[Transcription begins at 0:00:

Axel Pearson: Hey, everyone. For those of you that joined a little early, there's a trivia question on the screen. Feel free to answer that while you're waiting for us to get started.

[Break in conversation from 0:00:30 to 0:00:51]

Axel Pearson: See some good answers coming in. If you just joined, feel free to answer the trivia question. When was germicidal UVC first used to inactivate infectious diseases in classrooms and lecture halls?

[Break in conversation from 0:01:06 to 0:01:34]

Axel Pearson: See a good amount of people joining. If you just joined, answer the trivia question. Give it a shot.

[Break in conversation from 0:01:39 to 0:02:05]

Axel Pearson: All right, we've reached the top of the hour. If you've just joined, we've got a trivia question that you can go ahead and answer. I'm going to give it one more minute, 'cause I still see responses coming in. I wanna see what y'all think. Let's get started in one minute and we'll close the trivia question and we'll get started. Then I'll, of course, show you the answer.

[Break in conversation from 0:02:26 to 0:002:42]

Axel Pearson: Okay. Still answers coming in. if you wanna answer it, go for it. Okay, we've got a packed agenda so I'm gonna keep us moving. Thanks for joining everyone. Dana, let's go to the next slide.

All right. Thank you and welcome to this Better Buildings webinar, *Clearing the Air: Healthier, Safer, More Efficient Buildings with Germicidal UV Systems*. My name is Axel Pearson. I am coming to you live from Salt Lake City, Utah. I will be your host today, and boy, do we have a program for you. I'm really excited about this one. Today we'll hear from PNNL lighting experts who I'm honored to introduce and have on the call with us. We've got some information on DOE resources and how they can help buildings install advanced lighting systems and provide valuable impact. So thank you so much for taking the time out of your day to listen and participate with the lighting systems technology research team. Slides and recording will be posted shortly after today's webinar, so keep an eye out for that.

Okay, next slide. If you joined in time to answer our trivia question, the answer is D. There we are. Yes, the 1930s. That's right. About 85 years ago, William Wells hypothesized that confined spaces can be a vehicle for the spread of disease and set out to test the upper room GOV fixtures in schools, very relevant for today's conversation. So they monitored the spread of measles in that experiment and found that the spread can be controlled by this indirect radiant disinfection of the air. So you can see that old photo there of the fixture in the classroom. So let's see how many people got it right. Dana, can you show us the poll results? All right, yes. Most of you got it right. Forty-one percent, 1930s. And then a spread. No one went for 2010, so that was a trick answer there. No one got that, so well done for those of you – well, well done for everyone. Participation trophy there.

All right, let's go ahead and I'm gonna click off of those results. Okay, next slide. All right, so here's the agenda for today's webinar. First I will introduce you to the speakers – well, rather speaker that we have on the call today and briefly tell you about a little bit of the recent work that we're doing and some upcoming events. And I wanna give a shout out to the recently recognized ILC participants from this year's campaign if you weren't following that program. And then we'll get into the meat of the webinar. We'll continue the conversation that we had from our last meeting. This group last met on June 30, and we talked a lot about resources that we want to offer all of you, the building and lighting industry. And then we'll move into our technical topic of the day, which is germicidal UV systems and its impact on both energy use and airborne pathogens.

Okay, so that's what we have ahead of us for the next hour or so. If you have questions or comments along the way, feel free to enter them into the question-and-answer pane in Zoom. That should be an option for you down at the bottom. We will keep an eye on that as we move along, and I think we'll have some time at the end. And if not, I will follow up with you afterwards and we'll get those questions answered. Okay, next slide please.

So today's speakers, here we are. I'm there on the left. Again, my name is Axel Pearson. I'm a project manager here at PNNL. I lead the integrated lighting campaign, the ILC, and the group here today, lighting systems technology research team, and I get to put on events like this one. So that's me. In the middle there is Ruth Taylor, and unfortunately she can't make it today, but I'm gonna introduce her anyway because she's a person you should know. Ruth is a project manager on the advanced lighting team here at

PNNL. She's an experienced lighting practitioner. She currently manages the next generation lighting systems program which encourages lighting innovation, promotes excellence in the design of energy-efficient LED luminaires and connected lighting systems. Ruth has also been working on some of the educational resources focused on connected lighting controls that I will tell you about in a few slides.

On the right there is Gabe Arnold, a senior lighting research engineer here at PNNL. Gabe also has a wealth of knowledge in lighting and currently works on DOE's L-Prize, which if you're not familiar is a competition that will literally award millions of dollars for lighting innovation, so that's a pretty cool program. If you're not familiar with that, check it out. In fact, Gabe just was on another webinar this morning. He's an in-demand guy, so we're happy to have him. Some of his other work is the focus of today's technical topic. He's gonna tell us about the really interesting efforts and work around GUV, and I know he's got some poll questions to ask you for your input there, so thank you for being here, Gabe. Look forward to your presentation.

All right, as I mentioned, like to tell you a bit about some of the recent work and events that we are interested in and we're working on. First I call out similar to the field evaluations that we do on connected lighting, we are looking for host sites to evaluate GUV system performance, and that's because when studying and working to deploy new technology, examples of real projects with measurement and verification can really help demonstrate the benefits and encourage participation, really encourage the adoption of this new technology. So if you've got a system in your building and you're interested in working with us to demonstrate the benefits, please let us know. We'd be happy to talk with you about that.

Next up, I briefly mentioned the L-Prize, and Phase 2 of the L-Prize called the prototype phase just launched. This is where real physical prototype products are developed that really emphasize the innovation and challenges the competitors to think outside the box in terms of form factors, materials, price points of commercially available products. So there's two tracks to this phase: the luminaire track, the connected lightings track. If you're interested in learning more, potentially competing, I've linked some recent webinars here as well as the website, so when you get the slides from today's presentation, you can click on those links and find out more. You can also reach out to me or Gabe, and I'm sure Gabe would be happy to tell you more.

Finally, some events that you should be aware of if you're not already. Got the ASHRAE Building Performance Analysis Conference and Sim Build, BPAC – that's in Chicago right now, September 14 to 16. IUVEA Americas Conference. That is an ultraviolet conference in Cincinnati later this month. There's the 2022 IES Street and Area Light Conference in Dallas, Texas, in October. And there's also the 69th NALMCO Annual Convention and Trade Show in Arizona also in mid-October. So I hope to see you at some of those events.

Okay, next slide. Okay. I mentioned that another one of my efforts here at PNNL is the integrated lighting campaign, which I hope you're all familiar with, but if not, just like the name sounds, the integrated lighting campaign focuses on installations of integrated lighting, which means the lighting system can communicate and interact with other building systems to enhance overall building performance. So when participants are recognized, and that's what just happened late last month, they get announced at the IES annual conference, we'll develop case studies and short videos. DOE will send out promotions. They have a direct line of communication to all the lighting experts here at PNNL, so I'll tell you about our 2022 recognitions on the next slide, but I will also make a pitch for next year. If you're aware of a project that would be interested in being recognized by DOE and the Better Buildings program next year, let me know. Be happy to work with you on a submission. That submission process will open up at the new year, 2023.

Okay, next slide. So as I mentioned, we just got through recognitions for the 2022 campaign year. Eighteen organizations were recognized. Fifteen are lighting projects around the country and three are supporting organizations that help these installations happen. You can see the logos of all the installations there – or all the organizations there on the right. Some of these you might recognize, but really they range from manufacturing plants to long-term care facilities, greenhouses, public school districts, big city streetlight installations, and much more. Overall we got a really good mix of project sites and technologies, lots of advanced sensors and controls, HVAC integration, integration with asset tracking, horticultural control systems, and the lighting as a service project that was super interesting, even a diversity, equity, and inclusion champion. So you'll hear more from me on these projects at another time, another webinar, but if anything catches your eye here, you wanna learn more information, you can go to integrated lighting at PNNL.gov or e-mail me. Be happy to tell you a bit

more.

All right, next slide. Okay, so moving on to what brings us together today. This webinar is a production of the lighting systems technology research team. We aim to reduce lighting energy use by sharing insights and experiences related to emerging lighting and control systems and documenting the application of solutions. Really we wanna share our work with you, just like the GOV efforts that Gabe's gonna talk about, and also your input is super important. We wanna get your input on how we can help save you all energy and improve your buildings through advanced lighting. So we've been asking you to complete polls, we've sent out surveys for you to fill out, and you've given us some really valuable information, and we wanna give you an update on what we've heard from you all and the resources that we've developed and those that we're still working on. So I'll tell you about that, but before we move on, I just wanna say this is definitely an ongoing process. This is something that we're gonna be trying to do over the next few years. There's a lot more to be done, so we hope you'll keep joining our meetings and providing with us your valuable input.

Okay, let's got to the next slide. Oh, one more. Here we are. Okay. So this question may look familiar to you. Some of you received a survey that we sent out earlier this year. Thanks to those of you who filled it out. We asked a number of questions on resources that we should work on and who would find them most useful. This chart's a little busy, but the takeaway is that some of the longest bars there like system selection, benefits of connected lighting systems, operating and maintaining and cybersecurity of connected lighting systems are topics that need resources. And the different colors of each bar are groups that would find them most useful from building owners and managers, installers and contractors, lighting designers, utilities, and manufacturers. We have a pretty good spread between these. It's a fairly even split, but we can see what really pops out. Building owners and managers, installers contractors are groups that we really wanna reach, but really we're looking to work with you all. So if you're a building owner and manager, thank you for joining. We wanna get in touch with you. Let us know if you wanna get involved. Next slide.

So this is a similar slide from the question which topics do you see as the greatest need to address the educational resources on the connected lighting systems. So a similar question but really just focused on the topics, not so much who is – would find these resources valuable. Also, respondents were asked to select the top

five, so don't try to make these percentages equal 100 percent. It won't work. So those same topics of the greatest need and where – is where we're focused. The next gen lighting system, or NGLS, has resources on installation and configuration methods. There are two on the ILC website on capitalizing on the benefits of connected lighting systems. I'll talk about those a little bit more on the next slide. And Ruth has just completed a first draft of a resource on system selection that's in review right now, and I'll also talk about that one in a little more detail. Finally, we're in the planning stages for the operation and maintenance and future proofing and upgradability. So really what we're trying to say here is thank you for your input. You have kind of steered us in the right direction, and we still need some feedback on a few of these topics that I'll talk about. So if you have ideas, let us know. We'd be happy to leverage your expertise there.

All right, next slide. Okay, so these are the two documents that I mentioned that can be found on the integrated lighting website, and they're focused on understanding the potential benefits and strategies for success of connected lighting systems. So if you weren't available or weren't aware that these are available, check them out. They're good, and if you need more information, let us know. Again, the links are there below those documents for when you get the slides in case you might have trouble finding those on the web, but there are a link there. Okay, next slide.

So there are a handful of resources from the next gen lighting systems, the NGLS program. They're focused more on characterizing issues uncovered in the living lab projects, and that is – that's kind of a field demonstration type program that works with real installations of lighting. So these are – these five resources are available now, and planned to be completed next are assessing daylight harvesting performance and the role of configuration tools. So if any of those look interesting to you, those are also available. No links there. Let us know if you are interested in those and we can pass those along. Next slide.

So here's a higher-level look, and I've mentioned a few of these, but a higher-level look at what's being developed again. Also still looking for feedback. If any of these look interesting to you or something that you have experience in, please let us know in the chat. Send me an e-mail. Specifically there Number 3, guidance for selecting an appropriate lighting control system to meet functional goals. We're looking for reviewers there. We have that first draft available. If you're interested in seeing that document, and I'll talk a little bit more detail I think in a couple slides, let us know if

you're interested. Next slide.

I'll also mention that a number of these resources are partnerships with other organizations like the IES, and they're intended to be pretty interactive, and that means like a web tool that users can input information into and then get customized results, kind of like TM21 or TM30, those online tools if you're familiar with those. But that's what we're looking for, especially with Number 3 there again, the one I mentioned. It's a system selection tool where you can input some information about the use cases that a building owner or manager is looking for and then give you more information on what system can work for your use case. Next slide.

So here are those decision documents. This is my last slide on the resources. Decision Docs 1 and 2 are those that are currently available on the ILC website. These documents help equip decision makers with an organized approach to lighting controls when establishing defined objectives, and that includes best practice approach to design and implementation. So Decision Doc 3 is that system selection tool that really tries to connect the dots between the use cases that are defined by the building owners and the various system capabilities so that specifiers know what to suggest, and then they can communicate kind of the cost and risk implications. So that graphic there on the right side of the screen, you have some system capabilities. Someone can determine whether they, based on a use case, want that system capability, and then they can work through that document, help them understand what that really means in terms of a connected lighting system. So it's a very interesting document, really useful. So again, there's a first draft developed. If you're interested in seeing that and providing some feedback, let us know.

Okay, so thank you again for your input and guidance on those resources. I hope we can continue to work with you on all that and those that are still to come. So now the topic that we've all been waiting for. I'll hand it over to Gabe, and he can tell us about GUV irradiation and its impact both on energy use and airborne pathogens.

Gabe Arnold: Okay. Thank you, Axel, and hey everybody. So we've got an interesting and I'm gonna say exciting topic here for you today. It's about germicidal ultraviolet technology that can be used for disinfecting air in buildings, keeping people healthier and safer from disease transmission. We've, of course, all experienced the massive disruption and cost that COVID-19 caused to our world,

to businesses, to schools, to the workforce, to supply chains, and terribly lots of people getting sick and dying, and it seems we're hearing about more and more of these diseases, new ones, old ones resurfacing or expanding. In fact, experts believe we'll be seeing these types of biological and pandemic threats with increasing frequency over time. It's been communicated to us by the White House to all branches of government that investing in research to prepare for and prevent pandemics in the future is a top priority. This technology, germicidal ultraviolet, or GUV as we're calling it, is part of the solution, and we've got some new research to share about it with regard to the energy opportunity it provides. I'm gonna start with some basics, and then we'll talk through some of this new information we have to share. We'll conclude by getting your input to a few questions and answering any questions that you have, so please go ahead and write any questions you have into the Q&A pane there and we'll look to get to those at the end.

I am going to be sharing some photo examples of products in this presentation, and I credit the manufacturers for those images. This is – in no way constitutes or implies my or the US government's endorsement, recommendation, or favoring of those products that could be good, that could be bad. I don't say one way or another.

Let's start with a little science here. If you're not already familiar, there's several different types of UV depending on the wavelength of energy. We have UVA, UVB, and UVC. All of these types of UV are produced by the sun and have some disinfection properties. UVA and UVB do come through the earth's atmosphere. UVC is blocked by the earth's atmosphere. UVA and B are less desirable for disinfection because, number one, they're less efficacious than UVC at disinfecting, and number two, they are potentially more harmful. UVA and more so UVB actually penetrate the skin more deeply and can be carcinogenic and cause skin cancer or long-term injuries. Sunscreen is designed to block UVA and UVB. In contrast, we know that UVC does not penetrate deeply into the skin and it only causes temporary injuries. Not to diminish that at all, the temporary injuries are reddening of the skin and eyes, and it can be quite painful so it's definitely something that we want to avoid. So generally, when we're talking about GUV disinfection, though, we're usually talking about UVC as the most effective way to do that.

From our poll question at the beginning, this is not a new technology. We've known about its disinfecting capabilities for nearly 100 years. It was used back in the 1930s and '40s to reduce the spread of measles in schools. The graphs on the right were

from a study in Philadelphia schools where GUV was demonstrated to reduce measles cases. The images on the left are of what is called upper room GUV fixtures, and so these are pointed upward to disinfect the air in the upper cavity and avoid pointing downward where the students or teachers are. After antibiotics and vaccines became more prominent, interest waned in this technology but it continues to be used in healthcare applications and in places like homeless shelters to reduce the spread of tuberculosis. It's used in some other countries a lot more such as Africa.

There are many different ways in which this technology can be applied. Upper room is, as I described, for the classroom. You put GUV fixtures up that irradiate the outer portions of a room. The air is mixed through either mechanical ventilation and/or natural convection, and it's disinfected. Another way of applying this technology is called direct irradiation when unoccupied. Here we are directing the UV downward into the room, but we can't do this when people are in the space because it would cause injury. So this method requires some very good controls and potentially lockouts to be sure that it's not on when people are in the space. This method is probably better for surface disinfection. It is probably not very effective for air disinfection because you can't use it when infected people are in the room, when they're breathing out those virus particles.

It is possible, however, to use direct irradiation in occupied spaces and get some disinfection. You just need to stay below the threshold limit values, or TLVs, that are specified by an organization called the ACGIH. This is the American Conference of Governmental Industrial Hygienists, and they've set these values under which it is safe to be exposed to UVC without any temporary injuries. This approach is called direct irradiation below exposure limits, or DIBEL for short. And I don't wanna get too much in the technical weeds here, but one thing to note is that the threshold limit values varies by the wavelength of UV. When you get down to the lower wavelengths, this is sometimes called Bar UV. You'll see this term used out there. The TLVs are higher so you may be able to provide a much higher intensity of UV through this DIBEL approach of greater disinfecting power without causing temporary injury to people if they're using these RUV wavelengths. This is relatively new, and there's a lot of research and innovation occurring with these UV sources and wavelengths. It's something to pay attention to.

The fourth method on the bottom, UVC can also be applied in a

room air cleaner that takes in air through a chamber and disinfects it in there and then exhausts the air. This might be in a light fixture. More often you'll see it in a standalone device placed in the corner of a room that maybe also incorporates filtration. This approach could be effective for some applications with a well-designed product, but the issue is that right now there are currently no good certifications or rating systems to know how well these products work. Fortunately, some of that is under development.

The fifth method of applying this technology for air disinfection is UVC and HVAC ducts, and it's been used this way for a long time as a method to keep HVAC coils clean, which can offer some efficiency benefits and maintenance benefits. It could also be used in this manner to disinfect the air itself. The challenge, though, is that in these ducts you have high volumes of air moving very fast, and the system would require a very high intensity or long lengths of UVC in the ducts to actually provide enough dosage to disinfect that air. And so this system would need to be very carefully designed to be sure it provided enough dose to disinfect – to in fact disinfect the air of pathogens. If you're just installing the in-duct UV systems that are designed to keep coils clean, that's not gonna provide you a whole lot of disinfecting power.

Of all of these methods, upper room GUV is the most tried, tested, and proven method for air disinfection in rooms. We know this works, and there are many studies to support it. Here is a classroom application where you can see the UV fixtures are carefully designed. You probably can't see – it's a little bit small there, but they have these louvres that direct the UV horizontally and upwards. We don't want any directed downwards. This does highlight a critical issue for this technology in that it will require a trained workforce to install, operate, and maintain it. There's already been some poor installations. One that made headlines in New York State where the fixtures were unfortunately installed upside-down and shown right into a professor's eye and in the students and caused really painful eye injury. It was temporary, but nonetheless, it's a really big deal, and we have to avoid these types of installations. It's going to set the technology back if we don't address that. and so we really need to have protocols and training in place to be sure installation staff know how to install this, maintenance staff know how to maintain it. Maintenance is important with this technology because right now the current UVC technologies, especially low-pressure mercury or LED have lifetimes of about one year, so they need to be replaced approximately every year in order to maintain their disinfecting effectiveness.

So that's kind of some basics on GUV. I want to shift gears for a moment and talk about HVAC and ventilation. This is what most building owners and operators have turned to in making their buildings safer to be in and reduce the transmission of COVID-19. In fact, for many commercial buildings, HVAC use and carbon emissions are actually up from the pandemic and it continues to be up because they've ramped up ventilation. And this is despite the fact that buildings are less occupied than they once were. ASHRA and the CDC have recommended a number of measures for buildings, including upper room GUV and even room air cleaners, but most of the recommendations, the top five on the list on the right are about increasing ventilation. Increase air change rate, increase fraction of outdoor air, improve filtration to MERV 13 or higher, disable demand control ventilation and implement pre-and post-occupancy flushing. All of these HVAC measures increase energy use, especially increasing the fraction of outdoor air. Any new air you bring in from the outside is air that you're gonna need to heat and cool, and it comes at a significant energy cost. In northern climates, this is fossil fuel heating and it contributes directly to carbon emissions.

I do wanna note that these recommendations have been evolving over time. ASHRA's recommendations, they call them instead of core recommendations we can download from their website. They started at the early stages of the pandemic. They recommended increasing your minimum outdoor ventilation – air fraction and ventilation to 100 percent, upgrading MERV 13 filters, completely disabling demand control ventilation. They backed off on that a little bit in part due to energy concerns, also in part because HVAC systems, most all of them can't actually do 100 percent minimum outdoor. They're not designed to handle that type of load. And so where they stand today, at least with ASHRA with the core recommendations, is provide at least the required outdoor air as specified by code and do it with as much as you possibly can. Do more than code if you can. Use the MERV 13 filters. That's still in there. And they've changed the wording a little bit from just flat out saying disable demand control ventilation to maintain equivalent clean air supply design occupancy whenever space is occupied. That is still kind of effectively saying disable demand control ventilation. They're saying if anyone's in that space, even if it's just one person, maintain that designed occupancy ventilation, the maximum ventilation. So that's still effectively saying disable in a lot of cases.

So there's been some study of the impact on energy, so here's a

snapshot on some data from a study done by the National Renewable Energy Laboratory. They looked at what would happen across the national commercial building stock if all applicable commercial buildings had implemented the initial set of recommendations made by ASHRAE. So this is sort of an extreme case because we know many HVAC systems can't handle 100 percent outdoor air ventilation, but it gives you a sense of the magnitude of the potential increase here. This would increase electricity use if we went to this 100 percent outdoor air by 8.4 percent across the commercial building stock and natural gas use by 75.2 percent, which is just huge.

There's many other studies out there that illustrate this increase in energy costs from these recommendations, so here's one more. This is one that looked at schools, and schools currently the baseline spend about $4 per square meter on HVAC energy costs. Now, if they were to turn up ventilation to achieve an infection risk below 1 percent, that's what this study looked at. The energy cost increase would be massive, from this baseline of about $4 per square meter, and you would add on average with the ventilation increase, $24 per square meter. Starting to get to be almost an order of magnitude increase. If you used a MERV 13 filter in combination with the increased ventilation to get to this below 1 percent infection risk reduction, the energy cost increase is not quite as bad, but it's still pretty bad at an average of $16 per square meter, and that would be added on top of the $4 per square meter baseline. Just another example.

So this has led us and others out there to question if these ventilation measures have such a large increase in energy use and caron emissions, how does some of the other recommendations – how does GUV compare and how does it compare both in terms of its effectiveness to prevent disease transmission and its energy use. So we've just published a paper as part of the summer study that looks at this. You can download this from our website. There's a QR code right there to get to the download link as well. This was a deep dive literature review. We dug up all the studies we could find that compared or reported the effectiveness or the energy use of these ventilation strategies and GUV. And we don't have time to go into a lot of the detail on what we found, but I'm gonna give you highlights, a snapshot of what we found, and I'd like to encourage you to download and check out that paper. It gets pretty technically detailed in the body of it if you're not a scientist or engineer, but at least check out the introduction, the discussion section, and the conclusion.

So first let's talk about what we found with effectiveness. The way that you compare these strategies – ventilation and GUV – in terms of effectiveness sis often through a metric called equivalent air changes per hour – EACH. We have formulas and we know the math for how much ventilation can reduce the concentration of airborne pathogens, and we also have formulas and we know the math for how much GUV can inactivate airborne pathogens in a space. We can normalize these two through this EACH metric. One ACH of ventilation we know removes 63 percent of airborne pathogens, and so through that math, one EACH is the number of equivalent air changes of ventilation needed to achieve the same level of inactivation as upper room GUV. Every study we found that is out there shows that upper room GUV delivers the equivalent of multiple air changes per hour, in some cases the equivalent of 10, 20, even 30 air changes per hour of ventilation. These levels of ventilation are far above achieving this level of disinfection through ventilation. Getting to these levels, 10, 20, 30 ACH are far above what is typically recommended for buildings and what is generally feasible. So this is the evidence that very strongly suggests and demonstrates that this technology is more effective than comparable ventilation measures.

Okay, so what about the energy costs between these two? One eACH of ventilation is typically more expensive than one EACH of GUV. It could be orders of magnitude higher. It will vary by climate. It will vary by HVAC system type and many other factors. And there's a lot of work needed to better understand, characterize, and quantify this energy opportunity of GUV compared to ventilation, but from what we know now, what's shown on this chart here, the data indicates that this could be a very large energy efficiency opportunity. The UR-GUV in the studies we found is indicated by the blue dots, and you can see the 100 percent outside air by the kind of orange red dots, and the MERV 13 filters are in green. More work needed to dial in these numbers, but this indicates a potentially large opportunity.

I wanna be clear. By no means are we saying to use GUV as an alternative to ventilation at all. Ventilation is very important to make sure that we have good air for people to breathe in buildings. Good indoor air quality has been linked to worker productivity, linked to student performance. The energy efficiency opportunity that we're seeing here is to use GUV as an alternative to some of those energy-intensive recommendations that have been made by ASHRA. Maybe to use GUV as a more effective and energy-efficient alternative to increasing ventilation above code. So to provide that code level, maybe don't go above it. Use GUV

instead. It'll be more effective at disinfecting the air. Or use GUV as a more effective and energy-efficient alternative to disabling command control ventilation. This is also – it's a large decarbonization opportunity, especially in northern climates. If we can avoid increasing the amount of outdoor air that we're bringing in above code, that's directly reducing fossil fuel heating. And for those out there that may be involved in building electrification efforts, we see a potential benefit to this GUV technology as well whereby reducing the outdoor air ventilation load, this is going to reduce the required size, cost, and infrastructure requirements of the commercial heat pump, potentially making that electrification measure to replace a fossil fuel heating system with an electric heat pump system more cost effective.

The largest energy savings in any decarbonization opportunity with this technology, it is in this comparison to HVAC ventilation. It's HVAC savings. But I also wanna note that there's plenty of headroom to improve the efficiency of GUV systems themselves through more efficient GUV sources or fixtures, possibly using LED technology that's coming on quickly, or better application design approaches. But the magnitude of those savings are probably going to be a fraction versus what you might be able to save by using this as an alternative to some of those ventilation measures.

So these findings have certainly caught the attention of the Department of Energy, and they're funding our team at PNNL to expand our work on this topic. Actually gonna be working in collaboration with Lawrence Berkeley Nat Labs as well. We are dusting off some of – if you're familiar, our previous caliper testing program that provides consumer reports type testings of GUV products. There is a lot of work that we need to do in validating manufacturer claims and educating stakeholders of how to test, evaluate, and report the performance of GUV products, and so we're working on that issue, and we'll have our first report of product testing coming out by the end of October. We'll be doing some field evaluations and case studies of this technology installed in the field on the lower left of the slide there through our gateway demonstration program. We are currently recruiting post sites where we can evaluate the technology, either a preexisting installation, we can work with those, or someone that wants to work with us on a new installation. Get in touch with us, with Axel or myself, if you have any ideas for these sites.

Moving up to the upper right there, we just published this ATEEE paper on the energy opportunities that I talked about earlier. And

we've got another report coming out soon that will characterize the current state of test methods, standards, and testing infrastructure to test UV products. It turns out this is much more complicated than testing visible light products, and so you'll be able to learn more about that in the report we've got coming. Finally, we are taking the next step to better understand, characterize, and quantify the effectiveness, energy efficiency, decarbonization, and electrification benefits of this technology that I talked about across different building types and in different climate zones. We need to better understand this energy and decarbonization story and effectiveness to inform really the whole technology deployment, hopefully to inform design guidelines, standards from organizations such as ASHRA, as well as to give utilities the data and information that need to be able to provide rebates or incentives for this technology. So stay tuned. We're gonna have a lot more information coming on this.

So that's kind of all I have for content here today. And so if you have any questions about anything I've presented, please go ahead and write that into the chat or the Q&A – I should say probably the Q&A pane, and we'll get to a Q&A session in a few moments. Before that, we'd really love to get your input on a few key questions that we have about this technology and the value you see in it and some of the concerns that you may have. So let's go ahead and open up that first poll question. It's asking have you used this technology or have you seen it installed in one of your projects or in one of your buildings, and if yes, what type?

[Break in conversation from 0:47:20 to 0:47:38]

Gabe Arnold: All right. It looks like the responses have slowed there. Give it one more minute. There's more coming in now.

[Break in conversation from 0:47:49 to 0:47:57]

Gabe Arnold: Generally most people I talk to have not seen this. Let's go ahead and close the poll and share the results. A bit more than I maybe expected, so 23 percent have seen an upper room system on their projects or in their buildings, 5 percent a direct irradiation system, the in-duct systems. Those have been used for quite a while. There's some portable air cleaners, and someone has seen those GUV robot towers they use in healthcare operating rooms, but most of us haven't seen this yet. Got a lotta work to do, I think, to get this deployed. Let's go ahead and move to our next poll question here. Curious what do you see as the greatest value of this technology? Reducing sickness or absenteeism, safer buildings.

Oh, I should say your top two. Select just your top two here. Reducing energy costs and decarbonization, improving indoor air quality, preparing for future pandemics, or if you've got a different value that you see, go ahead and write that into the chat.

[Break in conversation from 0:49:07 to 0:49:34]

Gabe Arnold: Okay, let's go ahead and close out that poll and share the results. Not really a big winner here. I guess the two winners would be reducing work and school sickness and absenteeism. I can absolutely relate to that. I've got two kids in school. Of course, we're all dealing with the workforce shortage, huge issues. And then improving indoor air quality. Okay, those are really good. So let's go to poll question three, and let's talk about some of the possible downsides that you're seeing or concerns. What are your – and again, this is select your top two. What are your biggest concerns with deploying this technology with your clients, on your projects, or in your buildings?

[Break in conversation from 0:50:20 to 0:50:35]

Axel Pearson: Hey, Gabe, it's Axel. I just wanna say that a couple answers for the last poll came in in the chat, and those are electrification efforts and, in infrastructure projects, reducing bioterrorism risks.

Gabe Arnold: Excellent. Those are good.

Axel Pearson: Looks like one came in for this poll question. Ooh, a few. Perception of safety concerns, low efficacy compared to other sources, increased energy use.

Gabe Arnold: Okay. Yeah, let's go ahead and close this one out and share the results with everybody. So the biggest concern, which I agree with, is trained workforce to install, operate, and maintain it. That's just such a critical issue, not just for keeping people safe, but you know, in deploying this technology, if we don't get that right, people aren't gonna wanna use it. Interesting one here. Number two is cost, high cost of GUV fixtures. Yeah, you know, we've been purchasing some of these fixtures through our caliper program to test them, and you are right that the cost is currently high. I don't know if it ultimately needs to be high. This might be kind of what we saw in early days of LEDs, maybe manufacturers covering some R&D costs or something like that. And you know, they might come down a lot over time, but that's something that we can absolutely look into.

All right, let's go to our final poll question here. And this is – we're looking for your input as to how we can help move this technology forward. What are some examples of key data or information that you would need to make a decision to deploy this technology to clients' projects or buildings? And again, this is just select your top two.

[Break in conversation from 0:52:44 to 0:53:09]

Gabe Arnold: Okay, let's go ahead and close that one. Share the results. Case studies and data demonstrating germicidal effectiveness number one. That is excellent input. You know, it's interesting you talk to some of the scientists in this space, and they'll say this is already proven. And then you talk to people that are out in the world, and they'll say we need more of these case studies showing it works, so this is some useful information we'll be able to share with people. And it looks like it's kind of an even split between everything else here. So thank you, everybody. Really appreciate that input, and I think we'll shift to answering any questions that we received. Haven't been able to monitor those, Axel. How much time do we have for these?

Axel Pearson: We have a few minutes. Let's try to take a few. So let me ask one. Have any of the studies you reviewed assessed the potential for using GUV and enhanced filtration to reduce the ventilation below the design guideline for minimum ventilation?

Gabe Arnold: You know, my colleague who led all this research who unfortunately is traveling today, was supposed to be here presenting and I think he could for certain answer that question. I'm gonna answer it in that I don't think so. At least all the ones I looked at, I don't think so. But I'm gonna say that whoever asked that question, you can e-mail me. I think we're gonna flash up my e-mail address shortly, and I can give you a for-sure answer on that.

Axel Pearson: We can also follow up with the asker after the presentation too.

Gabe Arnold: Oh we can. We have their information. Great. Okay.

Axel Pearson: Okay, here's another. Is there evidence that upper room GUV is effective against person-to-person transmission at the room level where people actually interact?

Gabe Arnold: You know, that's another one I don't have a definitive answer to. I have heard this discussed by experts. I believe they call it – what is

it, closed something transmission, and what I have heard is that some – especially when you're talking about the far UV wavelengths, it is not strong enough to reduce this transmission – post transmission from person to person. The – where it's effective is really when people are breathing out those virus particles and then they're moving up into the upper room cavity and there they're getting enough dose from the UV to prevent it. I'm not sure of this one, so Axel, I'm gonna say that we'll follow up with this person as well and see if we can get a more definitive answer for them.

Axel Pearson: Okay, sounds good. Are you aware of a calculation tool or assessment checklist that can be used to evaluate the effectiveness of already-installed GUV systems? I'm seeing some in-duct installations that aren't accompanied by design details or documentation of intended impact.

Gabe Arnold: You know, I'm not familiar with in-duct installations and whether that type of calculation tool or assessment checklist exists. I'm gonna say that with the upper room systems, there is absolutely acknowledgement that this type of checklist is needed. Part of this is under development through an ASHRA group called the GPC37 committee. They're working on a design guidelines document for upper room GUV systems that would provide basically design, installation, operation guidance for practitioners to deploy this technology in buildings. I think that that may provide some of what's asked for here. Our organization – I didn't mention it, but one of the things that we will be doing at PNNL in collaboration with LBNL is developing an assessment framework that we'll use on those field evaluation demonstration projects that we'll be developing case studies for. And we'll be engaging relevant experts in the field to develop that framework and methodology. And the idea is, once we've developed that to make that available to a standards organization, maybe someone like an ASHRA to build into a standard. So I don't think that that exactly exists right now for upper room GUV systems, but it is being worked on.

Axel Pearson: Awesome. Okay, let's do one more, kind of a two-parter, but then we should wrap up. So what control mechanisms are built in for safety, and are there any long-term exposure risks for exposure to LED GUV and 222 nanometer UVGs?

Gabe Arnold: That's definitely two questions, and there's a lot there. All right, so what control mechanisms are built in for safety? It depends actually on the product type, and there are two UL standards – hopefully I get these numbers right – 8802 and 8803 that vary by product type. I think one of them is for actually upper room

products. Another one is for direct irradiation products. Now, for the upper room, because the UV is directed upwards, it's not shining down onto people, the safety controls you need for them are – I'm not even sure they have any requirements for that because it's never intended to be on – it's never intended to be directed onto where people are. But for the direct irradiation products, they have some very substantial control requirements in order to get that UL listing. And I don't have all of them at top of mind, but I know that it requires multiple levels of safeguards like a key lockout switch combined with a magnetic sensor on the door potentially combined with motion sensors. Nd so it's pretty robust in terms of ensuring that those lights are never gonna be on while someone's in the space.

The second question was related to far UV, the 222 nanometer. I'm gonna characterize this as being somewhat unsettled, up for debate. If you talk to a lot of the scientists in the space, they would say that 222-nanometer far UV light directly irradiating spaces where people are in is safe. You will hear some people saying, well, this hasn't been studied and proven enough. I'm not gonna say one way or another where I come down on it. I just wanna sort of acknowledge some of what I'm haring out there about it, and it's definitely a huge point of discussion in the UV circles, but if it is safe – if it is proven safe and we can start directly irradiating spaces, that's potentially a really effective approach for reducing disease transmission.

Axel Pearson: Great. Thank you. Let's go ahead and wrap it up. Thanks for your questions. Gabe, thanks for answering those. All right, so I'll bring us home with just one more pitch for the lighting systems technology research team. We want to continue to develop these resources for the lighting industry, including those for GUV and those we talked about earlier, and we want them to be valuable to you, so the best way to do that is to get you – for you to get involved and to get you involved. We have advisory committees and working groups to help you provide your valuable input. So if you're interested in this, please let us know either in the chat or via e-mail. And with that I will say thank you so much for your time today. Thanks for attending. Thanks for your comments and questions. You know where to find us in the meantime, but I hope you come back for our next lighting systems technology research team meeting. Thanks, everyone. Have a good day.

Gabe Arnold: Thank you. Bye-bye.

[End of Audio]