Hayley McLeod: Hello, everyone. We'll begin in just a moment.

Okay, looks like we still have a few participants joining, but I can go ahead and get us started. So hello, and welcome to the second installment of the Building Envelope Campaign webinar series. In this series we're sharing technical assistance and recognition opportunities through four of DOE's technology campaigns: the Building Envelope Campaign; the Efficient and Healthy Schools Campaign, which spoke at our last webinar; the Integrated Lighting Campaign; the Storm Window and Insulating Panel Campaign. It highlights free engagement and recognition opportunities and features campaign staff and participants sharing practical approaches to improving energy efficiency.

Before we dive in there are a few housekeeping points I would like to cover. Please note that today's webinar will be recorded and archived on the Better Buildings Solution Center. We will follow up when today's recording and slides are made available.

Next, attendees are in listen-only mode, meaning your microphones are muted. If you experience any audio or visual issues throughout the webinar please send a message in the Q&A box located on the bottom of your Zoom panel.

My name is Hayley McLeod and I will be your moderator and first presenter today. I am at Oak Ridge National Lab and I am the lead for the Building Envelope campaign. I've been at ORNL for a little over two years now and I joined ORNL after about five years in industry as the leader of the org and sustainability consultant. My colleague, Dr. Piljae Im from ORNL will also be speaking on his expertise in multifamily buildings.

Next slide.

So like I said, you're going to hear from several campaigns today. So I'm taking us through our welcome and introduction right now. Then I will talk about the Building Envelope Campaign and Dr. Piljae Im will talk about his expertise in multifamily buildings. Then we're going to switch presenters and hear about the Integrated Lighting Campaign and the Storm Window and Insulating Panel Campaign. And then we will switch presenters one last time and hear about Low-E Storm Windows and where those fit in multifamily buildings. And then once we wrapped all that up we should have time for a short session of audience Q&A.

Next slide.

So I am going to get started on the Building Envelope Campaign. So I always like to start my webinars by saying thank you to our organizers: the American Institute of Architects or AIA, the International Facility Management Association or IFMA, and the International Institute of Building Enclosure Consultants or IBEC. These folks have been with us since before the campaign even launched and gave us really invaluable feedback, so I always like to say thank you to those folks.

Next slide.

So the Building Envelope Campaign really came out of a goal to figure out how to assess the overall building envelope performance without accounting for how the building is being used, so really drill down on just the envelope performance.

Next slide.

So lots of engineers who are not me worked to develop this metric, but basically the HVAC heating and cooling demand is dependent on the building envelope energy load and the internal loads of a building. And so again, we're really trying to highlight that piece that's ingrained there, that building envelope energy load.

And so the main thing I wanted to point out here is that the building envelope performance metric that we're using for our campaign does have the same unit as EUI but instead of being across the square footage of the building it's spread across the envelope area of the building.

Next slide.

So what is the Building Envelope Campaign? So there are several current ongoing campaigns, which is the point of getting everybody together so we can kind of present to you guys in one fell swoop. So this is one of the current campaigns, and it was really just designed to help create more energy efficient buildings in the building stock in the US. And we're doing this by introducing a new building envelope assessment metric and a tool for helping you determine that metric, and we are calling that metric the Building Envelope Performance value, or BEP value.

Next slide.

So what are the goals of this campaign? If you launch it you have to have intention, and so we were really hoping to motivate action and increase awareness of the value of investing in these high-performance building envelope technologies. And that is for both new and existing commercial buildings, which means that we're interested in new buildings and we're interested in retrofitting existing buildings.

We wanted to recognize leaders who were achieving really high performance in their buildings through these high performing building upload measures, and then we wanted to demonstrate and document energy and cost savings – sorry about my dog – with integrated design construction, cushioning, and maintenance from implementation of these high-performing envelope systems. So motivate action, recognize those folk that are out there doing the work, and then work with those folks to demonstrate and document those savings.

So we do have – I'll talk about them a little bit later, but we do have details from all of our successful year one participants up on our website, where you can go learn more about those energy and cost savings.

Next slide.

So how are we going about achieving these goals? And the short answer is that we couldn't do it alone; we have to do it with a network, and so that's where all of you come in. so we have supporters and participants who engage with us in our campaign. Our supporters have full access to our technical expertise regarding envelope technologies, they partner with the tech team to help spread the word about the campaign, and they are recognized on our Envelope Campaign website as supporters if they choose to be.

As for our participants, those folks also have access to campaign resources and technical expertise. They're able to work with us to stay informed on envelope technologies and resources. But then the main thing that our participants do is use our assessment tool, enter their building information into the assessment tool, and then hopefully achieve awards for their buildings. Also after that point we can then work with them to develop case studies and short videos, additional information about their buildings that we can use to help us spread the word about these technologies.

Projects completed since January 2019 are eligible to submit. Like I said, it's new construction and retrofit buildings and it's all commercial buildings in addition to multifamily buildings.

Next slide.

So like I said, our participants go to the website and enter their information into our assessment tool. And so the assessment tool will give you your percentage improvement between if it's a retrofit building, between your existing building and the retrofit building. And if you're a new construction building, between the relevant code for your building and your as-constructed building.

So our retrofit tiers of recognition are either a 30 or a 50-percent improvement in that envelope performance, and then for new construction it's either a 20 or 40-percent improvement in that building envelope performance. So the reason those retrofit tiers are a little bit higher is that we assume that there's kind of more improvements to be made between an old building that's being retrofit as opposed to just comparing over code. So that's why those numbers are a little bit different.

Then on top of either of those two tiers we also have role model awards. If you've achieved your retro 30 or 50 or your novel 20 or 40 you are also eligible for either a technology role model award, or new this year, we have an equity in energy role model award. And so for a technology role model this may be that you've incorporated something really interesting in your building that's you know, a cutting-edge technology, really serving as a proving ground, and we would like to share that information with the public.

Alternately the equity and energy role model award, like I said is new this year. We are still sort of developing what that means in detail, but it could be the end use of the building, the community that the building is in, where those cost savings are actually being recognized in a community. So we're kind of excited to see what happens with that equity and energy award this year.

And then final thing, we do have Honorable Mentions. So if you come in right below that retro 30 or novel 20 but are still assisting the campaign in a real way – maybe you submitted a whole portfolio of buildings and you just had this one that came in slightly under, or it's a retrofit building that was just already in really good shape and so you still have a highly performing building, it just didn't quite hit that 30-percent improvement, you

may still be eligible for an Honorable Mention. So we do encourage folks to submit, even if you are at that cusp.

Next slide.

So quick cover of our timeline. We are wrapping up our second year. We launched at the 2020 Better Buildings Summit. We are always open for new participants and supporters to sign up and we are always accepting and reviewing submittals from participants. Like I said, all projects completed since January 2019 are eligible to submit and our spring submittal deadline for recognition this summer is Friday, April 8, 2022.

And I always like to remind people that this campaign is free and obligation-free to join and it's really easy to switch from a supporter to a participant; you just have to e-mail me. So if you aren't sure I do encourage you to go ahead and sign up.

Next slide.

I wanted to summarize our year one very quickly. We had 14 buildings that we were able to recognize that covered 1.5 million square feet of conditioned floor area and an annual savings of 9 million kBTU based on those envelope technologies alone. And we did get all types of buildings submitted in year one, including multifamily buildings.

Next slide.

Just a quick slide here. We have four retrofit projects that we awarded last year.

Next slide.

And then the rest were new construction projects, including the Vergennes Community Housing project, which was a multifamily project.

Next slide.

So that is my summary on the Building Envelope Campaign. And now I am happy to pass it over to someone with more technical knowledge than I have, Dr. Piljae Im, one of my colleagues at Oak Ridge National Lab. Thank you and take it away, Piljae.

Piljae Im: Thanks, Hayley. Hello, everyone. My name is Piljae Im and I am an R&D staff and subprogram manager for the Building Energy Modeling at Oak Ridge National Laboratory. I joined the lab about 13 years ago and I have been involved in many building energy modeling projects and technology field evaluation and analysis. Currently I am also serving as lab point of contact for the low carbon project for the multifamily sector.

So in this webinar I will start with some basic introduction of the multifamily building energy characteristics and what are the current barriers in energy retrofit of multifamily buildings. Then a use case for energy retrofit of a multifamily building will be present in this webinar, and this use case will give you some general idea how a typical energy retrofit is done in the multifamily building and what can be done differently if we have some different approach.

Next.

So here are some quick facts regarding the multifamily building. First, almost over 30-percent of the US population lives in the multifamily building, and multifamily building uses about 15-percent of the residential delivered energy consumption. And a high percentage of low-income households live in multifamily buildings currently, and they use almost 20-percent of their monthly income on energy bills. Their burden for energy bills is much higher than the level of the people – other stage of the people.

And in addition, most existing multifamily buildings were built before 1990 and sometimes more than before 1970s, which means they are mostly energy inefficient. So we can see that there are lots of the potential to save energy, and this can reduce the household burden for the energy bills. And one study performed by the ACEEE shows that the current programs have shown that the comprehensive retrofits can cost effectively improve the energy efficiency of the multifamily buildings by 30-percent for natural gas and 15-percent for electricity. Nationwide this level of savings would translate it into the annual utility bill cost of savings of almost $3.4 billion for the multifamily sector.

Next.

So although there are significant opportunities for energy savings in multifamily buildings by retrofitting, at least in multifamily buildings, there are several barriers existing today. As almost 90-

percent of multifamily buildings are rented and 70-percent of tenants pay for their utilities, there is no strong desire from the owner of the building to retrofit their properties. And although there are some incentives and programs and incentives for the building owners, it's not well informed to the owners and they are not really doing the retrofitting. In addition, uncertainty of the energy savings can hamper the building owner to participate in the retrofit program.

Finally, there is a lack of systematic analysis. In other words, most of the retrofit testing is done based on one-size-fits-all approach originating from the accustomed best practice and intended to merely meet the code compliance requirements. So this _____ the opportunity to do better in retrofit of the existing multifamily buildings.

So from the next slide I will print the case study to show how a typical multifamily retrofit will be performed and what are the typical energy savings and how we can do better.

So the case study shown in here is about the multifamily building retrofit project in Union City, Georgia. The building was originally built in 1993 and there are about 11 buildings with three different plans. The building owner expected and targeted 20 to 30-percent energy savings and funding was leveraged by a combined affordable housing subsidy and private equity.

Next.

There are several implemented measures and pretty typical measures, as you can see here. And I will go through the individual measures to explain why they selected these things.

Next.

So this table shows the comprehensive list of the measures pre and post. So basically the existing column in the middle shows that the precondition of the building and improvement if the basically what they've done for the building.

Next.

So first one is the foundation. And we found the existing foundation conditions pretty bad with deteriorated insulation and vapor barrier. And this was repaired and reinforced with more insulation, if you can see from the right side of the picture.

Next.

There are some energy upgraded for the exterior were only replaced the siding and front fascia.

Next.

And ceiling insulation, it was the R-30 and then they added more insulation to have the R-38.

Next.

For the windows they had a single-pane aluminum frame, the collating unit, and they replaced it with the double-pane low-e vinyl frame.

Next.

And of course the existing low-efficiency HVAV system was replaced with the high-efficiency one.

Next.

And electric water heater was also replaced. And it was a pretty old unit, but the new unit has a little bit higher the [inaudible], so higher energy efficiency than the existing one.

Next.

And all the lamps and the incandescent and fluorescent light have been replaced with the compact fluorescent light fixture.

Next.

And major appliances were also replaced with Energy Star qualified ones.

Next.

And finally we have done the guarded boulder test for this building to find out the infiltration rate of the building, air tightness of the building, and also we shield the gaps to reduce the air leakage of roughly 25-percent. And this reduced air infiltration was verified before and after blow door test.

Next.

So when we were engaged in this retrofit project with the partner the measures were already selected and the selection process of the measures were basically based on the best practice without no index analysis. So in this stage we attempted to see how the retrofit selection can be done differently based on there's a whole building energy analysis.

Next.

So here is the process of the whole building analysis. First we collect the pre/post building characteristics and build a baseline building energy model.

Next.

And we also gather the pre-retrofit monthly utility bills from the listing building and actually retro data and also get some monthly energy use from the bills.

Next.

Then the baseline building energy model was calibrated with the monthly energy use.

Next.

Then this calibrated model was used to implement the existing ECMs, the initial ECMs, Energy Conservation Measures are applied to the calibrated model.

Next.

And at the same time we also applied the optimization, which is alternative ECMs we found from the other resources.

Next.

And then we show the energy savings analysis.

Next.

So for the interest of the time I won't show all the detailed analysis, but this is the kind of findings and summary of our analysis. So implemented original retrofit package, capital cost to be estimated

about $39,000.00. And this calibrated simulation shows that there is a 24-percent of the potential energy savings, and when we calculated simple payback there was about a ten-year of the payback.

And then we evaluated other energy conservation measures not included in the original list. And we do some kind of sensitivty analysis and replace the high – to pay back the measures with the most – more – the optimal energy conservation measures. And through some work we found that with a little bit of the increase of the cost, which is about $41,000.00, the capital cost, we can realize a 34-percent of the potential energy savings with a reduced payback, which is a seven year of the payback.

And there are other findings from this project. Basically some certain retrofits for the improved building appearance – certainly retrofit is not for the energy retrofit; it's more about to improve the building appearance and durability, like wall siding and roofing replacement. But this can be integrated with the energy retrofit with just a little bit of the incremental costs. Because they are anyway removing the existing structure or some sidings and replacing the siding, if they add some more to their cost they can add some value for the energy retrofit.

And after they retrofit the building envelope we can expect the building load can be reduced and we can probably reduce the size of the HVAC system, which can reduce the initial cost. But there was no attempt to properly size the HVAC system.

And we found that the existing building has some ventilation deficiency before the retrofit, but after the retrofit it was not really addressed properly anyway.

Next.

So in summary, as you can see there are high energy savings potential existing in multifamily buildings, but this potential usually remains unrealized due to the apparent difficulty in the diagnosing the multifamily buildings first, and evaluating alternative measures and installing customized sets of the measures. And we found that the systematic approach for the retrofit analysis can be followed to maximize energy savings in a very cost-effective manner.

So this is my presentation.

Next.

So I'm going to pass this presentation Allegra Steenson.

Allegra Steenson: Hi, everybody. I'm Allegra Steenson. I work at the Pacific Northwest National Lab as a research scientist and I work on the Storm Windows and Insulating Panel Campaign, doing a lot of research as well as energy modeling. I'm also going to be talking about the Integrated Lighting Campaign today, even though that is not one of the projects I am working on.

Next slide.

First I'd like to take just a couple of minutes to talk about the Integrated Lighting Campaign, like I said.

Next slide.

Great. Just like the name sounds, the Integrated Lighting Campaign focuses on recognizing integrated lighting projects, which means that the lighting system can communicate with other building systems to enhance building performance. Integrating the lighting system with other building systems can achieve deeper whole building energy savings, for example, by exchanging information with HVAC systems or controllable plug loads for supporting the Internet of Things.

But that's not all this campaign is interested in. There are still luminaires and luminaire control systems that the team is hoping to capture as well. Advanced systems and controls in lighting that improve lighting performance are of interest, and the ILC would love to hear how systems are going above and beyond simple occupancy daylighting and scheduling approaches.

Through the ILC we hope to learn about and recognize some of these innovative lighting projects as well as supporters of these projects. Submissions for recognition is now open and will close on March 30th, so if you're aware of a project that would be interested in getting recognized you can visit the www.IntegratedLightingCampaign.energy.gov or you can e-mail the campaign organizers.

Next slide.

Axel Pearson at the Pacific Northwest National Laboratory would be happy to discuss or you can send a general inquiry to IntegratedLighting@pnnl.gov.

Next slide, please.

Next I would like to tell you about the Storm Window and Insulating Panel, or SWIP campaign. The SWIP campaign is a collaborative initiative sponsored by the Department of Energy and managed by the Pacific Northwest National Lab to accelerate the adoption of low-e storm windows and insulated panels, delivering energy savings and comfort in residential and commercial buildings at a fraction of the cost of full window replacements.

Inefficient windows waste energy and cost millions of dollars every year in heating and cooling. And the goal of this Web campaign is to leave no poor-performing window uncovered.

Next slide, please.

The SWIP campaign aims to increase awareness, visibility, and build a body of knowledge about low-e storm windows. When people think of windows what comes to mind are old, unattractive storm windows that need to be removed and put up seasonally, but these modern units are not your grandma's storm windows.

The campaign also acts as a national platform for collecting and sharing information and best practices related to storm windows. We work with utilities and energy efficiency programs to justify and launch and promote new utility and energy efficiency programs. One aspect of this work includes modeling state-specific energy savings associated with low-e storm windows for submission to state technical reference documents, which utilities will then use to inform what programs they're going to implement.

The SWIP campaign serves as a one-stop shop for resources and technical assistance to help overcome barriers to adoption. And we also work with weatherization agencies to provide support to increase the adoption of low-e storm windows into their programs. The campaign also provides national recognition for organizations that have demonstrated success in their adoption or promotion of this technology.

Next slide.

If you're interested in adopting or implementing low-e storm windows the SWIP campaign is here to help. By joining the campaign participants can stay up to date with the latest campaign news in the form of our campaign newsletter, learn about best practices for including low-e storm windows in your program, connect with low-e storm window manufacturers, receive technical assistance, and receive national recognition for demonstrating success in adopting or promoting low-e storm windows and insulating panels.

Together we can leave no poor-performing window behind. If you want to learn more you can visit the SWIP campaign Webpage, contact us through our tech challenge e-mail, or reach out directly to myself or my colleague and campaign lead, Christian Valoria.

With that I will hand it off to Tom.

Thomas Culp: Right. Thank you. This is Tom Culp. I've worked the last 20-25 years with the glazing industry with both manufacturers and on multiple DOE research projects and consulting with PNNL, including some of the early-on research projects around low-e storm windows and panels.

Next slide, please.

So I'll be talking about basically how low-e storm windows and panels, what are they, what are they in terms of a modern context, and how can they be used to cost effectively retrofit existing windows in existing buildings, today focusing on multifamily.

Next slide, please.

So first looking at the opportunity. This shows for residential, so not just multifamily, but all homes. There's DOE and then Katie Cort from PNNL did a market study, shows it's roughly 19 billion square feet of existing windows. And it might surprise you, but about 40-percent of that is single-pane glass. And then a similar amount is double-pane clear windows, meaning older windows without low-e, not modern, not what we would consider energy efficient in a modern context. So that's a huge amount of older windows, huge amount of wasted energy, and an opportunity for upgrades.

Next slide, please.

So we know that there's a lot of great new window technology, glazing technology, low-e coatings, modern frames, gas fill, and all that. The Energy Star Windows Program is a prime example. But that's not always the right solution for everyone. If we look at the numbers, only about 1 to 2-percent of the potential existing windows are replaced every year. So it's going to take a very, very long time before all these older windows are addressed.

So what do you do when rip out and replacement of an existing window is either impractical or cost-prohibitive? You're looking at income-sensitive populations as well as high-rise or places like that. What if it's not allowed or you don't want to replace existing windows, in particular in historic buildings? What do you do?

Next slide.

One solution are modern low-e storm windows and panels. And I'll talk a little bit about this. And as Allegra said, these are not your grandmother's storm windows; this is something new and different, you know, incorporating low-e glass, which I'll talk about. And it can be viewed as both an insulation and an air ceiling measure for upgrading your existing windows at a fraction of the cost. Some of the cost estimates show that because you're avoiding some of the heavy labor and disposal costs that it can be a quarter to a third of the cost of full window replacement, yet you can achieve similar energy savings.

These are modern products, they're aesthetically pleasing, come in in all sorts of colors, they can come in custom colors, and the photos you see here show that. So, these don't look like those clunky old things from the '50s. They're made for permanent year-round installation. They do not have to be removed seasonally, which we often hear people, that's what they think of when they think of old storm windows. They can be operable or fixed, so they can open up for natural ventilation. They can be interior or exterior. The three photos on the left all show interior applications; the two photos on the right show exterior low-e storm windows. And then in addition to the energy savings they improve comfort, thermal comfort, as well as acoustics are two of the main applications.

And real quick I'd like to thank the companies who provided all the photos throughout this presentation: Quantapanel, Larson Manufacturing, and Alpen.

Next slide, please.

So this is just an example of a number of real-life buildings. So we often think about low-e storm windows for low-income weatherization, and that is a very prime application for that, but it's not limited just to that type of application; it's useful anywhere in any type of buildings, from historic applications to the building on the lower-left there, that's a US Naval Academy. That's a 110-year-old building that they had to upgrade the windows with a custom sea foam green window, and to just regular homes, to even high-rise buildings. All these are real-life applications showing the use of low-e storm windows, either exterior or interior.

Next slide.

So I mentioned low-e glass or low-e storm windows. So what is that? So you've probably heard about this in terms of new windows, Energy Star windows, and so forth. But low-e stands for low emissivity, and it's a transparent microscopic coating. This is actually one of the first applications of nanoscale technology before that was a buzzword. But it's a transparent coating that you see through; it is a window, after all. Yet it reflects the radiant heat, the infrared heat back into the home. So it reduces the building energy usage by cutting that radiative heat loss.

Next slide, please.

And the best way you can tell this is with IR imaging. So this is three windows; there's two on the sides and one in the middle, all single-pane glass. The ones on the left and right have been addressed with low-e storm windows, the one in the middle was left alone. And this is an IR image taken from the exterior. And you can see the dramatic improvement. So you can see that temperature difference, that heat loss coming out of the original single pane window in the middle, whereas to the left and the right with the low-e storm window the heat loss is greatly reduced and it's looking similar to the exterior walls, so it's greatly improved performance.

Next slide, please.

So now the amount of the improvement depends on the existing window type. So if you're talking about single-pane windows the U-factor, again, depends on the exact window profile: wood, vinyl, you know, and what type of window. But we've done a bunch of modeling that shows that basically U-factor decreases about 50 to 60-percent with a low-e panel. Over double-pane clear glass

windows, so older windows without low-e, but you add a low-e storm window and you turn that double-pane window into a triple-pane window, you're still decreasing the U-factor by about 40 to 50-percent with that low-e panel.

It also improves the solar heat gain. Solar heat gain is reduced by about 20-percent with a standard low-e storm window, and if you are in a mixed climate where you have both cold windows and hot summers, there are solar control low-e glass options that will lower the solar heat gain even more.

And then more recently there's some new technology out there which incorporates adding a dual-pane secondary window, some using thin glass, where you add two panes of low-e glass to the existing single-pane window. So you're bringing that single-pane existing window up to a triple-pane window in one step.

Next slide, please.

So we've done a number of case studies. This was one of the first ones between 2003 and 2006 on low-income weatherization homes in the Chicago area, where doing nothing else in the home, just addressing the windows – added low-e storm windows, they saw a reduction in the heating of the home by 21-percent. Simple payback was 4.5 years, so very cost effective when these products are expected to last 20 years or more.

And as I mentioned, not only are you insulating the existing window by upgrading, you're also reducing the air infiltration. And so has to show that just by addressing the windows, not doing any other air ceiling in the home, you reduce the overall home air leakage by 6 to 8-percent. So that showed how much our leakage was occurring through these older existing windows and what potential there is for dramatic reduction in air leakage of the whole home.

Next slide, please.

Moving forward in time, there was a DOE research project in 2010 to 2013 that I was involved in. So we wanted to repeat this work for ten older homes in a mixed climate. So this was in the Atlanta area, places that have cold winters but hot summers, where all had single-pane windows. We addressed them with low-e storm windows and we saw a 15-percent heatings, a wide range in cooling savings, anywhere from 2 to 30-percent. Some of that is because it's a highly wooded – these are older homes in the

Southeast, so tree cover and issues like that create quite a bit of difference in terms of cooling demand.

But overall we saw very good energy savings. And again, we saw very significant air leakage reductions, 17-percent reduction just by adding the low-e storm windows to the existing windows.

Additionally, the occupants, some of their – from their perceived benefits were more than the energy. They saw improved – through surveys they saw improved home appearance, reduced drafts, improved comfort, and reduced noise reduction. And to them that was actually equally important as the energy bill reduction.

Next slide, please.

As part of this same project we addressed the multifamily building in Philadelphia – actually two large multifamily buildings, one of them showed there. Low, but large, so overall we addressed 101 apartments. In this case they already had old-style clear glass storm windows over single-pane windows, but they were in pretty poor shape. So we replaced the existing storm windows with modern new low-e storm windows. And just by doing that we saw a 20-percent reduction in heating energy use and a 9 and a 10-percent in cooling energy use. And additionally when we *[inaudible due to distorted audio]* our test on isolated apartment units we saw 10-percent reduction in the air leakage of that apartment unit just by doing the windows and that's it. So very significant.

Next slide, please.

And then lastly, PNNL, Pacific Northwest National Lab has their lab homes up in Richland, Washington, which is climate zone 5. It's a pair of homes that are like twin homes designed to match each other, highly instrumented for detailed measurements, designed to represent older homes so that they can test a number of technologies; not just window stuff, but heat pumps, control systems, cellular shades, all sorts of features that you can use to address it, but in a side-by-side comparison, so you can very clearly measure the energy improvement from different technologies.

So one of the projects was to add exterior low-e storm windows and low-e storm doors over the existing double-pane clear glass aluminum windows and doors. And there we saw a 10-percent annual energy savings from this upgrade. And if you think about it, we've basically turned these double-pane windows into a triple-

pane low-e, and interestingly they had done another study where they replaced some of these windows with triple-pane low-e windows and saw a similar improvement. So it showed that the concept was what we expected, that adding a modern *[inaudible due to distorted audio]* and get a similar energy savings as a full window replacement, but at a fraction of the cost. And the payback period in this case was about five to seven years.

Next slide.

So on the weatherization, a number *[inaudible due to distorted audio]* so they basically can *[inaudible due to distorted audio]* in 22 cities across all 8 climate zones. This analysis we did for 39 different single family, semi-detached, and row homes. *[Audio cuts out]* It was found to be very cost-effective. In this case you're looking at SIR or Savings to Investment Ratio, and you have to have greater than one to qualify as a weatherization measure in these programs, and the higher the number the better.

And in climate zone 3 through 8 when you install low-e storm windows over single-pane windows or over double-pane metal frame windows we saw SIRs ranging from 1.2 up to 3.2, depending on the specific location. Obviously more energy savings the colder you are, but also it depends on your fuel prices. So _____ especially if you're using something like propane versus just natural gas, in more rural locations those SIR numbers are even higher. So it's very cost effective. And we should point out that as the market study shows that over 30-percent of windows are still single-pane in climate zones 3 through 8.

Next slide, please.

And then again, this is just some more photos showing specifically multifamily – I should point out that neat study we did, that weatherization assistance study we did. That was mostly for single-family homes as well as some semi-detached and row homes, but we expect the results to be similar for multifamily. And this is just showing an example of the range of multifamily buildings that have been done in real life with low-e storm windows. There are exterior windows on the far-left pictures. You'll notice both of those happen to be three-story buildings and where it's a little easier to access from the outside. If you have a taller building then obviously you might want to consider interior low-e storm windows so that you can address them very easily without having to have cranes or using window washing scaffolding or anything like that, so you can easily address them from the inside.

Interior low-e panels also tend to be more airtight, so that's especially beneficial and helpful if you have a large stack effect in some of these older buildings that are tall.

Next picture or next slide, please.

Last thing, and I noticed while some of the *[inaudible due to distorted audio]* I came up about, well, there's a disconnect in multifamily between tenants, you know, those renting the apartments, versus the building owner. And there's a disconnect in terms of motivation that depends on the pay amount, who's paying for the energy costs, the utilities. But sometimes there's a disconnect. And the question was is there any motivation or anything out there that can encourage building owners – multifamily building owners to upgrade their buildings.

So I wanted to – whoever asked that question, this is directly aimed at that. There's a new phenomenon out there known as building performance standards. So on top of federal programs or building codes or programs addressing new buildings, specifically there are building performance standards, which are really taking place at the local level. So these are more proactive cities and a few states that are trying to address climate change by addressing existing buildings, and they're doing it first by energy disclosure laws, which basically say buildings over a certain size or buildings of a certain type have to report their utility energy usage publicly in a public database every year. And so that's to help people to know what their energy use is.

But then the next step are building performance standards, which take those numbers and then apply limits to it. So it can either be a building energy use limit or a carbon emission limit, and if you're above that limit you're going to pay a fine or a penalty every year. And these have been enacted in all the places listed there. New York City was the first. We also have Saint Louis, Boston, Washington State, District of Columbia, and Colorado. They each do it a little differently; some use carbon limits, some use energy use limits. They affect different building sizes, you know, thresholds. Some are like 50,000 square feet and larger, others are different sizes. Some exclude residential, some don't, so you have to look at each one.

But generally the fines for these locations start 2025 to 2026, but building owners – or at least smart building owners are starting to plan, because rather than paying a fine to the mayor they'd rather

use that money and invest in improving their buildings. So in New York City we have talked to building owners that have taken to builder owners that have taken their forecasted fine, multiplied it by five and said, "All right, I'm going to use that money to upgrade my building." And then that's in their mind an automatic five-year payback in improving their building and hopefully also get better lease rates or even to just reduce the energy use budget without having to just pay a fine that's going to the mayor, in their words. So it's a large incentive for upgrading existing buildings, and not just the lighting and mechanical systems, but including envelope and windows.

Next slide, please.

And this shows a map; this is from the IMT, Institute for Market Transformation. They have a nice website tracking all these building performance standards. And there's a National BPS Coalition that's been formed, and every location you see on this map has joined that and committed to passing the Building Performance Policy by Earth Day 2024. So again, if you are in any of these locations it's a key opportunity for the use of low-e storm windows and panels to cost effectively upgrade existing buildings to the benefit of both the occupants and the building owners.

And I believe – oh, one more slide.

So last you might ask "Where can I get product information or where is product information available?" Two areas really. One is we've worked with EPA to develop a new Energy Star program specifically for exterior or interior storm windows, low-e storm windows. There's a website there or you can just Google it. There you can find product information from participating manufacturers, provide low-e storm windows. And then there's also the Attachments Energy Rating Council. Both Katie Cort from PNNL and myself sit on the board of that organization. They're working on all window attachments, including things like cellular shades and automation of attachments that can improve window energy performance.

But there's specifically also a certification program for the storm windows and commercial secondary windows. So you can go to that website and pull up participating manufacturers, look at information on the performance of those products in both hot and warm climates – sorry, cold and warm climates, and find out further product information.

With that I think I will hand it back for questions.

Hayley McLeod: Thank you so much to all of our speakers. So yeah, I am going to jump back on as moderator for the Q&A session. So if you have any questions for the speakers, if you could put them in the chat, which it looks like some of you are already doing, so that's great. In particular, if you have any questions could you try to address them to a particular person? I'll try to figure out who you're asking about _____ _____ _____.

So I am looking at our questions now. So slide 10, which was probably one of mine – 20-percent over code, ASHRAE 90.1 – 2016 is shown. Why not 2019 version of 90.1?

That is a great question. I don't know off the top of my head, but if I had to take a stab at it without one of my engineers on the line, I think typically just rollout of some of that code adoption is slow enough that we didn't want to be artificially penalizing buildings. But if you wanted to send me an e-mail after the fact I could find out the definite answer to that question and let you know.

I also see the next question is for me. So how many of the 16 buildings – this may have been during my section – how many of the 16 buildings who were participating in the campaign are new versus existing? So we did get to those slides, so there were fewer retrofit. I think there were about four retrofit in our first year and then about ten new construction. I mean we have a lot more participants than that signed up, and I do think it's a more even split.

And then it says "Are any resources of recommendations for retrofits provided to existing building participants?" So yes, our full resource library is available to all of our participants. And are there any typical – I'm not sure what MF stands for in this. I'm not sure if I –

Thomas Culp: Multifamily.

Hayley McLeod: Multifamily. Sorry. *[Laughs]* Yeah, the whole purpose that we're all here today. I was like "envelope technologies." Are there any typical multifamily envelope deficiencies found in these buildings?

Maybe someone on the call who's more familiar with multifamily, maybe Tom or Piljae could speak to that. Can you guys think of any kind of typical envelope deficiencies found in multifamily buildings?

Thomas Culp: Like I know I was talking about, the windows are often a lacking place, depending on the age of the building, but I'm curious – you know, I'm obviously more focused on that area, so I'm curious what others see.

Hayley McLeod: Sure. Piljae, do you have anything to add, other than windows? Any typical multifamily envelope deficiencies?

Piljae Im: So in both deficiencies the –

Hayley McLeod: Your audio is very quiet, at least for me, Piljae. I'm not sure if – yeah, there you go.

Piljae Im: Yeah. I put my mic on the top. So the typical, you know, the things we can find, of course the wall insulation and roofing insulation, those kinds of things. But more about that insulation part – rather than the insulation part, we found that there's a lot of _____ air leakage between the unit and then outside the unit. So there is a lot of some potential by shielding the gap and the holes on the building between the unit. We can save a lot of energy from a building more airtight.

Hayley McLeod: Thank you very much. And then we had – I think these are some SWIP questions, some windows questions. So there are two here, which is how is condensate resolved with interior and exterior storm windows, and then just more generally what are advantages and disadvantages of an interior versus exterior application?

Thomas Culp: Yeah, I think they're talking about the potential for forming condensation between the storm window and the existing window. And the general rule is whatever's more to the outside you want to be leakier than the inside, or conversely, whatever's on the inside you want to be tight. So if you are putting an exterior low-e storm window on you want to make sure the weep holes on that are clear. That's why they're there, is to help avoid any sort of condensation. And you also want to do what you can on the existing window to seal it up as best you can. Not make it inoperable but look for obvious gaps or any things like that that you can seal it.

Conversely, if you're doing an interior panel, you want that to be as airtight as possible. That stops the warm conditioned air from going through and hitting the colder outer surface. So interior low-e panels are designed with no week holes, and they're designed to be very airtight, with tight seals around the perimeter, and that helps avoid that question.

So already that sort of answers the question, advantages/disadvantages of interior versus exterior. Interior's generally more airtight, so that will give you a better benefit in terms of reducing the window and overall home or apartment air leakage by using an interior. The other advantage of interior is if it's obviously easier to do if you're in a tall building. If you're on a ten-story apartment building it's much easier to do from an interior than it is from the exterior.

Conversely, exterior, sometimes it's a little easier. It depends on the case and depends what kind of mounting surface you have the _____. So sometimes it can be if you don't have much room on the interior it might be hard to install an interior, in that case an exterior may be preferable. Historic people – and I think we'll be talking about this next month as well – historic applications also a lot of strong feelings about interior versus exterior, 'cause exterior can help protect the existing window, but then you have to be careful about the appearance and maintaining the appearance. Interior doesn't do anything to protect the existing window from the elements, but it also doesn't impact the view.

So they're both good, there's just a lot of kind of choices that you need to consider for the specific application.

Hayley McLeod: Okay. Thank you very much. I'm not sure if any additional questions have come in. Tom, I see that you chatted and said that you would address a question that came in at the end of your presentation. Was there anything else you wanted to circle back and say about the low income families questions, the disproportionate impact by utilities?

Thomas Culp: Right. I mean, well, I guess two things. One, I mentioned the Building Performance Standards. That is a way that is encouraging building owners to upgrade their existing buildings, you know, hopefully to the benefit of their tenants and their renters. Now whether that results in them increasing rent or not, we don't know; that's a market decision. We'll see how that plays out in real life. But low-e storm windows in general are a very appropriate solution for low-income families and weatherization programs, because sometimes window replacement – even though I work with those people as well and we encourage putting in as good of a window as you can, it can be expensive. So if you're looking for a more cost-effective solution then low-e storm windows and panels is particularly a good solution for low-income scenarios.

Hayley McLeod: Okay. Thank you very much for that. I believe now we have answered – ooh, it looks like one more question has come in and it is a bit of a long one in terms of text, but I will try to read it out and we can – this will be our last question and then I have a couple of wrap-up slides.

So we have an attendee that says they work as the utility manager for a large low-income multifamily management company and they find that profit motive is imperative to survival. In discussions with managers of construction and re-syndication it is sometimes expedient to install conventional efficiency fenestration and HVAC equipment, how can the governing bodies balance the carrot and stick approach to making higher efficiency decisions a no-brainer to the bean counters that control loans and contractors? Efficient equipment specs vary widely by climate, utility rates and spark spread or fuel switching rules also have significant impact on decisions, so what can a carbon-constrained world do to address these conflicting forces?

So yeah, if you could just answer that whole question, Tom, in the next two minutes, that would be great.

[Laughter]

Thomas Culp: Yeah, there's a lot there.

Hayley McLeod: Yeah.

Thomas Culp: And it is that right balance; how do you find that balance of equity and fairness for addressing all income brackets, but also, yes, there are profit motivations to building owners. So it's how do you find that right balance.

So I mean I know from the SWIP viewpoint – and I don't know if Allegra wants to chime in – but that is one focus of SWIP, is that this is kind of hopefully finds that balance of improving energy efficiency, but in a cost effective manner. But, you know, I don't know if Piljae from on the mechanical equipment side or some of the other – you know, you would look more at the broad picture. Do you have any comments on that, on what the right balance is, considering cost effectiveness between mechanical and envelope and lighting and everything else?

Piljae Im: You know, though, my kind of experience, so everything we should start from the envelope side. Of course, it's easier for the people to switch the HVAC system and heater, that kind of things.

But the data approach and whole building approach, I think the building envelope side should be addressed at first to reduce the building load as much as possible, then we can provide energy efficiency [inaudible]. As I mentioned during the presentation, you know, the reduced building load because of the high-performance windows and walls and all those kinds of things can reduce the size of the HVAC shift, and which is the [inaudible] cost reduction.

So I think this approach for the right [inaudible] should've been started from the envelope end and we can go for the next [inaudible] HVAC shift and then [inaudible] shift.

Thomas Culp: Yeah, we have seen a couple cases where someone went in and put in very good, advanced high-efficiency equipment and then they left the building with single-pane windows. *[Laughs]*

Piljae Im: Yeah, that's exactly.

Thomas Culp: No, that's not the right approach.

Piljae Im: Yeah. Exactly. That's the problem. And, you know, there's a _____ about discussion, but there's another some discussion these days going on because of this decarbonization and electrification. Many older apartments doesn't have the power panel to provide an additional heat pump. You know, they have a very old – the old furnace and the heating system, and that we are trying to replace the systems with the heat pump systems, and they will a lot of the burden for the existing power panels. So how can we address that issue? It's also one of the big issues in the multifamily sector. I just want to mention that.

Hayley McLeod: All right. Well, thank you guys so much for tackling that big question right at the end. And yeah, now I just have a couple of summary slides to wrap up. And I will say that the final slide is contact information for all of the panelists if you have any follow-up questions that you didn't get a chance to drop in the chat, you can follow up with us after the fact.

But this webinar is not the last time that you'll be hearing from us. We hope that you can either join us or tell your colleagues about our third and final webinar in the series, titled "How Historic Buildings Can Benefit From DOE Technology Campaigns" and that will be next month on April 6th, same time, same place, but historic buildings.

Next slide.

And if you can't wait until then to hear from us, check out the '21-'22 Better Buildings Webinar Series. We have a great lineup of presentations through April. And please visit the Better Buildings Solution Center to learn more and register.

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Yeah, we also have the Better Buildings Better Plants Summit coming up. It will take place May 17th through 19th. This event will feature engaging interactive sessions as well as opportunities for attendees to network with their fellow industry peers and experts. And we are planning on an in-person even this year. Registration is coming soon. Please visit the Better Buildings Solution Center to learn more about this as well.

And then to close out I would like to thank all our panelists very much for taking the time to be with us today. Please feel free to contact the presenters directly with any additional questions or if we couldn't get to your question during Q&A, and hopefully see some of you or your colleagues here next month.

So thanks, everyone. Happy Wednesday.

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