Cedar Blazek: Thanks, everyone, for jumping on early. We're going to get started right at the top of the hour.

All right, everyone, we still have just – our numbers are rolling up; folks are still joining. I'm going to get started in just about a minute. Thanks.

Okay, I'm going to kick things off. Hello, everyone. Good morning and welcome to the 2021-2022 Better Buildings webinar series. Better Buildings is dedicated to bringing you the latest actionable insights from leading industry experts, and this annual series is a chance to explore the topics, technologies, and trends that affect your organization, as well as efforts to accelerate energy efficiency adoption.

Today's session, if you want to go to the next slide, will look at low-carbon technology strategies for different building types.

Before we dive in there are a few housekeeping notes that I'd like to cover. So please note that today's webinar will be recorded and archived on the Better Building Solution Center. We'll be posting slides and today's recording and we will follow up once it's made available.

Next, all of the attendees are in listen-only mode, so your microphones are muted. If you experience any audio or visual issues throughout the webinar please shoot a message to our team in the Q&A box located at the bottom of your Zoom panel. Next slide.

My name is Cedar Blazek and I'll be your moderator for today. I am a program analyst in the Commercial Buildings Integration program under the Department of Energy's Office of Energy Efficiency and Renewable Energy. Within the Better Buildings initiative I oversee the Technology Research Team program, which is where experts from DOE's national labs analyze the latest research and development on a range of building technologies with the ultimate goal of providing market-ready solutions for building owners and operators.

Next slide.

Today I'd like to share with you one of the resources that we developed recently as part of our Technology Research Team program. To date over 100 companies have committed to DOE's Better Climate Challenge, which asks organizations to set a 50-

percent portfolio-wide reduction goal for scope one and scope two greenhouse gas emissions over the next ten years. Many more companies have set other carbon and greenhouse gas goals. Better Buildings is committed to providing resources and highlighting pathways to actually achieving these goals and making meaningful steps towards decarbonization. We created the Low Carbon Technology Strategies Toolkit, which provides recommended strategies of retrofit approaches for ten different building types across all building energy end uses.

Next.

As you can see in this example – I know the print is small, but this is just to give you an idea of what they look like – the strategies are grouped by technology end-use, such as lighting or space conditioning, and are categorized into simple, medium, and advanced approaches. These documents are available for free online in our Better Buildings Solution Center. You'll see that the recommendations have been condensed into a digestible two-page format for simplicity, but they do provide many hyperlinks to more detailed best practice guides, especially for some of the more complicated technology strategies.

Next slide.

If you'd like to leverage these guides for your organization, whether you're a building owner, an operator, a consultant, an architect, or otherwise, we have a few key recommendations that are highlighted in our Getting Started Guide. First you'll want to assess your portfolio and make sure you have a good understanding of the existing equipment and the energy usage in your facilities, making use of things like energy audits, benchmarking, and commissioning efforts.

Then when developing a plan for reducing greenhouse gas emissions in your buildings look to energy efficiency strategies first, which are often more affordable, before seeking to procure renewables and energy storage. During our webinar today you'll hear from presenters who have put these strategies into action for low carbon buildings.

Next slide.

Today we'll be using an interactive platform for Q&A, polling, and feedback. It's called Slido. If you've been to our Better Buildings webinar series before you are very familiar with this website. So I

am going to ask all of you today to go to www.slido.com either on your mobile device or opening a new window on your internet browser. Today's event code is DOE. So you should be able to just put that in at the top and it will take you to the right spot.

If you'd like to ask questions to any of our panelists you're going to submit them anytime throughout the presentation into Slido in the Q&A wing. We will be answering your questions at the end of the session. You can then use the thumbs-up icon for questions that you like, so that way we get the most popular questions moving to the top of the queue, rather than entering it again.

Next slide.

I think we're actually going to jump to these Slido polls. Great. And we have tons of folks already interacting. But we do want to learn more about you today, so we are kicking things off with a few polls. If you go over to Slido you can respond to our questions. And if you do have any issues with Slido you can message our tech support team in the Zoom Q&A function.

So the first question, which many of you are answering, "Have you implemented low-carbon strategies or technologies in your building portfolio?" Never, a few times, most of the time, and in every building project.

I'm very excited to see that some of you have done it in every building project, just over 10-percent at this point. That's at least 20 of you. A few times is great. And for those of you who have never implemented low-carbon technologies in your building portfolio, we are glad that you are here today.

Okay, I think these numbers are sort of leveling out. If we want to go to the next poll.

Okay, second poll, "What is your primary motivation for implementing low-carbon technologies?" Why are you here today? Why did you decide to attend this session? Are you trying to meet a corporate or greenhouse gas target? Working to save on utility costs? Maybe maintenance costs? Because you think that it's the right thing to do? Or you haven't implemented, which we saw was a decent number of you, according to the last poll.

If there are other primary motivations that aren't covered here you're welcome to put them into the chat or the Q&A and share with us a little bit more. But it sounds like over half of you so far,

that's more than 100 attendees, do have a corporate carbon or greenhouse gas reduction target that you're trying to meet or help someone else meet. So that's exciting and really helpful for us in understanding why these strategies are important to you.

Okay, let's go to our next poll question.

So this one's going to get a little bit at the barriers, what are those challenges if you've never implemented them? Are there specific challenges you can cite? What are those barriers to achieving zero greenhouse gas emissions in buildings today? This can mean your portfolio or more broadly. Is it cost? Is it a lack of available equipment? Is it just a lack of support or knowledge within your organization? Or is it something else? And if it's something else we'd encourage you to put that in the Q&A for today's session.

It seems the most popular answers from a lot of you are upfront costs; that is certainly a huge barrier to overcome. But the lack of support and knowledge, that's something that I think can be overcome a little bit easier. And again, thanks for attending the session today.

I think we have one more poll. If that's correct we can move to.

So this one is a bit of an open-ended question. We do want to create a word cloud. So for those of you that have, even if just a few times, implemented low-carbon technologies in your buildings, what have you used?

Great. LED lighting is a big one. Heat pumps, very popular. Thank you all for these great contributions. It looks like LED lighting, heat pumps, and solar are the biggest answers. But we do have a lot of really great solutions in here: improved glazing, heat recovery, solar hot water, geothermal, wood pellet boilers, DRF systems, heat recovery chillers. Really, really fantastic technologies and strategies here.

I see BMS, building management system. Ooh, I love whoever put "comprehensive retrofit." *[Laughs]* Great. I think we do see the LED lighting and heat pumps have been the most common so far. But VRF, insulation also popular.

Okay. Well, thank you everyone so much for your contributions. We'll be able to sort of keep these and keep an eye on the strategies that you all are using and what you think is most effective.

Okay, I think we can move on.

So we do have a really great lineup of presenters today. I'm so excited to be able to hand things over to them. But I'm going to give them each a quick introduction first.

So up first we'll hear from Paul Torcellini, who is a principal engineer for the Commercial Buildings Research Group and has been at NREL since 1994. Prior to his current role he was the group manager for the Commercial Buildings Research Group. He also spent three years as a technical advisor to the US Department of Energy in Washington, DC and was instrumental in creating a process to achieve net-zero energy building status for NREL's research support facility.

Up next we'll hear from Stanton Stafford. Stanton is a senior principal professional engineer of LEED Fellow and business development leader at Integral Groups East Region. Over his 20-plus year career between Washington, DC and Atlanta, Georgia, Stanton has served as the mechanical engineer of record for over two million square feet of LEED Platinum Certified buildings and has helped design Living Building Challenge LEED Platinum, WELL, and Net Zero Energy benchmark projects for the Southeastern United States. Stanton is the immediate past chair of ASHRAE's Technical Committee on Building Environmental Impacts and Sustainability.

Finally we'll hear from Kent Peterson. As vice president and COO, Kent Peterson provides technical leadership for the team and maintains the quality of P2S services. His award-winning design experience includes high-performance green buildings, ultra-efficient central plants, and innovative control strategies. His mission is to not only maintain the success of P2S, but to redefine what's possible in the building and infrastructure industries.

Thanks to all of you for being with us today. And now I'm going to hand it over to Paul to kick us off. Go ahead, Paul.

Paul Torcellini: Okay. Thanks, Cedar.

Let's go to the next slide. Next slide.

All right, so as Cedar mentioned, and I just want to kind of go over some of the major strategies in talking about low carbon. And many of you identified all kinds of strategies that you use around energy efficiency, and really energy efficiency is that first step in

decarbonizing a building. And when you look at that there is a loading order that makes sense. And I realize that not everybody can do it in this order and we can discuss that as time goes on here.

But really starting with the envelope. And why do we start with the envelope and reducing infiltration? Because if I can reduce that envelope load, later on when I get to the HVAC and I talk about electrifying that I can make it much smaller and save money there. And often it is less money to work on the envelope first and get those savings back with the HVAC later.

Likewise, lighting plays an important role here. Even things like looking at where your windows are located and saying, you know, it's the first 15 feet away from the window daylit. Do I have dimming fixtures? Have I put in all LEDs? And I'd even say with the LEDs if you were an early adopter of LEDs, even looking at them again, because the technology has improved so much in the last decade. But that lighting, getting that lighting right will also reduce your HVAC loads.

A lot of people haven't looked heavily at plug and process loads, and that is one of the things that we are doing with the program quite a bit, is what is plugged in, what is operating. Because those things also generate heat and use electricity, which then impact the HVAC. And so by doing all of those things you can really downsize that heating and cooling load to the point that you can rethink it perhaps, or perhaps use the same coils that you used before with a different heating source. And our examples later will talk about some of these things.

And then finally trying to match what's left with renewable energy. Get that balance between what the building consumes and what you're producing, whether that's on-site or kind of locally off-site, or maybe having to go to even further range. Usually we're looking at most of the scope one emissions, that is stuff burning on-site is really for heat generation, and how do we replace that with heat pump technologies is really one of the core strategies that we want to look at.

Next slide.

And so think about your building. So I have a star here that represents today, and for a moment I want to talk about new construction and really thinking about that for a new building setting an energy and carbon goal that you can measure makes all the difference in the world. Cedar mentioned that I was involved in

one of NREL's large-scale office buildings, and we as an owner set that goal and then we used a procurement process to get the best team to help us meet that goal within the budget we had. In some ways it's easier to think about those decisions you make upfront before you start building something.

And one of the ways to think about it is every time you make a decision it has an energy or environmental consequence. And buildings are here for a long time. So if you build that building today and it doesn't have a very aggressive energy or carbon goal, you really have to work through the consequences of that for a very long time.

And then as we kind of go through the life cycle of a building things happen. Right? Things break, things need to get replaced, and this kind of charts the pathway where you might three or four years out need to start replacing lamps or replacing computer equipment. You may eventually – maybe it's 20 years out – have to start replacing some boiler equipment and other things. It's just all of these different events that happen. And one of the things to think about is as those events happen are you prepared to know what to change it to.

So go to the next slide and my little star is going to move over.

So for most us we have existing buildings, and here's where we are today. Right? And maybe in this case the building is old enough that the roof is ready to replace and the boiler has issues, or the steam distribution system has issues. And it's costing us a lot of money to repair these things. And one of the things is can I make changes as I do repairs.

So take an example of a flat roof. You know, maybe you have a flat roof that's now 25 years old and there was only an inch or two of insulation under that roof. When you re-roof it add four or five inches of insulation to that, and bring that up, maybe even exceed what the current energy codes say for that roof to really lower the loads. Interestingly, by doing that when you go to replace the boiler you can also then reduce those loads as well, and maybe use a smaller piece of equipment, or better use a piece of heat pump equipment to meet those loads.

But really think about when you spend money on a building, right, or a campus, where are those opportunities, and really look for those opportunities and get ahead of that. If you know that that boiler is going to be replaced – and "if" is probably not the right

word, but when that boiler is going to be replaced do you know how much heating load it's carrying? And I've seen cases where boilers are oversized by a factor of three in some cases. So do you really know what that runtime is, especially if you've done energy efficiency features upfront.

Go to the next slide.

So think about creating what we call an action plan. And I want to lay out some steps for you to think about with this. Where would you like your building to be in 20 years? Have you as an organization set a goal? I noticed on the survey that a lot of you are thinking about low-carbon strategies because of corporate goals. What do you want your building to look like? Have you made a goal that in 15 or 20 years you're going to be carbon-neutral? Well, to get there you really have to look at the energy consumption of your buildings and set some energy goals. Even if you don't think it's achievable today.

And then make a list of what you're going to touch in the building in that timeframe. You know, looking at that flowchart, like when do you think you're going to have to replace lights? Maybe it's for a tenant replacement. You know, every 20 years you're probably taking a serious look at your heating and cooling system. At what point do you have to touch things that we often say we're never going to touch, like windows? Or window frames, or even things like doors and weather stripping on those doors. When are you going to touch all of these things and what is the replacement plan for those items that need to be replaced?

You can start that process today by just collecting data. I was recently involved in a project where we were looking at a boiler and it was getting ready to be replaced and so the winter before we put a little data logger on the boiler just to record its runtime, and one the things that we found was it never ran more than about 40-percent of any given hour, and a lot of that 40-percent was when we were trying to warm the building up in the morning; it wasn't even for actual performance. So in looking at replacing it, certainly downsizing that piece of equipment. And as we studied it further the reason we could downsize it was that they had replaced the windows, they had added insulation, and yet the equipment was still the old equipment and the old signs.

Look at what your current maintenance dollars are, and even the capital funds you're going to expend in that building and how do

you turn those into strategies that also reduce energy and carbon consumption.

Next slide.

So just brainstorm a long list. Right? Just look at every system that's in a building and say, "What could I do with that piece of equipment?" And it's okay to say it's not realizable today. You know, and it may be that in a couple years that technology gets better. Maybe the price comes down. And just look at the cost of photovoltaics in the last 12 years has gone down by, what, 70-plus-percent. And so something that wasn't achievable 15 years ago is certainly achievable today.

And if those strategies are completed, will that get you to your end goal or do you need to think about some other things to add to that? You know, align the strategies with these possible building upgrades and maintenance. It may be that you want to reposition your building in the market and you want to fix things anyhow. It maybe that you have a tenant improvement that you can work into this. The objective is not to spend money to fix old systems if it is not in that long-term pathway. Right?

For example, replacing a steam boiler with another steam boiler versus thinking about how do I reduce the temperature to a high-temperature system – or I'm sorry, a low-temperature water system that then could get replaced with say a heat pump. Maybe even augmenting that heat pump with a boiler just for some peak times or a hot water heater.

You know, perhaps you've got windows that are leaking. Fixing single-pane windows is another good example. You know, why would you do that? I was involved in a project – it was a school project where they were going to need to replace the windows because they didn't meet the current egress requirements for schools. And so it was a perfect opportunity to think about those windows and to think about how to better the daylighting in the space, all because of some other driver.

You know, just the cost of replacing lamps and fixtures and trying to dispose of lamps, especially when they have mercury in them. When you're going to replace those, replacing them with LEDs, replacing them to the point that we really have good lighting power densities.

You know, part of this plan is really to think about the unexpected, right? For example, if the hot water heater dies tonight what are you going to replace it with? Do you know how big it really needs to be? Is there an electric or a heat pump solution? And if you need to replace it do you have a plan on how that heat pump can be installed? And thinking about these things ahead of time, even when it dies, then hopefully it's not an emergency and you can make a decision that helps reduce the carbon and energy of the building.

Next slide.

So I've put together a number of questions – I'm not going to go through these – but just some questions to think about. And I mentioned the roof one, the fourth one down, does your roof insulation meet or exceed current codes. Right? Do you know what's in that roof, and so when it gets replaced have a process to do it?

It's just a whole set of questions. I think I've got about 30 questions between this.

And you can go on to the next slide.

Just ideas to start with. Because I think what we have found is that as we interview building teams and building owners and start asking some of these questions it's like, "Oh, I hadn't thought of that before." So hopefully this will start you thinking about this and you can look at these questions and these slides at a later time and think through these questions.

Next slide.

And so it goes all the way down. I know some of you talked about using energy storage and what are you using that energy storage with. You know, do you currently purchase renewable power? Do you have on-site renewable power? Every building tends to have a rooftop, especially commercial, that would lend itself to some PV. You know, have you thought about putting that PV on the building. Even if it doesn't meet all of the loads it is something.

And then we're seeing a lot of interest now in EV charging stations and how to prepare buildings for EV charging stations, and even making them what I would call smart, so they can help you manage the building load at the same time.

Next slide.

And so I want to wrap up with some resources. Cedar had mentioned a couple of these. But one of them I want to point you to is the second bullet, mapping of gas and oil heating and cooling systems to electric options. This actually goes through different types of systems that you might see in your commercial building today and gives you some ideas on how to change that to an all-electric solution.

The other reference that I want to point you to is something that we helped develop with DOE and the National Labs, and that is an advanced energy design guide around zero-energy. We have buildings out there, schools out there, and multifamily is going to be released very, very soon in here.

And so these are a free download off of the ASHRAE website and they have got dozens and dozens of ideas on strategies to improve the energy efficiency of your building and even think about how do you incorporate many of these things into new buildings. And so I would encourage you to go look at these two resources.

And with that I will turn it back over to you, Cedar.

Cedar Blazek: Great. Thank you so much, Paul. And because we did get a question in the Q&A, I just want to note these resources will be linked on this PowerPoint slide, which will be posted on the Better Buildings Solution Center, but we do also have a resource page that we'll be sharing after the webinar that will link you to all of these resources.

And with that I am going to hand things over, if you want to go to the next slide, to Stanton Stafford. Stanton, take it away.

Stanton Stafford: Thanks, Cedar. Thanks, Paul. I think you'll see a lot of the themes in your presentation kind of carried over to my presentation.

So next slide.

The Integral Group was fortunate to work with ASHRAE Integrate Design and Construction Team on ASHRAE's new headquarters. Today I'll try to highlight the primary strategies that took us from an inefficient 1970s office building, pictured on top, to a modern zero-energy headquarters, pictured on the bottom.

Next slide.

So in 2019 ASHRAE sold its former headquarters and purchased a 40-plus-year-old 67,000-square-foot building outside of Atlanta, Georgia. ASHRAE's project goals were to through this project, demonstrate a replicable process – replicable in how buildings could be renovated to high levels of efficiency, achieve net-zero energy performance, and to target a baseline EUI, Energy Utilization Index, of 21.4 with a stretch goal of 15 kBtu per square foot per year.

Next slide.

Key principles for the project were climate in place to inform the design using daylight as the primary lighting source, using an expanded thermal comfort range to improve efficiency, and to deploy low energy use systems wherever possible.

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So the team's approach focused on the following. We needed to, one demand more from the building envelope and its program, to demand more from the building occupants in terms of plug load efficiency and how those plug loads were leveraged; deploy high-efficiency systems wherever possible; and deliver on a tight budget and schedule. So the budget goals were to renovate the facility for less than $200.00 per square foot on a project schedule design and construction over 18 months, and the overall goal was to demonstrate that building acquisition and renovations could be accomplished for less cost than new building construction and get the building to zero energy status.

Next slide.

So how did we do it? So first we started with envelope testing. So we tested the building envelope using blower door and thermographic testing and what was shown was significant envelope air leakage and heat loss. We then took the existing building data and the new building program and developed an energy use characterization chart. The chart is used to help visualize significant opportunities for energy use reduction. So in this case what the energy use characterization chart showed was windows representing the largest heat loss and heat gain component for the building, and also the largest opportunity for energy reduction.

Next slide.

So then we studied the programmatic organization as a means to reduce energy consumption. So we ended up choosing a stratified scheme that allowed optimal access to daylight and personal connection for staff, and also zoning to allow turndown or turnoff of intermittently occupied spaces. The impact of optimizing program layout equated to a reduction of 10-percent in the forecasted energy consumption, or a 30kw reduction in the size of the PV array that we'll talk about in a little bit.

Next slide.

So moving on to passive strategies. With respect to envelope strategies to use, reduce air leakage and thermal bridging were developed. We then modeled a large number of fenestration shading configurations with a focus on balancing daylight, access to views, and heat gain and loss.

So glazing area and office sides was decreased with the north and south sides employing more glazing than the east and west exposures. In the end the design reduced the glazing from over 60-percent to just under 40-percent, reduced the solar heat gain and loss for the building relative to the as-inherited condition, and increased access to quality daylight.

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So maximizing access to daylight was a key aspect of this project for ASHRAE. Based on the building configuration it was clear that skylights and glazing interventions were going to be required to meet the project goals. That said, extensive daylight modeling was leveraged to inform a skylighting and fenestration strategy geared towards 55-percent daylight autonomy for the building with 67-percent autonomy on the upper level occupied by the full-time staff.

The daylighting strategies worked really well in practice. On most days only task lights were required by staff to do their jobs. There's essentially adequate daylight to allow architectural lighting to remain off on most days.

Next slide.

So with design parameter in place solar was deployed – actually I think you skipped a slide. Go back one. Okay. Move forward.

So with design parameters in place solar was deployed to offset the building's energy consumption, with an annualized goal of zero net energy. So a 300kw solar array located on both the building's rooftop and at grade adjacent to the building is currently operational and tracking towards the zero net energy goal.

Next slide.

So because the energy reduction heavy lifting was accomplished via passive strategies, program, envelope, fenestration, daylighting, there was a certain level of flexibility relative to HVAC system decision. So all electric was the base strategy. Humidity and fresh air was separated through a dedicated outdoor air system. This system can capture energy on the exhaust and put into the fresh air stream. It also dries out the air very efficiently.

With the DOAS in place several system types for heating and cooling the building were explored. Two very different options, both of which achieve the project goals, made it to design development. One was a relatively conventional market rate all-air system. One was a decoupled hydronic system atypical to the East Coast market.

So to introduce a new system to the market ASHRAE chose to move forward with a dedicated decoupled solution which used radiant overhead heating and cooling panels, a heat pump chiller for warm and cool water production, the dedicated outdoor air system, and high-volume low-speed fans inside the office space.

Next slide.

So this chart summarizes the incremental journey that I just described. So of particular note, the passive strategies that we talked about first moved us 90-percent of the way towards ASHRAE's energy goals. The renovation of the building from that 1970s era building to zero net energy was accomplished for less than $190.00 a square foot. Because of the passive interventions doing all the work HVAC system options were, again, flexible. The renovation costs could have been even less with a different HVAC system choice. And as our initial goal set out to be, the total cost to acquire and renovate the building to zero net energy was less than the cost to build a new building.

Next slide.

Here are some photos of the completed building.

Thank you very much.

Cedar Blazek: Wonderful. Thank you so much, Stanton, for sharing that project with us.

Okay, just a quick reminder to the audience to send any questions you have at www.slido.com event code DOE.
We will look forward to answering your questions at the end of the session. And please upload questions that you really want to hear answered.

So now we'll hear from our final speaker, Kent Peterson. Kent, take it away.

Kent Peterson: Thank you, Cedar. You can go to the next slide. And Paul and Stanton, I really appreciate your useful presentations. There's no question the ASHRAE headquarter renovation project really did show that old inefficient buildings can be economically decarbonized and also save substantial and body carbon.

I'm going to focus on some additional existing building decarbonization strategies when retrofitting your existing heating systems.

Next slide.

Start out with some of the challenges. You know, I've found that there's a fair amount of information regarding new building decarbonization, but really very little information out there on retrofitting buildings that are served by large central systems. Decarbonizing existing steam, combined heating power, heating hot water systems really have their own unique challenges that we have to look at. We're going to go over a little bit of that in this presentation.

The existing investment that you've put into your existing hydronic piping distribution system, the reheat coils that might be in your large buildings can sometimes be factors that we really have to consider when we're applying these low-carbon, low temperature heating solutions that are really going to be preferred when we go for heat pump technology or heat recovery chiller type strategies.

We've also found that about 80-percent of all the existing heating hot water systems that we touch are grossly oversized. And Paul mentioned this. And when I say grossly oversized I'm saying

anywhere from 150 to 300-percent of the systems that we actually go and get the metered data and look at what the actual installed system size was. And this is a common problem that were finding.

Now one of the things that we did find was is one of the most used load calculation software programs out there in the market is oversizing many of the buildings that we're involved in, especially if they have high thermal mass. So that's something we need to actually look at. And then it's important to understand what the true size you need when you're going to look at low-carbon technologies, and it's critical information to determine, since low-carbon solutions can be substantially more expensive per MBH, when we start talking about heating systems and traditional natural gas-based solutions.

Next slide.

So along with the challenges come many opportunities in existing buildings. There's no question in my mind that when dealing with existing buildings that existing building recommissioning is step number one. In order to get the building operating as efficiently as possible, so we understand what the actual current load requirements are. Don't start with an inefficient building – you know, the loads are not working properly, the loads are too high. Get it working properly and then start to do your baseline and understand where your measurements need to be.

The first low-carbon strategy as Paul mentioned and Stanton mentioned is energy efficiency. So I'm sure many of you have already implemented this on your projects. I saw in the thing that people were saying they hadn't implemented any low-carbon strategies, but energy efficiency is first in the loading order all the time when we're talking about whether new construction or we're talking about retrofits in existing buildings.

So any opportunities to reduce the existing loads. Think about building envelope or heat recovery options that you can reduce the size of your equipment. It's going to be a lot of bang for your buck when you're trying to do these type of things.

Many times also decarbonization projects can also help solve other problems you might have in your buildings. So always have that list of problems that might be there, whether it's problems with the roof, you know, if you're doing building envelope-type upgrades it could be problems with your HVAC systems, IAQ problems,

things like that. You can solve other things while you're doing decarbonization projects.

Now in this presentation I'm going to review some – when sometimes during retrofits it makes economic sense to size heat pumps for less than the peak load, and we'll talk about that. And that's really because of the economic pressures. And I know one of the big questions that was said earlier on or one of the big barriers is economics on decarbonizing. So that's one of the primary focuses.

So let's go ahead and dive into a case study here.

Next slide, please.

So here's a case study of a campus. The campus was located in a mild climate; it was served by a combined heat and power large co-gen plant that fed all of the electricity for the campus. It provided steam, 125psi steam to all the buildings for heating. And the central steam system was roughly about 50-percent efficient when we measured it. So what was actually going out and what was actually being utilized in the buildings, only about 50-percent of the heat actually got utilized in the buildings. So that's a starting point to actually understand.

The other thing is that this initial project was just to remove three buildings from the existing steam system, and it was primarily because they were looking at extensive 60-year-old steam piping distribution, a lot of upfront costs that needed to be implemented, and they wanted to look for other strategies that they could possibly start to decarbonize. They knew that the co-gen plant would have a limited life; there's only about ten years left on it, and they want to start removing some of their buildings.

So their actual project, one of the constraints was there's existing single-row heating coils in the perimeter zones in these buildings and they're using 180˚ heating hot water in those zones. So you're talking about a 40˚ delta T, 180˚ water is not something easy to do with heat pumps. So their base case –

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-was to remove the – the project goal was really to remove the building heating loads from this existing steam system, increase the efficiency, decrease their scope one emissions, which they knew they could probably do just with gas boilers because they get

much more efficient than the 50-percent efficiency they were operating with. And whatever they did, if it had to be with additional decarbonization strategies above and beyond the base case, 15-year lifecycle costs by period for any incremental investment we're looking at.

Next slide.

So as I said, it's really important when we do these type of retrofits. You really have to understand what the existing load conditions are in the building. Now I'm going to walk you through this chart, 'cause it could be a little bit confusing. But on the bottom here are bins of percent of design load. So in that first bin, that's 5-percent. So 5-percent of the design load. Those blue bars are indicating the actual percent of annual load within that load bin. So a very small fraction. When you get to the 15-percent bin you've got roughly 37-percent of your load was – actually 37-percent of the time is spent in that area and you start to move up.

Now the red line is actually cumulative annual time that you spend. And these things are really important when you start to look at things. So when we look at that it actually intersects their right at the end of the 25-percent bin. So this is basically telling us that 80-percent of the annual therms that are used by this building, which happens to be a 60-year-old building, 80-percent of the annual therms occurred when the load was 25-percent of the size system that was currently in the building.

You'll also notice at the bottom there that you didn't see any loads, and this is 12 months worth of data; no loads existed in the building that were over 60-percent of the size of the system. So this is when we were talking before about many grossly oversized systems. This system was designed for 22 BTUs per square foot peak. The actual peak was only 13 BTUs per square foot.

Now why is that significant? It's significant because when we start to look at replacing systems I can replace that with an extremely expensive heat pump system if I was going to go with the heat pump system that's sized for 22. But it's going to be not only it's too expensive for its cost, but it's also not going to operate very efficiently because we have to have turndown ratio when we're doing heating hot water systems. So two very important things there.

But this is just one example. So if we keep this in mind, that we actually only had 60-percent of the peak load, and we'll move on to the next slide.

So at 60-percent of peak load, and that's what this horizontal line going across this, this is a single row heating coil at 180˚ water. And it's basically actually the water temperatures, we varied it, but the left axis – right there where it hits the y-axis it's 180˚, gives you 100-percent capacity at 180˚ water.

As we start to reduce the water temperature we're always interested, like what happens to that coil and that heat transfer or the heat exchanger as we start to lower it. And we see that when we're roughly around 130˚ we still get 60-percent of the heating capacity out of the system. So this right off the bat tells us when retrofitting things that we have the opportunity that we might actually just be able to go in and reset the hot water supply temperature, that because it was grossly oversized we don't need 180˚ water. And these type of things can happen in most buildings to operate your systems more efficiently, even if you're not changing out the actual equipment.

If you just wanted to do a decarbonization strategy, leave your gas boiler for the rest of the life until it needs to be replaced, you should be operating it as efficiently as possible and you should be only putting the hot water supply temperature that's actually required out there that's needed. You've got to be obviously careful when you're dealing with non-condensing boilers; those can have their own challenges.

Next slide.

So we also look at whether we go and retrofit with two row coils. We've done a lot of work on retrofits and I can tell you it's almost like going out and replacing all the terminal devices. So you're pretty much – it's easier to actually go and replace the entire VAV box with the coil than it is to actually pull the coil out and put a two row coil in. So these are very expensive, and normally not something just for a decarbonization project. If you're doing an entire building renovation certainly it makes a whole lot of sense. If you're actually thinking about any of your building designs today, whether they're retrofits, replacements, anything else, I would highly recommend that you not be putting in single row coils. I always put in two row coils, even if it's something in the future that you want to have that capability for your infrastructure to be able to handle the low temperature hot water.

But this shows you that this two row coil has no problem meeting 100-percent of the capacity at roughly less than 130˚.

Next slide.

So the base case for this campus was to provide natural gas condensing boiler plans. That's what they said. It was the base case instead of replacing the underground steam and condensate infrastructure and manhole systems that were basically having leakage problems and at the end of their life. And the campus said "We're very interested in looking at the possibility of putting in a supplemental heat pump that can actually also make a low-carbon solution to get us even lower than what we're doing just with the natural gas boilers." And based on the load profile you saw, requiring only 25-percent of the plant capacity.

Next slide.

So as we said, the campus had a 15-year life cycle cost requirement. We did a design build solution on this. We were just serving as the client's engineer, not the design build engineer. And we looked at a supplemental 150-ton 2,200 MBH heat recovery chiller. It's our first loading order in providing heat; it provides that first 25-percent, which is actually 80-percent of the annual therms on the campus – or on that campus heating plant. It had a 12.2-year ROI, which is very good. I can tell you if we decided we wanted to do it for 50-percent we would've not met the 15-year ROI, and if we wanted to do 100-percent we would've been out in left field as far as trying to meet the ROI. It didn't actually have a payback when we went to 100-percent.

So these are important things to keep in mind when we're starting to look at it.

The lessons learned is that heat pumps and heat recovery chillers are very expensive. I mean when we talk about expensive, you know, much more expensive than their natural gas alternatives that were going from when we're looking at existing buildings. If we're doing new buildings everything is envelopes and it's all an integrated solution and it's much easier for us to make that sell. But in retrofits it's very difficult. And sometimes you don't need to size it for 100-percent to get a whole lot of benefit in the decarbonization goals that you're trying to do.

Also, don't forget about fundamentals. Heating turndown ratio is extremely important. It's important when we're doing gas boilers. It's just as important when we're doing any other type of heat pump technology or heat recovery chiller or compressor-based solutions.

Next slide.

So to summarize on the existing building takeaways, I think it's really critical to determine the actual heating loads when we're decarbonizing systems. As we're trying to look for replacements what are the heating loads, what does that load profile actually look like?

It's also important to set goals for projects. Whether it's new projects, but especially in existing projects, what are the carbon reduction goals that we're trying to do? There's nothing wrong with actually setting a rate of return on investment, or what is that economic hurdle that you have to make on some of these in order to make it so that you can justify it to whoever's coming up with the funds.

I always look for economical opportunities to reduce the loads. This equipment is extremely expensive, and when I say it's expensive I mean when we talk about compressor-based solutions over natural gas solutions, you know, condensing boiler solutions, roughly just the equipment itself is about six to eight times more expensive. So things that weren't actually economical when we were looking at gas-fired boilers when it comes to envelopes or it comes to heat recovery solutions, now become economically viable when we're looking at these type of equipment. Because we can offset a substantial amount of that first cost.

You know, I'm a strong believer that load profiles are necessary for accurate life cycle cost analysis. Good metering of loads is very beneficial. As I said earlier in the slide, I'd use a minimum two row heating coils when designing systems today, because you want your systems, no matter what you're doing, even if you're replacing, you want it to be compatible with low temperature systems in the future that would be low carbon strategy.

And I'd say don't be afraid of partial decarbonization. Partial decarbonization and meeting lifecycle cost requirements is much better than having no reduction at all. If you are basically going for hitting the homerun and you miss the fence or you hit the foul ball you have no decarbonization, and that's not a good thing. This is a journey to get to full decarbonization. If it means incremental and

trying to do what we can do today, we should do those types of things and still make a lifecycle cost justifiable. And a lot of the same principles apply to smaller systems as well.

Thank you.

Cedar Blazek: Kent, thank you so much. Really fantastic takeaways. I know that a lot of those bullet points answer a number of questions that have come into our Q&A, so really helpful to wrap up there.

Thank you, Kent. Thank you to all of our panelists, Paul and Stanton. Now we're going to transition into the Q&A portion. So for our audience, if you haven't already please join us at www.slido.com event code DOE to submit and upvote questions.

The first question that we have that has been the most upvoted is around embodied carbon, not just operational carbon emissions. So what is the importance of embodied carbon emissions reporting in relation to low-carbon strategies? Should we be trying to account for embodied carbon, and if so, what tools are available?

I'd love to hear from Stanton and then Kent on any tools they're familiar with and how you incorporated embodied carbon considerations.

Stanton Stafford: Sure. So we do use a lot of embodied carbon tools as part of our sustainability practice. The names of the tools, since it's not my area of expertise, escape me. But yes, it was a part of the process. For ASHRAE it wasn't as much about embodied carbon as it was hitting that zero-energy goal.

Kent, I don't know if you have any comments.

Kent Peterson: I do. You know, embodied carbon is becoming more and more important, and probably I would say we're on a journey even on the embodied carbon side over the next five years. Today most people are talking about embodied carbon when it has to do with steel, concrete, wood, glass, some of the major structural elements. The reason is that we have EPDs out there, the Environmental Product Decorations for that type of material.

We're behind on the building server side. We're starting to get more traction I think in Europe on EPDs, where we're certainly behind in the United States on EPDs. The federal government right now with the Buy Clean Act that they're working on, and the GSA

has already started doing this on certain types of materials to reduce embodied carbon.

It's not just a matter of us not having the information. I mean there are some tools out there. I mean one-click LCA is one of those tools that seems to have the most EPDs for what I would say – EPDs or they have good information if you're trying to do building service.

When we're talking about new building construction it's extremely important on embodied carbon. Certainly the embodied carbon on the ASHRAE headquarters, when you have the opportunity to retrofit an existing building and not demo it and build a new building you save a lot of embodied carbon. And embodied carbon makes up roughly about 27-percent of the annual energy-related emissions in the world on an annual basis of buildings. So 27-percent of buildings is in embodied carbon, just in mostly new construction.

I wouldn't put a plug for Better Buildings, and Paul might want to say something about this, but we do have a working group that's been working group that's been working on an embodied carbon resource navigator that's really good and that should be coming out and be live probably, Paul, within the next month or two?

Paul Torcellini: That is certainly they target. So yeah, so under the design and construction allies, if you're interested in how the design and construction kind of delivery industry is thinking about some of these things. There's definitely a balance between that and the operational carbon of a building. And certainly what we have focused on in the retrofits is a lot of that embodied carbon has been expended, but these buildings are using a lot of energy, so anything we can do to really reduce that energy load still is the high priority.

Cedar Blazek: Great. Thanks, Paul.

One question we have in the chat that a lot of folks want to know the answer to, is there any document that shows the priority of carbon reductions based on ROI, both for new and existing buildings? Are any of you all familiar with any resources that might meet that requirement?

Kent Peterson: I don't –

Paul Torcellini: That's specific – oh, go ahead, Kent.

Kent Peterson: Well, I was just going to say, I mean ROI is an interesting animal. It depends where you're at, what your goal cost is. I mean the case study that I was showing, because they have a co-gen plant their actual electricity cost was only 8.5-cents per kilowatt hour, which actually makes for really poor ROIs on many energy efficiency strategies or decarbonization strategies.

But I think it's more so about a loading order of measures, and certainly ASHRAE is putting one out right now in a position document that Paul and I have been working on. I mean the loading order is fairly simple as far as – some of these were covered in the presentations – as far as, you know, reuse any of the existing structures that you have for embodied carbon, you know, optimize your building envelopes. It's always about reducing load first. Attack your energy efficiency with passive measures and active measures. You know, use, as we talked about, waste energy is very important.

So especially with heat pump technology, what are those heat streams that we can use for heat pumps to make it viable? Attack the embodied carbon side, electrify the loads whenever possible. Definitely be concerned about your refrigerants by using low-GWP refrigerants. I would also say demand-side management is going to be extremely important as we start to look at 24/7 renewables and what's happening on the grid.

And then lastly is whether it's your on-site or off-site renewable energy. You've got to supply – you have to be low-carbon electricity, or at least your fuel source that's providing your building.

Paul Torcellini: Yeah. I would say I guess I do wish I had this kind of magic book, right, is kind of what you're describing in the question here. And all of the people that agreed, it would definitely be a fabulous resource.

I would certainly look at the ASHRAE Advanced Energy Design Guides that I started to talk about. You know, going back to if you reduce the load, if you cut your load by 50-percent in energy, it's probably going to be pretty close to a 50-percent carbon reduction unless you start talking about the fuel switching discussion, which is a different kind of direction with that. But if you replace your lights and get a 50-percent reduction on your lighting load, there's probably a 50-percent carbon reduction associated with that component of making that change.

And so look at your current strategies of energy efficiency and what your return on investments are. Usually, as I said, lighting is very close to the top of the list. There's a lot of kind of passive things you can do with plug loads to get those down. You know, and then look at the envelope and the leakage in the envelope, saving energy in terms of motors and HVAC. All will have carbon reduction associated with them.

So I would encourage you to look at your own returns and what's possible. And again, one of the strategies is to put these strategies with other things you're already doing in the building. Right? When you replace equipment, when you've kind of pushed on with this presentation, that the money was used for something else and yet you're also getting carbon reduction. And that way you don't have to focus quite as readily on what that specific return on investment was.

And that's a great part about the story that Stanton said, where ASHRAE was able to take an older building that was an energy hog, renovate it to this level of performance using that existing building, reducing the embodied carbon, and it came out substantially less than building a new building in that market. So those are, again, how money got spent and thinking about this as part of your decision-making process.

Cedar Blazek: That's great. Thank you, Paul.

So I think we have time for one more question, and I love this one because I think it's really relevant for how to continue on with this discussion beyond the walls of our webinar today.

What kind of training and credential would we look for for training ourselves and workers for building efficiency? Where could we find that training? So folks want to implement these recommendations, they want to learn more. Where can they go for more development and training?

I will start with Stanton and then Kent and then Paul.

Stanton Stafford: I would, one, look to ASHRAE. ASHRAE has a lot of viable training courses, they have certifications tied to a lot of these topics. And then getting involved with ASHRAE as a volunteer. I mean I've learned a lot working alongside with Paul and Kent and others volunteering for ASHRAE and learning the tricks of the trade. And ASHRAE being a volunteer-led organization is always

looking for willing and able bodies to help with the mission and help with the work there. So that would be my suggestion.

Kent.

Kent Peterson: I'd say something very similar. I mean the ASHRAE taskforce for building decarbonization is putting together three courses – three three-hour courses that will be available next month, in June. They'll be offered first at the Toronto meeting and then they'll be offered via Web after the Toronto meeting, really getting into the fundamentals, getting into systems and equipment and getting into the application side of all the things you need to look at.

I'd also say there's a really good resource out there – I mean as we said, energy efficiency is very important. When we look at existing buildings it's the existing building retro commissioning, it's the efficiency strategies. We're talking about loading order and technology solutions for small, medium, and large buildings.

DOE has an advanced energy retrofit guide, which is Practical Ways to Improve Energy Performance. And I think it's a really good document that our government's put together. It's good to go out there and get that in your hands and be able to look through it. And there's good checklists to go down through that thing if you're an owner and you're kind of just looking for some of this information. So good starting point there, too.

Cedar Blazek: That's great. Thank you, Kent. Paul, I'm going to have to cut you short on this one so we can wrap up.

And if we want to pull the slides back up. I will say there were a number of questions that we couldn't get to today. We will be sharing contact info on the slides for all of our presenters, so if you had a question about a particular building or particular region or you want to learn more about any of these projects please reach out to our speakers.

This webinar was the final installment of the 2021-2022 Better Buildings Webinar Series. All of the webinars can be found on demand on the Better Buildings Solutions Center, and we will be announcing topics for our summer series as well as our 2022-2023 series soon.

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Next we're pleased to announce that registration for the 2022 Better Buildings, Better Plants Summit is now open. It will be held in Arlington, Virginia from May 17th through the 19th. And in addition to engaging in interactive sessions attendees can look forward to plenty of opportunities to network with their fellow industry peers and experts. You can find session tracks and book your accommodations on the Better Buildings Solutions Center.

Next slide.

If you're interested in learning more about the topics discussed today I encourage you to download our additional resources handout from the Zoom chat box. This will also be posted online. It contains links to resources from Better Buildings and our speakers, so if you have questions about where to find the resources discussed today, they are here for you.

And then finally I'd just like to thank our panelists for taking the time with us today. Please feel free to contact our presenters. And I encourage all of you to follow the Better Buildings Initiative on LinkedIn and Twitter for all of the latest news.

You will receive an e-mail notice today when the recording and slides are available on the Better Buildings Solutions Center. And again, thank you all for attending and listening in. Have a wonderful day. Bye, everyone.

[End of Audio]

Low-Carbon Technologies: Strategies for Different Building Types

Additional Resources

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

Better Buildings Resources

- Low Carbon Technology Strategies Toolkit
- Better Climate Challenge homepage
- Low Carbon Pilot homepage
- Decarbonization Resource Hub
- Decarbonizing HVAC and Water Heating in Commercial Buildings resource

Explore more resources on the Better Buildings Solution Center

Other Resources

- ASHRAE Advanced Energy Design Guides

Register for the 2022 Better Buildings, Better Plants Summit Now!

This annual event for Better Buildings, Better Plants Partners and other key stakeholders will be in Arlington, Virginia from May 17 – 19, 2022. This event provides the opportunity for professionals to explore emerging technologies and share innovative strategies in energy efficiency, decarbonization, and water and waste reduction. Attendees take part in interactive sessions with industry experts and market leaders as well as multiple opportunities to network with peers.

For more information and to register, visit https://betterbuildingssolutioncenter.energy.gov/summit

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