Rois Langner: Hello, everyone. Welcome to the Better Buildings Alliance Renewables Integration Team webinar today on Selecting and Connecting EV Chargers to Commercial Buildings. I'm Rois Langner. I'm a senior research engineer at NREL. I'm an architectural engineer by training, and I'll be moderating today's webinar.

So the Renewables Integration Team, for those new to this call, historically has had a focus on strategically integrating renewable energy resources into commercial buildings, but over the past four years, we've really shifted our focus to building load flexibility, grid interactive efficient buildings, electrification, carbon reduction , and grid coordination.

Today's call we're going to go through a few quick announcements that I will provide and also my colleagues from NREL, Kim Trenbath and Tim LaClair. And then we're going to go into two different 15-minute technical presentations by Omkar Ghatpande. He is a building research engineer with NREL's building energy science group, and then John Kisacikoglu, who is s a team lead for the electric vehicle grid integration team. When we – at the end we'll have some Q&A time, so while we go along, please ask your questions in the Q&A chat box, and then we will respond to them at the end of the technical presentations.

Our points of contact for this team are myself, I'm the lead, and then my co-lead is Zahra Fellahi. She's also on the line. She'll help facilitate the Q&A at the end, and she is a research associate with the University of Colorado at Boulder. Please feel free to reach out to us at any time. This webinar is being recorded. We will be sending out a link to the recording and a link to the slides at the end of this webinar.

So we're going to dive into a few announcements. I'm going to hand it over to Kim Trenbath to talk about the upcoming Summit.

Kim Trenbath: Hi, everyone. I want to remind you that the Better Buildings Summit, which is the annual conference for the Better Buildings Alliance, is coming up here really soon. It's going to be April 11 through 13 in Washington, DC, at the – and I blanked on it. I'm sorry. Capitol Hilton, I think. So this is a great opportunity to learn about renewable integration, and I would say a vast majority of the presentations are going to be on how to incorporate renewables and energy efficiency into your buildings.

So there'll be presentations on PV and solar integration. There's going to be presentations on decarbonization with case studies on the low-carbon pilot, so partners who've actually gone through and implemented low-carbon strategies into their buildings. There's a lot on electrification, and also EV implementation into commercial buildings. And there's also presentations on how you could work with your leadership to incorporate low carbon, energy efficiency, and solar energy, PV, renewable energy into your building as well. So join us in Washington, DC, April 11 through 13 for the Better Buildings Summit.

Rois Langner: Great. Thanks so much, Kim. Hope you all can join us at the Summit. It really is a great conference to attend. Let's go to the next slide. I'm going to go through a lot of these updates really quickly so we can get to our presenters. I want to announce, though, that Department of Energy is doing this cross-DOE coordination and technical assistance effort called the EVGrid Assist to really help accelerate the transition to electrifying our vehicles and integrating EV charging infrastructure into our buildings and connecting to the grid. If you scan the QR code on this slide or go to the website that's listed there, you can sign up for announcements through EVGrid Assist, you can access their resource library which has national laboratory tools and relevant reports, and you can also register for upcoming webinars. We're going to be coordinating more with this group at DOE also to share some of the resources that we're developing under the renewables integration team.

As I said, I'm going to fly through the next number of slides. These are more for your reference, and let's even go to the next slide here. All of these webinars that we give through the renewables integration team are recorded. You can go to the Better Buildings on-demand webinars website, which I have listed here to access these recorded webinars and our presentations at a later date or share them with any partners that you might have.

A few notable publications that we have listed there. This one – again, I'm going to go through these very quickly, so you can go to the slides and click on the links at a later date. This one highlights incentive mechanisms that utilities and policymakers can use to encourage demand flexibility as a grid asset in our commercial buildings.

We've also worked very closely with the Rocky Mountain Institute, RMI, in doing some large studies to assess the value potential of GEBS in a number of portfolios. So we've worked with GSA. We have a report and webinar on that. We've worked with a large big box retailer. There's a link here to the report there and we have a webinar as well. And then we have a third report that's coming out very soon on multifamily buildings, so stay tuned for that.

This is a recent publication we did last summer that looks at propose – provides proposed metrics to quantify peak load reduction in buildings and the emissions impacts from GEB measures in the field and what those decision parameters and approaches to accurately conduct M&V would be. So great report. This was presented at ACEEE summer study last summer.

If anybody is working with performance contracts, this resource would be really great. This was developed for GSA, but it is a blueprint for integrating GEB technologies into performance contracts.

And this publication is hot off the press, and we're – Omkar will be presenting this today. This is a main driver for this webinar that we're providing. This is a shorter fact sheet on the logistics of connecting EV charging infrastructure in commercial buildings, so Omkar will dive into this resource during his presentation.

And as follow-up work, we're working with individual Better Buildings members to understand what their decisions are around integrating EV charging into their buildings and their portfolios, so we're really excited to develop a number of short case studies on those decisions and considerations that they've had to make in their portfolios. So we'll have a couple in the commercial real estate sector and a couple in the K-12 school sector as well. And with that, I'm going to hand it over to Tim LaClair to talk about the Stor4Build consortium real quick.

Tim LaClair: Okay, thank you. So my name's Tim LaClair. I'm a senior researcher in the building energy science group at NREL, and I'm happy to have this opportunity to introduce a new consortium for building energy storage that's called Stor4Build and share what the goals and expected impacts of the consortium are. So due to the limited time, I'm just giving a very high overview of the Stor4Build consortium, but I'm happy to share more info for anyone that has interest.

So Stor4Build is a DOE-sponsored consortium led by the National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, and the Oak Ridge National Laboratory for building energy storage. The Pacific Northwest National Laboratory and

ACEEE, that's the American Council for an Energy Efficient Economy, are also involved, supporting market and policy activities.

The consortium will address energy storage needs in buildings to enable electrification and decarbonization, and we will develop and demonstrate technologies to lay the groundwork for large-scale deployment of energy storage in buildings in the future. Key objectives of the consortium include performing R&D to develop new energy storage technologies and strategies to address technology adoption barriers and accelerate market penetration of energy storage technologies.

So just as a very quick summary, the end goal for Stor4Build is to enable the large-scale implementation of electrification to help achieve net-zero emission goals. The consortium is complementary to other DOE initiatives to achieve this goal. So if you're interested in receiving updates about Stor4Build and participating in the consortium, you can send an e-mail to the Stor4Build e-mail address. We can add you to our distribution list. We don't have a website set up yet, but we expect to have one online within the next month or so. If you sign up for e-mails, we'll let you know when this is available, and feel free to reach out to me as well directly if you have any questions or like more information. Thank you.

Rois Langner: Great. Thanks so much, Tim. All right, let's dive into our technical presentations. I'd like to introduce both of our presenters today. And before I do that, let's – just a quick reminder if you have any questions, please enter them in the Q&A option on Zoom and we'll keep track of those and hopefully we'll get to all of them during the Q&A session.

The first presenter today is Omkar Ghatpande. He's a research engineer in the Building Technologies and Science Center at NREL. He has completed his graduate and undergraduate studies in electrical engineering. At NREL, his research focus is electrification and electrical distribution systems in buildings, conducting load flexibility experiments in the lab, and evaluating new technologies in field study projects. He's also a member of the Better Buildings Alliance plug and process load team. Before NREL, Omkar worked as a senior electrical engineer at ABD and as a solutions development engineer at Honeywell in their buildings team.

And then I'm going to actually introduce John as well, and we'll just roll through the presentations after that. So John Kisacikoglu is a team lead for the electric vehicle grid integration group within NREL's Center for Integrated Mobility Sciences. His research areas include power converter development for EV charging, microgrid, and smart grid integration of EVs, machine learning, supported distributed control, power electronics, and mass scale control and integration of distributed energy systems. He has more than 15 years of multidisciplinary professional knowledge in power electronics, transportation electrification, and smart microgrids. Welcome both of you guys. We're really excited to have you today. I'm going to hand it over to Omkar to start presenting. And we can skip forward two slides here.

Omkar Ghatpande: Thank you, Rois. Hello, everyone. My name is Omkar Ghatpande. I'm a research engineer here at the National Renewable Energy Laboratory at Golden, Colorado, and today I'll be presenting on connecting electric vehicle charging infrastructure to commercial buildings. These are all of the contents which I'll go through today.

As Rois mentioned previously, we are very happy to share a new resource which we have recently published. This resource describes how EV chargers can be connected to commercial buildings, and the presentation which follows today is a bit of overview on that fact sheet.

So I'll go to the introduction. EV charging equipment, which is also known as EV chargers or EV supply equipment, comprises of various subsystems which could be power conditioning module, control software, safety devices, metering communication, cooling connectors, and all its wiring. EV charging at commercial buildings could be used for its public workplace or even as commercial fleet charging. The power distributed by electrical grid is mainly alternating current, which is AC, while the EV battery operation is direct current, or DC. So EV charger can convert AC from the grid to battery usable DC either through the EV's onboard hardware or through EV converter equipment. The majority of EV charging currently happens at residential buildings, however, the demand for the EV charging at commercial buildings will significantly increase with wider mainstream EV adoption. EV charging at the commercial buildings could us – could be used, as I mentioned, for either public, workplace, or commercial fleet charging.

This figure shows AC chargers which are one of the types of EV chargers. Most EVs are supplied with cords that you connect to the common three-prong household plug. This 120-volt outlet connected AC Level 1 charger is the slowest charging rate, and it's generally utilized in residential application or only during emergency charging situations. AC Level 2 is currently most implemented EV chargers for residential and public or workplace charging and comprises of 80 percent of installed EV charger share. Level 2 chargers can connect to a 240V wall outlet plug, which is a typical electric load receptacle, and some of the very high-powered commercial Level 2 chargers can also be connected to its dedicated electrical circuit which can charge at much higher rates compared to the residential ones. The conversion of AC to DC for AC Level 1 and Level 2 chargers takes place on the onboard vehicles converter.

And there are other types of chargers which are DC chargers. So this DC fast charger sometimes – which are also referred to as Level 3 chargers – convert the AC voltage from grid to the output DC voltage, and these are available at a variety of input voltage ranges to connect to buildings' electrical distribution systems. These are typically connected in a building to a dedicated electrical panel.

So for a typical EV battery charging curve as shown in the figure attached, the EVC will not consume its rated power demand even if the EV's actively plugged in. And it will depend on a number of factors like EV's onboard electrical system configuration, the connector rating, the battery's speed of charge, the individual component temperatures, battery chemistry, and even user-selected charging priorities. So initially the battery in the car and the EV station decides on the best charging speed, and it runs up to its top charging speed for a while, where it charges to 80 percent and it drops down significantly to trickle charge the battery to protect the battery's life.

Most residential EV 1 and EV 2 chargers are non-network chargers with no communication capabilities except for supplying power and controlling power to an EV. Recently many utilities are offering residential demand response incentive programs for EV, which helps with the installation of network chargers. But the commercial user of non-network chargers is very limited as they are only used where the charging is either free of cost or it's the charger is dedicated to a single user. Network chargers are chargers enable additional benefit to the commercial buildings in that they provide a method of collecting revenue for the operators, and it can also interact with the user and put self-diagnosed problems to communicate out of service information to its stakeholders.

So now we'll move on to how to connect an EV charger to a building. This is a typical scenario which we'll look into. So before we go there, we'll see what is the EV charger selection criteria for different building types. The EVC type and quantity depends on the user requirements like average daily electric vehicle mileage, battery charging patterns, expected charge time, and number and type of EVs that are expected to be connected for the charging. Level 1 and Level 2 chargers are most suitable for the buildings where we have high average parking durations such as residential buildings or office buildings. Level 2 and DC fast chargers are ideal in commercial buildings where the parking duration where the EV will be charged is short such as grocery stores, retail stores, restaurants, medical office buildings. Level 2 and DC fast chargers are suitable for overnight charging of large commercial vehicles like short-haul delivery vehicles, buses, and fleet vehicles. High-powered DC chargers are suitable for long-distance interstate EV vehicles which require large power to charge and also require quick charging compared to others.

This figure shows typical locations where EV charger equipment connects to the building's electrical distribution system. The charging equipment will require independent electrical circuits for operation at different voltage levels depending on the charger type. For example, there was one which is shown on the bottom right connects to a 120-volt circuit in the building. Level 2 and DC chargers connect to a 480-volt circuit, while high-powered DC chargers could be connected at high voltage distribution systems.

Before any EV charger system is installed, a thorough review of building's existing electrical infrastructure, it's power and energy consumption has to be conducted. Based on the current market share of EVC, the commercial buildings are most likely to consider a fleet of Level 2 chargers. Many commercial buildings currently have a limited additional capacity for adding these charging equipment and would require significant infrastructure changes to accommodate them. Some of the infrastructure changes might be panel changes or additional wiring, circuit breakers, and also an evaluation of the utility service main which comes to the electric to the building. And after this evaluation, depending upon which EV chargers are – and the quantity of them is decided, changes to the electrical distribution system may include new panels, wiring, safety devices, and connections to the EVC. If it's network chargers which is most possibly for a commercial building, a network and communication infrastructure would be also need to be installed for EVC. Depending upon the electrical capacity available for the building, a new transformer or new service utility can be required for the building.

But these panel and service upgrades are very expensive and time-consuming, and building performance improvements could be done which improve efficiency of other building components which could allot additional electrical capacity to support this additional EVC loads. Supervisory control can also be used that monitors and controls power consumption of EV chargers. That could be useful to limit overloading on the circuit.

Once the modifications to existing electrical distribution systems are determined by building owners, electrical utility will also have to evaluate if electrical service requirements can safely deliver proper power and voltage once new charging equipment is installed. Studies show that once a fully operational EV charger system is installed, it can become one of the highest electrical loads in the building. Utilities typically charge commercial customers based on their service type, the maximum demand charge for that month, and tiered energy using pricing or time of use. Electrical metering in a typical commercial building could include a dedicated utility meter for just the EV charging system or EV charging and a building load's under a single utility meter.

This figure shows steps to integrate an EV charger into commercial buildings. This is a very general overview, and there might be additional steps in each of the main steps.

Next we'll go to discussing EV charger ownerships and cost. The total of various business models exist currently to maintain and operate EV charging station at commercial buildings depending upon the level of engagement that the facility operators want. So they could be in full ownership where the host site operates and maintains all the EV charging stations, or it could be a lease option where the host site use an external EVC management company to supply hardware, operate the EVC, and maintain the equipment for a fixed cost. And there could be only hardware ownership where the host site owns the charging system and contracts the operation and maintenance to an external company for a fixed cost, monthly cost.

The total ownership cost of EVC includes an initial capital investment, ongoing operational charges, and maintenance expenses. These expenses are not trivial and should be considered before the project begins. The capital investment for a typical EVC project would include the EV charger hardware cost, installation cost, electrical infrastructure upgrade equipment, auxiliary systems like payment systems, networking equipment, et cetera. Capital costs can also include the parking space where EV chargers will be parked during charging, and also the enduring costs associated with this upgrade. Operational costs, as we discussed before, includes the electrical utility monthly bills, payment transaction fees, networking and internet charges, and ongoing maintenance and upgrades to the hardware of the charging system.

Next we'll discuss about upcoming trends for EV charger connection to the buildings. There is a lot of research currently going on on EV chargers that is focused on decreasing charging time to match the traditional gas station refilling times. So one of the continued efforts would be on high-power EV chargers. Some other future trends include a vehicle to grid bidirectional operation of EV battery charging system, supplying the power back to the local electrical distribution system. As we discussed in the introduction, EV chargers battery works on direct current or DC, but the grid works on AC. So a modified EVC input which can be fed by PV which is also direct current and energy storage which is also direct current can be done where DC distribution can be used to power the EV chargers.

Thank you. That's the presentation.

Rois Langner: Thank you so much, Omkar. Great presentation. And for everybody in the audience, I know Zahra has provided a link to the fact sheet that Omkar was presenting on in the Q&A little chat box there, so please check that out. And I think the last slide that Omkar presented on future trends in electric vehicle chargers and connecting them to buildings really presents some – it was a good lead-in for John's presentation, and John will be talking about the research that we do in NREL to address some of these EV charging challenges and how we approach that and what are these new trends that are coming online. So let's skip forward two slides, please, and I'll hand it over to John.

John Kisacikoglu: Thank you, Rois. Hi, everybody. Thank you very much, Rois and Zahra and the rest of the team for inviting me for this presentation. It's a new audience for me. I am coming from more on the vehicles and politics background, and it's a very interesting audience, and glad to be here today. As Rois said, I think Omkar set the stage really well in terms of explaining the fundamentals, and starting from there, I'd like to take you and explain you what we are doing at NREL in terms of EV integration research and the status of our current projects and some results on our interesting projects and kind of provide you an opinion about the device, how we can improve the technology.

So maybe a little bit about myself. I have been working in this area for quite a long time, and at the early year when I started in this topic, I looked into providing some services to buildings and grid from electric vehicles. This was like 15 years ago, and it's really nice to see finally those ideas are coming to practice and right now we are seeing vehicles that are able to not only charge through charge management but also provide power backup for the buildings and provide different grid services. So this is great. Before I start, I'm a bit sick, so if I lose my voice, please bear with me.

I'd like to just give you an outline of the areas of research that we do within the EVGI team. By the way, the EVGI team is under Center for Integrated Mobility Sciences within NREL, and we actually do research starting from analysis. When I say analysis, we look into modeling the behavior of how people move, commute, either with daily commutes or fleet operations or interstate for different vehicle types, and just understand the energy procurement of the vehicles. And we collect data to understand, primarily of course there are not much electric vehicles out there, primarily from internal combustion engine vehicles and have understanding about what would electrical power consumption of those vehicles be if those vehicles were electric or hybrid vehicles. And also on the grid side, we also look at the grid modeling to understand the impact of the charging load on the grid, so we do look at this and actually also involves some data collection from the buildings as well because buildings are also a huge impact on the grid power consumption and integrate with the vehicles how that changed the story.

On the equipment side, we look into from Level 2 to high-power charging the test equipment and test them under different grid environmental conditions. We also test electric vehicles, and I'm going to show you some of our test results today. One thing I should note that new vehicles coming into market, they actually – they can accept higher onboard charging power, meaning that they're going to draw more power. I always tell when you connect a vehicle to a residential neighborhood, it's like adding a new – building a new house within that neighborhood from a grid impact point of view. And new vehicles are coming with higher – high-power charge accepting capabilities as well, so in excess of 200 kilowatt of power right now. And also V to X, how these vehicles connect and integrate to buildings, to grids is another topic that we look into. And also a storage aspect, what are the storage needs to – especially in high-power charging sets behind the meter storage needs. And also, finally, we look into understanding the operations of the charging site so that we can model and quantify the performance of the charging site depending on the application type.

So before I start discussing the projects, I would like to inform you about a consortium that Department of Energy established a year ago called EVs@Scale, a lab consortium, and there are five project pillars that we are running our project. This is a multinational laboratory consortium, so in addition to NREL, there are various other national laboratories involved in this consortium. And you can get more information about the types of research at the consortium website given there. If you can Google EVs@Scale consortium, it'll take you to the website. And one thing I would like to mention, we have our second biannual stakeholder meeting in the first week of April, so if you are interested, please join us within the consortium.

I like this slide because I wanted to summarize our approach in terms of how we model the charging demand starting from the mobility to grid integration. We start with the data acquisition. So whether your vehicle is light-duty, medium-duty, heavy-duty or commute pattern, it will start and get the data, and sometimes third parties to collect wide-scale data if you are focusing on a certain geography to understand geography-specific needs, and then process that data and then we have – we do adoption modeling as well to see the future growth of the electric vehicles within that geography. And then we generate synthetic travel itineraries to account for the needs of those vehicles based on the data and the adoption modeling. And then we designate where the charging stations should be sited and also the number of ports, the size of those charging stations, again depending on the application area. And then finally we generate the load profiles that would help us to understand the power and energy demand from the grid.

So if I need to put all the framework into one slide, this is what I have. And I'd like to emphasize that NREL has a lot of tools that we develop out of the projects, and we kind of integrate those tools to help us understand the problems and provide solutions to those problems. For instance, here you can see our EV adoption modeling tool, EVI Park, EVI Zep, EVI Pro, and EVI insight. Those are the tools that we developed under different projects. And generally when we approach quantifying the demand from the grid, we kind of integrate those tools, and some of these tools have light versions publicly available such as EVI pro, and we are planning to make EVI insight – I'm going to provide more information about EVI insight in a minute, also a light version publicly available in the future as well. So kind of starting from data collection, post-processing of data, and then connecting it to the generating the charge and energy demand requirement and then connecting and converting it to the time domain power profiles for operating under specific theaters and locations.

So I'd like to talk a little bit about charging site specific studies that we do. Of course when I say charging site, it depends on the use case. It could be in route fast charging, it could be a travel center type charging, or it could be a depot type charging. Every application has different requirement, and that's very important, and it's not one size fits all type of solution I should say. And then solutions should be developed with understanding the requirements of that specific application. And in the end, you will see a little investment cost savings as well as operational cost savings if you understand the requirements of the site better.

So with that, I would like to mention about a tool called EVI Insight that we developed to better understand the site requirements as well as develop solutions that would be specific for that site. And there are a lot of factors that should be considered when selecting and designing the charging site, and I list some of them here, and the link actually will have – you will see more publications that provide more information about the tool and the types of studies we have done before. And first of all, like the electricity charge rates, the cost of the equipment, again the mobility behavior of the customer that you have, and the types of vehicles. Those are all influencing factors while the site designer have specific decision variables such as number of ports, port tower, station power capacity, and the controls that could be implemented within the site.

And considering those targets are minimizing the investments as well as operational costs and making – selling the energy to the customer at a competitive price, and as well as making sure that the customer gets the expected quality of service. That's actually very important, so while we can do more smart charge management, then the development time is longer during the in route charging customer would like to charge and go, so again, depending on understanding the customer requirements will help you make better decisions but even a small amount of power procurement can save in the long run in the duration of the lifetime of the site can save – can have a lot of cost savings for the site.

So the tool can answer questions such as how should I design a station? What would be my expected queuing time? If there's high demand in the worst case, what would you like to have the queuing time? What is the average charging time, and what is the utilization of the station? So you have a certain amount of power demand and what is the average power demand, what's the maximum power demand, and attach this what is the cost of operating the station. So the tool actually considers and provides information for those questions.

So like to show some of the projects that we are running, and this slide is a bit complex, but would like to show you two different approaches Omkar mentioned in his slide the common AC and connection to the building with the building, which is similar to what I show on the left-hand side on our next gen profiles project. These two projects are under the EVs@Scale consortium, so you can get more information at consortium website.

One option is actually to connect your station to building AC power, AC power and then have the conversion to DC for each cabinet like the product that I show here. And this is actual state of the art right now, so most of the high-power charging stations have a direct AC connection and individual isolation transformer, and they connect to a vehicle on the DC side. And as well as on the common DC hub, the difference is with the ability to have onsite energy storage renewable energy systems. You have – you save with connecting your site on a common DC hub, you can save from efficiency, from component count, and you can increase the utilization of the central inverter that you put in the site. And also it provides an easier and more flexible integration of onsite renewable energy systems and energy source systems. So this is an area that we are covering on the eCHIP project, and we will provide more information during the biannual consortium meeting about our progress on those topics.

I was kind of talking about these topics, but more importantly why DC hub. As I mentioned, higher efficiency, more natural and flexible interface with EV, PV, and ESS, and also no issues in DC with reactive power flow, frequency synchronization, angle synchronization, less issues with the harmonies. On the negative side though, there are not much product out there commercially available. It's increasing. The number of products are increasing. We have a more complex protection, and the standards are still being developed on how to connect DC chargers on a common DC hub and have them be integral between one another. So this is an example of a use case operating under a DC hub.

And I'd like to talk one of the test cases for instance we did under the DC hub approach utilizing Hyundai Ionic 5 and also at the back end it's just on the corner 321 PKM 150. It's a 150-kilowatt DC charger. So we provided DC power to the charger and did this test. So what I would like to highlight is you can see we have the ability, we are communicating through OCP and open source communication protocol. We are able to – the blue curve shows our referencing of Pref (power reference) we are controlling the charging of – that is going on the vehicle at every minute, whereas this is a very cold temperature environment, whereas in the yellow curve it's what the vehicle tells us that this is the maximum amount of power that I can accept from the station, and as you can see that the red curve that is the actual power going to the battery is limited by the charge acceptance of the vehicle because this is a very cold temperature. As a matter of fact, better auxiliary battery heating on to cool the battery pack and prepare it. And later on at the end of the experiment, the vehicle – the battery's conditioned and can accept higher amounts of power. So this is just an example of how granular you can control the charging. The battery we are charging in the building and you are trying to make a more effective integration.

I believe this is my last slide if I'm not mistaken. Yep, so I'll be happy to answer your questions, and make sure that you check our EVs@Scale consortium website. Thank you for listening.

Rois Langner: Thank you so much, John. It was great to hear about what NREL is doing in this research space and dive into these topics a little bit more in depth. Let's go to the next slide. Now it's my favorite time. It's time for Q&A, and we've gotten a lot of questions in the Q&A chat box. If anybody has additional questions, please type them in. We've been keeping track of them throughout these presentations. I'd like to invite Omkar to turn on his video, and then Zahra, if you want to chime in too with your – to lead the Q&A session.

Zahra Fellahi: Great. Thanks, Rois. Omkar, I have the first question for you. The question is who will own, install, maintain and repair EV chargers?

Omkar Ghatpande: That's a great question. So we tried to cover that in one of the slides, but I did not go into very detail. But there are various business models currently which exist for maintaining and operating EV chargers for a commercial building. So I can go over that slide one more time. So there could be a full ownership where the host site operates and maintains the charging station, so they buy, they install, and they operate. And there could be other options where like a lease option or hardware ownership only. In these options, host site can install but the operation can be done by an external EV charger management company, or everything from installation to operation can be outsourced to an external company. Hope that answers the question.

Zahra Fellahi: Thank you. John, I want to point this question to you. The question is about if Level 2 chargers are appropriate or not for demand response programs.

John Kisacikoglu: Good question. So yes, and some of them are appropriate, some not. Of course, the chargers have to be networked as Omkar said, and also it should be – to be able to operate under demand response program, it should connect to the utility operator's network or program. But right now there are chargers that can communicate with the utility or an external EV charging service provider to be enrolled in demand response programs and to be able to provide services, integrate with the grid operations. But it should be networked. If it is not networked, then it is just if it is on, it is charging. Even it may not be available if there is a charger at that specific location.

Zahra Fellahi: Great. So on the topic of network charger, Omkar, I wanted to ask if cellular networks are used for these types of chargers or it would need to have fiber or copper run to them.

Omkar Ghatpande: So both those options are relevant, so it depends upon which EV charger manufacturer specification you are applying. So there could be an option where you have a cellular modem for each of the EV chargers, or there could be an option where you run fiber optic cable to the chargers.

Zahra Fellahi: Great. John, can you give us more information on the anticipation of new electric vehicles and if they are going to be all equipped with bidirectional charging capability and how soon that might happen?

John Kisacikoglu: So it is happening right now. Ford F150 can power your house. So if you can check their website, the vehicle is, from a hardware point of view, is equipped with bidirectional charging. I think the number one market is actually improve the resiliency of the building. That's what we are seeing right now, but I believe in the future we will see more grid integrated services as well because the vehicles are compatible to this of course. One thing to consider always, the number one requirement of the vehicles is to provide mobility for the customers, but there are multiple services that the vehicles can also provide while they are parked.

Zahra Fellahi: Great. On the topic of vehicle to grid integration, Rois, can you give us a few comments on how utilities are anticipating working with electric vehicles and the rise of penetration of electric vehicles?

Rois Langner: Sure. I think a lot of utilities are really starting to think about this demand and how do you create the infrastructure for this. I think there's this difference between how you're integrating EV chargers into individual buildings or portfolios but then also providing public infrastructure or public charging ports and how you dive in there. We've seen some utilities that are really putting an initiative toward equitable access to charging, and they're providing incentives to put in the electrical distribution infrastructure into more underserved areas in their territory. So I think that's really great too. I do think that it's going to be an enormous load that we're dealing with, and there's a lot of research that needs to be done and that we're currently working on on this vehicle to building integration and how to manage the demand of the building, integrate renewables, integrate storage, and then integrate electric vehicle charging loads as well. So that's all a really big problem that we're trying to figure out that coordination and then also on top of how do you coordinate all those loads within the building and the vehicles, but then how do you coordinate that with the grid as well and provide some load flexibility as a service to the grid or just as a continuous demand management for the building itself.

Zahra Fellahi: Great. Joh, have you used the model to predict what building types would be best served by having a common DC bus?

John Kisacikoglu: To be honest, we haven't looked into the building load types. Of course, if there are any loads that can accept DC, then a DC-to-DC conversion unit could be utilized to provide those DC power need. But in addition to that, that also provides us an ability to convert from DC back to AC and serve all 120 and 240 building loads without any problem, either single or three-phase depending on the need, so basically it could just provide a better integration overall to the site. Or maybe I can add to that. this could be also in hybrid option, not just only DC hub, but also it could be in hybrid DC and AC configurations where your building is directly connected to the AC output of the inverter.

Omkar Ghatpande: To add a bit to that, we have done some studies on DC distribution in buildings, and one of the production properties of getting DC distribution is adding EV and BV along with back restorers in the buildings. That's the best case scenario where we can get maximum benefit of the distribution system all the way from DC to DC. But I think John did mention before there are not many commercially available standardized options right now, so that's one of the hurdles in getting end-to-end DC distribution for these technologies.

Zahra Fellahi: Great. Omkar, can you also provide some comments on configuration of having solar generation and storage and EV charging on the distribution system?

Omkar Ghatpande: Yes, I can expand a bit on that. So for the legacy AC system, there has been years of standardization of full digits and power levels, but for DC it's relatively not standardized, so every new manufacturer or every new technology has its own set of connectors, have their own sort of voltage levels. So once the standardization happens, the DC distribution in buildings could have solar EV, which is DC connected to a common DC bus, which is a high-voltage, high-power, which can rinse down to a lower voltage level something similar to what current AC has where we have a high-power 480-volt bus and then a plug load, a receptacle 120V. Something similar for a DC system for widespread adoption.

Zahra Fellahi: Great. John, do you think gas stations are going to be an item of the past?

John Kisacikoglu: It's a good question. I think if you look into the current division of how people are charging, they say 80 percent of the EV vehicles are being charged at home. However, we have still – this is just a tiny penetration into the whole market, and the issue if you keep that percentage, the issue will be how to be – to be able to continue delivering power to the houses. As I told in the beginning, this is like adding a new house in the neighborhood. So if you buy a vehicle, if your neighbor gets another one, and your neighbor that are connected, and the second their circuitry gets another one, that will actually cause stress on the service transformer, and you'll trigger an interruption at the secondary site. So that will need to be handled by the utility and will require additional investment at the distribution system. So long story short, I think that domination of home charging right now will need to kind of be balanced with other charging options. So we could see maybe not exactly gas station type charging stations, but charging stations that can provide power at different power levels depending on your stop time, dwell time at that particular location starting from low 50 kilowatt up to 350 kilowatt solutions that are available today. And depending on the vehicle type, this could even go higher.

Zahra Fellahi: Thanks. Omkar, can you comment on the addition of EV impact on the power factor of a house and the load of a building?

Omkar Ghatpande: Yes. Many of the EV chargers contain a power conditioning module at the beginning, so they have a power factor correction included. But it again depends upon the manufacturer and the EV charger.

Rois Langner: Great. Zahra, we have, I guess, two minutes left, maybe a minute and a half. I don't know if there's a quick question in there.

Zahra Fellahi: Good questions. I'm trying to find the last one. Actually I will now ask this last one from you, Rois. Are there any resources that are developed or being developed in terms of vehicle to grid integration and vehicle to building integration?

Rois Langner: Yes. We are definitely doing quite a bit of research here on this vehicle to building integration piece. We do have a field demonstration with a bidirectional charger, EV charger happening right now through the GSA green proving ground program. NREL's vehicle team is heavily involved in the measurement and verification of that. So yes, we do have quite a bit of work that's happening in the space and really understanding what that integration is.

Zahra Fellahi: Great. Thank you. And with that we are at the end of our webinar. If we couldn't answer your question or if you have more questions, please feel free to reach out to Rois and I and we will provide further resources or connect you with experts. Thanks, everyone.

Rois Langner: Thank you so much.

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