedIn and Twitter for all the latest news. You can find our handles by the respective icons on the left hand of the slide. You'll also receive an email notice when today's recording slides and transcripts are available on the Better Buildings Solutions Center. Thank you everyone for joining today.

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