Nate Allen: All right. Good afternoon, everyone. Good morning to those on the West Coast. Thank you for joining us for this webinar to talk about Zero Energy Schools, and in particular, the recently released Advanced Energy Design Guide for Zero Energy Schools. My name is Nate Allen. I'm a fellow at the US Department of Energy and I run our Zero Energy Schools Accelerator, which is an initiative under the Better Buildings Challenge. I want to let everyone know that we are recording this webcast and there will be time for Q&A at the end. In addition, if you want to chat questions that you'd like addressed at the end, please list those in the chat box and I'll compile and we'll try to address them one by one when we have time.

I was reviewing our registration list for this webcast last night and it's great to see some familiar names as well as others who hold important roles in school districts and school facilities around the country. So the presenters here have discussed this, and based off the I'd say predominant type of attendees, we're gonna try and focus our attention on how school district sustainability officials can think about zero energy and what's within your purview to promote it, and I get to say welcome but I won't be doing much more talking.

Next, I'm going to hand things over to my colleague, Crystal McDonald, who runs the K-12 sector within the Better Buildings Challenge and she's a great collaborator. Crystal's gonna share some updates related to DOE activities that you see listed on the slide right now, things coming up in the coming months, and then she's gonna pass to Paul Torcellini, who is exactly the person we want delivering this content today.

Paul, for anyone who doesn't know, I think his title is principal engineer out at NREL, the National Renewable Energy Laboratory, but he's, in my opinion, a Renaissance man. He's also on the faculty at Eastern Connecticut State University. He built his own zero energy house, and perhaps most relevant for this webcast, he chaired the working group that created the latest advanced energy design guides. So he's an expert on zero energy in his own right and we're thrilled to have him for this hour.

I'm gonna hand things over to Crystal now. When she's done, she'll pass to Paul, and then we'll make sure to have time for Q&A at the end. Thank you, again, for joining us. Crystal, you're up.

Crystal McDonald: Fantastic. Thank you, Nate. I appreciate that. Hi, everyone. Thanks for your time today. I would just like to highlight a few items for your hearing and use, as Nate mentioned.

First up, I'd just like to remind everyone of the Better Buildings Challenge, and for those who are not familiar with the Better Buildings Challenge, it is a call to action to leaders in every sector of our economy to commit their entire building portfolio to a 20 percent energy use reduction over a ten-year period. We offer PR promotions and support for your work through publications, conferences, and campus visits, and then you receive local, regional, and national recognition for the work you're already doing, and then we also help you access DOE experts, such as Paul, at our national labs and beyond, and that way, you're able to stay in the loop on the latest technologies, case studies, technical specifications, and more.

And then finally, I think this is one of the highlights, is that we're able to provide data _____ reviews of your building portfolio data, and this gives you an unbiased, third-party review of your data, where you're able to locate energy savings as well as potential problems. So currently, we have about 28 school districts from across the country participating in the challenge and we always welcome more. We have very small districts as well as very large districts, so again, we invite you to take a look at the challenge. If you have questions about the Better Buildings Challenge, just let me know.

Secondly, I just want to call your attention to the Better Buildings Summit. This year, we will be partnering with the Department of Energy's Energy Exchange, the nation's premier conference on energy management and federal facilities. Combining these events allows us to bring together thought leaders from the federal, private, education, and state and local government sectors to share best practices, insights on new technologies, and innovative strategies that increase energy efficiency, lower cost, and improve the environment. Summit sessions will be primarily on the 22nd and the 23rd, with pre and post event workshops, so we're expecting a schedule to be published over the next few weeks. Some of the highlights include sector meetups, a full day of crosscutting sessions, special events such as building tours, financial allies, speed dating ask an expert with DOE's national lab staff, and then other networking opportunities.

So the summit event will be similar to previous years, but the combined event will give attendees access to all energy exchange offerings, including access to all sessions, technical trainings, opportunities to earn continuing education units, and access to the trade show. So registration is open and cost is similar to previous years. The biggest difference is that we're combining with the Energy Exchange in Cleveland, Ohio versus having the summit here in Washington, D.C.

And then finally, I'd like to give you a heads up on the new Energy Data Management Guide that will be released over the next few weeks or so, and this is a product done in conjunction with NREL and is in digital format. It is a step-by-step framework highlighting best practices in the energy data management world, so it provides guidance on how to establish a robust and sustainable energy data management program, and by following the steps listed in the guide, organizations will be able to cut energy waste, save taxpayer dollars, or course, demonstrate leadership, improve the efficiency of their operations, and of course, create a culture of accountability and high performance.

So with that, there's more information to come on the Energy Data Management Guide, and those are our announcements for today, so thank you.

Paul Torcellini: Okay, so this is Paul Torcellini at the National Renewable Energy Lab, and I'm going to talk about the newly published Advanced Energy Design Guide for K-12 Schools focused on achieving the goal of zero energy, and I just want to start a little bit high level here on where energy goes in this country. A little more than a third of it goes into buildings and a little less than a third goes into transportation largely to get us to and from those buildings, and then about a third of it is to make stuff and to transport stuff to and from those buildings, and so really buildings end up being a key piece of how we use energy in this country. Almost three-quarters of the electricity in this country goes into buildings and a little more than half of the natural gas.

Schools fit into the commercial sector and it's always interesting to note how much lighting loads are a part of what goes on in commercial buildings, followed by heating and cooling, and a lot of the cooling load is to remove the heat that has been generated by those lights.

A couple of trends that I note that are out there. One is that we continue to build buildings, and we've done a huge amount over the last 30-plus years in terms of energy efficiency, but we continue to build buildings at a rate that is faster than we can save energy, so even though we can talk about our buildings today being a lot more energy efficient than they were in the past, we have a lot more buildings out there today. I think the estimate is something worldwide by 2050, we'll have twice as many buildings as we do today.

Another important piece of this is that every decision we make has some energy or environmental impact, so you could look at even things like where did you get your coffee this morning? Where was it sourced? What kind of cup did you put it in? Did you use a reusable cup, did you use a disposable cup, or did you use a cup that you could recycle? We make the same kinds of decisions around buildings. How are we going to layout the building? What kind of spaces are we gonna have? What kind of windows are we gonna select for the building? What kind of HVAC?

All of those have energy and environmental impact, and if we back up and think about all of the decisions that we make in our jobs and in our personal lives, Nate mentioned that we made a decision to live in a zero energy house and to design it and construct it, but all of these decisions have an energy and environmental impact.

The last piece is because we're making all these decisions, one of the things about buildings is they're here for a very long time and we hope that they're here for a long time because there's a lot of material resources that go into those, but if you want to figure out how we're gonna build buildings in the future, look at the decisions we're making around buildings today because they're gonna be here for a long time, and so these buildings are going to mortgage the energy futures of this country and of the world.

So as we're talking about making decisions, so here you see Isaac on the screen, and his dear father put his puzzle together when he was three. He, by the way, is no longer three, but look at the puzzle carefully and you'll notice that all the pieces were used, all the pieces fit together. There are no gaps or holes, but something doesn't look quite right. So even though I put the puzzle together and made these decisions, I'm not sure I was motivated to necessarily do it the same way that maybe the three-year-old thought it should be put together, and at the end of the day, Isaac was, "No, daddy. This is wrong. You've gotta fix it and we've gotta do something about it." But as we build buildings, once you make some of the decisions, it's really hard to go back and fix those things, so it's always to the advantage to try to make decisions early and to follow a pathway that goes to establish it all.

The other part of it is who are these decision makers. The obvious decision makers might be the owner. It could be the school board, the superintendent, maybe some of the teachers, facilities folks. Those are some of the obvious ones, coupled with the engineers and architects. We did an office building that houses about 1,200 people and we sat down and counted how many people made decisions that could have impacted the energy performance of the building all the way down to people that were installing insulation maybe in a window header, and the question is if you don't get your job right and have the motivation to do it right, what happens is that something won't work as it was planned to work, and quite often, you lose energy performance because of that.

We took our building, we counted about 1,000 people that had some influence over decisions and the real key is now you've got this army of people helping you deliver your new school or even a renovation of a school and the question is are they making decisions the way you want them to be met in order to achieve that goal?

So in setting goals, measuring those goals are always better. I always like it when Crystal talks about the Better Buildings and the challenge is to get a 20 percent reduction. You can look at where you were. You can measure progress towards that and know when you've achieved the goal. We want people to do this on individual buildings because if you say I want a green building, in fact you could say, "I want a green high-performance passive low-energy solar building," and not everybody might know what you're talking about, but everybody may have a different idea of what that means to them, and so one of the things that we've done as an industry is the LEED rating system and you can say, "Well, I want a building that meets a certain LEED score, it gets to a certain level of certification."

And that started helping us think and define what green buildings were and that was one way to set goals, but one of the things to think about is any time you create a test, and Nate mentioned that I also teach, my students come into class, and I, as the professor, say, "I want you to learn. I want you to be inspired by me and learn something." And the students look at me and they say, "Okay. How many points do I need to get an *A*? How many points do I need to pass this class?" And the focus is different and there's a disjointedness between what I want and maybe what a lot of the students are trying to get out of it.

And so what happens is that people look at any test mechanism, whether that's LEED or some other rating system, some other scoring system, and they say, "What's the easiest way I can get to the end goal?" And they sort those things and so people have come up with strategies of how to sort LEED points based on dollars per credit, which is the cheapest point to achieve.

If we want to focus on the energy piece, we've gotta put a lot more emphasis on that. When you go back to that original pie chart that I started with, 40 percent of the energy is going into buildings and we've gotta solve that problem and yet it takes a lot of decision makers. It takes a lot of thinking about how to do that, and so we talk about things like design a building using 30 percent less energy than a code-compliant building, and you can pick a version. I have ASHRAE 90.1 as an example of that, the energy standard that's out there, but when you do that, now you also have to create this fictitious base case, so you're doing a comparison against that fictitious base case, and so as a result, what's better is saying, okay, I've got a school building. If I can characterize what school buildings look like, I could actually set an absolute goal, design a building that uses less than say 25,000 BTUs per square foot.

One of the nice things about zero energy buildings is that it has some market traction. People are talking about it. People conceptually understand what it means and there's definitely a lot of details there, but conceptually understand what it means, and it's a number. We can measure it at the end of the day. In fact, DOE created a definition around zero energy buildings so you know if you meet the definition or don't and achieve that goal. Ultimately, you want to be able, as an owner, to influence the purchasing decision around a building such that it meets this goal as well as all the other goals you might have for a project.

So conceptually, what is a zero energy building? For a long time, we used energy consumption as a long-time surrogate for environmental impact. I wish I could go in front of a building and have this meter that magically told me what its environmental impact is and we could have a long discussion about what that might mean and what other metrics we have, but historically, we've equated energy consumption with that and largely because energy consumption requires a lot of infrastructure on the utility grid. It uses fossil fuels. It uses nuclear fuels. Even the renewable fuels on the grid require lots of land, lots of infrastructure, lots of capital, and all of those come with environmental impacts.

Different energy sources have different amounts of impact, but they all have some impact, and so the idea of a zero energy building is conceptually a building that has no adverse energy or environmental impact because of its operation. At the end of the day, it all comes down to what boundaries you select, what you're going to measure, and what energy flows you're concerned about.

So here's my little fat building and very typical to energy consumption of buildings, they have lighting loads, base heating loads, cooling, water heating, et cetera, and I think there's a lot of interest out there in just putting some PV on buildings. In fact, it's really easy today to sell PV because it comes with this environmental image, but what happens is if I stick PV on an energy-wasting building, I can't make the balance happen until I really think about energy efficiency and reduce the consumption of that building in order to achieve that balance.

And so as we talked about how to create design guides around zero energy buildings, we wanted to focus on first reducing the consumption and that reduction is roughly a 50 percent reduction, a 50 to 70 percent reduction, and we wanted to then apply onsite renewable energy in order to achieve that balance. There is a formal DOE definition for that, an energy efficient building, where on a source energy basis, the actual energy delivered is less than or equal to the onsite exported energy in order to achieve that balance between you and a utility.

So as we're thinking about this, a lot of this came down to setting goals and how to think about a decision-making process. So on the screen now is a graph with a little orangeish-red bar that represents the cost of a typical building, and for this discussion, we can say a typical school building, and lots of decisions are made around energy savings and I can save energy going to the right of this diagram or use more energy going to the left. I can spend more cost by going up or reduce cost by going down, and I create these four quadrants. Historically, people think about energy savings, in order to get energy savings, you have to spend more money, and it doesn't matter if you're trying to do a lifecycle analysis on that, or return on investment, or a simple payback.

There's lots of metrics that are related to that, but one of the interesting things they all have in common is that they all cost money. In order to save energy, the idea and we've thought about this for a long time and in some ways it's institutionalized that you've gotta spend some money to do that. That could be a more efficient chiller. It could be more efficient glass, more insulation. All those strategies come at some kind of cost premium.

But there are lots of things that we do with buildings where energy is wasted but actually costs us more to build that structure. Some of my favorite ones are things like curved walls. The one I usually pick on, not quite as relevant in schools, are fountains, so fountains use energy, they use water, they're a maintenance nightmare, but people still buy them and they still put them in and around buildings. Well, why is that? Because people want those things. They want some of those amenities. They want some of that look and feel and they're willing to pay for it.

The same question even comes up with things like how many speakers does your car have? I have an old Toyota pickup that has one, barely one speaker in it, and it works okay, but my car doesn't have six or eight, and in fact, a lot of people do have cars with multiple speakers in it. Does that help the car move? Does it help it go? It really doesn't but we're willing to spend extra money for those kinds of things. And so right off the bat, we have this conflict between some of these things that I want expressively about a building and it could be the architecture.

Maybe it's extra trim, or a brick façade, or larger windows, and those things are competing with the energy efficiency strategies, and yet on the energy efficiency strategies, we've mastered the technique of how to rank order them by cost effectiveness or whatever your other decision criteria, and when money runs out of a project, quite often, it's really hard to take away some of those kind of architectural pieces of it that we've added in, and instead, we take the things in Quadrant 1 and we value engineer them out of the process and get to Quadrant 3, and many designs are this iterative process, trying to go around a circle in these three quadrants.

So several years ago, we had done an analysis where we took a building and we let the computer design it and we had a cost model built in and energy models built in and we said if the computer was designing buildings purely on logic, and I will stop, and yes, I'm an engineer, but I will preface that. You probably don't want to be in the computer's building because of what it chose as decisions, but interestingly, and it was somewhat independent of building type, it always found solutions that could save energy and it reduced the cost at the same time, and so that got us thinking in terms of there's the curve of what the computer generated that got us thinking in terms of how can I get a deep energy savings and not impact the cost and what does that look like? How do I start thinking about that?

And a lot of the solutions started looking like integrated pieces. Can I use the windows that I want in the building to help light the building? Can I use the windows in the building maybe to help ventilate the building? Can I use the thermal envelope of the building and how it is oriented and set up on a site to help heat and cool the space?

What is very interesting to me is if you look at historical buildings, and I consider historical maybe anything before 1940, and what happened what we didn't have air conditioning and we thought very hard in how we designed that building because we didn't have great lighting technology so we relied on day lighting, and especially as they get closer to 1900, we had windows that provided natural ventilation, and all these pieces fit together because we were still trying to meet comfort criteria, fresh air criteria, a lot of the things that we want out of our buildings today, but we didn't have air conditioning, and in some ways air conditioning became this crutch in order to design whatever we wanted to design and not bring all the pieces together.

That curve represents a value added, so if I can figure out how to design along that curve, and interestingly, where the red bar is now on the screen, we found was about a 50 percent energy savings, and so that was very consistent with where we needed to go goal-wise for zero energy buildings. So we took all of this information and set up a collaboration between six organizations, so ASHRAE, AIA, actually there's five, the US Green Building Council, the Illuminating Engineering Society, IES, and the Department of Energy, and created a specialized project committee, so each of these organizations has a member that represents a steering committee which oversees the whole process, and then that steering committee finds people specific to the building type that we're working on to help us put together design guidance that is relevant and easily adaptable by the industry.

DOE financially supports this and through, in the case of this K-12 guide, NREL provided simulation support and technical analysis. We really wanted to show readers of the guide that this was technically possible and to give out a set of solutions, solution sets, that are starting points in thinking about design. The guide did have an open peer review and commentary process that ASHRAE administered and so we had a lot of industry input as well as having this industry team. So one of the pieces is that a lot of people think about this guide as is it a new code? Is it an advanced code? No, it's not a code.

It's really educational guidance on how to get to zero. It's not a standard. It's not a guideline, if you're familiar with some of the

ASHRAE terms. Its intended audience really is architects and engineers that are looking for this beyond code guidance, but it is a powerful tool for school owners to sell the idea, to set goals, and actually use it as a guiding mechanism for architects, engineers, and contractors. It is available for free as a PDF download from ASHRAE. ASHRAE is the cognizant publisher of this guide, at ASHRAE.org/freeaedg.

We have put together their other guides. There was actually about five years ago, a 50 percent guide, about a decade ago, a 30 percent guide for K-12 schools. There's actually 12 guides that have been put out in the last 15 years or so. This is the newest guide. It just came out a couple of months ago and it's the first one to really look at zero energy.

DOE provided the funding to NREL. NREL manages the project and provides funding to ASHRAE to really cover the cost of producing the guide and bringing that industry team together. There's a steering committee, as I mentioned, that has a chair, Tom Phoenix is the current chair, and representatives from the four organizations I mentioned before. The project committee is made up of volunteers representing the schools' industry ranging from engineers, architects, lighting designers, owners, that all come together to say how can we make this happen and how can we get repeatable results.

So really the purpose of the guide is to demonstrate that zero energy schools are obtainable, provide direction for designing and constructing these schools in all climate zones, and actually talking about what the differences are between the climate zones, but provide methodologies that are financially feasible, that are operationally workable.

Just an aside here. One of the things I often hear and it seems to come in context of high-performance buildings is how complex they are. You're providing something that school districts can't manage, can't control. Really we want to be able to make these things work for schools so that they're readily achievable and that schools want to build these, and we also provide measurable goals and give you targets to hit in order to achieve zero energy. It really is about the energy balance and the guide looks at both bringing energy in, renewable and non-renewable, looking at onsite renewables is a piece of it although it's not a huge focus of the guide. It really focuses on the building systems, what those building needs are, and how to meet those in as efficient a way as possible such that renewable energy can meet the final loads.

We started from an analysis point of view. So again, I mentioned NREL had done this analysis, a little background on that. We actually started by looking at a two-story school building and said if I covered 75 percent of the roof, what kind of EUI targets do I need to achieve in order to get that? And so we worked it backwards based on how much solar resource was there. There are other renewable resources such as wind and maybe some micro hydro, but for the most part, we focused on the solar resource because everybody has it available, but that doesn't mean you can't use some other highly site-specific renewable resource.

But you can see on this map that in the Southwest, they get a lot more sun than they do in the Northeast and the Northwest, and so it actually allows you to use more energy in the Southwest, if you wanted to, than in the Northeast, and I'll talk a little bit about that in a minute. My general thing is that's not perfectly fair, but at least that gives us a starting point to think about. We then used input from the committee and some other databases to create two what we call prototypical schools. One was a primary school, one was a secondary school. Middle schools fit in between somewhere. Each of these two schools had different functions, so a little bit more meeting space, gymnasium, auditoriums in the secondary school, more food service in the secondary school, than we had in the primary school, and so we addressed some different space needs, looked at some different plug load densities and uses between those two, and we created these typical schools so that then we could look at their energy performance.

And we did exhaustive simulations to determine what kind of strategies made sense, how much insulation makes sense, how much window area makes sense, what kind of windows should we use, what kind of plug loads, what kind of lighting loads, and came up with energy use targets to show that zero was possible and the types of strategies to get there. And so because this focus really on energy efficiency and we realized a lot of places are not quite ready to have renewable energy on their grid. I would say that some utilities and states are more renewable friendly than others when it comes to putting these things on. Some states really limit the size. Sometimes it's just because you're putting a commercial building typically in a residential area, they don't have the capacity to be able to export the amount of solar energy needed through their electrical infrastructure, and so we really focus then on can I create a zero energy ready building, buildings that are so efficient that onsite renewables could offset the energy needs but really focusing on the energy consumption piece of it.

So grinding the crank, and several months of analysis, and looking at it, we came up with numbers. These are site numbers so that is measured at the building site in terms of thousands of BTU per square foot annually, and you can see that across the climate zones, the middle part of the country we would anticipate where you don't have really big heating loads, don't have really big cooling and dehumidification loads, you get a little bit less EUI allowance than you do in the hotter zones, which start with Zones 0 and 1, and end in the colder zones at 7 and 8. I do have to note that these are worldwide climate zones, so my AME sits in Climate Zone 1, but you have to go to the Middle East to actually get some of the zero climate zones, but we did do these on a worldwide basis as we were doing the analysis.

The other important thing was that we try to normalize against technologies and strategies that were not climate dependent. So for example, if in Chicago, which has a fairly balanced heating and cooling load set up, a little bit more on the heating side, you had to achieve a certain plug load reduction to make it work, i.e., making things get turned off at nighttime, using computer settings that shut down computers. If we were going to use those as recommendations, those plug load recommendations are climate independent, and so we had an expectation that if it should work in Chicago and be climate independent or be needed in Chicago, I should be able to apply that anywhere in the United States, and so there are some strategies that are climate independent and we considered that when we put together this map.

So you notice that the EUIs on this map are much tighter than just what the solar availability is. At the end of the day, what that means is you actually would cover less of the building in places that are sunny, like San Diego, compared with putting the school say in the Boston metropolitan area.

There's a lot of information on here. I'm not going to dwell on it, but we did it both for site energy as well as source energy. Source energy is what is measured at the power plant and includes any transmission losses, losses because of inefficiencies in generation electricity from mainly fossil fuels, and so that is a more holistic look at the energy picture than the site energy. The site energy is what you physically can read at your meter. And again, you can download all these numbers and graphics from the actual design guide.

So what is in the guide? We talked a little bit on the audiences.

Right up front in the introduction, we really did work and talk directly to school owners and decision makers on behalf of the owner, but a lot of the guide, especially when we get into how to do building simulation in Chapter 4, and one of the most powerful parts is the how to strategies. A lot of that is geared maybe to facility management, but especially to those who are doing the designs.

We did talk about some of the rational for zero energy. A lot of it is information that I've been covering in this webinar already, and what are some of the keys to success? How can you process through this and actually make it happen and get achievable results? So we have tables that show how the strategies are applied and really it's collections of little bits of text with lots of strategy. Each one of those strategies will help move you towards zero, and we divided it by building inside planning envelope, lighting, which includes daylighting, electrical lighting, plug loads, kitchen equipment, service water heating, HVAC, and renewable energy.

When we did that model development, we also produced what we call gems, and available for download off of NREL's website, you can actually download the snippets of modeling software that were used, so someone that you're asking to do modeling can actually download what we did and strategies we used as a starting point, so in some ways, you can start with a zero energy school in your climate zone and then work the design from there.

The guide also, one of the powerful parts about it, has case studies that have actual measured energy performance in them. This is a little bit of a chicken and egg because none of these buildings actually used our design guide, but they all are schools that are within the same range of EUI that we're recommending, so you can see those on the screen. These three in particular, we also have some more detailed case studies and information about outside of the guide and I'll show you a URL to get to those at the end of the presentation.

So everybody want to know what pathway to do, so really set the energy goal first and there are strategies on how to procure design teams. We've used design build strategies to integrate all the pieces and that's probably a whole different discussion is what we call performance-based procurement, but a lot of that is first reduce the plug loads. When I say reduce plug loads, that doesn't mean we're not going to have any computers or no plug loads in the buildings. It's understand what those plug loads are, and most importantly, turn those plugs off when no one's in the building. A vast majority of the year, buildings are unoccupied and one of the keys to hitting goals is to have buildings turn off when they're not occupied.

Next comes reduce the lighting loads. We can use daylighting, which then starts to look at the mass in the building, the orientation, the amount of glazing. Daylighting is only effective if people are willing to reduce the electric lighting because of the daylighting. If you do daylighting and people still feel they have to have the lights on full tilt, that is not an effective daylight design. That needs controls and the next one was with the new generation of LEDs, low lighting power densities are very achievable. The guide has recommendations on what goals you should put in place for things like just lighting, what is an effective lighting power density.

Then look at the thermal envelope and the water envelope of the building, two very critical pieces. The thermal envelope won't work if it's leaking water or it's got condensation, and so you have to manage both the thermal aspects and the water aspects. We want to be able to test these buildings and there are now methods to test it. The guide talks about methods of testing. Building envelopes as part of the construction process to make sure that the contractor has a good quality control mechanism in that.

View glass is important. We want to be able to look out of the buildings. I mentioned before the computer designing buildings would not have glass just for people to look out of but that is important but we have to realize that is Quadrant 2. We are spending money in order to actually use a little bit of energy, but we should put it in a very constructive and thoughtful way. What is interesting to me is we will think about very high performance glazing and then it falls apart when we put window frames together, and that is part of the window. Thermally broken does not necessarily even solve all of that window frame problem. Natural ventilation is another strategy that can work in some schools and bringing in fresh air through that mechanism.

And finally once we do all that, you actually hope that you've designed a building that doesn't need a heating and cooling system, but in a lot of these very low energy buildings, you can get very specific and have very efficient, sometimes what we call low-lift heating and cooling systems, selecting that type of equipment and sizing it appropriately. It is not uncommon for these buildings to have only 20 percent of the air conditioning capacity as a traditionally designed building. That becomes a big deal. It helps you manage the cost and it also helps with a lot of the comfort issues in the building.

So we've got several resources out there. One is the design guide. Here's a picture of the cover of the design guide. We also have feasibility studies coming hopefully pretty soon as a technical support document that has a lot more detail on exactly what we did to come up with the numbers in this design guide. It is available both in hard copy. You can order it from ASHRAE. There is a price associated with that printing and distributing that, and the electronic version is free. And I already mentioned these energy simulation gems to help others put buildings together.

And really some of the message here is and really the challenge is, and we've seen several examples of this today, that we can create zero energy buildings today, and that includes schools, at little or no incremental cost, and every day I hear of another project that's really kind of gone through this barrier, the idea that an energy-efficient building, and especially zero energy building, has to come with big price tags is not necessarily where we are today. The technology has improved tremendously. The price of solar has come down and so we can do these at little or no cost.

And some of what we want feedback on and feel free to continue the dialog after this webinar, what are your barriers? How do we help solve those barriers? What kind of resources, what kind of analysis would help it be easier for you to deliver these? And even the effectiveness of this guide to meet your needs.

And so kind of the challenge, to wrap up here, what is your next step? What are you going to do? So now you've spent 35 minutes listening to me. What is your next step? What are you going to do with this information and how can you use it to create the next generation of schools in terms of an energy impact?

So I'm going to wrap up there. I think we have time for a couple of questions. Nate's gonna help us with that. There are a couple of resources I've put on the screen. The general resource is BuildingData.Energy.Gov/ CPRD, that's Commercial Buildings Resource Database, another good government acronym, but if you use the URL that's below it, I've actually put together a collection of three or four case studies that we've put together. There's one video up there of Discovery Elementary School, as well as the feasibility study that we've put together on this project. That is one starting point. You can go to the general database and do searches on things like zero energy buildings or cost control for zero energy buildings. There's resources around those topics specifically.

So with that, I think we have some time for some questions and answers, and actually, Nate, I think I'll put that URL screen back up in case people want to copy that information down.

Nate Allen: I think that's perfect. Thank you, Paul, and thank you for sharing all this. Always love hearing you describe how you think about zero energy.

We have everyone muted right now, so I believe a message went out suggesting that if you have questions, send them through the chat box. We haven't gotten any just yet, so we'll hang out and if folks want to raise anything, please do submit them electronically, but you're also welcome to contact us after this and we would love to hear from you, particularly as Paul outlined on the slide just before this, I believe, around challenges you're experiencing or barriers and where next steps could be. That's something that we're starting to aggregate, compile, and see what lessons we can learn from at large.

So one question that has come in is can we get these slides, and that's certainly fine by me. Paul, I assume, yes, absolutely, is the answer, because we are recording this and it will be posted, so attendees, yeah, we can share that information with you for sure.

We have another question. What form of testing would you suggest for the envelope pressure testing? There's a number of ways of approaching that.

Paul Torcellini: Sure, so one of the more common ways, we started with blower door testing on houses in order to do this. There are organizations out there today that will do the same kind of test usually using multiple fans. I've actually seen setups where they'll come in and basically put eight fans in a row in a large doorway opening and they've got the technologies to do that, to move that quantity of air in order to get that pressure difference and achieve that level of tightness of that envelope. There's a couple of very effective tools that really help keep buildings, and contractors, and stuff on target. That is one of them and putting it in a specification, and again, there's details in the guide about that.

Another one that I found very effective is requiring your design team, just like you ask them to create as-built models of the building, also create an as-built energy model, and hold the contractor accountable for meeting your energy goal as shown by the energy model. What I have found is from an effectiveness point of view, it takes the owner out of the role of policing everything. So an example of that might be somebody didn't quite put the insulation in properly and you, as an owner, can say, "I noticed this but it's not a problem from our point of view. Just make sure that the energy model reflects that level of insulation that you actually installed," or maybe there was a substitution for the glass and make sure the model has that property and that that model still achieves the final energy goal as required for the project. And what I have found is that contractors who are bound to that discussion become very in tune with delivering very high quality usually around these envelope issues.

So those two pieces I have found very effective at really improving building performance. One added note on that. If you do that, then it makes it much easier for the engineers to right size the HVAC if they know that's gonna happen. If you don't do that, a lot of HVAC engineers are going to oversize equipment because they know that the quality control may not be there on the envelope construction and they don't want to be the ones holding the bag because the hearing and cooling system wasn't big enough because of faults that really were outside of their purview on the engineering side. So if you get those pieces together, it actually has lots of benefit.

Nate Allen: That's great, Paul. Thank you. We have a number of questions coming in. I'm going to read off four and let's just maybe turn this into a discussion. So going in reverse order here, Paul, several features that you mentioned seem fairly dependent on human interaction with the building. Does the guide discuss behavioral training to maximize effectiveness?

Another one that's come in here, one challenge that we hear from schools is how do they strike the balance between energy savings and indoor air quality air exchange rates? Does the guide give advice or address this topic? Yes.

How many net zero schools are in the US? Well, we can talk about that.

And then finally, our favorite question, do you have any data that supports the initial cost of zero energy building's first light cycle cost?

How should we tackle this?

Paul Torcellini: Sure. Why don't you read the first one again and I'll start there.

Nate Allen: So this is about human interaction with the building behavioral training.

Paul Torcellini: Buildings are for people and if you design a building and the people don't know how to operate it or they get uncomfortable, they will take things into their own hands, and so there's some simple ones like motion sensors can be a real pain in some of these spaces. They get damaged. When people don't like the way they're behaving in a classroom, they'll cover them with who knows what, the lunch bag, in order to try to get systems to work they think they should work. We found a lot of success around light switches and those light switches are very simple. Up is on, down is off, because people know how to interact with that, and even things like temperature control, very simple, either a lever or dial of some sort, and let people adjust temperatures within reason so they feel comfortable with spaces.

We have been very successful with sweep lighting controls, so at the end of the day, you sweep the lights and you know everything is off, very simple, easy-to-implement strategies, but challenge design teams to think of what are the simple solutions that interact with people in the space. Part of it is when people interact with the space, they're going to have a desire to do it, which gets into things like dashboards. There's a lot of success around dashboards in schools and engaging students and tying it to curriculum, things like math lessons, science lessons. There's a zero energy school in Virginia that has a patio on the roof that students have access to and they can actually move solar panels around, and tilt them at different angles, and collect data, and compare that data with what their large PV array is doing, and so design it for the people. In that school, the students are the ones that give the energy tour.

I've seen schools that actually showcased the mechanical room and show what's going on and how heating and cooling gets to your space, so they became an educational tool and then people start embracing the building instead of just saying, "Oh, this is just a diffuser in the ceiling and I really don't have any idea what's being attached to that." So lots of opportunities there, educational and engaging teachers and students with that.

Now with that said, it's always useful to have some kind of training for folks. You can set up competitions between grades or wings. There's lots of ideas on how to manage the operation and make sure the building achieves its potential.

So what was next on the list, Nate?

Nate Allen: That's great, Paul. Thank you. This I think can be fairly quick, striking the balance between energy savings and indoor air quality. Does the guide give advice or address this topic? And I think there's a short section on that.

Paul Torcellini: Yes, there is, and it does provide that information. We use some boundary conditions in this guide. One was around thermal comfort and the other was around air quality as specified by ASHRAE. There's a lot of discussion about what happens if you increase it, but we make sure we're meeting code minimums and that we're not going against other standards that have their own functions associated with it, so that's kind of the easy answer. A lot of these systems then end up with dedicated outside air systems so that you can really control the amount of air and where that air is going in the space. You can use heat recovery for that. There is a whole section around just what to do with kitchen fume hoods and odors and stuff coming out of kitchens, and again, that was all done and modeled within the ASHRAE standards and still we're able to achieve that. It's not sealing everybody up in a plastic box and you don't give them any air.

Nate Allen: Okay. We've got about five more minutes here and three questions that I see. One, how many net zero schools are in the US? Do you know how to answer this?

Paul Torcellini: So if you go to the New Buildings Institute's website, they just released their 2018 list of zero energy buildings. That list is divided into two pieces. One are zero energy buildings that have been verified and one where they call them emerging, that is they're on our radar screens. I don't recall exactly the number of schools on there.

Nate Allen: I think it's 17, if I remember correctly.

Paul Torcellini: That have actually been verified. That's probably as close to a comprehensive list as possible. There are also a large number of schools that we have found and probably on the order of 50 that have measured EUI data in this target range.

And I think your next question was around the cost effectiveness and cost data. That's an interesting question and partly because when you talk to a cost estimator, they will tell you that only their numbers are right and other standardized databases may not be right and that they understand local markets and conditions. At the end of the day, the only way you really get at cost is whoever is purchasing the materials and having it delivered to the site and they are paying the bill. That ends up being what that cost is. These are commoditized items, steel, and wood, and concrete, especially, and those prices vary a lot with economic conditions, with local conditions, and as well, labor prices change.

I heard a discussion around one of the cities in the US and five years ago, they used a model where they invested lots of money in better thermal envelopes, and today in that same city, they've shifted their focus because of the way the labor markets are and they're saying now it's actually more inexpensive to really focus on better HVAC systems, and they end up with the same energy endpoint but it was highly cost dependent.

The other way I think about these things is that all of these buildings are built by school districts. They all have public pressure to not spend excessive amounts of money and so you've got this public input and the case studies are real buildings. Each one has its own story about what it cost, and how they did it, and how they made it work, and so in some cases what I've heard is that some architects will look at a project budget and say, "If you hire me, I will deliver a zero energy school for the same price that you are allowing for that school," and they make it work within that constraint. That's back to this performance-based procurement. Set a target and set a set of goals. Set a price ceiling and then say can I make those two match? And we've found a lot of success with that.

There are several case studies that come out of Kentucky. You can probably search around for those. I know they're not one of the ones that we've done, but they've done several zero energy schools with measured performance or what we would call zero energy ready, achieved a certain energy use intensity that is very similar to what we presented within a very respectable cost budget which, if you move to a larger metropolitan area, they would be, "How on Earth did you ever do that for that price?"

So it varies a lot and it's a hard question to generically answer. My normal one is people are building them and you have to say, "Well, what is your story? How did you make it work?" which is why we like to connect folks with some of these zero energy projects through the case studies.

Nate Allen: I think that's the most powerful way to respond to that is to look at some of the recent examples that have come in at comparable regional construction average because that's proof in the pudding.

There's also, Paul, if I remember correctly, a couple of years ago, you worked on a document on cost control strategies based off of your experience with the RSF project, and I think that's available for free online.

Paul Torcellini: Yes, so RSF is NREL's research support facility, which is a very large zero energy building office building. If you go to that resource database, the first URL on the screen, and type in cost control, you'll come up with that. Another whole family, which is very closely related, if you do a search on performance-based procurement, you'll find several excellent resources around how to put some of these pieces together.

Nate Allen: These are all good questions. I would encourage you if you want to follow up on these to please e-mail us. Paul's contact info is listed there. I think mine is in the initial invite. I know another question has come in that's fairly specific, how much to pay for an 82,000 square foot primary as-built energy model. Whoever asked that question, please contact us. We'd be happy to talk to you through resources that do exist, but given that it's now 3:00 Eastern, I'm gonna suggest that we wrap this up and thank you all for joining us this afternoon. Thank you, Paul, for presenting. Crystal, unfortunately, had to drop off, but she sends her regards as well, and I mean this genuinely when I say it. Please do contact us. We'd love to hear from you and figure out how we can help.

So with that, I will bid everyone adieu and say thanks, again. Take care, guys. Bye.

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