Hannah Debelius: Welcome, everybody. We are gonna give it just another moment as folks are logging in. Thanks for being here. *[Brief silence]* We have lots to get through, this morning, on a really popular topic, so we're gonna go ahead and jump in.

Welcome to today's Better Buildings webinar, a series is a chance to explore the topics, technologies, and trends that affect your organization, as well as efforts to accelerate energy efficiency. We are really glad to have you onboard today for a very popular topic for us, "The Heating System Balancing Act: Heat Pumps and Beyond." However, before we dive in, I do have a couple of housekeeping items, as usual.

The first is that today's webinar is recorded and will be archived on the Better Buildings Solutions Center. So, after the fact, you will get an e-mail with this recording you can share with colleagues, or if you have to step out and you miss a part. Additionally, everyone on the line today is in listen-only mode, so you're not able to unmute. However, if you have any tech issues with AV, you can use the Zoom Q&A chat function, and our team will help you out with that. And we'll be introducing another tool that you all can use to actually interact and engage with us for Q&A.

Next slide.

So my name is Hannah Debelius and I am with the Department of Energy, and I have the wonderful pleasure of working with our commercial partners through the Better Buildings Initiative. And for today's agenda –

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– we are gonna be diving in to all things heat pump and heating systems, which is great. And we will have a little bit of a level-set with one of our experts that I think many of you know well. We wanna get to know you all and your interests, through some polls. And then we have two other wonderful experts on the line who are gonna be jumping in with some more specifics around this. And as usual, we will also save time at the end for all of your questions. I know there's a ton on this topic and we have a pretty good turnout today.

The tool we're gonna be using –

Next.

– is Slido. So, I'm hoping you all can engage with us, and right now open up your phone or another browser and go to slido.com, and you're gonna put in the event code DOE. This is the tool we're gonna use for a couple of polls at the beginning, so we can learn a little bit more about our audience. And then also, this is what we're gonna be using for Q&A at the end.

So the whole time you're going through the webinar today, you can put in those questions. And you'll have the opportunity to add questions or you can also hit the little thumbs-up and up the questions that you see, so that we can try and address the questions that are most popular and most pertinent for our audience, first.

I'm gonna say this one more time, 'cause I want you to do it right now. Go to slido.com, enter the event code DOE, you can do this on your phone or another browser, and this is what we're gonna be using for all of our Q&A today.

All right, with that, we are gonna go into our polls. So, again slido.com, there's also instructions in the chat, and we're gonna launch our first poll. This is for you all to give us some feedback about where you are on this topic.

All right, so our first poll is, have you used heat pumps for HVAC systems? So I know we have a lot of owners and operators on the line today. We just wanna know, have you installed and used heat pumps in any of your properties. Most folks on the line are sometimes, which is great, that's a great place to be joining this webinar, because we'd love to get your questions from your real experience. But also, we are here to share a lot of information and then do a lot of level-setting, as well.

And about a third of people have not used them, but hopefully are at least thinking about it, and that's what brought you here with us today.

All right, we're gonna go ahead and launch the next poll, please. And again, if you're just joining us, you can go to slido.com, with event code DOE, in order to participate in this.

So your next poll is, what is your primary motivation to use heat pumps for HVAC systems? I know, from speaking to partners across Better Buildings, there are a lot of different motivators here. And sometimes those are coming from internal and the stakeholders are working with; sometimes it's about meeting external goals or just pursuing efficiency and cost savings. So, maybe not surprisingly to me, a lot of saving on costs is top of the list here, and next, meeting emissions targets. Maybe those are targets that are set externally; maybe it's something that your leadership has bene pursuing these public goals.

We certainly see folks pursuing this technology for a variety of targets. All right, and also a couple of people who are not using heat pumps, yet. Which we saw in the last poll, too.

All right, we are gonna go to our next poll, please, on slido.com. And this one is, what are the barriers to using heat pumps for your HVAC system? Hopefully, we're gonna be able to address some of these barriers on today's call with our experts.

So, yeah, upfront costs. Not surprisingly, if cost savings are one of your primary motivators, then the upfront costs of this technology would certainly be a barrier and something I think we can talk more about today. And a lot of folks may be just looking for more support and knowledge on it. Great, and if you put something else, hopefully, you'll be able to drop a question into the Q&A that's on slido.com, so that our experts can address your other barriers, if they're coming up for you.

All right, well, this is really helpful to me and our program, and also the experts on the line today, but with that, I wanna go ahead and jump into our content. So we will switch back to the slides.

We are very fortunate, today, to have three wonderful experts on the line. Paul Torcellini from NREL, who I know works directly with many of our partners and is a frequent flyer on our webinars. Jess Farber, one of our design and construction allies, is joining us from CMTA. And also, Stet Sanborn, who wears a lot of hats. He comes to us from Smith Group, but also, he is an LBNL affiliate working with some of our partners as a technical account manager.

We are gonna kick things off with Paul Torcellini, today.

Next slide.

So, Paul is the principal engineer for the Commercial Buildings Research Group and has been at NREL since 1994. He just actually celebrated his 30-year anniversary at NREL. So, Paul, step on up and take it away.

Paul Torcellini: Okay, thanks, Hannah.

Next slide.

I just wanna talk for a couple of minutes, just a little bit of level-setting, here. So, when we use the term "heat pump," it's really just moving heat from one location to another. In fact, that word, "pump," you can almost equate it to trying to pump water. And so, the first part is you need some place for that heat to come from, usually a cooler environment; it could be the air, a body of water, the ground. And you're going to pump that heat into a high temperature, usually something like your building.

Now, if you think about it, this is exactly the same as your air-conditioning system, except, in an air-conditioning system, the cooler area is inside the building and the hotter area is outside the building. And so, one of the things about heat pumps is we often talk about reversing the cycle from heating to cooling. In essence, what that's doing is moving the building from the high temperature to the low temperature. It's really trying to pull that heat from the air.

And there was a discussion on one of the polls about efficiency. Part of the reason for that is it's harder to extract that heat the colder it gets outside. And so, it's a matter of how cold is your climate and will your heat pump operate to what those design conditions are. There's definitely lots of heat pumps, today, that will work down to subzero values, and more and more coming every day. And they fall into a number of different types.

Ground-source heat pumps are gaining a lot of attention again, because of, you know, kind of the moderation of the ground and the temperature, easier to extract that heat. On mini-splits, we see a lot of residential and spot cooling applications and commercial. And then kind of more traditional ducted systems, as well as water-based systems, as well. And Stet and Jess will talk a little bit more about that, but part of this message is, is that it doesn't have to do it 100 percent of the time.

And so, some of what our discussion about balancing act is what else can I balance it with, especially if I've got an existing building.

Go to the next slide.

So, something else I wanna bring up is that this is a projection of what the utility grid of the future could look like. NREL, for years, has done these scenarios, and really, it kind of represents a surrogate for how much renewable energy is on the grid versus how much fossil energy is on the grid. And so, you know, when we look at this, even long-term, what we see is that there's always going to be some fossil fuel on the grid somewhere at some hour of the day. And, yeah, we've got some pretty big decreases in that, especially during daylight hours, especially in windy areas, you know, at nighttime, but these scenarios don't predict 100 percent renewable energy.

And so, we have to kind of put that in the balance of, like, what is the best path moving forward, you know, in a large scale.

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Another way to think about this is, and one of the terms we use is electrification, but if you look at a gas hot water heater in a typical 40-gallon hot water heater that runs on gas, you know, it takes about 126 units of gas to get 1 unit of hot water out. And we have to get that gas to the site, and that takes energy to move that gas, so at the end of the day, it's about 1.74 units. If I switch that gas hot water heater to an electric resistance hot water heater, it's pretty close to a 1-to-1 ratio in and out.

And if I then run it through the inefficiencies of a powerplant, even if I'm still using natural gas, now I've got about the same amount of natural gas consumed as just burning it with the gas hot water heater, and they're very close in many situations. Now, what that doesn't allow us to do is to have some of the variability in fuel types, such as using renewable energies with that. But the real message, here, is when I move to the heat pump down in the bottom one, that one unit of hot water out only needs about a third of a unit of electricity in. That then goes back up through the power system, and that clearly, even if natural gas is used, is the least-impact solution.

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So, some things I want you to look for as you listen to Jess and Stet is that, you know, what are you trying to achieve? Are you trying to achieve 100 percent solution? And what does 100 percent solution mean to you? You may find that the 80-20 rule applies, especially for existing buildings that already have gas infrastructure, that can take advantage of the biggest benefits of today's technology, while paving the way for future technologies coming along.

And just really strive for that balanced solution with that largest benefit, and that will get projects rolling faster and more confidence in the marketplace with the equipment. One of the places that we see that always is an issue is that, if you have to increase the electrical capacity, that is a common way to kill a project. I know that we're gonna have some discussion about oversize in heat pumps and what that means. In the past, it was really easy just to oversize boilers. We're gonna hear about why that's not necessarily a good idea with heat pumps.

And then another thing is, you already own a cooling system in most of these buildings, so how do you turn your cooling system into a heating system and reuse parts of the capital you already own.

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By the way, if you're interested, this was done by our design and construction allies, really designed for architects and for people looking at details *[audio cuts out]* the details technically. But this is a guide on improving the efficiency of heating systems and looking across the board at different options, you know, what the differences are between ground source and air source, a ton of good data in here. We're actually working on expanded content for this year, as well. And if you are a designer, you might be interested in our design and construction allies, both of which Jess and Stet actively participate in. And there's a URL listed, there, if you're interested in that effort.

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So, one last thing is that we're also working with manufacturers to really push, to make sure that you can buy products that you need. One that's currently going on is a rooftop challenge to create highly efficient rooftops, maximizing that heating capacity by not having much, if any, degradation of cold temperatures, based on a peak rating. Minimizing the peak demand of the equipment, to help with the electrical infrastructure *[audio cuts out]*, which that really becomes one of the key pieces. We're currently working with manufacturers for some field testing, next winter and the winter after. So, and if you want more information about that effort, there is a link for more data on that.

And I think that might be it, so, next slide? Yes, let's turn it over to Jess.

Hannah Debelius: And a reminder to everybody, you can hop onto slido.com with event code DOE, to submit questions at any time.

We are glad to have Jess on the line. As vice-president for CMTA, Jess Farber is an innovation leader with nearly three decades of experience in engineering and sustainability in a range of markets. So, Jess, thanks for being here and take it away.

Jess Farber: Thanks, Hannah, appreciate that. Yeah, don't forget to hop onto Slido. I see there's well over 700 participants on this, so I'm sure somebody has some questions, so feel free to throw those in there as we go through this.

So, I'm gonna transition a little bit and build upon what Paul talked about and get to more of the beyond discussion, here of heat pumps. So next slide, please?

So before we get into some of the technical details of heat pumps, I think what we wanna talk about here is the process. And so, when we talk about heat pumps, we're really getting into the root is we're trying to decarbonize or electrify and save utility, right? Those all came up in the themes early, so, how do we do that? Well, there's this four-step process that really applies to, whether it's a new building, whether it's a single existing building, whether it's a campus of buildings, the process is the process.

So we have to discover what's there, understand how buildings are performing, benchmark our buildings with baseline, to see how our buildings performing compare to a peer network, come up with ways to reduce energy. And we do that through screening and tuning of options of how we can cut energy and reduce energy, and that comes down to cost. If we think things cost too much, we need to save energy, so we're not buying so much stuff. So that comes down to that implementation of getting that done. So we gotta make sure something's affordable and pragmatic, so we can implement these solutions.

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So we always wanna define, again, every project is unique, every client's unique, but the themes tend to come around to be the same kind of goals and key drivers, with maybe some variances and nuances between. And I'm focused probably more on the existing building, 'cause that's where we see the biggest technical challenge in the market _____ what we're trying to do to decarbonize and electrify. So I think when we're looking at existing building stock, we really need to take an inventory of what we have, to understand what the lifecycle of current systems in place are.

Because when we think of things costing too much money, we need to really value-stack that and make sure we're, as we need to replace a rooftop unit, "Hey, let's put in a heat pump instead of a gas rooftop unit." And it shouldn't really cost you that much more to do those, provided you have infrastructure in place to do it. So it shouldn't be like a sticker shock completely, but think about those value-stacking pieces you can do as you look to replace equipment over time.

We're not trying to just flip a switch and suddenly it's all electric. We wanna do this over, you know, glide to the finish line, here, to get these things done, by eliminating those fossil fuels over a period of time. It just takes a lot of time and work to do it, but it can be done. And in existing buildings, we always deal with phasing and implementation, and this can be a cost-driver, as well, so we really need to be thinking about how do these systems get surgically inserted into these buildings, to really minimize phasing and implementation disruption that comes along with that.

So be thinking about those things, and those are huge cost drivers, if you're not careful with that. We wanna make sure we're not impacting program needs. These systems do typically need to go somewhere, we have to find space for'em, so we wanna make sure that we're thinking about the building program and what we're doing and impacting that program, whether it's a school or a lab or office building, but whatever, we need to make sure we're keeping that in mind. And then, again, rightsizing of building systems and programs, we can't say that enough.

I think the cost comes into play so many times where things have become oversized, not for intentional, it just happens, right? So we need to be thinking about what are we doing to size these systems properly, holistically looking at the building envelope, infiltration, all kinds of other features. Just don't do a one-for-one replacement; that is generally not gonna be what you need to do. Loads have dropped tremendously in commercial settings with lights and equipment, so the loads we used to see when I started in this business 30 years ago are wildly different than they are today.

Lighting loads are massively different, PC loads are massively different. So, don't do a one-to-one swapo-chango; that's not gonna get you where you need to go.

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So the challenges and opportunities, I think a lot of the polls kind of reflected this, access to capital is always an issue. There's no project I run into that doesn't have an issue with challenging and financing, so we understand that. So, the age of infrastructure is gonna be an issue we need to deal with, you know, nobody wants to go and throw away brand-new equipment, right? So let's don't do that; let's phase it over time and do it in a way that's smart. And again, we gotta find a place to put this equipment.

There are some limitations for air-source technologies and some climate zones. Just check local listings about what you can do and what you can't do and where you are. Any solution should consider energy recovery and you wanna be looking to reduce energy any time we implement these strategies. Reducing loads and energy will have it translate it to cost, and so those are the things we have to be looking for. And what we see is, over time, everybody has these aspirational goals.

If you look on the orange dot slide from left to right, we have all these exciting goals and just things get in the way. We get into design, we find roadblocks, so we lose some of our features. We get into cost and estimating and, gosh, we can't do this now. In the construction, there's roadblocks, operations, and we're lucky if we can get a building done in the end. But they're being done and there's plenty of'em out there, examples and case studies you can go to of how to make this work.

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And as I said earlier, it's not a light switch. We're not trying to just throw it all, go all in and do it at once. As Paul mentioned, you know, if you wanna look at about an 80 percent decarb reduction, you can probably invest half the money you thought you needed to. So, there's tremendous amounts of practical solutions in that lower piece of the pie, and what you can do is start getting baby steps towards decarbonization, towards electrification with heat pump technology. So those are kind of just some things to be thinking about.

And again, the value stacking is so important, back to this point, where if I need to replace a rooftop or I need to replace a boiler, let's think about that before we jump off and start budgeting money for it. Let's come up with a plan to how we can do this over time. So getting a plan put in place will help you chip away at this, over a period of time.

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So, Paul mentioned heat pumps. We use air-source heat pumps a lot, we use geothermal heat pumps a lot, and every project really probably can use these in any combination that you wanna do. There are some cost benefits to looking at hybrid approaches, to where maybe you can marry two of those system types together, to help mitigate some of the first cost premiums. We see pretty large variations in first costs for geothermal around the country that have to be dealt with, right? We can't just blindly go into this saying we can afford to do this 'cause we have all the money in the world; it doesn't work that way. So, we do know there are some hybrid approaches that go, to where you can look, again, stepping towards electrification.

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And Paul mentioned this, as well, earlier. There's nothing wrong with keeping some of your existing fossil fuels, if you have them there, for a period of time. So we call this that interim hybrid approach. So we have a lot of facilities where there's a lot of steam infrastructure in place, there's a lot of natural gas infrastructure in place, and those are the hardest things to undo and redo, to get to full electrification with those systems, right? That's really where the technical challenge comes into. You know, we did a study for a hospital here in Boston, and that was the biggest part of it was we have to go replace all of this infrastructure just to even think about getting low-temp hot water.

Over time, those technologies will improve and get better, so part of it is, let's wait for technology to catch up to our problem, instead of us trying to just tear this place apart and redoing it. So, we need to be a little bit pragmatic about our approach to doing some of these things. So there's nothing to say we can't keep fossil fuels, either to help for backup, like, if something were to fail, I have that steam and natural gas sources there to help me. Or maybe we keep it there for the extreme temperature conditions, to when it's, you know, my systems carry me most of the way.

But then when it gets below ten degrees or whatever, we have to fire those things up to help us for those really few, if you think about it, there's very few hours out of the year, in most climates, we are doing that anyways. So, there's nothing wrong with that kind of hybrid thought process, and again, it's a cost thing. It really helps you mitigate costs and get you baby steps from Point A to Point B and over a 20-year period of time. So just thinking about that a little bit different perspective might help you get some things accomplished.

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And so, we always focus on energy reduction, and I think when we're looking to electrify, energy reduction and reducing of the consumption and the equipment that's doing all of that will go a long way to helping you reduce cost. So we need to invest in strategies that help reduce costs, whether it is, you know, just typical energy savings measures. Like, you'd go through your building and do an ASHRAE Level One, Two, Three audit to come up with ideas to reduce energy. Those are all steps you need to take, that you're probably doing already anyway, that are important to stairstep down in energy consumption.

Looking at your operations, obviously, you know, shut something off if it doesn't need to be on there, obvious things, but they go a long way, you'd be surprised. I'm surprised, every time I go in the building, of, sometimes, things that aren't under the control that maybe somebody thought they were. And we do that through a lot of aggressive, what I call aggressive retro-conditioning, really getting in down and dirty into the weeds, and figuring out how these systems work and how we're gonna make them get better. So there's plenty of tools in the toolbox to go about doing this, so, keep those in mind.

And again, it's not just go put in heat pumps and call it a day; there's a lot of things that are available to you to tackle these problems.

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So that's why we always go back to, one rule remains constant. You always wanna look to first reduce that demand before you jump off and do anything crazy.

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Which would be, then, you start to look at generating supplies. So if you're looking to put photovoltaic panels or other renewable energy sources in your building, reduce the demand, first, and then buy less PV to do that, right? So that makes sense, so keep that in mind when you're doing these things, as well.

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A little bit of a change in gears, here. I think, you know, again, whether you're a – this is more of a campus discussion or maybe a building owner that has a portfolio scale. We have a lot of clients that have buildings all over the country, or there's maybe a higher education campus that has a lot of buildings kind of grouped together. It's really important that you understand how your buildings are performing, and really, even, to deeper-dive in that, how your buildings are performing related to how they consume steam and natural gas.

And so, that's where we look to benchmark our buildings, so then you know where the problem childs are and how you're gonna go fix those. So put your time and effort into the top emitters on your campus or in your buildings, to help reduce it. So don't waste your time on the far-righthand side of the scale. There may be some things you need to do there, but when you come to prioritizing what you need to do, focus your time where you can get the biggest bang for your buck. And that really helps you organize getting that dataset.

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And if you go to all this trouble of doing all these great things and you decarbonize, you put heat pumps in and you think you're saving energy, you'd better be measuring and verifying that you did that. So we do this a lot on projects where we get the monthly utility bills, we track how the building or buildings have performed, we benchmark that against how we anticipated it to perform through energy modeling, and we check that monthly. And you need to check it monthly, so that you know, if something's gone wrong, you can fix it.

You don't wanna wait a year to look back and this and go, "Oh, my gosh, this didn't give me the results I was expecting to have happen here." So it's important that you do that measurement and verification. You can typically do that with your own forces, to do that from a facilities perspective. So, it's important to take that step and do that, so that you know that you've gotten the results that you've sold to your leadership, that you said you were gonna make this happen and, boom, here it is, you made it happen. So it's good to have that data.

And with that –

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– I'll say thank you. And we're gonna hold Q&A to the end, so again, load up Slido, if you would, and I'll let Hannah take it from here. Thank you.

Hannah Debelius: Great. Thanks so much, Jess. Not only did you pitch Slido *[laughter] [crosstalk]*.

Jess Farber: *[Crosstalk]* for Slido *[crosstalk]*.

Hannah Debelius: Yeah. *[Laughs]* And also appreciate you including so much strategy, there, and prioritization. I am pleased to also say that a lot of the strategy items you pulled in are also incorporated in our missions reduction planning framework, which we include as a resource for Better Buildings.

Speaking of resources, some of the questions we have in Slido are about links or resources. In addition to us recording and sending out the slides and recording for this webinar, we do also have a resource sheet that'll go with that, so we'd be able to get all those links all in one place with this webinar.

So with that, our final speaker today before we get into Q&A, is Stet Sanborn. He is vice-president and mechanical discipline leader for Smith Group's San Francisco office, and leads Smith Group's national climate impact and performance analytics team. We're also very glad to have him as part of our technical account manager team for the Better Climate Challenge. So Stet, go ahead and take it away.

Stet Sanborn: Thanks, Hannah. So we can just go ahead and jump in. So we can skip this intro slide, go to the next one.

So I'm looking at a ton of questions in the Slido, and these are all questions that we get all the time, so this is really great. We'll try to get in and start getting responses in there. But really, we wanna change, I think as Jess mentioned, also, we wanna change the dialogue around just randomly throwing heat pumps at projects, to really making sure that we're doing so in a beneficial way. And that could come down to operational costs, utility cost, O&M, infrastructure upgrades, all sorts of things.

There's a ton of barriers that we see all the time when we're talking about especially retrofits. New buildings are a little bit easier to deal with, but retrofits tend to be the challenge that a lot of you come to us with questions about.

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And I wanna really focus on making sure that we're talking about beneficial heat-pumpification or electrification, whatever the words that you're choosing are. We wanna make sure that we're providing a benefit and we're not just doing one-for-one swaps. 'Cause a lot of the questions that I'm seeing in Slido actually are a result of doing one-for-one swaps, where we are just throwing a random heat pump at the problem, and then we're wondering why the operational costs might not be so good or the coefficient and performance might not be good. So we don't wanna focus on just ripping out a boiler and throwing in an equally-sized heat pump.

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The responses that you guys gave, earlier, in terms of the barriers to adoption of heat pumps are eerily similar to ones from a multiday heat pump design workshop that I led, recently. But cost of install was the number one barrier for folks that I was working with, and it echoes a lot of what you guys said. So I'm gonna go through some strategies of how to break down both that install cost, the operational cost, and really target the coefficient of performance that you need in order to actually achieve better ongoing utility costs compared to natural gas.

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So let's get into it. So we're ready off to the race, so how do we approach the problem.

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I think the thing I cannot stress enough is that the worst thing you could possibly do for your project is walk down into your boiler room, look at the size, the nameplate size, and capacity of your boiler, and just pick a heat pump that matches that. I can guarantee your project will be over budget, you're likely gonna run into electrical infrastructure upgrade constraints that are gonna just blow your budget out of the water. And you're also gonna likely end up with really poor performance. So, let's talk about why, in the next slide.

So, this is from a recent survey of almost 260 buildings that the

Center for the Built Environment completed. This curve represents, on the y-axis or the left side, the percent of operating hours that the boiler, existing boiler, these are all boilers, were operating, compared to, on the x-axis, the normalized heating load compared to the max size of the equipment. And if you click next, what we're gonna see, from all those datasets, and these are real-life buildings operating in the real-world, is that 90 percent of the hours, the building was actually operating at less than 50 percent of that nameplate capacity on the boiler.

I'm gonna say that again. Ninety percent of hours, we are operating at less than half of the design load of that boiler *[audio cuts out]*. And so, those hours, you know, those last few hours right at the top on the righthand side, if you were to apply a heat pump to those hours, you're buying a pretty expensive equipment that's almost never going to run. And so, this is the first barrier that we wanna overcome in our project.

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This is similar data, pulled from another campus project that one of my colleagues, Kent Person at P2S, did as part of their survey work. And for them, and this is probably a more mild climate than the first dataset, but 80 percent of hours were at less than 25 percent of the load. As Jess mentioned earlier, a lot of these existing buildings, it was really cheap to put in an oversized boiler. It is not cheap to put in an oversized heat pump.

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And so, when I start to break down some of those bin hours, you know, all those hours on the far-left, it's sitting at part load. And so, one of the first strategies that you can do to reduce first cost is focus on a hybrid system. If you already have gas boilers in place, you can use those to trim out those last few hours of peak load, the worst weather outside, super cold, polar vortex, all the things that everyone tells me are the most horrible things on their projects and only they see. Focus on those first few buckets of getting the heat pump to cover 80, 90 percent of those operating hours, and perhaps let, rather than installing very expensive heat pumps for only a few hours, let your system, the existing system boilers, pick up that load.

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So, as Jess mentioned, we wanna focus on efficiency first. You know, I see a lot of chat in Slido about, "Well, I don't think my building, a heat pump's gonna work." Well, it might not be the right heat pump for your project, but I guarantee you there is a heat pump that could likely work just fine for your project. Before we throw the heat pump at it, what other efficiency measures can you deploy? Envelope upgrades are a key one in cold climates, especially focusing on infiltration and leakage. We waste a lot of energy just letting heat leave our buildings.

So, phasing this work as part of an envelope upgrade will also help you downsize those heat pumps. So, part of that then leads into phasing of the work; we don't have to do everything all at once. But the most important thing is at the bottom, and I wanna stress this a lot, is collect some data, so that your engineering team can actually help do a better design. If you can give us a year's worth of hourly heating use, so, throwing a little BTU meter on your boiler and running that for a year, I can guarantee you your engineering team will come up with a better solution than just throwing an oversized heat pump into your project that's likely gonna have some turndown issues and capacity challenges.

Next slide?

One of the resources that's in the link, through the Better Climate Challenge and Better Buildings Challenge, for the Solution Center, we have a decarbonizing audit guide in that resources. And it goes through a pretty exhaustive list of what kind of data can be used to help us design a better system for your project. And once you come up with all those options or the dataset, then your design team can give you, actually, a series of options. Some of them could be full heat pump solutions, some could be hybrid, and I'll talk a little bit later about the benefits of adding thermal storage into your heat pump options, to overcome some of those peak loads.

Next slide?

So this is what one of those graphs might look like. So this represents a full year worth of hourly data. On the x-axis, you can see it from left to right, January through December. On the y-axis, we have two things shown simultaneously. The upper part that's blue, those are the hourly cooling loads, and the bottom part are the hourly heating loads. So if I just looked at this graph, I'd say, "Well, this is probably in a mid-mild climate, you know, it gets awfully hot in the summer, but still has a lot of internal loads in the winter."

So this could be your IT equipment, it could be a lot – and I do know this building was an office building, and so there's quite a bit of actual cooling load that still occurs in the wintertime that's normally achieved through economizer. But I'm gonna talk about why we might wanna turn that economizer off. So in this case, we have a chiller that's already existing and they've got a boiler that's existing. And if I was asked to heat-pumpify this project, here are some of the strategies I might go through.

Next slide?

What I see, too often, is folks just rip out the boiler and throw in a heat pump. And the very scientific number of electrical diagrams on the left is just showing that you're likely gonna double your connected load, connected electrical load, if you just throw out your boiler and add a separate set of heat pumps just to cover your heating load. And there's a much smarter way to approach a load profile like this, and we can see that on the next slide.

So this is one of those options where, now I'm looking at simultaneous heating and cooling, and Jess mentioned this and Paul mentioned this, is heat recovery. If instead of focusing on replacing your boiler with a heat pump you actually, at end of life of your chiller, look at replacing your standard chiller with a heat recovery chiller, that chiller, normally, during cooling mode, is dumping lots of heat to a cooling tower, or directly outside if it's an air-cooled chiller, just dumping that heat in the environment. You're spending a lot of money to get rid of heat, when at the same time, you actually want to provide heat.

So a heat recovery chiller can do both things at once, it's a really amazing technology to use, and that whole yellow zone are hours where that simultaneous heating and cooling is giving your free heat. So all the folks that are, like, "Oh, my heat pump's not efficient enough. I can't use a heat pump on my project," start focusing on heat recovery chiller or heat recovery heat pumps. Because you're gonna be getting, essentially, free heat off of the waste coming from your cooling side, which can offset a tremendous number of hours of heating load.

And so notice the area that's left in red is really small. That might be able to be picked up with your existing boiler, a tiny little pony boiler, or, in the next option, a very small heat pump.

Go to the next slide?

So, if you are doing a full plant replacement, it might be a great opportunity to switch from a traditional split chiller plus boiler and actually look at what we call 4-pipe heat recovery heat pump. These are air-cooled pieces of equipment or air-heated pieces of equipment that can do both cooling, heating, and simultaneous heating and cooling at the same time. So all of those hours are covered with a single piece of equipment. This is especially important for those of you that have space constraints.

First cost constraints, it's a single set of equipment that could do both cycles, and so they're running year-round. And again, this is a way to focus on lower connected load on the electrical side, because you're asking one piece of equipment to do both things simultaneously.

Next?

And one of our just absolute favorite systems, if you ask folks on our team, especially for folks in northern climates, geothermal heat pumps are an amazing resource to ride out that extreme weather event. Because the ground temperature is gonna change much more slowly than the outside air temperature, you have a chance to, on an annual basis, balance your load between summertime cooling, wintertime heating. I can give you an anecdote that, when I designed my parents' house more than 14 years ago now, it's an all-electrical home in Climate Zone 7, the very northern tip of Minnesota where nobody should actually live. So cold. So cold.

It has a three-ton ground-source heat pump and rides out winter just fine. And last year, the average annual temperature up there was 12 degree below 0, through the winter months. The ground-source heat pump rode through that absolutely no problem.

Next slide?

And it would be remiss, if anybody knows me or works with me, you know that I have an obsession with pairing heat pumps with thermal storage, for a whole host of reasons. But thermal storage can show up in a lot of different ways, between water, phase-change materials, even brick, ceramic bricks, there's a whole host of ways that we could store excess renewable energy for later use, and storage and heat pumps are just an absolute beautiful thing to marry together.

Next slide?

And I say that because a lot of times when we look at profiles like this or other buildings, we're bumping up against an electrical capacity issue. And folks are asking, "Well, how can I still decarbonize even if I don't have enough capacity to meet those short incremental peak loads?" And that's where thermal storage comes into play. There was a really great question in the Slido about houses of worship. I actually did a retrofit of a worship house that was trying to do a heat pump adoption, and their loads were not at all like a commercial office building.

They all peaked on Sunday morning as they tried to warm up this massive sanctuary, and they had a massive boiler to do that and it ran for four hours every week. Instead, we paired a small heat pump with a large storage tank, and actually used that storage volume to meet that four-hour peak load, and then used several days to recharge the tank. And so, no electrical capacity upgrade required, and rather, let that tank of water do the work for that short duration load.

Next.

So this is an example, if you are running into an electrical service limit on your project, which typically occurs on the heating side. This particular project doesn't really have one on the cooling side, 'cause that chiller was already in place. But if on the heating side we're running into that limit, you can see that those red lines get past that electrical limit only for a few hours. That's a beautiful place for storage to be paired with your heat pump, because all those hours that you're not crossing that green line, your heat pump is charging that tank. And then for the few hours that you go past, the heat pump plus the tank can operate in parallel and provide that peak load, so it's a really great solution.

Next slide?

So, when you're pairing heat pumps with thermal energy storage, you can buy a lot less heat pump and let the storage ride those peaks much more cost-effectively. We had a project where the storage was cheaper than the heat pump module, so we added more storage. It also lets your heat pump run when it really wants to. Smaller connected load means less infrastructure upgrades, which means lower first cost. In addition, all those nonpeak days, like think of your shoulder seasons, you've got a lot of grid flexibility.

So for those of you on a time-of-use meter where your power might be really expensive or you pay really high demand charges, thermal storage allows you to shift your load to match that profile, so you can save even more money. So instead of a spark gap of electricity being three to five times more expensive than gas, you can shift your load until that cost is much more on par during off hours. So thermal storage plus heat pumps are perhaps the most beautiful thing that you could possibly put on your project.

Next slide.

So I think I'm gonna hand it back to Hannah and talk a little bit about some of the other resources that are in the Better Buildings Solutions Center, and look forward to all your questions.

Hannah Debelius: Great, thank you so much, Stet. I love hearing you talk about heat pumps, because your enthusiasm for heat pumps, especially with thermal storage, is truly palpable. And I even learned something new, this time, which is that you designed your parents' house. *[Laughs]*

Stet Sanborn: I did. The downside of being an architect and a mechanical engineer is that your parents have high expectations. *[Laughs]*

Hannah Debelius: I love that. I only get the texts of, "Is this recyclable?" *[Laughter]* Excellent. Well, thank you so much to Stet and Jess and Paul. I am gonna invite all of our experts to come back on. As a reminder, we will be sending out the recording, the slides, and also, this additional resources sheet, which will include links that all of our folks reference.

We are gonna be drawing the questions from Slido, and we have almost 70 questions, which is great. We'll get through as many as we can. It is not too late to add questions or also upvote the questions that are there. So if you hit the little thumbs-up, that does actually move things up the queue, and so we're more likely to be able to address those.

All right, so, I'm going to hop over to our Q&A, again, slido.com with event code DOE, if you wanna follow along or add. The first question is one that I have heard you all talk about, but it continues to come up, so let's address it.

The question is, what do you think of the studies that show heat pumps are not cost-effective in cold climates? And Stet, I'm gonna go back to you, because you are top of mind for this for me.

Stet Sanborn: So, there's a lot of things. There might be heat pumps that are not cost-effective in cold climates. I always try to share with folks that not all heat pumps are created equal, not all heat pumps have been designed equally, and there's been a ton of change, even within the technology, over the last even three to five years. So if you're talking about a heat pump that was deployed a decade ago, yeah, I bet it's not running that efficient. Right now in cold climates, some of the key words that you wanna look for, if you're looking especially at air-source heat pumps, you wanna make sure it has inverter technology, so that the compressor is really being run to match the load profile. Way more efficient.

And also, and this one's really sexy, but enhanced vapor injection is EVI. You'll see a little tag in the specification. What that essentially does is adds another heat exchanger inside the heat pump, and it's doing a little secondary refrigerant and it lets the refrigerant that's in your outside condensing unit get extra-cold. So if you guys have five layers on today and you're seeing the polar vortex that's wiping through the East Coast, today is a day that enhance vapor injection is still providing an amazing amount of heat, even from an air-source heat pump.

And then as Jess mentioned, ground-source heat pumps, they don't care how cold it is outside; they are running pulling heat out of the ground. So it's really about matching the technology with your load profile and still focusing on efficiency. I cannot stress efficiency enough, for matching load profiles.

Paul Torcellini: I often to go back to even the graphic that Stet had with the, you know, installing a heat pump that never runs is not gonna be cost-effective.

Stet Sanborn: *[Crosstalk]* very expensive. *[Laughs]*

Paul Torcellini: And so that goes back to, that first 25 percent of capacity might be really cost-effective, but if you did the study based on 4 heat pumps being used in that situation, it's probably no way, you know, it would work. The other thing, and it kind of goes to the next question, a lot of this is very dependent on what your utility rates are, what your demand charges look like, what kind of time of day rates you have, where you're located and how that compares with natural gas, if you have natural gas available. I mean, I have people that tell me, "Oh, I don't have natural gas available and I may use electric resistance."

Well, that doesn't make sense compared to using a heat pump, you know, from a cost point of view. So, really study what those rates are. I've also seen a lot of analyses where the COPs don't get added in on the heating side, you know, toward the electric rate. And so, in essence, they're doing the comparison with electric resistance. So, make sure that that analysis makes sense, and if it doesn't, ask for a second opinion on it.

The other piece on that is that, especially if you're generating renewables onsite, you can almost always generate renewables onsite far cheaper than buying that grid power. And if you're going to make a commitment to increase your electrical load, often, paired with PV at the same time makes a lot of sense. Because now you're buying or you have a use for a long-term asset that you own, both sides, the production side and the consumption. And that is another way to get that cost down even as low as, say, seven or eight cents a kilowatt hour, over a long time period. And that can also change the economic dynamic.

Hannah Debelius: Thanks. And I think, Paul, I'm gonna keep you in the hotseat, since you already are sliding into the next question that we have here; it's related. Which is, "Even though heat pumps are more efficient than gas, electricity is about four to five times more expensive for the same amount of energy versus gas, in my region. Do you have ideas for overcoming this barrier?"

Paul Torcellini: Like I said, you know, at four to five times, I'd ask is that on a per BTU basis, or what does that actually mean? Because if you apply, especially for a ground-source system which have COPs in that same four to five range, now you're at cost parity, operationally. If you can generate the electricity onsite, you're buying your own power cheaper than you're buying it off the utility. So again, you know, there are gonna be places where that is so, but I would definitely sharpen my pencil and take another look at these numbers. The other thing I've learned is that these numbers change wildly, you know, what was so six months ago is not so today, on both sides of the fence.

Jess Farber: And if I can add to that, I think we've got some case studies where we've done some, you know, as part of major renovation projects, you have a lot more flexibility in what you can deploy in terms of your features to update buildings. And so, we have several buildings, school buildings, for example, that were built in the '50s, that went through total renewal. If you go back and look, they hardly any air-conditioning when we started, it was all hot water boilers feeding to radiators or unit ventilators or whatever it was, just garbage systems that needed to be thrown away.

And the buildings used, even, and then converted to all geothermal HVAC with dedicated outside air, all the whole nine yards you would do in modern buildings. And the building energy dollars are a third of what it was before we started, by adding all of this stuff to the building. Obviously, a major investment was made in the building in terms of renewal of that building, but again, I think every case is gonna be different, and just think about it and, you know, maybe what you can deploy to help reduce those costs and energy at the same time.

Stet Sanborn: And I would just add in, Hannah, that, to echo Paul and Jess' points, heat pumps plus storage and onsite solar, if you have the space and footprint for it, are a really great pairing. When you're investing in solar, you're locking in your utility costs for the duration of that life and that equipment, effectively. You're saying, "Goodbye, inflation. Goodbye, rising utility costs over time." You've locked in your cost to power, and so, that gives you long-term flexibility, it gives you long-term certainty in costs, for operations.

And when you generate that power onsite, you're giving your utility folks, your inhouse facilities folks, a lot of certainty of how your buildings are gonna cost long-term. For our clients, that's a huge difference. We have a campus that we are working on where their costs for heating, through the winter months, jumped by three x because of a change in gas prices overnight. That kind of certainty, by doing onsite renewables, you can flatten that out. So, risk and resilience is also a huge factor when playing a part.

So, day-one costs for onsite generation plus heat pumps will likely save you money. Long-term, it gives you way more certainty of where your price point is gonna sit, regardless of what craziness is happening in the world around you.

Paul Torcellini: I think that's a great point, Stet, is the idea that, when you buy in energy efficiency strategies, I mean, even onsite renewables, you are buying your own energy futures. And those energy futures are yours, they're guaranteed, those rate of returns are guaranteed. I mean, I did a PPA on a school ten years ago, and they thought they were getting ripped off at eight cents a kilowatt hour. Now the utility rate is 35 cents to the kilowatt hour and they're, like, you know –

Stet Sanborn: And they're just swimming in money, just, like. *[Laughs]*

Paul Torcellini: Oh, yeah, literally. Maybe not quite, but, you know, every year that that price goes up, they're just making more money, you know, is one way to look at it. Or they hedged a really good investment upfront.

Hannah Debelius: *[Audio cuts out]* hearing lots of reasons to prioritize efficiency and renewables. *[Laughs]* I'm liking that.

We're gonna move on to the next question, here, and I believe I will maybe start with Jess on this one. Which is, "Why are air-to-water heat pumps not more common?" And Jess, if I could ask you to, for our audience, define air-to-water heat pump versus the alternative, as well, that would be really helpful.

Jess Farber: Yeah, I mean, I think Paul mentioned, earlier, air-to-water heat pump, it's just, think of your air-conditioning system in your house. It's got an outdoor unit that has the compressor in it, and in the summertime, that's blowing hot air, getting it from your house and putting it outside. So effectively, we're just flipflopping those systems, right? So we're taking the air from outdoors and generating heat from it, so what happens with those systems is that, obviously, the colder it gets, the harder it is for equipment to extract the heat from that outside air.

So you see a large variation in efficiency and capacity with air-source heat pumps, because it just swings along with the outside air temperature. When you compare that to ground-source technology or geothermal or closed-loop heat pumps, the ground's pretty constant in temperature, so you're always working against a pretty constant temperature, to push BTUs into and pull BTUs out of. And so, that's really the fundamental physics between the two of why ground-source is so much more efficient than air-source.

And, you know, we see a lot of air-source heat pumps; it really depends on where you are. And there are some markets that have more than others; it really is, there's a variation we see all over the United States with it. And I think Stet's point was spot on, when you say heat pump, it's a gazillion options, there's so many different ways to do this. So don't feel like, when you say heat pump, you know, it's not this silly little wall unit you're putting on the wall with an outdoor unit. And so, there are some that are much more sophisticated, and we see those.

We have some schools we've designed up here in the northeast that are using four-pipe air-source heat pump systems, we're making hot water, we're making chilled water, using the air. You have to size all of this stuff the right way, you know, this is what you have to – so when it comes to engineering, getting it sized correctly is really paramount. Again, we spend a lot of time and engineering doing that. So, does that answer the question, you think, Hannah? Okay.

Paul Farber: So, Hannah, just quickly on that, when you pull apart the words, when it says "air-to-water heat pump," the first word, "air," is where the energy is extracted from on the outside of the building. The second one is, what kind of fluid or air is that putting into it. So when it says an air-to-water heat pump, it's extracting heat from the air, usually outdoor air, and in this case, it's putting it into water. So a heat pump hot water heater, by definition, would be air to water.

And there's actually a very common type. So you can buy these little units that sit outside, say, your house, they are air-to-water heat pumps, they will generate lots of hot water from cold air, and then transfer that heat into a storage tank in your building for when you take a shower, or use it for some other heating use. The beauty of water is, most of the engineers, when you talk about water, they love water, because it's easy to control, it's easy to move, you get very, very good temperature control out of it.

And so, the idea is that, and as Jess just mentioned, you move towards putting pipes in buildings that carry hot water and cold water, that then go to different rooms to provide heating and-or cooling as it's needed. The other advantage of that is that all the refrigerant is contained in a central usually outdoor unit.

Jess Farber: So the only limitations, or I guess limitations that we see, it's obviously easy – I'd say easy tongue-in-cheek – it's easy to deploy that technology in new construction, 'cause you can control every single variable you're dealing with in the building. So when you're working with existing buildings, you're going to be, depending on what infrastructure you're trying to connect to, you'll be limited to what an air-to-water heat pump can do in terms of hot water temperature production, depending on the style of heat pump you buy.

So there are some limitations in today's market with some of those. You can still accomplish it, and again, you can get most of the way there by doing that. So just think about, you know, how many buildings you have to have air-cooled chillers sitting outside that cool the building. Well, just like Paul mentioned here, it's the same thing, you just turn it in reverse and it makes hot water. So the equipment's the same, it just has to be sized and operated a little bit different.

Stet Sanborn: And Hannah, I know that we're closing up, but I have to put a shot-out for the decarb audit scope of work that came out of Better Buildings Solutions Center. It actually goes in and has a really detailed process that you can show on how to get an auditor to come into your building and do a wintertime stress test on your heating system, to essentially find that sweet spot of how low you can go with that water temperature and have your building still meet its heating load. The lower you can go in that supply water, you might be able to double the efficiency of the heat pump in cold climates, for its performance.

If you can get down into that 130-140 range, so many more options. So doing that investigation work on your building is critical to hitting those efficiencies that you really want. And the guide that we can provide a link for actually has a step-by-step procedure that you can share with your facilities folks.

Jess Farber: Don't let the tail wag the dog when you do that, because what you're gonna find, there's one room at the far end of the building that's always hot or always cold, so we set our system to make sure that that room is satisfied. Well, go fix that problem instead of *[crosstalk]*.

Stet Sanborn: Exactly. *[Laughs]*

Jess Farber: So, we see that all the time, too, so that's something to think about. That's a great suggestion, Stet, to do that audit, so.

Hannah Debelius: Love how you all, in fact, I barely even need to conclude, because you all were able to wrap up that discussion together, which I really appreciate. And the resource that Stet references is included in our resource document that we linked and also will be sent out with the slides and recording for this webinar.

A huge thank-you, again, to all of our experts on the line today. This is a popular topic for a reason and I really appreciate all your expertise. And also, enthusiasm and, honestly, professorial skills that come out and explain even the basic concepts, which are super helpful to our audience.

So, a couple reminders, programmatically. First, is that we do invite you all to join us this spring, for the Better Buildings, Better Plants Summit. It'll be here in Washington, D.C., April 30th through may 2nd. Registration is open right now. It's a great opportunity to engage with peers in interactive sessions, and meet folks that are having the same barriers and also find the same solutions that you might be able to use in your portfolio.

So with that, thank you, again. Thank you, again, to our panelists. It's wonderful to have your time and your expertise today. And you all can reach out to our panelists if you have other questions. I know we didn't get to about 60 of them today. *[Laughs]* Or check out the Better Buildings Solutions Center, so that you can search for specific case studies and other great resources. And, of course, follow us on all the socials.

You all will get an e-mail when this recording and other resources are ready to be viewed – I hope you share it widely. And have a wonderful rest of your day.

[End of Audio]

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The Heating System Balancing Act: Heat Pumps & Beyond

Additional Resources

Learn more about the topics discussed on the webinar by visiting the resources below.

Better Buildings Resources

- Commercial Building Heat Pump Accelerator
- Design and Construction Allies

Explore more resources on the Better Buildings Solution Center

Other Resources

- NREL How-to Guide for Heat Pump Systems & Beyond
- NREL 2020 Standard Scenarios Report: A U.S. Electricity Sector Outlook

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