Hannah Debelius: Welcome, everyone. We'll be starting in just a moment here as we're filling the room. *[Brief silence]*

All right, hello, everybody, and welcome to this Better Buildings technical webinar. You're in the right place if you are here to learn more about integrated strategies for building decarbonization. In particular, I'd love to give a special welcome to all of our Better Climate Challenge partners, because this webinar is gonna be a part of the technical assistance for that. But we are also glad to have everyone across the Better Buildings network joining us today, so thank you.

A couple of housekeeping items before we jump into it. The first is that everyone joining is in listen-only mode, and this is a recorded webinar. However, if you have any issues, you can use the chat function, and we'll be able to help you out on the back end with some easy things, I hope. However, for Q&A or for input on the webinar, we're actually gonna be using a separate tool we'll talk about in a couple of slides called Slido. So we won't be using the Q&A function in Zoom.

With that, I'm excited to talk a little bit about our agenda for today.

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We are gonna start out with a couple of polls, so we can learn a little bit more about who we've got on the line. Then, we have some wonderful speakers representing our Lawrence Berkeley National Lab, who will be getting into the content here. And then we're also gonna have plenty of time for Q&A at the end to answer all of your questions.

So with that, I would like to welcome –

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– Stet Sanborn, who is a Berkeley Lab affiliate, and I think familiar to many of you if you've seen him at Summit or maybe you're working directly with him for the Better Climate Challenge. And also, Nora Hart, who is a key team member of our Better Climate Challenge technical assistance.

So now –

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– I am gonna ask you to start engaging with us, and you are gonna do that through this platform called Slido. I'm gonna speak really slowly on this, because in real-time, I want you to go ahead and open up a new browser or *[audio cuts out]* your mobile device, and go to slido.com and you're gonna enter the event code DOE. We are gonna be using this not just for a couple of polls at the beginning, but also, again, for Q&A at the end.

So, take the time right now just to open it up on your laptop or something else. Go to slido.com. Our tech support has also dropped that link in the chat, and you can enter the event code DOE. Hopefully, saying this twice helps us out. So we're gonna go ahead and launch those polls.

Our first question for you all today that we're doing through Slido is, what state are you calling in from today? Well, I'm glad to hear someone made it. *[Laughs]* We're gonna launch that first poll about what state you're calling in from today. I will tell you all that I am currently calling in from Maryland, although I am stationed at our D.C. headquarters.

All right, Michigan, California – I know this webinar is a little bit more West Coast-friendly for the timing, so, I'm glad to see some West Coasters on the line – Hoboken, Maine, Ontario – great, great. I appreciate people taking the word state a little more loosely, *[laughs]* for those of you that are calling in from Canada or outside of the US. Excellent. And a strong showing from California, Massachusetts, and my home state of Maryland. Excellent. I'm also really glad to see Texas, Kansas – a really great representation across the US, here.

Okay, we are gonna move forward to our second question here, which are, what are your biggest challenges with integrating heat pumps into your building? And this is a "select all that apply," so you can choose multiple options here. I know there are a lot of challenges, so, we wanna hear about'em, because hopefully we are gonna address some of those today on our webinar.

All right, it's possible that my screen is not updating, but hopefully you all can hear me and that you're going to Slido to answer this question about your biggest challenges with integrating heat pumps into your building. Great. And I know Stet's taking note, because he's gonna be addressing a lot of these today.

Stet Sanborn: Yeah, and cost constraints is coming in at number one, *[laughs]* which is great.

Hannah Debelius: Excellent. Thank you. *[Laughs]* I appreciate that. And actually, I was just kicked out of the visual Zoom, but that's actually wonderful timing, because it is time in this webinar for me to toss it over to my colleague, Nora, at LBNL. So, Nora, you can take it away.

Nora Hart: Awesome. Thanks, Hannah. So I'll just summarize this real quickly. Like Stet popped in to say, cost constraints were the highest barrier, but Stet will be touching on all of those during his case study.

And I'm Nora Hart. I'm an energy technology researcher at Berkeley Lab. And on the next slide, I'll tell you about the two DOE resources here that have come out of the Better Climate Challenge. If you'd like to access these resources immediately, I will give you a second to whip out your phone, scan this QR code. If you're like me and you struggle with QR codes for some reason, you can get the link out of the chat. And you'll have one more chance to scan this QR code at the end. So, back to these resources.

Over here on the left, you'll see the Greenhouse Gas Emissions Reduction Audit, A Checklist for Owners. This resource is really meant to be a high-level description of how an energy audit and a decarb audit differ. And it's very owner-facing, or you can use it to help educate other people in your organization on greenhouse gas emission reduction audits. Over on the right, you'll see the Greenhouse Gas Emissions Reduction Audit, Scope of Work. This document's a little bit more technical and it is meant to literally be handed to an auditor so they can execute an audit in your building.

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Now, for just a second, I'd actually like to take a step back and we can go over a high-level overview of the major differences between an energy audit and a greenhouse gas emission reduction audit. So let me orient you to this graphic. We have a building here, and then the icons are representing the different systems and energy consumers within a building. Now, everything in this slide is covered in a decarbonization audit.

If we start over here on the left, you'll see Building Envelope Remediation. That is a key scope item for an energy efficiency audit, but also for decarb audits. We always want to focus on energy efficiency first. Next, down here in the basement of the building, you'll see Combustion Equipment Phaseout, and you'll notice it has a blue box around it. All of the items with blue boxes are meant to represent the fact that these are additional scope items when you compare to a traditional energy audit.

So, instead of just looking at HVAC equipment replacements that might be in-kind or one-for-one, you'll be scrutinizing anything that uses natural gas, and you'll work with the auditor to make a plan to phase it out. If we move up to the middle here, you'll see Analyze Inventory of Refrigerants. In a decarb audit, you'll work with the auditor to create a refrigerant inventory. And this is to determine not only where you have refrigerant leakage, and you can find ways to reduce those scope one fugitive emissions, but it's also to talk about and plan for ways to replace current refrigerants with low global warming potential refrigerants.

In a decarb audit, you also have Thermal Energy Storage, Electrical Service Assessment, and Onsite Renewable Energy, and I'll let Stet talk about those in detail.

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Here, I'm just giving you a screenshot from that Audit Checklist for Owners. Now, you don't need to read this whole slide, but this is just meant to give you an overview of what this resource looks like. So, as a checklist, it literally has checkboxes, as you might expect, and this is really great for you to go through and make sure you're covering everything in an audit, because there's a lot in here that you may not be used to. These audits are new to the industry, so not only are owners learning what's included, but also the auditors.

And then, this resource also has additional owner considerations. So if you look in the bottom-right of this slide, it's giving you additional tips for how to conduct these audits successfully.

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On this slide, I'm showing you the audit scope of work, and this resource is a literal Word document that you can download and edit and adapt as you need. So, there are instructions within the document on how to use it, there are yellow highlights, which are places for you to fill out information about your building, where you can edit or delete based on organizational needs. This audit includes a base scope, but there's also different optional scope items that you can choose to leave in or you can take out.

So, for example, we have a scope item for commissioning. While you're getting an energy audit, you may also want to commission the building, but this is an optional scope. So, again, this is meant to be edited and then handed to an auditor for them to execute.

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So this is my last slide here. I just wanted to give a couple of key considerations that you might want to think about when you're procuring one of these decarb audits. So like I said, energy efficiency first, O&M improvements, deep retrofits, right sizing. So, if you right-size a heat pump, it can operate three to four times more efficiently than gas boilers, so that's super, super important to right-size. Next in the middle here, you'll see electrification phasing.

And that's really important, because if you want to electrify your HVAC equipment, you have to be ready for it; you can't just swap out a boiler one day when it fails. So you have to do those measures that we call getting your building electrification ready. In addition, what's really important is thinking about renewables and thermal energy storage. You know, some people use the excuse of, "Oh, well, my grid region is really dirty. Why would I electrify?"

Well, if you also electrify and put on-site renewables, then the additional electric load can be covered by renewables. And that is zero-emission energy. And then finally, in the bottom here, I'm showing this arrow. Stet was, like, "You need to put this. It's very important." *[Laughs]* So when you're getting an audit, add time in the scope of work to complete data collection to support right sizing.

And this is because, if you wanna right size, you have to know what's actually going on in your building; the original equipment could've been completely oversized. And so with that, I'll pass it to Stet and he'll talk about this in kind of a real life scenario.

Stet Sanborn: Awesome. Thanks, Nora. So I'm gonna go ahead and share my screen, as well, and quickly hop back in. And Nora, just let me know when that pops up so I don't talk endlessly. *[Laughs]*

Nora Hart: We can see it.

Stet Sanborn: Perfect. So thanks, Nora. And so, it was really great to see the Slido poll responses. What we decided to do to talk through our strategies today was use one of our real-life case study examples from the Better Climate Challenge. So one of our partners graciously agreed to let us anonymize some data that they got in from an audit, as we worked through some of the challenges that they were having on a particular property that they were trying to do a deep greenhouse gas reduction project on.

So, we're gonna use that, and I'm gonna try to touch on how this process that's described in the resources that Nora just shared, how important those resources are in setting up a process to allow you to get to the right answer without breaking the bank. Because we're definitely seeing the same things in the marketplace that you all responded to being limitations for cost, utility upgrades, finding equipment, and all the infrastructure that you might have to support in the building or upgrade in order to do the retrofits that we're talking about.

So, we're gonna use a quasi-fictitious example, but totally based in an actual exactly detailed real life audit and cost model. So, I'm gonna walk through a 17-story, about a 400-unit mixed-use building, and the desire was to do a deep GHG reduction. And so, oftentimes, we hear in the marketplace, "Just electrify your building. No big deal. Just hot-swap equipment. You'll be fine." And I can tell you from experience that that's a horrendous process to go through if you don't follow really good practices.

And so, you're lucky there's a resource, now, that can kind of guide you through that, but I'm gonna walk you through why it really matters for a project. So in this particular project, they were trying to get rid of the natural gas risers that went through the building, and specifically get two areas that we're gonna focus on. One I would consider sort of apartment- or multifamily-focused, and the other is basic HVAC heating-cooling systems. So the first one, and this is super common, in a large multifamily building, you might have individual panels that serve each unit.

Those are typically not large. And so, if you're looking to get a range or cooktop switched over to electric, plus laundry electrification, those two things can often break the bank in terms of trying to fit onto your existing panel. So in this example, the default study was using an electric range, electric resistance dryer, as the replacement into the system. We'll talk about HVAC separately, but you can see in the load calc that the consultant provided, you know, that bumps us up into over an 80-amp requirement. So obviously not gonna fit on the 60-amp panel.

On the HVAC side, this building has a very traditional four-pipe layout. It's a high-temp hot water boiler serving a hot water loop, and then a chiller and cooling towers serving a chilled water loop. And we see this a lot in decarb audits, so I'm gonna flag it as something to make sure you download that scope of work, 'cause you're gonna see some language that talks around this. But the proposed solution in this project that came back to the owner was replacing a gas-fired boiler with electric resistance boiler.

And if you wanna watch your mechanical and your electrical engineers' eyes explode, try putting an electric boiler into a project that's gonna serve the entire heating load of a building. Your electrical engineer is gonna have a heart attack, you're gonna have to wheel him out of the room, and you can see this in what that meant for this building was essentially needing to come up with more than 2,000 additional amps of electrical feed into this building, at 277-480.That's a substantial upgrade of the electrical infrastructure.

And this is a huge barrier, both physically, phasing, building disruption, as well as, obviously, just plain cost. So what we wanna do is start to think about these things, step back and stop looking for one-for-one replacements of individual technology. And understand, as Nora said earlier, understand how the building is actually performing. So you can see, from a cost standpoint, these three things that they are trying to do, an electric range, electric boilers for the central plant, and electric dryers had a substantial cost impact to this project.

Over $3 million on a 17-story building, 400-unit. That price barrier does not work for most folks, especially if the building isn't in need already of a gut rehabilitation or repositioning. So, we're gonna talk through how you might approach this that might bring down those costs systematically, and end up with still achieving GHG reductions, but without the cost burden associated with just doing one-for-one replacements.

So first off, that electric dryer, that is a beast. Electric resistance in any form is a huge power draw, and that alone is gonna tip up most apartment panels above their rated capacity. So one of the things that we're seeing introduced in the market, within the last year-and-a-half, are heat pump dryers. So you've heard of the old-school electric condensing dryers where your clothes came out and they were slightly dry? Heat pump dryers are amazing.

I have one in my own house. I got my parents to install one. Which, trust me, getting my parents to do anything takes an act of God. But this new generation of equipment, and they're especially valuable for apartments, are these all-in-one washer dryer combo with a heat pump component. So the dryer is heat pump-based, but it's an all-in-one space-saving ventless design. There's at least three manufacturers now that have these out on the market.

But the key thing of why I bring it up is, in lieu of bringing a dedicated circuit to that space, these can plug into a standard 120-volt 15-amp circuit. So these can go into a standard outlet; they don't necessarily need a dedicated 240-volt circuit brought into the space. The next one is the electric range. Again, going from gas to electric, that's a pretty big load.

That's a really big instantaneous load for cooking, especially with four burners going and you're cooking Thanksgiving dinner, all that electrical draw. There's a new class of equipment that's coming on, there are two manufacturers that I know of in the marketplace that are playing here. And these are electric ranges, but instead of the old coil style, these are induction-based and they have what we call battery integration into the equipment.

And this serves two really important roles. One, it allows you to plug in into a lower voltage outlet. So again, just like the washer dryer combo, these can plug into a 120-volt 15-amp circuit, although still it's usually a dedicated one, but it's not at 240, it's not a 30-amp or higher circuit. The other key component, which we hear a lot of questions about, are around resilience, "What if I have a power outage and my tenants can't cook?"

Well, this is a great solution. Because that battery storage is allowing both a peak draw reduction for the equipment itself, it's also giving you almost a day's worth of cooking before that battery is totally drawn down. So you have that resilience built in. Those two things alone, when we go back and look at the electrical sizing calculation, now bring us back under that 60-amp for most apartment in most climate zones.

And so, it's a key way of saying, "Well, do I wanna do the disruption of ripping out my entire systems in my building, or are there alternate solutions that actually keep me within the capacity limitations that I already have?" When we look at that horrible, scary $3 million cost for this particular project, all of a sudden now we can strike out the electrical riser upgrades, we can strike out the new load centers, we can strike out, for a good chunk of this, the new switch gear that it was gonna require to support all that electrification upstairs.

And that's just through thoughtful equipment selection. Now, it's true, these two pieces of equipment cost more than your off-the-shelf typical electric range electric resistance dryer, but with far less disruption, not having to go in and rip up the entire building, and potentially have to move folks out while you re-energize, you know, take power off and re-energize the building. So, a much lower cost of entry and a lot lower impact into the project.

So that frames, from a plug load standpoint, that kind of gives an idea of things that you wouldn't traditionally think about in a traditional energy audit. Usually it's, like, "Okay, we're gonna go in and just hot-swap equipment and pick higher efficiency equipment and you're fine." One of the key things that the documents that Nora shared, so the greenhouse gas reduction audit scope of work and the guide, they highlight these areas of looking for opportunities.

And one of the really important ones, and Nora mentioned this, is listed as an optional audit scope of work around the electrical panel. So what a lot of folks don't realize is that electrical panels, you may not be using all the capacity that you have on that panel, even if all the breakers are filled up. And that's because you may have already gone through, over the last few years, a lot of energy efficiency upgrades. You might've done an LED lighting retrofit, you might've replaced pumps with VFD-controlled pumps in your building.

And so, you might actually be riding much lower on your capacity curve than you might think. And so, you might actually have additional capacity on that panel, but you won't know unless you do the study. And so, the National Electrical Code provides guidelines on how to do that study, and references to that are included in the documents that Nora shared. So, make sure you click on those, you can get the information.

It's a really great resource to actually ask the question, "How much capacity do I have?" That's gonna give your auditor a lot more flexibility to give you innovative solutions that don't break the bank and don't require a full upgrade of the entire building. So something that might come out of an exercise similar to that, and I love it, every time Nora shouts out, "Put time in your scope of work to get the data," my heart pumps a little faster.

Data on how buildings are actually working are critical to making smart decisions, especially in electrification or greenhouse gas reduction retrofits. So this is a graph that we produce all the time for our own clients, where we take measurements from the building for an entire year. If you've got a larger building that has a BMS system, amazing, give us access to the data. If you don't, work with your auditor to put a little CT onto or a flowmeter or a BTU meter onto your system.

There's a lot of non-invasive ones that can get strapped right onto your hot water and chilled water lines. Those can provide us really invaluable information about how your buildings are actually performing. So this is a curve that has the cooling, hourly cooling load profiles on the top, and the hourly heating profiles on the bottom. And for this building, you'll see it's got a chiller, you know, electric chiller that's running the cooling, and you see the gas-fired boiler.

The worst thing that we see is when folks say, "I just wanna replace that boiler with something." Oh, man, there is a lot of opportunity already for heat recovery, to offset a ton of your energy use in the building. So the question that you wanna ask your auditor is how much of that heating load, and heating load's the one that's often hardest to do with the heat pump, how much of that heating load could be provided for heat recovery.

So instead of saying just throw in a heat pump, 'cause you'll notice if I throw in a heat pump to cover that heating load, all of a sudden I've probably doubled my electrical demand in the building. I've triggered an upgrade in the service. Those are things that I want to avoid. So instead, what if I replace my chiller with a heat recovery chiller? And this is gonna depend on what temperature regimes your building are at.

But there are more and more products now coming onto the market that can do higher lift temperatures, 160, 165, even 180. And a couple of products that are on the market, now, where you can take your chiller, and instead of rejecting heat to the cooling tower, you actually reject that heat into your heating loop. And so, all that yellow in this graph represents all the hours and how much load a heat recovery chiller in this commercial building could've offset the heating load.

So now, without putting in brand-new spanking heat pumps just for heating, I've replaced my chiller, and I've accomplished an 80% reduction, 90% reduction in the greenhouse gas associated with heating. So, instead of just focusing on heating, let's focus on heat recovery first, and maybe leave your boiler in place both for backup or to meet those few hours that aren't met. An alternate solution is replacing that chiller with what we call four-pipe heat recovery heat pump.

This is an air source piece of equipment, but it can do both heating and cooling and simultaneous heating and cooling. So now one piece of equipment is doing all the things at different times of the year, but you're not doubling the size of the infrastructure required to support that system. This is key. Work within your electrical budget, instead of trying to just put in a new technology.

And obviously, if you've been on any of my other webinars or met me at ASHRAE, you know I have a fondness for ground source heat pumps. Obviously, due to space constraints or cost limitations, sometimes they're not a great application for a retrofit, especially in dense urban areas, but that's changing. There's a lot of new technology with directional drilling and really dense borefield designs that are bringing geothermal to the forefront, especially in cold climates.

We're also seeing a lot of attention in it right now because of IRA funding and opportunities for the tax incentives associated with it. One of the key things that folks don't often realize is that, when you pick a heat pump that's a geothermal-based heat pump, the heat pump is often smaller, has a lower connected load on the electrical side than what you would need for an air source heat pump to deliver the same amount of heat. And so again, if you're working within the limits of an existing electrical system, a geothermal-based heat pump actually might fit in really nicely, be able to meet your entirety of your load, without necessarily upgrading the electrical service for the entire building.

So again, these are strategies that you're gonna wanna ask your auditor. If they're coming in and do an evaluation, ask them, "Hey, could you show me a load profile for my building? What are the chances for doing heat recovery? And what's the size of a heat pump that I could use that fits within the electrical capacity that I already have?"

Oftentimes, auditors have never been asked these questions. They're just coming in and they've been said, "Oh, I just need to throw an electric boiler in here. " Well, that's not what we're trying to get to. We're actually trying to get for meaningful greenhouse gas reductions at the lowest installed cost that we can. Okay, so with that, now we can say, you know, if I was able to do a chiller replacement, for example, on that project, especially if I had planned for the end of life, if I already need to do a chiller replacement, it's a great time to do a heat recovery chiller replacement instead.

Now I've offset all of those infrastructural upgrade requirements in my building, and I'm still sitting within a very similar footprint that my old equipment sat in. So rather than always trying to think of something new I need to throw in, think about replacing what I have with something that can do dual duty. A number of those heat pumps can also do domestic hot water production, so if you are in a multifamily building, it's gonna give you a ton of benefit in the summertime by essentially getting free hot water on domestic hot water side, especially if you have tremendous cooling loads.

Okay, so the question is, what happens when you're, like, "Those are all great ideas. Yeah, yeah, yeah, we talked to that, but it's not quite enough. My peak load for heating or cooling is still higher than what I can support with my electrical capacity." Then I would say enter one of my favorite things in the world, which is thermal storage. And I know all the rage in the marketplace and everyone is talking about batteries, batteries, batteries.

A lot of buildings have challenges putting batteries in them. If you're in New York City, you've got crazy challenges to get a battery into your project. And a battery does not make your heat pump smaller, but thermal storage can. So I wanna talk through some of these applications of thermal storage that can actually help you right-size your equipment and get better performance out of it at a lower price point. So I'm gonna share a case study of our own.

One of the projects that I've been in design with for the last, oh, last year or so that's just gonna be starting construction soon, the tiny little project up in Humboldt, California. And before everyone tells me, "Oh, great, another California story," you know, this is northern California, it actually a pretty chilly place to sit. It doesn't get quite as peak cold as a New York or Chicago, but it has a very similar annual cooling load profile, because it's constantly cold *[laughs]*, as opposed to having winter and summer. It's just always cold.

When we approached this project, there's a number of things that we are trying to balance. Obviously, for us, the project, we are told "It's gotta be all electric. We want the lowest emissions profile as possible. We're also gonna be doing an onsite microgrid on our campus, so wanna make sure we're taking advantage of that," all those things. And then, in our own research and through our work with ASHRAE and the Better Climate Challenge, we know that heat pumps can be challenging when they're working at part-load conditions or have to turn down.

There's a lot of premature failures from short cycling heat pumps, and we know that we can design a heat pump system better if we combine it with thermal storage. And so there's a lot of benefits of pairing the two things together, not just for footprint, but also for cost. Something else that I wanna share is that this is some recent research that's actually gonna be published next month, and we were lucky to get a sneak peek of it.

But this is a project where researchers at the Center for the Built Environment at UC Berkeley actually went in and measured heating loads across the US in 259 commercial buildings. And this curve on the right is the one that's really compelling. And I know you're, like, "Great, Stet, another graph," but this is a really compelling graph and you should be excited about it. This graph is essentially showing you that 75 percent of the year or so, your system, so right here, 75 percent of the hours that that heating system is running, it is running at 30 percent capacity.

Ninety percent of the year, you're at 50 percent capacity. There are very few hours in our commercial buildings where the heating system actually needs to be running at its peak load. And this goes back to Nora's question or point earlier, where, what if your system was oversized? Almost every building that I go into to do an audit, the heating system has been oversized. It's never operating at full capacity.

And so, when we're thinking about cost, one of the other really important questions we wanna ask ourselves is, "Do I really want to install a heat pump for that last 25 percent or 10 percent of hours that's covering this huge cost, but running maybe 50 hours a year?" That's a huge investment for very marginal, minimal savings on a GHG impact. So, in our guide, in the document, in the scope of work and the associated guide, there's questions in there to ask your auditor about hybrid solutions.

And this is where you design a heat pump maybe to cover 75 percent of the hours of the year, and it may only have to be sized for about half of your load. And then let the existing boiler that's sitting there already, it's already been installed, let it be there to pick up those last few hours, instead of putting a very expensive piece of equipment that's never gonna run. So these are questions that you wanna pose to your auditor to make sure you're getting the most value out of your installation as you can, and the biggest

GHG reduction per dollar spent.

That's our goal. 'Cause if you could save some money there, you might be able to go and retrofit another one of your projects and get bigger savings than trying to chase those last ten percent. So how does that come back to that heat profile that we showed? You know, I already talked about the yellow being the simultaneous hours where one piece of equipment can do both heating and cooling and save you on the electrical capacity.

But if that's not enough, if you say, "Well, Stet, I overlaid, here, my electrical capacity for the size of the heat pump, and this is the best I could do," I would come back and say, "Well, that's pretty darn good. We might be able to meet the rest of it with thermal storage." So instead of designing a heat pump that's really big and only operating for a few hours, let's right-size a heat pump, pair it with thermal storage, and help pick up the gap.

So this is what that might look like on an annual profile, and this is the sort of comparison that we did for our project. So we could either size a heat pump for the absolute peak hour, peak load, everyone's happy, it's very comfortable, but more expensive. Or in the case of the system that we designed, we did a smaller heat pump, with thermal storage on the hot water side, thermal storage on the chilled water side, and that solution actually came out cheaper on day one and to operate than the two heat pumps.

And if you think about it from a lifecycle investment, those tanks of water or phase change material or whatever material you select for thermal storage, those can sit there for a very long time without needing to get replaced. Compared to a heat pump that typically has a 15-ish year lifespan on the commercial sector. So we've made the part that you have to replace a lot as small as possible, and let the part that can just sit there and be dumb and low-cost, but highly valuable, let it be there.

And pairing the two things together gives you a really good investment and gives you all those GHG reductions. So this is kind of what it looks like when we start to put that into a pumping package. And again, you're, like, "Stet, I don't have space for all of this." You are saving a considerable amount of space by not having this massive heat pump, air source heat pump system. Those take up a very large footprint; right-sizing them paired with storage, you might actually have the footprint.

If you're challenged, still, with footprint, instead of hot water or cold water storage, consider phase change materials. There's a number of manufacturers out there that are doing both hot storage and chilled storage with phase change, and that can reduce the footprint by upwards of 60 percent. So again, a number of technologies out there that can actually get a tailored solution that'll operate more efficiently.

So what does that look like on your peak day, your worst day? 'Cause everyone says, "Oh, Stet, that's great, but, you know, storage scares me. And what about the worst day ever?" so we modeled it. We looked at historic weather patterns for worst-case scenario, then we made them even more worse, for projecting out into the future, for cold snaps. For us, this is our graph of our 24 hours of our worst day, and you can see this orange line kind of comes up around four AM, and then it peaks right around seven AM.

That is very typical for a commercial building. And that peak tends to occur with what we call morning warm-up. So that's when somebody said, "Hey, at six AM, we need to turn this building on so it's ready for the first folks that come in, so they don't complain. We don't want any complaints." Well, you're spending a lot of money for that three-hour period. And something that we would prefer to do is spend the money on a smaller heat pump and let the thermal energy storage tank carry those three to four hours to help meet that peak.

And then, as you go into the middle part of the day, as your peak heating load goes down, everybody's turning on equipment, you know, life is happening inside your building, now you can recharge that tank. That thermal storage is gonna give you a lot of flexibility, both to meet the peak load, downsize my equipment, but it also lets us run our equipment in hours where we don't need heat. But we can store it when the grid is cleanest because of solar, or, as Nora mentioned earlier, if you install solar on your own building, you wanna make the best of it.

You don't wanna send it back to the utility and get paid cents on the dollar. Use that power onsite. And so this is a chance to run your heat pumps in this green hash zone. This is in the middle of the day, I might not need heat right in that moment, but I can recharge that tank and get ready for the next morning warmup, or late-afternoon. In the case of this project, we also wanted to actually shut off our heat pumps completely from four to nine PM, because in California, that's where we pay through the nose for electricity.

And so, we sized this tank to not only handle that morning warmup, but also to be able to turn off our heat pumps completely in the afternoon, and just ride the tank out until nine PM. And then we could turn the heat pumps back on, recharge the tank, and be ready in the morning. So thermal energy storage gives you all the value of a battery, without the chemical complexity, without the fire hazard, and it also lets you make the heat pump smaller. If I paired a heat pump with a battery, my heat pump would still have to be jumbo.

But thermal storage lets me make that heat pump smaller. And I don't wanna go too far into the weeds, but if anyone wants to nerd out with me at a conference on heat pumps and right-sizing, I'm happy to. But I did wanna share out, this is a different way of looking at that same chart that I showed from the Center for the Built Environment. But if we take all the heating hours of our year and we stack them from highest to lowest, you can see, again, even our own modeling shows that we have very few hours at that peak load.

And a lot of hours at very shallow load, very small load. Heat pumps don't like to operate in either of those regions, and so thermal storage allows us to meet the peak with a small heat pump. But even better, it allows us to meet what we call part-load conditions with the thermal storage, and then let the heat pump just turn on periodically to recharge the tank. And so we're not asking the heat pump to keep turning off and on really fast or try to hunt for a low load.

On the emission side, thermal storage also gives you that benefit of, even with a really dumb clock that says, "Hey, charge this tank at these hours, you know, turn the heat pump off on these hours," even the most basic control sequence can see five to ten percent CO2 or greenhouse gas emission savings just with that. So that's not even taking into account smart controls or AI or any other buzzword in the marketplace. Thermal storage gives you that flexibility to see immediate reduction with your system and self-utilize your own electricity generation with PV.

So with that, I just wanna reiterate, looking at these integrated strategies, whether it's plug load, changing what type of equipment you plug in, or finding the right heat pump that can do heating and cooling off of the same electrical supply, those are all ways that are gonna help reduce that cost, reduce the barrier to entry to doing a greenhouse gas reduction on your site or your property. But there's a whole lot of other really great benefits that these technologies can bring together.

Thermal storage plus a tiny heat pump gives you a lot of load shift capacity. Your heat pump is actually gonna run more efficiently, because it's at its design load. And it's gonna let you self-utilize any PV that you're generating onsite. The last thing that I wanna share is that, you know, and this might be beyond what a typical auditor is gonna provide you, but we always like to look at solutions that are gonna give us more resilience, as well.

So battery storage obviously helps with resilience during a power outage, but so does thermal storage. If you have enough onsite power backup to run pumps, thermal storage can give you several hours of additional conditioning without the heat pumps even running. And from an overall lifecycle levelized cost of energy, which is a model that we run for all these scenarios, typically, thermal storage comes out ahead.

It's a great solution to give you right-sized equipment on day one, reduce that electrical infrastructure upgrade, but still provide you all the benefits of a GHG reduction and resilience. So with that, I think I'm gonna hand it back over to the team, and we can take some questions and have a little bit of a discussion.

Nora Hart: Awesome. Thanks, Stet. I'm proud of you for staying on time. *[Laughter]*

Stet Sanborn: It's rare, I know, but I tried.

Nora Hart: We have plenty of time for questions. And one thing I'm hearing from your whole presentation is, like, grill your auditor. Make sure they're designing the way you want them to. But now it's time to grill you, Stet. We have lots of questions for you. So I will start with, what are the key differences between a heat recovery chiller and a heat recovery heat pump? They sound like the same thing.

Stet Sanborn: Oh, so they can be very similar, and you're gonna hear different names for them. So sometimes you'll hear a heat pump chiller; that's, effectively, a heat recovery chiller. The typical difference that we see in the difference between, like, a four-pipe air source heat recovery heat pump and a heat recovery chiller is that a heat recovery chiller doesn't have its own source to pull in extra bonus heating, if you will. So it's still tied to a cooling tower; it can reject heat all day long.

If you're in a cooling-dominated climate, it's a great option, 'cause it can cover a large portion of your heating load and then cover your cooling load at the same time. And then if there's extra cooling that needs, it can reject that heat to a cooling tower. Air source heat pump, a four-pipe air source heat pump also has the benefit of being able to reject or grab heat from the outside air. So it can do both of those things.

There's typically not a cooling tower, although you can combine it, so there's a lot of nuance there, but typically, it uses air source to make up whatever you're not using simultaneously. So they're doing very similar things, and I would say that the true difference is really in scale of the product itself. So, heat recovery chillers, you're looking at larger commercial-scale buildings that might have a chiller plant already.

And maybe, you know, they're typically _____ 1,000 tons, 2,000 tons, and larger, as you go to large campuses. Heat pumps, on the other hand, at the commercial scale, you're typically seeing them in the 30-, 70-, maybe 120-ton module size. And so, you're using several of them lined up to reach the capacity that you might be targeting for your project.

Nora Hart: Awesome. So, there's a related question.

Stet Sanborn: Okay.

Nora Hart: So, in cold climates, how often will I be operating my chiller and at the same time providing space heat or need heat elsewhere? *[Audio cuts out]* how does that work when using a heat recovery chiller for heating loads?

Stet Sanborn: That's a great question. To answer that, I would say it totally depends on what building you're looking at. So those graphs that I was showing you, that is literally pulled from a building in Washington, D.C. So I wouldn't call Washington, D.C. an extremely cold climate, but you guys have winter. And that building, it's a commercial building, but you can see that, year-round, it's got a cooling load.

Even in the dead of winter, there's a lot of equipment inside, you know, especially with more and more buildings doing IT infrastructure, there's a ton of waste heat in the building that typically is rejected to the cooling tower. So in that climate, almost all of the wintertime heating load could be made up with free heat from the cooling system. Now, if you move into a multifamily building, that ratio changes.

There's less equipment inside of an apartment building or multifamily building during the winter, and it's much more skin-dominated. And so, for a retrofit, that's why asking your auditor to go in and give and measure, you know, and you don't need a full year. You could take six months, you could take three months, or one month in winter, one month in summer, you know, there's ways to target that from a budget standpoint. But that data is so useful to share with your team, so they can look at how much of the opportunity.

If you're in Minneapolis, or further north, even in New York, in a multifamily building, you likely will need supplemental heating that's not achieved through heat recovery. So in that case, we start to look at other opportunities before we look at air source. So there's opportunities for doing wastewater heat recovery. If you've seen any of our other presentations, I'm doing energy exchange with the sewer system.

Multifamily buildings are a delightful place to extract heat from the sewer system, because you've got all that shower usage, hot water demand. That's a really great source to steal hot water out, and there's products on the market that can actually use a heat pump to steal that heat out. So that's a great solution in a cold climate.

Nora Hart: Awesome. Thanks, Stet. So this next question is kind of moving on to smaller buildings, you mentioned this, but a lot of this discussion has been focused on boiler-based heating systems. What about buildings with distributed gas fire furnaces, air handling units, and unit heaters?

Stet Sanborn: Yeah. So we did another webinar that looked at different types of equipment that you might swap at different scales, so definitely take a look for that. But for distributed furnace units, there are, just like those, in almost the exact same footprint, there are distributed heat pump versions of those. Now, they're not gonna typically be able to take advantage of heat recovery, because once you start to distribute everything and you have one-offs in every apartment, you have fewer opportunities to recover energy that's being wasted elsewhere in the building.

However, there are heat pumps that you can get, in a sort of unitary or standalone situation, that can go into smaller buildings. They typically will have an outdoor unit that needs to be paired with them, so think VRF, or mini-splits, multi-splits, that kind of family. I have a strong love in my heart for hydronic systems, and so, oftentimes, when I am approaching a project, I'm trying to steer away from systems that have too much refrigerant in them and are running refrigerant lines all through the building.

I get nervous around that, for long-term maintenance issues, refrigerant leakage, and the impacts of refrigerant leakage on the environment, but in some cases, those are the best solutions. But you're totally right, for buildings where you have your equipment scattered in every apartment, you have much fewer opportunities to do heat recovery. The one exception is that there are a couple of products coming on the market right now that combine space heating and a hot water tank as a combo, and the same heat pump can do your domestic hot water that's doing your space cooling.

So, in the event that you're in the summertime and you're air-conditioning your apartment, it can actually make hot water at the same time and give you some free hot water all summer long. But then the rest of the year, it's air source-based from outside.

Nora Hart: Awesome. A lot of great new products coming on the market in response to this demand.

Stet Sanborn: Yeah, if you're living the dream of heat pumps right now, you know, this is the age of the heat pump, and I should have a song that comes out *[laughs] [crosstalk]*.

Nora Hart: I'll be waiting for that, I'll be waiting for that song. And I also love, every question we ask, Stet has a webinar for it. He has done webinars, just google his name, "webinar," and your question, something might come up, who knows. *[Laughter]*

So, the next set of questions, I am going to talk a little bit about thermal energy storage. So, this first one is, do you see thermal systems that conserve both heating in the winter and cooling in the summer? Or are they typically separate systems?

Stet Sanborn: So we definitely see both, and it kind of depends on what your load profile looks like. We can do it with a single tank; we typically call that a seasonal changeover tank. And so, in the wintertime, it serves as hot water storage, and then in the shoulder seasons like March and April, when you're kind of, like, "Ah, do whatever you want. Everyone's comfortable," it doesn't really need to do anything. But then, as you switch into summer mode, you can do a valve configuration that essentially changes it over into a chilled water tank.

It just changes which side you're pulling water from and pushing water back in. So if you're on a budget and you don't have a lot of footprint, you can still get a ton of value of doing a single tank that we call a changeover tank. You may not get as much of the ability to do this what we call a simultaneous or slightly non-simultaneous heat recovery. So if you're doing air-conditioning and you need heat three hours later and you don't have two tanks, it might be a challenge to do that game. But for a lot of applications, a single tank is beautiful and can definitely give you all the benefits without the footprint space.

Nora Hart: Awesome, a beautiful single tank, that's a great answer. So the next one is, do your thermal energy storage solutions use some sort of weather prediction feature to predict amount of thermal storage needed for the next day?

Stet Sanborn: So that's a great question. So, on our projects, we do. There's something called model-based controls, and there's a lot of resources, actually, from the Lawrence Berkeley Lab on this. If you're super fascinated, they actually have some examples that essentially learn both your building's behavior – and now you'd call this AI and there's always a widget that can do this, but it's a control sequence and it can measure two things.

One, you're trying to understand how your building performs to certain outside air conditions. And you can look ahead at the weather file to predict what the upcoming weather is and adjust how much of that tank you need to store for a given time. That's the most basic of those control sequences. They have additional ones, now, where it's also looking at what the grid is doing.

And is looking ahead and being, like, "Actually, I don't need to make hot water right now, but if I did, my GHG emissions footprint would be smaller than if I make that same hot water in four hours." And so, those are some I would say the newer control sequences coming on the market, definitely more sophisticated. You're not gonna get those sequences from a guy pulling a heat pump out of the back of his pickup or the trunk of his car. That's typically moving into more sophisticated controls that you'll definitely wanna consult a pretty good engineer for.

Nora Hart: Right, that makes sense, it gets complicated. *[Laughs]* So, the next question goes back just to heat pumps. So, what about climates where the outside air temperature gets too cold for the air source heat pump to operate, what would be a good strategy for those cold days? Keeping in mind it's one to two weeks, some really cold places, and not just a couple hours.

Stet Sanborn: Yeah, well, so, if this is a retrofit, there's so many things you could do. So, I didn't touch on it for this webinar, but for climates that experience extreme conditions, building efficiency goes a long way to reducing the impact of those peak events. So if you have a building that is ready for repositioning and you have a chance to improve the envelope performance and retrofit the envelope, new glazing, air sealing, things like that, that building is now far less susceptible to those cold snaps.

And so, you actually might be able to make do with the heating system that you have, even though you're experiencing these one- or two-week duration, you know, Arctic vortexes and things like that. That's one stage is make your building more efficient, and you're less susceptible to the impact of climate change. The second one is, if you have an existing boiler, as I mentioned, in the building, maybe don't get rid of it.

Do your heat pump retrofit, it's gonna cover operating 95 percent of the time, but your boiler there is available both for backup if you have a power outage, as well as meeting those peaky conditions that you don't wanna invest that much in a heat pump. So that's a great solution. And then for every cold climate, looking for opportunities for heat recovery, whether that's wastewater heat recovery or a ground source heat pump or heat recovery off of an exhaust system on your building, those are also great places to pick up heat that might supplement the system.

We have a multifamily project that we're actually installing a cooling coil in the laundry room's ancillary space behind all the dryers where all the venting. It's a centralized laundry in the building and they've got all the dryer vents all manifolded up to go out. That back of house space is, like, 120 degrees year-round. So we actually threw a cooling coil in there so that we can steal that heat and put it back in the central system.

And essentially, everybody doing all their laundry all the time dropped the heating demand in our building by, like, five percent. So it's all these sort of integrated strategies of looking for places where we're wasting heat all the time, and if I can steal it, great, let's recover heat before we try to make it new.

Nora Hart: It's so funny, I feel like people don't think of engineering as creative, but you're getting very creative with *[crosstalk]*.

Stet Sanborn: Oh, yeah, engineering is like the most fun career you could ever choose in your life. And buildings are amazing to work on. So, just a shout out to all my AE friends. *[Laughter]*

Nora Hart: Oh, too funny. Well, with that, we have time for maybe one more question, so, this one kind of sums it up. Can you talk about, in general, how cost-effective it is to electrify heating loads? What are you seeing in the market? Because everyone seems to think there's a premium.

Stet Sanborn: There certainly can be a premium. Like I said, you know, the example I shared today is a real-life example that one of our partners came to us for technical assistance with. So, join the Better Climate Challenge; we'll help you find better cost solutions. So that's my shoutout to joining BCC.

It doesn't have to be that much more expensive than what you're doing for O&M on a building. So as an example, if your chiller is approaching end of life, that is a typical replacement. You know, it's at maybe 20 years old, although we've seen some that are 60 years old that should've been replaced a long time ago. But say your chiller is at 20 years old and you're, like, "Man, I'd really like to upgrade to a more efficient unit."

That's a great opportunity to, instead of just thinking about your heating side, use that opportunity where you're doing a chiller replacement already, it's already been budgeted into your O&M plan, use that as a chance to do heat recovery, heat recovery chiller or air source heat pump. That is likely to cover 60, 70, 80 percent of your GHG emissions, and it's already kind of built into your plan. So, there are cost effective ways to do this that can be phased in over time.

You don't always have to do a rip-out-the-boiler-and-throw-a-massive-heat-pump-in, because you might have other opportunities. And that's what we wanted to stress in both the guide and the audit scope of work is to focus on these other measures first, before you're putting in the most expensive solution. 'Cause right now, I can tell you from my survey of the industry and all the peer review work that we do and through all of our partners in BCC, a lot of the first round of strategies that are coming in, especially for folks that are in places with building performance standards, you know, they're all freaking out, "Electrify, electrify, electrify," the solutions that you're all getting are some of the most expensive strategies that you could deploy.

And so, that's why this resource is so important is that you can hand that to your auditor or your consultant and say, "Hey, let's pump the brakes a little bit, let's gather some data, let's look for opportunities, and let's find a cost-effective way to grab as many of those emissions as possible. But maybe not fight a million dollars for the last three percent," 'cause that's not that's not an effective way to use that money. I'd rather you put in a right-sized heat pump, reduce your emissions by 60, 80 percent, and take that other bucket of money, instead of spending it to save 4 hours, grab that and electrify or decarbonize 60 percent of your next building.

So, it's a process and the guide provides a lot of really great resources to help you go through that. So I hope you guys clicked on the QR code, 'cause we put all of our brains, an incredible team put all of our thoughts into that guide, so we really hope you use it.

Nora Hart: Definitely. Well, thank you, Stet. Thanks for your presentation. We really appreciate it. And with that, I will pass it back to Hannah Debelius to close us out.

Hannah Debelius: Great. Thank you so much, Stet and Nora, and also to all the folks online who put in such great questions. I love to see Stet get so excited about heat pumps. *[Laughs]* It's a perfect way to spend your afternoon.

So with that, I will say thank you, again, to all of our current Better Climate Challenge partners. If you are not a Challenge partner and you'd like to be, I hope you will follow this QR code to become involved directly in the program, where you can interact with experts like Stet and Nora on your decarbonization journey. We also have more than 3,000 solutions on our Better Buildings solution center, which you will find also on the other end of that QR code.

With that, I'd like to thank, again, Stet and Nora and the whole team behind the Better Climate Challenge and Better Buildings. You can reach out to us anytime. These are our real e-mails; it comes to us and not robots. We would love to get you involved in the program, answer questions that you have, and provide resources. And as always, you can also follow Better Buildings and all our happenings across social media and our various listservs.

Thank you all so much for attending. I hope you have a wonderful rest of your afternoon.

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