[Dictation begins 0:00:25]

Julie Fornaciari: Hello, everyone. I see a lot of people joining right now, so we will get started in just a few moments, and we'll get started soon.

[No conversation from 0:00:34 to 0:01:05]

All right. Let's get started. Hello, everyone. Welcome to the 2022-2023 Better Buildings Webinar Series dedicated to bringing you to the latest actionable insights from leading industry experts. This annual series is a chance to explore the topics, technologies and trends that affect your organization as well as efforts to accelerate decarbonization and energy efficiency adoption.

So today's webinar is called *Hydrogen 101: the Basics of Hydrogen and Fuel Cells for Buildings and Plants.* Before we dive in, there are a few housekeeping points I would like to cover. Please note, today's webinar will be recorded and archived on the Better Buildings Solution Center. We will follow up with today's recording and slides that will be made available. Next, attendees are in listen-only mode, meaning your microphones are muted.

If you experience any audio or visual issues throughout the webinar, please send a message into the Q&A box located on the bottom of your Zoom panel. Next slide. Hello. My name is Julie Fornaciari and I'm your moderator for today. I am a Hydrogen Shot ORISE Fellow in the Hydrogen and Fuel Cell Technologies Office where I'm helping on the fuel cell team develop hydrogen technologies that you'll learn a little bit about today.

Then we can go to the next slide. So today I'm going to talk a little bit about Hydrogen 101 to give everyone a good understanding of the status of hydrogen and where we're at and for the context of our speakers for today. Next slide. So, hydrogen is what we're going to talk about today. Next.

And so the key hydrogen technologies we want to focus on are fuel cells and electrolyzers. A fuel cell actually uses hydrogen and oxygen in partnership so we can get electricity and water out. So this makes electricity using hydrogen and there's no combustion whatsoever involved. On the flipside, if we run this system sort of in reverse, we're going to have an electrolyzer, and that's where we can make hydrogen just from water and electricity.

So this operates very similarly like a fuel cell in reverse. Next. So we just want to give some key facts about hydrogen. Hydrogen is the most abundant element in the universe. It's present in most common substances like water, so H2O, sugar, and methane among others. It's very high energy by weight, so it's three times more than Vaseline, and it can be used for many different products, including fertilizer and steel and can be used as a fuel in trucks, trains, ships and more.

It also can be used to store energy and make electricity with only water as the byproduct as we talked about in the fuel cell, and can be produced from multiple, abundant fuel sources within the US. Next. There are key challenges with hydrogen right now especially being made through electrolysis. Hydrogen is at a high cost. It also needs energy like solar, wind or nuclear, or certain types of fuels to produce it. It is difficult to transport and store since it is a very, very small element, and there's limited infrastructure to move and use hydrogen around the US.

Next slide please. So there is an abundant amount of hydrogen sources. So clean and domestic energy sources can be used to produce hydrogen, and most of today's hydrogen comes from natural gas. But you can see there are multiple hydrogen sources available, and there are 10 million metric tons of hydrogen produced annually in the United States and most of them are used for oil refining and fertilizer production. Next slide.

So hydrogen benefits, it could help with reducing greenhouse gases. There are no carbon dioxide emitted. It can reduce oil consumption, has the ability to store renewable power, especially during peak performance times. It also has the ability for industry and transportation, so that's two sectors that hydrogen can help, and it can help reduce air pollution and provide reliable grid support. Next.

Now hydrogen production, there's multiple ways to produce hydrogen, and any of the previously mentioned energy sources can help produce it. For that, I just want to highlight really quickly is the electrolyzers, so using electricity to separate water into oxygen and hydrogen. There's also biological means to make hydrogen, so using microbes or enzymes. There's also energy that you could use directly from the sun and the sun heat to split molecules up to make hydrogen. And then the typical one that's used currently is using steam and hydrocarbons such as natural gas to produce hydrogen as well.

Next slide. But for fuel cells, for instance, there's a lot of benefits to a fuel cell. So one is it's highly efficient and we can use domestic fuels for a fuel cell. It's also reliable, quiet and clean, which is all extra benefits, and its versatile and easily scalable. And today we're going to talk specifically about some buildings and plants, but it can be used for transportation, homes or other applications, so it's very easy to scale.

Next slide. And hydrogen uses, there's multiple industries and multiple applications, and these are just a variety of them here shown on the slide. A couple I want to highlight is hydrogen can really be helpful in the hard-to-decarbonize sectors such as steel, cement or ammonia production. It can be used for transportation, especially for heavy duty trucks. But today we're going to specifically maybe focus on the stationary fuel cells, which will be really helpful for buildings such as datacenters or hospitals or supermarkets, among other applications.

Next. So DOE is helping to advance hydrogen since there are those multiple challenges I spoke about earlier, including the high cost. We still would like it to be more efficient and more reliable and durable, and currently there's not as many deployments out there, especially for hydrogen and water electrolyzers and also fuel cells, as well as there's little to no public awareness of these technologies. So what we're trying to help solve these challenges is, one, the DOE H2@Scale Initiative to help support projects to demonstrate the value of hydrogen across many of the sectors, as you can see, from transportation to chemical industries.

Also, the DOE Hydrogen Shot, which is a part of the Earth Shots that have been released, which is the goal to reduce the cost of hydrogen of $1.00 per kilogram within one decade. And then also the DOE Hydrogen Program is supporting work to improve technologies and accelerate the progress so we can see more fuel cells and electrolyzers out there. Next slide.

And so with that, I just want to say thank you for listening to my introduction. Please feel free to reach out and don't hesitate, and if you want to learn more about the DOE hydrogen strategy, you could look up the DOE National Clean Hydrogen Strategy and Roadmap that was just released in September. Now I want to introduce my colleague who you'll be hearing from shortly. Meegan Kelly is a technology manager in the Industry Efficiency and Decarbonization office at the US Department of Energy where she manages the technical assistance initiatives focused on onsite energy resources and decarbonization strategy in the industry sector.

Meegan Kelly: Thanks, Julie. Hi, everyone. I'll take just a couple more minutes of stage setting before we get into the panel to lay out some of the synergies between hydrogen and fuel cells with combined heat and power. Next slide please. Really briefly, what is CHP?

CHP systems produce both electricity and thermal energy at very high efficiencies and can use a range of different fuels, including hydrogen, and a range of different prime mover technologies, including fuel cells. So in a CHP configuration, fuel goes into the prime mover, that makes electricity, and heat that's recovered from that process through a heat exchanger, maybe steam or hot water or even cooling, and because CHP is used onsite in buildings and in plants, you get to avoid the losses from having to send electricity long distances across the transmission and distribution grid, and you get to capture that heat that would otherwise be wasted, which results in really significant efficiency gains. Next slide please.

Today, there are 81.5 gigawatts of CHP installed in the US at more than 4,700 different sites, and it has long been used in buildings and in plants to save energy, to save money and to reduce greenhouse gas emissions. Most of the existing capacity, as you can see on the left side of the bar graph, is in industrial applications that have high demands for process heat, but the use of CHP, including fuel cell CHP systems, has been growing a lot in recent years in commercial and institutional facilities, places like hospitals, multifamily buildings, colleges and universities and other facilities that maybe need a little less capacity but really value CHP for its resiliency and for liability. Next slide.

Today, more than 70 percent of CHP is natural gas fueled, but about 15 percent is fueled by non-fossil resources such as biomass, biogas, waste heat, and also hydrogen mixtures, and those are reflected in the greenish or lighter shades in these pie charts. So there's already this enormous track record and experience base of CHP technologies operating on renewable and non-fossil fuels, and we expect that the increased use of these alternative fuels will enable CHP to contribute to our decarbonization goals in a meaningful way, and hydrogen, as that infrastructure is developed and becomes more available, can play a big part as a fuel for that future, and then we can imagine this pie chart could start to look quite different. Next slide please.

So just a few takeaways I'd like to leave you with about CHP and hydrogen, and those are that most existing CHP systems can already operate on mixtures of 10 to 40 percent, so it's possible and happening with prime movers on the market today. At the same time, all the major equipment manufacturers are working on capabilities to operate at higher mixtures, shooting for 100 percent hydrogen-fueled products to be on the market by 2030. There will be opportunities to modify existing systems that are already in the field to enable them to run on 100 percent hydrogen, and you can do that at intervals that align with your site's equipment, maintenance or overhaul schedules but that makes sense for you and your timing.

And another last important takeaway is that the high efficiency of CHP and fuel cells configured for CHP make it a really strategic way to use these sometimes scarce alternative fuels. So CHP and fuel cells use less and they can extend the supply of these limited resources like hydrogen and thereby extend the impact that these fuels can have on decarbonization. Next slide. This is the last thing I'll just share, that my office runs a CHP deployment program where we provide stakeholders like you all on today's webinar with resources to identify CHP opportunities.

We have a regional network of technical assistance providers. We have e-catalogue of packaged CHP systems and other market resources. So if you're interested in learning more, please don't hesitate to reach out and visit our website. Thank you.

Julie Fornaciari: All right. Thank you so much, Meegan. So next slide. Today we will be using an interactive platform for Q&A and polling. Please go to Slido.com on your mobile device or opening a new window on your internet browser.

And today's code is #DOE. If you would like to ask our panelists questions throughout this, please submit them at any time throughout any of the presentations. We will be answering your questions near the end of the webinar during our Q&A session. You can select the thumbs up icon for questions that you like additionally on Slido, which will result in the most popular questions moving up to the queue. So next slide.

Today we're going to learn a little bit about you, so let's start off with a poll. Please join us over at Slido to respond to the following question, and if you're having any issues please message our tech team by using the Zoom Q&A. And this is question is looking at what sector best describes your organization, so we know who is all listening today, over the 400-plus people who are listening in. And we have quite the spread for sure.

Industry is definitely leading. *[Laughs]* Consultant is very close, but then we also have state government and higher education among others. Yep, industry and consultants seem to be the leaders here. So that's great. And as you guys got a little sense of what the polling takes, please put in any of your questions on Slido so then we have a better idea of what you're all interested within our presentation today.

And we can go I think to the next slide. So today we have a great lineup for presenters today; Tony Leo from FuelCell Energy, Sathya Motupally from HyAxiom, and Paul Wilkins from Bloom Energy. Thank you all for being with us today. So now we're going to hear from our first speaker, Tony Leo. Tony Leo joined FuelCell Energy in 1978, and has held key leadership roles in research development and commercialization of electrochemical systems during his tenure.

He is well known throughout the battery and fuel cell industry and has authorized numerous papers, contributed to technical books, holds several US patents, and has served as Chairman of the American Society of Mechanical Engineers PTC 50 Fuel Cell Performance Test Code Committee and has a member on the Department of Energy's Hydrogen and Fuel Cell Technical Advisory Committee. And with that, I will hand it off to you, Tony, to kick is off.

Tony Leo: Thank you for that great introduction, Julie, and I look forward to talking about fuel cell energy, what we do and how we're addressing decarbonization of buildings and plants. So if we could go to the next slide please. You don't have to read all this. This is just some legal discussion about don't go running out and buy stock based on what I say here today. We are a publicly traded company, and so just looking for a little bit of restraint there.

Next slide please. So we like to start out by talking about our purpose, which is to enable a world empowered by clean energy, and we do that two ways, decarbonizing power by producing either low carbon or zero carbon power, or by capturing CO_2 from other power generation sources, and the other way is producing hydrogen through electrolysis or through coproduction of hydrogen with power generation in our trigeneration system. I'll talk about both of those today and how they all relate to buildings. Next slide please.

So a little bit about the company. We are a growing company. We're closer to 500 employees right now. We have been producing commercial power generation systems deployed in CHP applications around the world since early 2000's, and we have about 225 megawatts of systems deployed around the world. You can see there's a cluster of logos to the right that represent different commercial industrial customers who deploy our technology behind the meter, making their own power, supplying their own heat, and utilities, for direct utility sales as well as some development partners like ExxonMobil. We are based in Danbury, Connecticut.

Our factory is in Torrington, Connecticut, about an hour away from Danbury. We have facilities just outside of Munich in Germany and in Calgary, Canada as well. Next slide please. So the two technologies that we are working on is the carbonate technology that has been our long-term commercial product since 2003 and the solid oxide technology that we've been developing since the early 2000's and we're just now entering into the demonstration phase for some of the products based on that.

They're both high temperature electrochemical systems that they can be fuel cells or in reverse, as Julie said, as electrolyzers. They both are really good high efficiency combined heat and power platforms for behind-the-meter applications or in-front-of-the-meter applications. Solid oxide can run on pure hydrogen fuel. Carbonate needs to run on a blend of hydrogen and natural gas if you want to use hydrogen because the carbonate chemistry needs some CO2 in the internal recycle system. Both of these technologies are amenable to capturing the CO2 from their own platform.

If you fuel these fuel cells with natural gas, at the point at which they convert the methane to hydrogen and produce CO2, that CO2 has not yet been mixed with air so it's easy to extract it. So we can extract the CO2 that would otherwise be omitted from the platform. Both of these technologies are capable of that. Carbonate can do something unique, though. It can capture CO2 from an external source. If you send blue gas into the carbonate air intake we can actually capture CO2 from that flu gas, which sounds like it might not be applicable to industrial applications but we'll see in a few slides that it could very well be.

They are both capable of what we call trigeneration. Because we efficiently produce hydrogen from methane inside the fuel cell stacks with less water than is usually used and less heat than is usually used, we can export some of that hydrogen and it's low carbon hydrogen and we can actually coproduce water along with it. Solid oxide is also capable of pure hydrogen electrolysis, very high efficiency, which is unique to it. Carbonate can do electrolysis, but again, there needs to be some hydrocarbon involved from the CO2 transfer. Next slide please.

So this is just an illustration of what the carbonate equipment actually looks like. In the picture on the left, that fellow is holding a single carbonate fuel cell. It's a fuel electrode, an air electrode and a thin, porous layer between them called the matrix, which is where the electrolyte is. There are 400 cells behind him in a stack. Four of those stacks go into our 1.4-megawatt module we manufacture in Torrington that goes into our megawatt scale systems.

We also deploy single stack systems in Europe that range from 250 to 400 kilowatts. In the tower of pictures in the middle there, the top one is a 400-kilowatt system running at a Radisson Blu hotel in Germany, one of our single stack carbonate deployments, and that's producing baseload power and heat for the hotel. The picture just below it is a 1.4-megawatt system with one of our four-stack modules. Below that is a 2.8-megawatt system that has two modules.

Below that is a 2.3-megawatt system that produces power but also coproduces 1,200 kilograms a day of hydrogen, and it's derated a little bit from 2.8 because of the power for hydrogen purification and compression. And the one below that is a three-module system. The third module runs off leftover fuel from the first two, so it's very, very high electrical efficiency. Those are the biggest systems we make, but we do larger projects, as you see over to the right, by putting multiple systems at a single site. Next slide please.

And this is an example of some actual applications. In the upper right is the one that is perhaps least applicable to this discussion. That's a utility scale, 15-megawatt system in Bridgeport, Connecticut. It's the largest system in the US. It has five of those 2.8-megawatt systems. Just to the left of that is a system running at UC San Diego California. It's a 2.8-megawatt system.

Waste heat from the system supports absorption chilling and it's deployed in a microgrid. In the event that the power goes away, the fuel cell plus a couple other power generation systems stay online and provide power to the university. Just below that is a 5.6-megawatt system, two 2.8s, that are deployed, providing power and heat to Pfizer's R&D facility in Groton, Connecticut. We're particularly proud of this one because that facility was instrumental in the development and manufacture of the COVID vaccine.

So they had a lot of power quality issues there, and the way fuel cells work in terms of enhancing resiliency is a little different from a typical backup power generator. You don't have the system sitting there doing nothing until the lights go out. The system continuously provides power and heat, clean power, clean heat, avoids grid emissions to the facility, and when the grid goes away the system keeps producing power. That's how we provide resiliency with a fuel cell.

And in the lower right is a similar application. It's a 1.4-megawatt system at the University of Bridgeport. It provides power to the university, heat to the rec center next to it. In the event that the grid goes away it continues providing power to some critical buildings around the campus. So just some examples. Next slide please.

So I mentioned the carbon capture and carbon aspect of the carbonate, and this is a little of a discussion about that. On the left, we refer to this as carbon separation or carbon export. This is where we're extracting the CO2 that would otherwise be emitted from a carbonate fuel cell itself if fueled by natural gas. And how can this be deployed in industry? Well a lot of industries use CO2.

So you can think about an industry that's buying CO2, getting it delivered, perhaps not very sustainably. You can have onsite power, heat and CO2 production supporting their CO2 needs, and you can see there's a whole list of applications next to it where there are a lot of CO2 users in industry. They're all suffering from CO2 shortages these days for a variety of reasons, so there's a lot of interest in this application. And this is commercially available today.

And to the right is the carbon capture application, where we actually capture all the CO2 from our platform, but in addition we capture CO2 from an external source, and that is an application we're developing with ExxonMobil. That would be larger scale applications for capturing from industrial boilers perhaps but also from larger power generation systems. Next slide please.

And then this is my last slide. I just want to touch a little bit on the solid oxide technology that we're demonstrating right now. What we're developing is we're developing a common stack and stack module platform that will be used for power generation, electrolysis and hydrogen-based energy storage. So these stacks can be run in power generation mode, send fuel into them and get power out. In the upper right is a 200-kilowatt DOE-supported project that we did.

It was a demonstration in downtown Pittsburgh. You can also, instead of getting power out, send power in with steam and split the steam very efficiently into hydrogen and oxygen and 1-megawatt electrolysis system that would produce 550 kilograms a day is shown there. And that's a size that could be used for onsite hydrogen production to a glass factory or another type of industrial hydrogen user. Then if you produce hydrogen and store it, you can actually send that hydrogen back to the same stacks and run them in fuel cell mode, and we think that's the basis for a really interesting hydrogen-based energy storage system.

The key there is if you want to increase your discharge duration by five times, you don't have to buy five times as many batteries. You just have to buy more hydrogen storage. So it's a very cost effective way to get to the longer duration energy storage we think we're going to need as we get more and more intermittent renewables out of the grid. And with that, I believe that is my last slide. I'll just say thank you and I look forward to the Q&A session later.

Julie Fornaciari: All right. Thank you so much, Tony. Now we will hear from our next speaker. Dr. Sathya Motupally is the Chief Operating Officer of HyAxiom, Inc. He has over 20 years of experience in multiple Fortune 500 companies in the functions ranging from program management, business development to R&D and engineering. Prior to HyAxiom, he was head of R&D at UTC Power, a division of the United Technologies Corporation and Vice President of Research Development and Engineering for Clear Edge Power.

He also spent four years at the Gillette Company, now a part of Proctor & Gamble, where he led a mathematical modeling team tasked with battery technology development. Thank you for being here, Sathya.

Sathya Motupally: Thank you, Julie, and thank you to the DOE for organizing this webinar. So far it has been awesome, so hopefully, you know, people are learning a little bit about how fuel cells can help decarbonize and get to our ultimate goals of zero carbon one day. Next slide please.

I will quickly go over where I come from, a little bit of introduction to HyAxiom, and then I'll focus mainly on hydrogen and hydrocarbon fuel cells and the stationary fuel cell market. Next slide please. Okay, so as mentioned in my bio, in 2014 UTC Power Fuel Cell Business and Doosan came together and from HyAxiom. Doosan is a very large Korean conglomerate, top 10 Korean conglomerate from South Korea. A lot of EPC experience, a lot of construction experience, a lot of manufacturing scaleup experience combined with the 60-plus years of fuel cell technology by UTC Power United Technologies, gave birth to HyAxiom, a new fuel cell company that had the manufacturing scale for market penetration along with the technology fundamentals.

A little bit about our history. UTC Power pioneered space exploration with the Apollo Mission Space Shuttle, and then using that technology, UTC had commercialized a number of firsts in commercialization of fuel cells and hydrogen, transportation included, stationary fuel cells, and then since 2014 Doosan has been able to take those technologies and scale up to about close to a gigawatt of stationary fuel cells being installed around the world. Next slide please.

So as I said, we are going to focus on stationary fuel cells. Our current focus in the area of stationary fuel cells is stationary fuel cells that can run on three different fuels. Obviously two of those are hydrocarbon fuels. We have a natural gas model or a biogas model. We also have an LPG model. LPG is a logistics fuel. When there is no pipeline for natural gas, these fuel cells can run on LPG.

And also our fuel cells are highly efficient converters of hydrogen to electricity, and I'll show you an example of what we are doing that at scale. So the top line of stationary fuel cells on the three different fuels and the bottom part of the page is the products that we have in development. Tri-gen is at a pilot scale, and I think Tony talked a little bit about Tri-gen. So our product is also capable of producing power and hydrogen on demand.

So think about this product basically at a filling station where it's powering the building behind the filling station, and also whenever a car drives by you can actually switch the unit to actually product hydrogen. We're also developing SOFC technology for its high efficiency, and the electrolyzer technology for obviously hydrogen production, as Tony had mentioned, and also the entire gamut ending with PEM mobility with the PEM Powerpack for buses and trucks. I want to focus on the stationary fuel cell over the next few pages. Next page please.

Okay. So this is our flagship product. It's called the PureCell Model 400. It's actually a 460-kilowatt model or a 440-kilowatt model depending on what efficiency you want. There are three key components to this fuel cell. In fact, I think any fuel cell, high temperature, low temperature, you will have these three functions.

The only difference is the extent of fuel processing that happens in the fuel cell. So a simple description of this fuel cell. Either hydrogen or a hydrocarbon fuel enters from the left, and if it's hydrogen you don't really need any fuel processing. But let's assume we're talking about natural gas. The natural gas fuel input goes into the fuel processor.

The fuel processor basically cleans up the sulfur that's added as an odorant and then reforms the natural gas or the LPG to produce hydrogen. And this hydrogen is the second component, which is a fuel cell stack, which is a very, very efficient electrochemical device, and this electrochemical device takes the hydrogen and produces electricity. As a part of the reaction in the fuel processor, and as a part of the electrochemical reaction in the fuel cell stack, every fuel cell also produces heat, and depending on the temperature of operation it dictates how much heat you can actually be able to use as useful heat.

So the reactions in component one and component two shown on this page lead to heat, and that's one of the major differences between HyAxiom fuel cells and some of the other fuel cells, is that we actually like to operate in the CHP mode. CHP is combined heat and power. If you remember what Meegan was talking about, CHP is a great way to sort of get to a very, very high efficiency on hydrocarbon fuels. Now the power that's generated in the fuel cell stack is taken to the power conditioner and the power conditioner basically gives you very, very clean power.

Now the power that's generated from this box is about 440 or 460 kilowatts, and the amount of heat generated is also very similar, about 450 to 470 kilowatts. So if you have a building and you're able to use about 440 kilowatts of power and you are able to use heat on the order of about 440 to 450 kilowatts, this makes great sense because this is actually giving you very, very high utilization on the hydrocarbon fuel that you're using to make your power and heat onsite. Next page please.

So the benefits of the fuel cells, stationary fuel cells and the HyAxiom fuel cell as I described it on the previous page, is we have very high system efficiency. And because we are able to utilize 90 percent of the heating value of the hydrocarbon fuel, we have very low CO2 and NOx and SOx emissions, in fact, almost zero NOx and SOx emissions, and the fuel cells can run in water balance for the majority of the conditions, so there's really no impact on water uptake. These fuel cells are very simple machines, so they are used for continuous onsite power.

They can run independent of the grid so that basically your building's running – the fuel cell is running parallel to the grid, your building's on the fuel cell, and your grid becomes your backup. The beauty of the lower to medium temperature fuel cells also is that these fuel cells can load follow. So if you don't want to use the entire load all the time, these fuel cells will basically be able to manage to cycle like your building or your factory cycles.

And because the fuel cells are simple with respect to their makeup, they have very, very reliability. From a cost-effectiveness perspective, especially with the natural gas prices – I mean, they're high right now, but if you look at the average natural gas prices over the past 10 years, if you're able to use the heat, the high efficiency of the fuel cells will lead to a cost effective solution for most of the applications. The other advantage with our fuel cells is they're flexible. They can be placed indoors, they can do on rooftops, and they can also be stacked in multi stories to give you basically multi megawatts.

Next page please. Okay. So where are our fuel cells used right now? There are three key segments where our fuel cells are used. Areas like datacenters, hospitals that are considered mission critical are developing their own microgrids or running in GI mode with multiunit load sharing, these customers of ours are looking for reliable baseload power and they basically want the grid to be backup.

They are trying to get to 24/7 resiliency and can also use heat onsite. So this is a big piece of our marketplace. Customers of ours, universities, large buildings, factories that can use the heat and can actually offset the boiler loads with what they're currently doing are also a big segment of our customers. Some of our customers are shown on the right. These folks typically tend to be needing a lot of heat or cooling depending on the state that you're in, and they're also looking to further their ESG goals, and certain urban areas they're also looking for quite applications with some of the other technologies can't meet.

The last segment is our large installations multimegawatt, and these are either the municipalities that are looking to take some of their buildings off grid, create a microgrid, or utilities that are looking to supplement local substations rather than adding more generation capacity. Some of these are supported by states like Connecticut and New York and Massachusetts with the RPS program. Next page please. So I want to go through a few examples before I end.

We talked about where our fuel cell is used and why people use our fuel cells. This is an example of a large US residential complex. This is in Hartford, Connecticut. It has one unit of ours running in the back of the building. It meets about 55 percent of the building's 500 apartment building load. The entire building also gets its space heating and domestic hot water from our fuel cell.

So when you look at what this building was paying for electric bills versus what they're able to do now because of the high utilization of natural gas, we've taken their monthly electricity bills down by quite a bit. Next page please. So this example is one of the microgrid, mission critical examples. This is a datacenter, which has two of our units running at 800 kilowatts.

This is an example where our fuel cells from a CHP perspective are integrated to an absorption filler. It's about a 90-ton absorption chiller. And again, from an availability capacity factor perspective, this particular datacenter has run over 95 percent over the past five years, and from an ESG perspective this was a great win for Verizon. Next page please.

Okay, so now moving into large municipalities and what they can do to sort of take large towers out of conventional power generation and looking at fuel cells for clean power. This is an example from Korea. This is the town of Busan or the city of Busan has 31 megawatts of clean power. About 45,000 households get their power from here and also the district heating loop supplies heat to the 40,000 to 45,000 households in Busan.

This was one of the largest utility scale fuel cell examples that we had taken part in. Next page please. Okay, so we talked a lot about fuel cells, and all of the fuel cells I talked about so far have been hydrocarbon fuel cells, natural gas, but when hydrogen becomes abundant and when hydrogen does start getting into our pipelines with natural gas, with our ready with the product and we've actually – this is the first and I believe only largescale, 50-megawatt scale hydrogen fuel cell demonstration, and this is

Daesan in South Korea. And if you look at the bottom picture, it's basically the tower complex is run by roughly 115 fuel cells producing about 50 megawatts of power, and this is a great example of what hydrogen can do for us in the future. That was my last slide, and thank you for your time.

Julie Fornaciari: Thank you so much. That was a wonderful presentation. A quick reminder to our audience to send in any questions you have at Slido.com with the event code of #DOE. We look forward to answering your questions at the end of the session, so please be putting those in and upvoting those. Now we will hear from our final speaker.

Paul Wolkins joined Bloom Energy in 2016 and serves as the Vice President for Federal Policy. In this role, Paul manages Bloom's relationships with federal policymakers and represents Bloom before federal agencies as well as members of Congress and their staff. Before joining Bloom, Paul spent nearly a decade working on federal tax, energy, and environmental policy as legislative assistant, legislative director, and then chief-of-staff to the chairman of the Senate Finance Committee, Senator Max Baucus. Paul lives in Washington, D.C. with his wife and three daughters. Take it away, Paul.

Paul Wilkins: Julie, thanks so much for the introduction, and to Julie, Meegan and everyone on the DOE team, thanks for hosting this webinar today and thanks for all of the attendees and my fellow panelists. So I'm going to start out by telling you a little bit about Bloom Energy, what it is we do, our current applications, and then give you a window into where we're going as a company and where we think the industry is going. Next slide please. So really Bloom's purpose is to be a partner for our customers in the energy transition.

All of our customers have ESG goals, they all have net zero by 2050 goals, and our goal is to offer them a product today that gives them cost predictability, improves their resiliency and sustainability all without sacrificing the power that they get, and then also being a partner for them in the future by developing options for them to continue on their decarbonization pathway, so really to be a partner for them in decarbonization. Next slide please. This just gives you a little overview of Bloom and the company. We are up to just a little shy of 2,000 employees worldwide.

We manufacture our systems, the fuel cells themselves in San Jose and assemble the systems in Newark, Delaware. We have deployed over 750 megawatts of systems globally. Next slide please. So first, a few basics on how the fuel cell application works. So similar to what you heard from Tony and Sathya, Bloom's technology is solid oxide technology.

Our systems are fuel flexible. They can run on natural gas or biogas to extract hydrogen from the methane, either in the natural gas or the biogas, and reform it internally in the system into two parts hydrogen, or they can run off of pure hydrogen if the hydrogen is available for the customer. It is an electrochemical reaction as has been mentioned previously, so you're able to produce electricity at really high efficiencies with virtually no SOx or NOx or smog-forming pollutants. And because of that high efficiency in the markets that we operate in, we are also displacing the marginal generator on the grid and reducing CO2 emissions for our customers, even in the configurations running off of natural gas.

We also have customers that choose to power the systems with biogas so that that customer is getting a carbon neutral baseload 24/7, 365, highly resilient solution. On the bottom of the slide there, you can see how we assemble the fuel cells themselves into stacks, and then each one of those modules that looks like a large refrigerator is a 50-kilowatt power module. They're modular systems, so the more of those modules you put together, the bigger a system you have. Next slide please.

So our largest system that we've deployed is currently a 30-megawatt system, utility side of the meter, but most of our systems are deployed behind the customer's meter so that we can provide that onsite resilient power. These are a few of the applications you see, several datacenters here, a university campus. Because of the modular nature of the system, they can be deployed in a variety of configurations. On the far right there, you see what we call a power tower, which is an 8.35-megawatt installation in South Korea where we've essentially stacked the systems on top of each other, and by doing that it actually makes the heat capture from that configuration easier.

So we've got CHP configurations of the systems as well. Next slide please. A few more examples of the configurations for the system. I'll draw your attention to the bottom center. That's a Home Depot installation. So Home Depot is one of Bloom's largest customers by number of installations. A 200 or 250-kilowatt system provides the baseload electricity for the Home Depot store, and then we often sell them a microgrid configuration so that when the grid goes away because of climate-induced extreme weather, the fuel cell can island itself off from the grid and continue to power the facility for the duration of the outage.

For companies like Home Depot that really serve a community resiliency need by selling products that homeowners and businesses need to rebuild in the wake of the type of hurricane that we recently saw in South Florida, it really provides an important community resiliency benefit and it's part of Home Depot's mission as well. Similar to what you saw from Sathya as well, you can see that we also have the ability to do rooftop installations. As you can see there on the bottom righthand side, that installation really just speaks to the friendly nature, the low impact of the installations.

That's actually an installation that's on the second floor of a facility in the Bay Area right next to the outdoor lunch facility for that office building. So the systems are quiet, there's no smell or odor associated with them, and they're very efficient. Next slide please. This just gives you a sense of who is buying the systems today. So a lot of customers are in the datacenter business because of their need for clean, reliable and cost-predictable power.

A lot of customers in consumer and retail, a lot in manufacturing, biotech and pharma, hospitals and healthcare as well. Where we especially see growth is in semiconductor manufacturing as more of that industry looks to onshore and they really have time to power issues. Typically we can deploy a system to a customer within six months of an order, and in some cases when you have a large semiconductor installation going in or a large datacenter, the time to power for utility service can be significant in some cases.

So we often partner with the customer as well as the utilities to provide a time to power solution for those customers. We also see a lot of growth in manufacturing as well for that same three-part value proposition of sustainability, resiliency and cost predictability. Next slide please. So I want to talk just a little bit more about the resiliency of our systems. As you can see, we've deployed over 140 microgrid configurations since 2011.

These microgrids can vary in complexity from standalone Bloom systems that isolate themselves off from the grid and integrate with the building management software to shed any noncritical loads to complex microgrids where we are integrated with solar and storage and backup generators if necessary to provide multiday outage protection for those customers. As you can see in the bottom there, for one of our recent customers in California that was affected by a public safety power shutoff, we actually powered the customer for five and a half days in microgrid mode.

I also want to draw a special note to Taylor Farms. So if anyone has ever had a bagged salad from Safeway there's a high likelihood you've had a Taylor Farms product. They're a large agricultural and food manufacturer here in the US headquartered in California. So we recently announced a really exciting project in partnership with Ameresco where we will be providing Taylor Farms with a 6-megawatt Bloom system that will form the backbone of their microgrid for one of their production facilities. It'll also be paired with solar as well as battery storage.

And for that facility, Taylor Farms has actually decided to take the facility completely off the grid. So there will be no grid connection and the microgrid provides all of the onsite resilient power. The motivation for Taylor Farms to do that is they felt like they had been a customer of their local utility for several decades and costs had gone up but yet service had gotten worse. So there is that ability to really do deep decarbonization and at the same time really high levels of resiliency for customers.

Next slide please. Let me give you a little sense too about where we're going as a company. So as I said, we want to be a partner in the decarbonization story for our customers as they navigate the energy transition. So we're doing that today with our existing solid oxide fuel cell product running off of natural gas, but we can also do a number of things with that existing product. So first, we can run it off of biogas, and we have a number of customers that do that in order to ensure that they're having carbon neutral electricity generation.

We can also blend in, as Meegan mentioned earlier, hydrogen into that existing system up to 50 percent, and then beyond 50 percent it is a in-the-field upgrade to make it fully hydrogen capable. So what this means for customers is they're not investing in a stranded asset that in order to reach net zero by 2050 they're going to have to swap out or discard. They're investing in an asset that even in five years, if they have the availability of hydrogen at the price point that works for the customer, they can upgrade the system to run on pure hydrogen.

The other thing that we're doing is finding new applications for our systems. So one of those is marine and cargo – so cargo ships and cruise ships running off of LNG, powering both the hotel load as well as the propulsion with the fuel cells, and we have a partnership with Samsung Heavy Industries to do that. Similar to what you heard from Tony and Sathya as well, Bloom also has commercialized a solid oxide electrolyzer product where we can take electricity and water and split those water molecules to produce hydrogen very efficiently. Because solid oxide electrolyzers are high temperature electrolyzers, we can boost the efficiency of the systems by utilizing not just electric energy to split those water molecules but also steam from any exothermic process.

And then lastly, we're also developing our systems to be carbon capture enabled so that we can capture the anode exhaust from the system with a few steps, purify that stream, and provide a very high stream of pure CO2 either for sequestration if the customer has access to it or for beverage, food industry or other utilization. Next slide please. Lastly, I also want to show some of the existing systems that we have up and running off of pure hydrogen. This is an installation, a hydrogen solid oxide fuel cell up and running in South Korea where we're demonstrating the ability to produce high efficiency electricity running off of pure hydrogen. Next slide. With that, I want to thank everyone for their interest and time and look forward to the Q&A.

Julie Fornaciari: Awesome. Thank you so much, Paul, and to all of our panelists for your insights and insightful presentations. Now I'm going to move to Q&A. If you haven't already, please join us over at Slido.com with the event code #DOE to submit and upvote any questions. So next we're going to have the questions. So some of these I think are related to mine and Meegan's, but all of the panelists you can hop in wherever you want to as well.

So the first question is you said hydrogen could help reduce greenhouse gas emissions. Why could only – oh, why only could? Is it because you could burn fossil fuel to generate hydrogen? If that's the case, what is the balance of energy units consumed versus units of energy generated? I'm happy to answer this, but if any of the panelists want to answer it too, happy to give it over to the panelists.

Tony Leo: No. They're simply stated, different forms of hydrogen production have different carbon content. So if you have a hydrogen production process like conventional steam methane reforming that has a fairly high carbon content, you might not be decarbonizing if you swap methane for hydrogen.

Julie Fornaciari: Thank you, Tony. Yeah. And the goal is to hopefully not have hydrogen being produced just by natural gas but also through water electrolysis, and that's kind of the push for decarbonizing the generation of hydrogen, but fuel cells will, if they're hydrogen fuel cells, have just water as the byproduct. So next question. As natural gas is a natural resource and not renewable, is there a concern about using natura gas in fuel cells and for hydrogen production on a widespread basis?

Paul Wilkins: I'll jump in and answer this one. So first, as I alluded to in my comments, when you're doing a behind-the-meter installation of a fuel cell, you're displacing the marginal generator on that region of the grid. Fuel cells, because of their efficiency are significantly cleaner than the marginal generator on the grid today, and so you are – even running off natural gas, you are reducing CO2 emissions for that customer relative to what their demand on the grid would do in terms of CO2 emissions. However, as I also noted, the advantage that fuel cells have is that they are fuel flexible, so that same fuel cell, even though it's emissions reducing today, it still does have some CO2 emissions if it's running on natural gas, but you can transition those fuel cells over to hydrogen to provide zero – and provided that the hydrogen is decarbonized hydrogen, you can produce zero carbon baseload electricity for that customer.

Tony Leo: And just to add to what Paul said is fuel cells, for the reasons Paul gave, do avoid emissions. They don't avoid as many emissions as pure renewables like wind and solar, but they run all the time. So in many cases, fuel cells actually avoid more emissions than wind and solar, because while wind and solar avoid more emissions when they're running, they don't run all the time. Solar, for example, as a capacity factor of about 15 percent here in Connecticut. So you really have to look at the whole avoided emissions picture to see when you're making gains.

Sathya Motupally: Just one last point, adding to Tony's. When solar and wind are not running, utilities are actually using a lot less cleaner peakers and other plants to sort of supplement what the grid needs to do. So, you know, based on what Tony was saying, you're reducing the marginal emissions at the grid if you use base-loaded cleaner power, even using natural gas fuel cells.

Julie Fornaciari: All right. Thank you all for answering that question. I'll move on to the next question. With the need to compare energy types when making decisions, why doesn't DOE use dollar-per-unit energy, that dollar-per-kilogram fails to allow effective communication with the public, and use both if you have to to be transparent? So I guess that's to me where Meegan wanted to mention to that, but that's kind of what I mentioned for the Hydrogen Shot.

So that will really depend on more the end use of the hydrogen, so that's kind of why we chose dollar-per-kilogram. I was not a part of that, so I actually will give this feedback because I think that's a really fair point, that for different end uses it may depend on the efficiency, and so dollar-per-unit energy would actually be more effective versus a dollar-per-kilogram. So I will take that back as feedback because I think that's a very fair point. So thank you for whoever asked that and for upvoting it. So next question, unless anyone has anything to say about that from their experience –

Tony Leo: Well the only thing I'll throw out there is a quick rule of thumb. For those of you who are interested in this is the factor is something like 7.3, I believe. So $1.00 per kilogram is $7.3 per million BTUs, and you can think about that in terms of what natural gas used to cost.

Julie Fornaciari: Great. Thank you so much for that, Tony. Good context. So onto the next question. How much infrastructure cost impact should sites anticipate when migrating from natural gas to hydrogen or hydrogen blends of over 40 percent, i.e. new piping? Anyone have a good answer for this one or want to chime in?

Sathya Motupally: I think there are some theoretical studies modeling hydrogen in natural gas pipelines. I don't know 40 percent, but I think they've been able to show without changing a lot of the infrastructure about 30 percent is possible. So if you actually do a search on papers recently published funded by utilities, you can see some of this stuff.

Julie Fornaciari: Thank you so much. Go ahead, Paul.

Paul Wilkins: The other thing that I'll add from the fuel cell perspective is if you think about all the things the system has to do, if you're going to upgrade the fuel cell to run on pure hydrogen, there will be some costs associate with new piping – seals, gaskets, those types of things – just because hydrogen is a different molecule than CH4. However, there are also some things that you don't need for the hydrogen-enabled system. So because you don't have to take the sulfur out of the natural gas and you don't have to reform the natural gas, there are some components that actually you don't need enough fully hydrogen-enabled systems. So it's a matter of netting out the additions and the lower costs from a capital perspective.

Julie Fornaciari: Great. Thank you so much. So we are getting low on time. Should we do one more question? So I guess the last question we'll ask before we have to wrap up, so given the most modern US hydrogen production is by steam methane reformation, how does Hydrogen Shot intend to really decarbonize the hydrogen supply? SMR have high methane emissions, which is even more potent than greenhouse gas than carbon dioxide. Paul, you unmuted so go right ahead.

[Laughter]

Paul Wilkins: I'll jump in. You know, I'll focus on electrolysis as a method for decarbonizing hydrogen production. So yes, it's a fraction of the hydrogen that's produced today, but the reason that there's a growing interest in electrolysis is when you're talking about producing hydrogen from electrolysis, about 75 percent of the cost of the hydrogen is driven by what's the cost of the electricity that you are putting into the electrolyzer? And with the cost of renewable electricity falling precipitously over the course of the last decade, you're at a point where the cost of that renewable hydrogen has fallen significantly as well.

When you've got two-cents kilowatt hour wind power and in some places they're talking about sub two-cents kilowatt hour electricity prices, you start to get into that point where you're within shouting distance of the DOE's moonshot goal. And then additionally, the electrolyzer industry is still pretty small. So as all of our companies scale up, improve our processes, improve our technologies, there's significant economies of scale that can come from that to squeeze down on the cost coming out of the rest of that 25 to 30 percent as well that's associated with the capital cost of the electrolyzer.

Sathya Motupally: Paul, real quick, the only thing I would add is the IRA basically drives you much more towards electrolysis and getting rid of SMR. So I think the passing of IRA has been a great, great help with respect to people understanding electrolysis and green hydrogen.

Julie Fornaciari: Yes. And with that, that's going to be our last question. Especially what the panelists said, the IRA, so the Inflation Reduction Act, or the bipartisan infrastructure is really focused on clean hydrogen production, so trying to drive manufacturing and other programs to clean hydrogen versus SMR. But with that, that is our last question. Thank you all so much for all of the questions.

Sorry we didn't get to too many of them. But thank you, and thank you to the panelists for your insightful responses. This webinar is a part of the 2022-2023 Better Buildings Webinar Series. As you can see, we have a great lineup of presentations through March, so visit the Better Buildings Solutions Center to learn more and register for future webinars.

So the next webinar that we hope you will join is on October 18^{th} for it, which is Financing Solutions That Improve Efficiency in Both Energy and Water: A Focus on Hospitality. Join this webinar to learn how market leaders in the hospitality sector finance and deploy projects that tackle energy efficiency and the water nexus. And that is next – coming up. And with that, I'd like to thank our panelists very much for taking the time to be with us today.

Feel free to contact our presenters directly with additional questions, or if we couldn't get to your question during the Q&A period, please reach out. I encourage you to follow the Better Buildings Initiative on LinkedIn and Twitter for all the latest news. You can find our handles by their respective icons on the left of this slide, and you will receive an email notice when today's recording, slides and transcripts are available on the Better Buildings Solution Center. Thank you everyone for your time and have a great rest of your day.

[End of Audio]