Interviewer: Good afternoon, welcome to the Envelope Technology Research Team webinar, where we're going to focus on innovative wall technologies for commercial buildings. Please note that all lines are muted. If you are having any issues, feel free to write them into the question field or chat box and we'll try and address those. We do have a full agenda today. So why don't we go to the next slide? My name's Caroline Hazard and I help support the Envelope Research Team, which is managed by the Oak Ridge National Lab. And today we have some great speakers, Dr. Mahabir Bhandari from Oak Ridge National Lab and also Diana Hun from Oak Ridge National Lab. They'll be talking about research that the lab is doing on passive walls and then we'll do kind of a switch over to looking at cross-laminated timber, a new technology area. And then we'll hear a great case study example on modified atmosphere insulation panels from Tapan Patel from the U.S. Army Corps of Engineers. He's got a good case study from Fort Drum, New York.

So before we get started why don't we go ahead and do a quick poll to get a sense of who's on the line. We like to do this so we know who's there and we can try and speak better to our audience. Go ahead and run the poll, Megan, if you would? So if you could pick an option here on whether you're a building owner/manager, architect/engineer, manufacturer, energy service provider or maybe a researcher from academia. And if you don't see your option up there, go ahead and type something into the chat field and we'll capture that there. This is a really big help to us to make sure we tailor these sessions appropriately. We'll give it a few more seconds here and let people vote in. Okay, it looks like we've got most folks in, so why don't we go ahead and close out that poll. And we've got a higher count than usual for our research/academia types, but we also still have a lot of architects and engineers on the line. And of course we welcome our building owner/managers and manufacturers, and last but not least our energy service providers. So why don't we go ahead and go to the next slide, please?

The next slide? Great. So some of you have heard this before but some of you are new to our technology team. The Better Buildings Envelope Technology Research Team is one of six teams focused on envelope technologies, obviously. The Oak Ridge National Lab works with the Better Buildings Partners on trying to do case studies and look at resources that need to be developed to help advance building envelope technologies. So this is our team here. Melissa Lapsa, the team lead, wasn't able to make today's event, but we are happy you all are here today. So why don't we go to the next slide? As indicated by our poll question, we find that this community for envelope technologies is really unique and diverse and we try and capture all of the different types of entities out there, since there are usually a lot of professionals that are interested in pursuing the technology as well as the building owners. A lot of communication and information sharing is important for this technology area since it is such an important component of the building. So if you aren't a member, please do join. If you go ahead to the next slide?

This gives you a quick example of the types of members that we have. Tech Team members are usually the building owner/managers, property managers, architects, engineers, construction and installation – we definitely need some of those. We also have friends, so if you could scroll to the next slide you'll see we also a lot of organizations such as the researchers, academics and trade associations, energy service providers, manufacturers and subject matter experts. So we want the whole community here to help us advance this technology area. So please do join. If you scroll to the next slide? I'm going quickly so we leave lots of time for our speakers. These are the kinds of things that the team does. We work on building awareness, verification studies and technical assistance. So these slides will be available on the Better Buildings Solution Center site. We also have a webpage there for envelope if you put that search term into the solution center. Do e-mail Melissa Lapsa if you're interested in joining and we will get you on the list and involved in the group.

So let me give a quick overview of our speakers today. Dr. Mahabir Bhandari will go first. He's an R&D staff member at Oak Ridge National Lab's Building Envelope and Urban Systems Research Group. He has more than 20 years of experience in the field of building energy performance. In recent years his focus has been on the fenestration, research, whole building energy simulation, manual and auto-calibration, industrial energy data analysis for energy savings impact, THP, deployment analysis, building energy monitoring and performance analysis and the evaluation and integration of energy-efficient technologies in buildings. So that's a lot. So Dr. Bhandari is a great expert to have on the team here. He'll be speaking on passive walls.

He'll be followed by Dr. Diana Hun, who is also from Oak Ridge. Her research areas include improving the airtightness of buildings, while minimizing risks due to the potential building material deterioration and indoor air quality problems. Moreover, she's investigating the integration of the latest developments in materials and manufacturing into building envelopes. For instance, she leads an interdisciplinary team that aims to decrease energy consumption and greenhouse gas emissions in the U.S. and China by developing the next generation of precast insulted architectural panels. Dr. Hun received a Ph.D. in Civil Engineering from the Texas University of Austin and with a grant from the National Science Foundation. So another awesome expert to have with us today to speak about CLT.

And last but not least, Mr. Tapan Patel is a mechanical engineer at the U.S. Army Engineer Research and Development Center Construction Engineering Research Laboratory in Champaign, Illinois, where he's served since 2012. In this position Dr. Patel is responsible for leading research projects related to energy research and the development for DOD facilities. Specifically he performs research in cyber security for control systems, demonstration and validation of advanced metering equipment and innovative building envelope components, testing of hydrogen fuel cell equipment and development of hardware/software for prototype testing. So we welcome Tapan to our session here today. Why don't we go ahead and get stared? I think up first is Dr. Bhandari. Next slide please? Mahabir, do you want to get started?

Mahabir Bhandari: Thank you, Caroline, for introduction. Greetings, everyone. My name is Mahabir Bhandari and I'll be presenting the first part of _____ a study we are doing on existing commercial wall systems. And the goal is to estimate the role and potential of these walls in future bid activities. Next slide please? So to provide a context here to this study, I borrowed theses slides from BTO presentation, and this slide shows that with the accelerating pace of renewable energy systems, the electricity system is changing, because we have so many solar and win coming into the grid. That creates an opportunity for buildings to serve as a flexible, responsive, demand-tied resource. And moreover we know there are more than 5.5 million commercial buildings with a total area of 87 billion square feet. So we can see here there is a great opportunity for buildings to be part of the future grid. Next slide, please?

So this is just – you may already have heard about grid-interactive efficient buildings, or GEBs. So there is an interest and focus on developing GEBs and if you haven't, you will hear about it. So these are basically by definition efficient and connected in a smart building – you know, that can participate in adjusting the demand or _____ the elastic load and respond to grid. So building systems in one way are already playing some role in demand/respond, like in terms of pre-cooling, but building envelope so far has not played any big role. Next slide, please? So in that context, the objective of this study is to look at performance and gap analysis of current commercial wall assemblies, and we're calling it passive walls, not to be confused with passive house and passive construction. But just to say that these walls do not actively play any role. You cannot control the walls. You can have a thermal _____ but it can produce your peak, but you cannot switch it on and off. So the goal here is, can these walls play a major role in future grid-interactive buildings? So with that we want to identify first, what are the current common commercial wall constructions? And then what kind of data is available there for these walls to measure data, or simulation base? And then looking at it to identify some indices which can be used for the control and energy optimization. And Dr. _____'s finding – so that if we _____ that these are the possibilities or these are the best-case scenarios; can you develop technologies which can be active or controllable wall systems? So this is not a recent project. It's more like informing future research. Next slide, please?

So to do this first we wanted to look at different sources here, like design guides and standards so we can identify different schemes of categorizing these walls and then find what type of these walls or what are the predominant walls, are there in the market for now? So we can look at it and then see, "Oh, are there any simulation-based studies or wall-performance-measurement studies out there, and what do they tell about the wall performance?" Next, please? And if not, then do we need to – if there's no data available for wall types and their performance, can we get that data or do that in future, or do some simulation-based studies to get would be the potential of these buildings to play that role? Next one, please?

So to do that what we were doing is, what are the different characterizations of the walls, because they can be based on building form and function and it really depends on where the building area, number of floors, building type – that will determine which kind of walls are there. And it can _____ _____ _____ of structural strength, integrity of construction, not-thermal comfort or _____. So to do that we looked at, in terms of building structure where they can be load-bearing and non-load-bearing, but _____ _____ whole building design _______ and other _____. While they look the integrity of the structure and the constructional materials. So they characterize that cavity walls or barrier walls and mass walls. Next one, please?

And if you look at the building codes and standards, it really dictates the insulation requirements that you have, if you have continuous insulation or cavity insulation. And based on that they determine the wood, steel or metal building wall or mass wall.

Next one, please? And then if you look at the commercial building and _____ _____ survey – so the walls are defined a little differently. Like you will see they are brick, stone, stucco, basically based on what kind of cladding or structural requirement is there, and then they define the walls different. If you look at this whole slide together, you'll notice that there is no common – the walls are characterized differently by different _____ or different commonly-used sources. The next one, please?

So then to do that we looked at this cross-map of how can we _____ somewhere that they have something in common? So we look at the wall space and the standards – like wood frame walls, and what _____ _____ with the possible structure rules. It can be load-bearing and non-load-bearing walls or it can be cavity or barrier walls in terms of ordering design. The whole idea is that if we are doing some simulation studies later, then we don't want to create some fixis wall layers and just say, "Oh, if we put these four layers together or three layers together that would be performing." But we also want to make sure that all of the structural and other requirements are met and that's how the wall construction, we can – we can kind of recommend. Next one, please?

So then after we kind of characterize those wall different categories, then we were looking for, in the current systems or kind of existing buildings, what kind of walls they are. So we first look at by building area. If you notice there, less than 25,000 square foot are in some number that 88 percent of buildings, but in terms of floor area, only 36 percent. And while more than 100,000 is – even though only 2.4 percent of buildings can have 35 percent of floor area. Next one, please? So based on that characterize, then you will notice that frame walls with heavyweight covering are predominant in all of the buildings, even 40 to 50 percent are in small, medium and large buildings. Frame walls are generally in the small buildings, and metal panels are less common with increasing building size. The next one, please?

Then we also looked at by the building height, because generally building height, that determines what are the structural requirements. So we looked – again, the same, with 3 floors or less, almost 97 percent of buildings with 78 percent floor space, followed by four to eight and nine and more floors. And then when we looked at the different wall sizes in these buildings based on the building heights – next one, please? – you will notice that again, frame wall with heavyweight covering are 40 to 60 percent in low-rise to high rise buildings, followed by mass walls, which are both concrete block or poured or pre-case concrete. They, combined, almost 40 percent in high rise buildings. And the newer trend is windows or vision glass. The curtain walls are increasing and they're generally in high rise buildings. Next one, please?

So we also look by building type, because building type determines what is your thermal comfort requirements. For example, the office building will have a different requirement than like supermarkets and different food services. So we looked at what kind of walls if you look through the building types. Next one, please? So again, frame walls with heavyweight covering are predominant in all building types, the number one you can see up in the graph. And next one? Mass walls with either concrete block or poured, and they are equally common in other types of buildings. And the last one here is a mass wall. They could be precast concrete or metal panels in all building types. Next slide, please?

So we also looked at the building type from the prototype buildings and I don't know if you are familiar with that, but these are the buildings which have the building models available. They're also done based on different surveys and then they are kind of your typical building. These building models are used for energy efficiency measure estimation and potential. So if you looked at these then – next slide, please, or next click? So a steel-frame wall is in most of these buildings, followed by the mass wall. So you can notice that we wanted to look at the different aspects of these – building height, building area – and then see where the different buildings fall. So that was the idea, to get all of the information about existing walls. Next slide?

So in summary, we are looking from the different perspective or different way of doing it. We found that the steel framed walls and heavyweight covering is the most common commercial wall type and then frame wall with light covering is common only in small buildings. Then concrete block or poured and precast concrete is normally common in high-rise buildings, and metal building are predominant in the small and large buildings which are low-rise. So next one, please? So based on all of this data we collected or analyzed, we thought the steel-frame wall and mass wall are the two predominant wall types in commercial buildings and next phase then, we can focus on just these two building types instead of focusing on all different wall types and then see what kind of study we need to do further. Next one, please?

So just yeah, if you have any questions, let me know, but like part of this team is we all are a team member just to get some feedback.

So we are looking for the next step and what kind of thermal impact – what should we look for _____ _____ performance? Should we do laboratory setting or in a real building? And is thermal mass the only thing we should focus on, or we can do other indices – or if you have any measured data that you could share with us? So that's the ask from us, our team, to other team members. So that's for me, thanks.

Caroline Hazard: Great, thank you, Mahabir. So Diana, why don't you go up next? And I'll remind folks to type any questions either for Mahabir or the other speakers and we'll get to those at the end. Go ahead, Diana.

Diana Hun: Sure, thank you. So I'm just going to give a very brief overview on cross-laminated timber. And most of you guys probably are familiar with Glulam, and that's what is shown on the left side of this slide. So the difference here between Glulam and cross-laminated is that in CLTs, the lumber boards are stacked crosswise. And that's what differentiates it again from the Glulam. And with the CLTs, then the boards can be attached to each other, either using glue, nails or wooden dowels. The minimum number of layers in CLTs is three layers and the pieces, the lumber pieces – the dimensions with regard to thickness can vary from around 5/8 of an inch to two inches. And the width of the individual pieces varies from about 2.4 inches to 9.5 inches. Next slide?

And here in this slide you can see the dimensions in which the CLT panels typically are available. Their widths vary anywhere from two feet to ten feet, and the maximum length that they can stand is currently 60 feet. And as you can see from the slide, they're currently being used for both walls – in other words, vertical components and horizontal components. Next slide? And this slide just shows a few examples of how these panels are connected. As you can see on the left-hand side, you can use shiplabs or splines with screws. Also you can use brackets or a special inset as is shown by the picture on the bottom left. Next slide? And this image then shows how these panels then can be put together or assembled with respect to walls and floors. Next slide?

So one of the reasons CLTs are gaining momentum is because of their size, the dimensions that I just mentioned. They're 60-foot spans. Now you can ship to the site these big panels that can then expedite installation. And also, again because they have several functions, then you decrease the number of _____ that you need at the site. Okay, next slide? So as you can see on the left picture here, in some buildings the CLTs are only used let's say for the floors and perhaps for the columns, and then the building owner may decide to use conventional prefab panels as the cladding. However, there are a few buildings in which CLTs are being used as the envelope, as is shown in the picture on the right-hand slide. Next slide?

So if, again, the CLT is used as part of the envelope, then this slide here shows some common details on how to install the air and water barrier and then over that then you put the exterior _____ insulation, and then you have your rain screen and your cladding. So in other words, the materials that are used on the envelope are very similar to what is currently used in regular buildings. Next slide? Similarly this slide here shows how the materials or the air, water and thermal barriers are installed on the roof against using common materials that are commercially available. Next slide? And although I am not an expert on fire, I included this slide because this is a common question that arises when people are giving presentations on CLTs. They ask about fire. So in this slide, what I'm just trying to show here is that in general, when the CLT is a structural component, they are designed so that it has what is called a char zone, so it's a sacrificial area that is in addition to the wood part in the CLT, that is supposed then to have all of he structural capacity that is needed. Next slide?

And one of the features that has made CLTs attractive to let's say the Department of Defense is their blast resistance. In other words, CLTs can be designed with the proper connections so that they can resist blast loads that are currently designed for the Department of Defense. Next slide? So this graph here shows how CLTs compare with regard to cost to other types of building construction. In particular, in the graphs where it says "non-wood," that pertains to concrete construction and steel framing. And then with the blue bars, those are representative of lightweight construction. So what this indicates on the left-hand side is that for buildings that are three stories and shorter, in those cases light-wood framing is the most economical system. So now when your building starts increasing in number of levels, let's say five and higher, this is where CLTs start becoming more competitive. Next slide?

So here, this diagram shows the instances in which CLTs could be potentially the most value, okay? When there are schedule constraints, as I mentioned, you have these large panels that expedite construction. Also when there is scarcity of labor, because as I mentioned you need fewer _____ or fewer people to install these panels at the site. Also locations where labor is high, CLTs are attractive, because again you need fewer people at the job site.

And also these are attractive where you have poor soil, and it's important then for your structure to have lower weight. So CLTs here would be more beneficial than potentially let's say concrete, which has a higher – those structures usually are typically heavier. Next slide?

So ORNL will probably be working with Lendlease, which is a developer and owner of different commercial buildings, and they have built several hotels out of CLTs. An upcoming one is in Fort Bragg, North Carolina. And in this case what the case study would entail is for ORNL to help determine what are the potential energy savings and peak reductions due to the use of CLTs in this building. And that's the end of my presentation.

Caroline Hazard: Great, thank you, Diana. Tapan, if you want to get started? And remember, if you have questions, feel free to type them in and we will address them at the end.

Tapan Patel: All right, thank you, Caroline. Good afternoon, everyone, my name is Tapan Patel. I'm a mechanical engineer with Energy Branch at the Army Corp of Engineers Construction Engineering Research Lab. So today I'll be talking to you about a demonstration project that we did at Fort Drum, and we installed, modeled and validated a technology called Modified Atmosphere Insulation, also known as MAI. Next slide, please? So here is the agenda. I'll talk a little bit about the background and objectives of the project, but I really do want to focus on, for the architects and engineers – I notice there's quite a few here – I do want to focus a little bit more on how to install these panels, what we did in terms of sensor and model calibration, to make sure that the savings we saw were realistic, and then I'll talk a little more about where the technology will go from here and some future work. Next slide, please?

Before we get started I do want to acknowledge several folks here on the screen. You know, the technology was introduced to us by Oak Ridge National Lab and they helped us with a lot of the work here on this project. Fort Drum was the demonstration site. NanoPore Inc. is the technology provider and funding was made available through the ESTCP Program. Next slide, please? Okay, so for those of you who are not familiar with MAI, it is a new generation of advanced insulation. You have heard the term VIP or vacuum insulation panels? The idea is basically to reduce heat transfer by encapsulating a vacuum within a panel. And so the benefits this gives you is it's much thinner, it's much lighter and it has a significantly enhanced R value. Where MAI comes in, MAI is another name for a VIP product, except that there's a much simplified manufacturing process. It has on the order of 50 percent fewer steps, and so the cost ratio really starts coming down when you look at about 10 to 15 cents per square foot for R value compared to 25 cents for some of the traditional VIPs that are on the market. Just for reference, traditional Polyiso, which is used widely, is about 10 cents per square foot. So really this project was looking at A, how does the technology hold up in a real environment, and then B, what are the cost implications for such a technology? Go to the next slide, please?

By way of characteristics, a few things to notice here. In the left figure we've got the R value of the MAI compared to – as a function of temperature. And you'll notice that as the temperature decreases, the R value actually increases. And the reason for this is because there's a vacuum within the panel, the partial pressure drops when the temperature is lower, and so that increases the R value. On the right side you'll see a curve that talks about the R value as a function of pressure within the MAI panel. And one of the concerns with vacuum panels is if they get punctured they can somehow – they'll lose their vacuum and so then they're no longer useful. And so if that is the case, you can see that if there is a puncture, even at a high pressure, atmospheric pressure, you're still on the order of R-7 or so, which is pretty good compared to some conventional installation materials.

I will mention that Oak Ridge is also working on a self-healing technology. It's a technology that you can put on top of the MAI panels or the VIP panels and when it gets punctured it kind of heals itself and so it keeps the vacuum in place. And I think Diana could talk more about that later if you have any questions. All right, next slide? So our demonstration site at Fort Drum involved two buildings. One was kept as a control and the other was retrofitted with this MAI. The characteristics I've listed here. It's a pretty standard building, about 2,000 square feet, 2x6 wood frame construction. I'll note that there was insulation in place already and that will affect our results. I'll talk about that later, but there was R-13 in the wall and R-40 in the ceiling. It's a metal panel, exterior platting and both facilities were used as a classroom. Next slide?

All right, so because it was a demonstration project, we have several performance objectives that we were trying to validate. Here's a big list. But at the end of the day really what we cared about was, how much energy does the MAI save us and what's the cost – you know, return on investment or price point of the technology? Next slide, please? One of the things you have to keep in mind when you're installing these panels is you have to do some careful planning. So what this slide shows you is how we planned out our workflow. We got measurements of the building. We then used a CAD program to overlay the panels, so we could get a really good idea of where each panel needs to go. Anywhere where there's a gap – you can see in the pictures there's a dark gray Polyiso? And the Polyiso is there so that we can reduce the amount of thermal bridging between the insulation and the MAI panels.

In the pictures there you can see, all of the white areas are MAI. The panels we used were generally about 24 inches by 20 inches. Their dimensions are generally limited by mechanical stresses from the manufacturing process, so it is difficult to get large panels. On the other hand, you don't want large panels, because if you do get a puncture in one of them, you want to be able to isolate those panels to the extent that you can. So the picture on the right just shows you what the wall looked like in our planning phase and what it looked like after we were done, and so you can see there that they match up pretty well. Next slide, please?

One of the questions we had going into this is, how can we tell if a panel has failed or punctured once it's been installed in the facility? It turns out it's actually quite – IR imaging works really well. We did have to crank up the heating into the building or the heat in the building and get the interior to about 80 degrees or so, and Fort Drum, in the winter – I think when we took one of these shots it was about just above freezing or just around freezing. So that's the kind of differential we had to get, about 50 degrees differential between indoor and outdoor, in order to clearly see where the panels have failed. So in the bottom-left picture, my cursor is on one and two. You can see spot one is a little bit warmer, spot two is a little bit cooler, and spot one was actually where one of the panels had failed. We noticed that it had failed during the installation. We decided to leave it in so that we could validate it with V-IR imaging. Next slide, please?

Here's another example of some failed panels. These failed because of some poor coordination. After the building was sealed back up, some folks had come in and put a new sign on and they didn't realize this was a different building and they ended up puncturing through the panels. So we learned that we should coordinate better with the folks on the ground, but this was also another good opportunity for us to take some IR images and figure out exactly where the damage is. So on the left you can see kind of on that top row in the middle there's several empty spaces where the panels have deteriorated and they've lost their vacuum. On the right side the rest of it is still in tact, so you can pretty clearly see where the panels are. And we think – over the long term this project looked at the panels for about a year and a half after they were installed, but over the long term we're pretty confident that IR imaging is a good way to periodically check your building and make sure it's still holding up. Next slide?

One of the things we also looked at is – you know, we calculated the overall area-weighted R-value of the walls compared to the percentage of failed panels and this was really to meet our metrics that we set out at the beginning of the project. We wanted to try and make sure we have no more than five percent of our panels fail, and so you can see from this graph here that it's a pretty linear drop off. So the higher percentage of panels that fail, the lower your average area-weighted R-value will be. Next slide, please? One of the other considerations we had in this project – I mentioned earlier we had two buildings. We wanted some way to normalize against that. When we're measuring – I'm sure as many of you know, when you're trying to measure the energy savings just from one technology it's really difficult to isolate the savings from that technology.

Things in the buildings are always changing. You know, people are moving in and out, you've got your HVAC system that might be going through some changes, and that's especially true when you have two buildings. No two buildings are identical. And so our goal, our approach here was to put in a sensor suite to take lots of measurements and then conduct some detailed modeling so that we could normalize for some of those effects. Here's the kind of sensors we installed. We installed solar trackers, we had several temperature and relative humidity combo sensors on the interior and exterior of the building and we also measured heat flux on all of the walls, including the ceiling and the floor. Next slide?

A couple of other thing we had to do, we measured the natural gas consumption of the buildings, we measured the electric consumption both at the whole building level as well as the HVAC level. We also did some blower door testing to quantify the infiltration rates for both facilities. Next slide? So this slide just looks at the baseline facility versus the retrofit facility. Really the important thing here is that the process of installing the MAI panels did not significantly affect the infiltration rates and we don't' expect it to. Although the MAI, the panels are covered with an air barrier and a vapor barrier, we still have those spots of Polyiso throughout the building, and so Polyiso is porous, so we didn't expect much of a change. All right, next slide?

So here's a graph just showing one week, one representative week, I'll say. On the x axis you have the day and on the left axis you have the energy, the heat flux. The green lines represent the retrofit building; the red ones represent the baseline building. And the outdoor air temperature is in the blue. So where I pointed the arrow, you can see that in general throughout the week the green peak is significantly lower during the morning when the building starts up, and then throughout the day it generally ends up being lower. One side effect of tightening up your building – or, I'm sorry, one side effect of adding a significant amount of R value to your building is that your HVAC system now becomes oversized. And so you can see that, because you see rapid cycling or increased cycling of your natural gas consumption there. And we noticed that the HVAC system would turn on and off more often, and so we had to go in and make some adjustments to tell it to run for more extended periods of time so that we aren't prematurely killing that unit. Next slide?

Heat flux data here, looking at one of the walls. Again on the x axis you've got the day and on the y axis you've got the heat flux. The baseline building here is in blue and the retrofit is in red. And you can clearly see that we're significantly reducing the heat flux through the walls. In this particular case, in this week, it's 62 percent on this wall. And again, in the red you can see that there's a lot more cycling, which is indicative of your HVAC coming on and off to try and meet the load. Next slide? We created an EnergyPlus model, as I mentioned earlier, to compare the actual data we had versus the simulated data. And again, this is important, so that we could normalize a few things across the building, such as occupancy, time of use, lighting loads – those kind of things. Next slide?

I'm not going to go into detail on this slide, but this graphic shows the process we used to collect the data, compare it against our energy models and go back and forth to calibrate the models. Next slide? So these charts show the simulations that we ran versus the measured data. As you all I'm sure are familiar, energy modeling at this level is more of an art than a science. And so you can see here in almost all of the graphics the simulated output matches the measured data pretty well. There's obviously some discrepancies, which is unavoidable. But in general we got pretty close. And so we used these sets of simulated data for our calculations that I'll show you later. Next slide?

So here's where the data is. This is what we were trying to get to for this project. So after you normalize across the two buildings, we see a total percentage reduction of very little on the electric, because Fort Drum is a pretty cold climate, so there's not a whole lot of electric savings to be had there. We did have some pretty significant natural gas savings on the order of 11 percent, for a total of 6.5 percent. And keep in mind here that the facility already had R-13, so if you go into a facility that does not have insulation or has less insulation, we expect these savings to be much higher. And you can see we did have also a pretty significant monthly electric demand reduction of 3.5 percent. August is the most important one, because that's the highest rates that Fort Drum pays. It also ends up for this particular facility being the highest baseline. All right, next slide?

Here's a table of all of our performance objectives that I put up in one of my first few slides. There's a few that I wanted to focus on here. The first one is the energy reduction, which I showed you earlier was 6.4 percent. But the second to last one the system economics – so this is something we expected. We know the technology is still maturing and people are working on finding ways to drive down the cost, and so the economics are not where we'd like to be to see this go commercial scale. A couple things we learned out of this. The real expenses, one of the big drivers for expenses was the installation cost. As you can imagine, putting up all of those panels – we had about 225 panels that we put up manually – it takes a lot of time. And so one of the things Oak Ridge is working on is developing four-foot by eight-foot boards that are basically the MAI panels sandwiched between Polyiso. And the idea is you can take these big boards and just put them up on the building and then it reduces the installation time by about 80 percent. Next slide, please? All right, I got ahead of myself there on the previous slide, but this is essentially what I was saying. These integrated MAI/Polyiso or foam boards are expected to reduce our cost by 80 percent. All right, next slide?

So in conclusion, we saw some significant savings for this particular facility. It actually beat our expectations based on what we found from some initial modeling, which is great. And so we think this technology is definitely a viable potential, especially in retrofit applications. It's lighter, it has a higher R value and it generally over the year and a half that we tested it, it worked out pretty well. All of the failures we had were due to errors during the installation. None of the panels that failed were because of manufacturing defects or anything like that, so that was promising. We know that we need some additional material and insulation cost reductions. That will help drive the viability of this product. And finally, for anyone who's looking to validate the savings, energy modeling and normalizing against your different buildings, they're very important. Without that it's really hard to isolate the savings just from this particular technology. And I think I'm done.

Caroline Hazard: Great, thank you so much, Tapan and Mahabir and Diana. Why don't we go ahead and flip to the next slide? We do have a handful of questions so we'll get through these. I'll give Tapan a break for a second and throw one towards Diana on the CLTs. The question is, "Can the CLT be used as a concrete form? It was unclear in the one project _____ Commons, where it looked like there was a cast in place columns in at least one floor level."

Diana Hun: So in that picture from the _____ Commons, what you're seeing there at the bottom of the picture is the podium, and in this project they decided to make the podium out of cast in place concrete. Also sometimes the owner or the designer may decide to put a concrete topping over the CLT to reduce vibration if that is a concern.

Caroline Hazard: Great, thank you for that response. Let's go over to the MAI topic. And one of the first questions I have here is, "What causes the MAI panels to fail in a one-year span?"

Tapan Patel: Good question. So in our case it was just some mistakes we made during the installation process. You know, if you're careless and you drop something on them – that happened a couple of times. Somebody dropped a screwdriver from one of our scissor lifts and we had the panels out of the floor and it just went right through them. So all of the errors we had were avoidable. We didn't see any panels fail due to manufacturing defects. So really if you install everything carefully the panel should last way more than a year. And there is some eventual leakage, and that's on the order of maybe one to two percent a year.

Caroline Hazard: Okay, great. I'm going to combine a couple of questions that came in, kind of about attaching them and sort of ensuring their functionality. The first part of the question is, "How are the exterior finished materials attached over MAIs if you can't puncture the panels?" And then the next question is, "Does it matter where in the wall assembly the MAI is installed? Would it perform better in the center of a wall location?"

Tapan Patel: Yeah, great questions, and those are some things we've asked ourselves. For the first one, the fasteners – if you go back to drawings that I had where we laid out all of the panels, what we did is we actually put Polyiso strips where all the fasteners are supposed to be. So we used the same screws except we just made sure to line them up so that they're going through the Polyiso as opposed to the MAI when you're reinstalling the metal siding. For the second question, it is possible that the MAI could function better in the middle of a wall. It does depend on climate zone and that's something we have to investigate. We've done some preliminary moisture migration modeling to look at that. Because the MAIs effectively act as an air barrier and a vapor barrier, that's something we have to consider. So I don't have an answer for you yet, but that's something that definitely needs to be looked into.

Caroline Hazard: Okay, great, I appreciate that. Another question here for you, Tapan. "The IR images show pretty clearly that there is greater heat loss at the seams between the panels. Can you give us an idea of how this affects the overall efficiency of the wall?"

Tapan Patel: Yes, so the reason for the higher heat loss between the panels is because we put Polyiso – it was roughly an inch. So that's an R-8 to 10, depending on what you're using, compared to the R-36 to 40 for the MAI panels. So absolutely we're losing heat through there. Unfortunately we haven't found a better way to improve the efficiency there just given what's currently available on the market. If there was some way to get away from putting fasteners through the wall, that would probably be a great. Then we could just make sure the entire wall is MAI. But if you have to go put fasteners through the siding and into the wall, then – we found that Polyiso is really the best way, at the moment.

Caroline Hazard: Okay. "Are MAIs currently being used in mainstream construction or is this material still in development?"

Tapan Patel: So this project was the first that we are aware of, where it's been installed into a full facility. So it is still in development. The biggest driver here is cost. So folks such as Oak Ridge and the manufacturer here are working to bring down the cost.

Caroline Hazard: Great. And one last question here for Diana on the CLPs. "How does the embodied carbon of CLT compared to light-wood framing and non-wood framing?"

Diana Hun: Okay, so the studies have shown that the embodied energy of the CLTs compared to concrete is lower. I don't recall seeing comparisons to light-wood framing. It may be out there, but I haven't looked for that information.

Caroline Hazard: Okay, great. So we're almost at the top of the hour. I just have a couple of more messages to share. So if we did no get to your questions we will follow up via e-mail and feel free to e-mail us and Melissa or any of us to ask us questions and we'll follow up. If you can advance to the next slide that would be great. We'll try and run this super quick here. So go ahead and launch this. We'd love to get your opinion on what sort of topics we should have for our next webinar. Please pick one, and if you can't just pick one, feel free to type into your window what other ideas you might have. The options are technology showcase on walls, or maybe one on roofs, or one on windows and attachments, or perhaps more examples of things like commissioning your building enclosures system. So please go ahead and vote on that. We'll give it a few seconds here. We've had some great technology showcases so this is something we'd love to do again, and of course we know the case examples are always a lot of fun for people to learn about.

So why don't we go ahead and close that out and see what our winners are? It looks like it's fairly even here, but like I said, the case examples are usually a real winner here. So let's go ahead and do this last slide here, a plug for the Better Buildings Summit. If you haven't registered, please do register. This is a great opportunity to hear about those kinds of examples. We will have few sessions that will be of interest related to envelope. Dr. Mahabir Bhandari will be on hand as an expert. You can speak to him during session breaks. There will be a panel session Pushing the Building Envelope, with more examples from some of our members, and lunch plenary on emerging technologies. These are just a sampling of the things related to envelope. There are a lot of other great sessions, so do go ahead and register for that and we'd love to see you there. So you can see the link at the bottom, betterbuildingsinitiative.energy.gov/summit.

And with that, if we go to the last slide here, I'd like to say a big thank you to our panelists. Really great job to get through all of that material today. And we really appreciate everybody spending the afternoon with us and I hope you have a great day. Bye-bye.

[End of Audio]