*Thomas Wenning:* All right. Welcome, everyone out in Cyberland. It looks like we have some people joining us still, but we're really excited to get into today's talk and discussion. So as many of you know, this is a continuation of the 2021 Better Buildings Summer Webinar Series. This is just a really great opportunity where we are profiling the best practices from our Better Buildings, Better Plants partners, as well as other organizations that are helping us all to improve our energy efficiency. And so today, we're going to be talking about combined heat and power and how that's going to improve your efficiency and resiliency. So we've got a lot of really good stuff here, today.

Marissa, I think we can move slides here. So as some of you know, I'm Thomas Wenning. I'm with Oak Ridge National Laboratory. I'm a program manager helping to run and keep the wheels turning within our Better Plants Program. Obviously, time has not been quite as nice to me as the picture and video feed show, but let's keep moving.

Okay, so as many of you know that have been joining us for the various Better Buildings, Better Plants activities and anything online, we love to use slido. So if you get a chance, open either a web browser or get your phone, pull up in slido.com, enter the chat code DOE, and get in there. So we can use that to collect our questions and answers, really our questions for this session, and towards the end of this, we will throw some not softballs. We'll throw some fastballs at our two esteemed guests and presenters, today. So get into slido, make sure you can use that, and we'll use that for all of our questions as they come in today.

All right, Marissa, let's keep going. And now this is the good part. We're actually gonna transition, so you don't have to look at my ugly mug too much longer. We've really got two of the topnotch, in my mind, some of the biggest titans in the area of combined heat and power. We have Dr. Gavin Dillingham and we also have Bruce Hedman. I've worked with both of them and they're esteemed colleagues and excellent in this area, some of the best in the world, in my in my estimation.

So Dr. Gavin Dillingham is a program director for the Clean Energy Policy at HARC and he's the director of the US Department of Energy's Southcentral and Upper West Combined Heat and Power TAP. Dr. Dillingham joined HARC in 2012, where he leads the research and program efforts focusing on policy and regulatory efforts to improve the climate resilience of the electric power infrastructure and built environment. So that was a mouthful, but he's doing some really fantastic work down there.

And then right alongside him today, we're gonna hear from Bruce Hedman with Entropy Research. Bruce is a senior advisor to the Department of Energy's Combined Heat and Power Program Deployment Program and he also serves as a coordinator for the Department of Energy's Packaged CHP Accelerator, a really great resource for many of you. Bruce has 40 years of experience in industrial energy technology research development and commercialization, including combined heat and power and distributed generation technologies and markets.

The intros don't do it justice. These two are real powerhouses and there's a lot that we're gonna learn today. So with that, I think we're going to switch over to an agenda slide, and I will be passing it off to Gavin. And just as a reminder, as you're going through this and you have questions, please enter those over into slido and we'll handle those towards the end. So, Gavin, the floor is yours, sir.

Whoop, Gavin and you are muted. I can't hear you.

*Gavin Dillingham:* All right, I had been muted by a higher authority and so I could not unmute myself, but now I've been unmuted I think as I clearing my throat a little bit, so I apologize for that. So, thank you, Thomas. Thank you for the introduction, wonderful there, and very much excited to be a part of this webinar series. We do a lot of webinars out of the CHP TAP, out of the Southcentral and Upper West TAP, but it's great to partner up with the Better Buildings folks and have this opportunity to engage with many of you, today.

I'm just gonna quickly cover the agenda and then get right into things. Bruce Hedman's gonna come in at the decarbonization and CHP, and he's challenged me to get through my myriad of slides in order to give him plenty of time to kind of talk through the decarbonization piece, which is very important for CHP, at this time. So just to quickly get started looking at CHP overview for some of the new technology, and how it works, and kind of the state of where it is now. We're going to cover that.

There are great benefits that CHP provides to improve resilience of our power systems. And we're also going to jump into waste heat to power. A lot of discussions there about using that bottom cycling approach waste heat to provide emission-free electricity, and also, reduce the amount of waste heat that's coming out there and just being vented into the atmosphere.

Cover some snapshots about some great projects that are happening working with the CHP TAPs. There's actually going to be an event on July 1st where you get even a deeper dive from one of the other TAP directors, Cliff Haefke. It's going to be, once again, on July 1st. And then Bruce is going to jump in with some decarbonization and CHP discussion here.

So go ahead and get started with the next slide there. CHP overview, next slide, please. What we're doing here is just once again, combined heat and power. What is it? It's an onsite generation resource that combines both electricity generation and thermal production that can provide either cooling or thermal services to a building there. It's highly resilient. It's much more efficient than say a traditional grid system and it provides a significant amount of resource benefits from space heating to space cooling, process heating, process cooling, and a variety of other benefits onsite.

Much of our region, we're really focusing a lot more on how CHP can be used on space cooling using absorption chillers or steam driven chillers. But a lot of great efficiencies come out of the CHP system there.

Next slide. One of the key things we like to really discuss here is just that the CHP comes in a variety of different sizes and shapes. A lot of people kind of think about CHP as being kind of industrial-focused, manufacturing-focused, large, large, very large systems. But we're seeing CHP systems that can go fairly small, five-kilowatt systems, up to, of course, the very large systems. Still seeing those deployed. But once again, the technology changes that we've seen and the applicability across a variety of market sectors, in many cases, nontraditional market sectors, is very important to keep in mind. So there's just so much more flexibility with CHP than there had been in the past.

Next slide. Some of the key benefits around CHP is really the efficiency of operation, as I alluded to earlier, and that really leads to lower operating costs, overall operating cost reductions, as well as improvements in your emissions profile and reduction in pollutants there. One of the areas that we're really trying to emphasize a lot these days, especially in ERCOT market down in Texas, is a lot of the resiliency benefits that CHP can provide, especially when your grid is under significant strain due to extreme temperatures, or due to major extreme weather events, or just an overall growth in demand that's happening there. The ability of CHP, when strategically placed to provide that reliability and resiliency benefit, is key.

One of the other pieces is that utilities are really growing more interested into CHP because it can provide some significant non-wire alternative benefits that we'll go into a bit later, as well. So not only do you get the efficiency and lower operating costs, you also get some significant resilience benefits from CHP.

Next slide. Just to kind of give you an example or an idea of where CHP is these days, of course, most of it you see as far as overall generation capacity and the chemicals refining pulp and paper sector there, so kind of some of the traditional areas in the industrial side of things. And you see that CHP is providing some significant benefits to the overall energy space here, providing seven percent of overall total electricity production in the United States and reducing CO2 considerably.

A lot of people think, well, CHP, natural gas-based. Typically, it's going to be a large emissions producer there. But what we really see and what Bruce will get into further later, is that CHP can provide significant reductions in greenhouse gas emissions when you compare it to the overall grid, as well as when you look at CHP being part of a microgrid system, a solar plus storage integrated type system, as well.

Next slide. One of the things we like to point out here, and this is applications that have gone in from 2015 to 2019. A good number, over 790 installs, about close to three gigawatts, have gone in in the last several years. A lot of the larger systems, once again, you still see in the chemical space pulp and paper industrial space there, but I also like to point out that you see a lot of new systems that are starting to show up from office buildings, hotels, multifamily, and so just a widening depth of applications that are happening. A lot of that is to the introduction and development of CHP package systems, as well as just smaller, more efficient systems coming onto the market, as well as people seeing just greater application of this technology.

Next slide. This is based on a study that came out a few years ago from Department of Energy. This is the technical potential that's still out there. And so you see in the blue the existing CHP capacity that's available and then the technical potential. There's still a significant amount of technical potential and that's all the green bars there. Across the industrial and manufacturing space, of course, there's just a lot of needs for thermal energy, as well as a lot of needs for more resilient power systems.

So once again, not surprising there. But then also you see, once again, a wide berth of different types of CHP applications that are still applicable, especially in the commercial and institutional space, as well.

Next slide. One of the other things we want to really start pointing out is that historically, utilities really have not been overly friendly to CHP. You would see these CHP killer rates that would come out here or standby rates, for example, that would be set very high, that would make a project not economical. But now we're seeing utilities being much more willing to partner up with CHP systems or own and operate these CHP systems as part of their resource planning because they see a significant benefit that CHP can provide to help alleviate grid congestion, be that non-wire alternative I spoke about earlier and really kind of defer investments.

And some of that is because public utility commissions, public service commissions are pushing back against some of these large transmission distribution upgrades or some of these large rate filings that are out there due to concerns potentially around stranded costs there. And so CHP is, as a distributed energy resource, especially those that are strategically placed, can really provide a significant benefit to the grid and you see utilities becoming a lot more willing to be strategic partners and a lot more willing to kind of work with end users to develop those CHP plants and have them be a robust addition to the overall grid system there. And this is particularly the case among very large industrial and manufacturing CHP end users there.

Next slide. One other thing that we've actually done a lot recently in the Southcentral and the Upper West TAP is really looking at CHP and microgrids. And a lot of that is really looking at bringing together a variety of different generation resources coupling with the building with smart controllers that allow you to have different types of generation resources onsite and optimizing those to ensure you have a most economical set of say solar storage natural gas CHP operating there to provide both resilience and reliability.

And we're doing quite a bit of these at universities and military bases, but we're also seeing a growing number of these happening for mixed-use communities, multifamily communities, as well as when we're talking with large corporations, especially large refining, manufacturing, industrial organizations that are looking to improve some of their ESG goals, their environmental social governance goals, reduce their carbon emissions.

They want the solar plus storage. They understand that that's a key piece for emissions reduction and they also see the benefit of CHP coming in there providing a more robust 24/7 operation that really covers a significant large portion of their load there. So the combination of CHP with solar plus storage is very much an area that's really growing in interest, and we're doing a lot more work than what we have done in the past there.

Next slide. All right, so I kind of mentioned this earlier and Bruce is our in-house expert on this. He helped develop the packaged CHP e-catalog. This is a growing online system that really allows end users to identify what are some of those packaged systems that are available. And really, the packaged systems here are really to help reduce risks for the end users, and really potentially help reduce costs, and development time, and design time by having these packaged CHP systems. And you see here, there's a significant number of packaged offerings from recips, microturbines, gas turbines, a very wide-ranging number of types from very small systems, 24kW, up to close to 17 megawatts national coverage here.

So if you're interested in looking at CHP systems that kind of fit within that range, looking for opportunities potentially to reduce your design, your cost, your overall engineering development costs, checking out the e-catalog would definitely be something you want to consider there. And if you have any more questions about that, Bruce can really go deep in the weeds as far as the use of this catalog, but it's a great new resource that's available now.

Next one, Okay, so CHP and resilience, and once again, this is an area that we've been doing a lot more discussions and really helping people understand what is that resilience benefit that you may see from CHP and why should that be part of your financial calculation? Why should that be a key piece of the decision-making process there?

And if we go to the next slide, we'll see that there's really a growing need for greater resilience due to increasing amount of electric energy or electric system outages or disturbances here. The trend is upward. Especially in the last several years, you see an ongoing increase in the amount of disturbances that are happening. Most of them are caused by natural disasters and storm events. There's only expectation that these extreme weather events are going to continue to increase.

We've witnessed quite a few already in Texas. I'm based out of Houston, so of course, we experienced the great Texas blackout in February, but also now in early-June, we're already under kind of conservation settings here to where they're discussing rolling blackouts. And so once again, you see these concerns around resilience and reliability growing. And so it's just important to really think about what can you do as distributed energy resource in order to ensure you have those systems in place to continue operations there.

And if we go into the next slide, this is just to kind of indicate that there's been some work really trying to value what is that outage cost. And a lot of you folks know what it costs if your system is out for an hour or so, and so I don't need to tell you what that cost is. But it's a really key piece there to really better understand when you're making the case for CHP, it's not just upfront energy cost savings. It's a long-term operational cost savings, especially when you start taking into account the likelihood of disturbances and outages that could affect your operations there.

Next slide. Just once again kind of reiterating some of these benefits of resilience. Of course, for end users, it's really to make sure you have that continuous supply of power for those critical loads. CHP systems can be island, put into island mode. They can operate separate from the grid. They can be black-start capable. All things that are very important to consider when you're looking at improving the resilience of your system and using CHP. For utilities, we kind of covered this.

Of course, it helps with the grid congestion and grid stability, but it also helps really maintaining that power supply, ensuring that some of your critical customers are online during those major winter hurricane events, or flooding events, or extreme heat events, et cetera. And really for communities, that resilience benefits comes from making sure your critical infrastructure stays online and those first responders can continue to operate during these major outage events.

If we go to the next slide. This is a study that was done through one of the Department of Energy's resilience accelerator that wrapped up a couple years ago, and it really looks at different types of distributed energy resources and understanding what are the weather impacts that are going to happen to these resources here. And you see from battery storage, to solar, to wind, to CHP, to standby generators, and you see that though in any of those hollow circles there are really those that where you see there aren't going to be any types of impacts associated with that, whether that's a fuel supply interruption, damage to equipment, performance limitations, forced shutdowns, et cetera.

And so natural gas CHP does really well under flooding, high winds, snow and ice conditions, and extreme temperatures there. Earthquakes, of course, can cause potential disruptions with the natural gas supply chain, and wildfires just wreaked havoc across everything there. But in any case, CHP can really demonstrate an opportunity to keep the lights on, reduce those power disturbances across a variety of different type of natural disaster events. And when you couple it with solar and storage, you gain some additional benefits overall for the resilience of that system, as well as if optimized correctly, have those emission reductions, as well.

Next slide. Okay, so this is the last part in my CHP and resilience, and we always like to point this piece out because there's always a lot of discussions about CHP versus backup generation. And most facilities currently rely on diesel generators for backup in case there is some sort of power outages, and historically, backup diesel generators have issues with starting. Sometimes they're not, and in many cases, they're not properly maintained and may fail in emergency situations or may have issues during extended outages. Can you get fuel to the site there?

So CHP systems can, once again, kind of provide that resilient backup power during grid outages. They're already operating 24/7. You know it's up and running. You know it can provide the power to your site, so there's no question about that piece of it. And if configured correctly, which we've ran across some that have not been, they can operate flicker-free, and island themselves from the grid, and operate during and throughout that entire storm there.

Once again, CHP systems are a bit more pricey upfront when you do a direct price comparison to backup generation, but you really have to take into account what is that disruption cost, what is that overall lifetime benefit, that life cycle benefit, I get from the CHP system that I may not get from a generator that's sitting idle and may or may not operate. And so it's really kind of key to look at a variety of different questions and the CHP TAPs do help kind of look through those different types of scenarios there and talk through what are the pros and cons of each one of these systems and how do we best identify that most appropriate system for your needs there.

Okay, so enough on the resilient side of things. Once again, very key for power outages, very key for reducing those disturbances to your business. But another thing we want to talk about is some of the significant emissions benefits that CHP can provide, especially through waste heat to power, and that's really kind of growing in interest as far as we're seeing new entrants coming into the market. We're seeing growing interest in this case. Because people realize that the significant losses that are happening with waste heat just being vented to the environment from different industrial and manufacturing processes here.

And if we go to the next slide, we look at what are the benefits to waste heat to power. So just four key issues in this regard. Once again, it's a pollution-free power. It's essentially just grabbing that waste heat that's coming off an existing manufacturing and industrial process. If you're looking to improve industrial energy efficiency at your site, it can very much improve in that regard, and really allows you to grab that electricity from what otherwise would been a wasted resource there.

And if we go to the next slide, you can kind of see some of the opportunities that are out there, and there's a wide breadth of opportunities out there. This is, once again, from the Technical Potential Catalog that was developed back in 2016. This information is specific to waste heat power. So about 1,100 applications out there still available and ready to benefit from waste heat to power. Most of the work that we're doing is with oil and gas extraction. That's where we see a lot of interest, especially in the midstream side of things. But you can also see it especially on the refining side, so on the downstream side, as well as we're seeing some applications on the upstream oil and gas.

You also see a significant amount of opportunities there in the stone, clay, and glass market, primary metals. And we're seeing a bit ourselves in food processing. But once again, a significant amount of megawatt potential there, so 7.6 gigawatts of potential for waste heat to power across the United States there. So very much something that is a great opportunity to really provide that pollution-free electricity and really just kind of dive into that.

Next slide. So I just wanted to give some examples of how can waste heat be used, because there's a variety of different ways in which to look at it. So on that thermal process side, energy can be recovered from a furnace, an oven, a kiln, other industrial processes, and converted to electricity using some sort of thermodynamic process. Most common in this case is the Rankine cycle.

For mechanical drives, you see engines and turbines can be used to drive compressors, pumps, and electrical generators. A good example, and I kind of mentioned this earlier, is the on the oil and gas midstream side of things, where you're using a pipeline compressor station that utilizes the gas turbine to provide a compressor to move that natural gas through the pipeline. Of course, the waste heat can be recovered there and used to generate electricity. And then other industrial process generated heat as a byproduct that could be through an exothermic reaction, for example, making fertilizers, incineration of sewage sludge, heat release from pressure relief valves, et cetera. So a wide variety of different ways in which waste heat to power can be applied there.

If we go to the next slide. All right, so some of the key questions that we get and want to look at, and you don't need to read through all these. These slides are going to be shared, of course. But this is the questions we try to ask people and get a better understanding of what's happening at their site, what are some of the processes that are happening, so we can better understand and develop appropriate assistance or technical economic analysis for them to better understand what those opportunities look like. And so on the technical side of things, we're really most concerned about what's that waste heat source. Is it a gas or liquid stream?

What's the availability of it? Is it intermittent? Is it continuous? What does the temperature look like? That's going to very much determine the amount of electricity you can provide and whether or not that temperature varies over time and to what degree does it vary over time. Also looking at different types of pressures coming from the waste stream, the flow rate, the composition, et cetera. So all these are just key questions that we kind of go through as we look at the different technical factors that are important to consider for waste heat to power there.

The other piece is more on the economic side. What is the cost of grid electricity? That's going to make a big difference. How do you integrate waste heat to power on your site? Do you have enough footprint there, enough space in order to put it onsite? And then also, what the TAPs really work quite a bit on is just that financial incentives. What are the rebates? What are the incentives? What are the tax credits that are available in order to really make this project work out?

And so we'll go into that more a little bit later about how the CHP

TAPs work with everybody, as well as, as I mentioned, the upcoming July 1st webinar that we're going to be doing that dives a lot more deeper in the technical assistance that the TAPs provide there. But I just want to give you a taste of these are some of the things we're really trying to think about and that needs to be considered by the end users whenever they're looking at waste heat to power opportunities there.

Okay, so waste heat to power. We can now run into project snapshots. We always like to show some good examples of projects that are out there that have really kind of met those goals, have really stood out as far as being successful projects and have really led to whether it's improving resilience of the site, reducing costs, reducing emissions, whatever that end goal is, just really kind of highlight that and show real examples.

The project snapshots come through our large database of project profiles. I believe there's over 200 or so now project profiles across the United States from all market sectors that give good examples of best practices, lessons learned, just different sizes and shapes of these different systems, how they were designed, what was the motivation behind putting them in place. And so just very much suggest you go check those out.

But if we go to the next slide, look at our first example, here. This is the Shaw Industries site out of South Carolina. Focus here was really on reducing emissions associated with this carpet fiber production process, and so you can see here 26,000 metric tons annually, so not too shabby in that regard. Fairly decent-sized system at 14 megawatt national gas combustion turbine, and as the case in many instances here, the CHP system is providing not only the heat, the process heat, but also space cooling and water heating.

So when you think about a CHP system, it's not only kind of a one-hit wonder there. Essentially, it can provide a variety of different types of thermal uses and thermal resources, and you really when you're talking with the TAP or talking with an engineering company, really kind of think about what are all the different ways in which we can use this waste heat. It really helps the economics of the project there.

All right, we'll go to the next one. All right, this is another facility here really focusing on working with the local utility, and that was a key piece here is how do we best partner with the utility to design a system that can help reduce grid congestion, that can help overall facilitate kind of the operation of the grid and take some of that strain off the grid there.

This one is a relatively new system, as well, 2018, similar to the Shaw system. This one just focuses on providing process heat, similar size at 16 megawatts, but really seen as a way for the Sofidel Paper folks to really improve their tissue paper manufacturing here, and they see this as one of their top plants in the world based on the application here.

One other project snapshot we want to look at. This one's here in Texas. This is a great project and it's actually won the 2010 Energy Star Award. It's been around a little bit longer, since 2005, and this one provides a significant amount of benefit to the to the Port Arthur facility here. It's a petroleum refining unit, five megawatts, using both waste heat recovery boilers and back pressure steam turbines, and provides both steam and electricity generation there.

And a key benefit of this site was a significant reduction in emissions here, and we always kind of show this one off as a real key example of how waste heat to power can not only help provide the power generation side of things, but then also provide the necessary steam or additional steam to help facilitate the process at this site.

All right, next slide. Working with CHP TAPs. So we're going to go into this quickly because, once again, I'm going to plug the July 1st webinar that's really going to focus on this more deeply. But if you go to the next slide, you can see how the CHP TAPs work through a variety of end users, stakeholders, really doing these outreach efforts, webinars, workshops, we do tours, when tours were allowed. I think we're gonna be able to do some of those in the near term, but really helping end users, and policy makers, regulators, understand the benefits of CHP and how best to deploy it out there. And then the last piece is the technical services component where we do these economic technical analysis and assessments for end users and really help understand how CHP may fit.

We go to the next slide. This, once again, kind of covers some of the work that we do. We work through the whole kind of project development process from doing those very early stage screenings all the way through potentially commissioning helping with the procurement process, helping with an RFP or RFQ development, helping to be a kind of a third party reviewer of engineering drawings and documents, et cetera. So we really kind of help through that entire approach there.

And go to the next slide. This is just a list of where we're all located. So we have expertise around the entire United States that really knows our CHP and waste heat to power, and really knows how to kind of help you get your projects off the ground there and provide that no-cost technical assistance.

And so now I'm going to slide over to Bruce, and I'm going to let him talk about decarbonization and CHP.

*Thomas Wenning:* Bruce, you're muted. I can't hear you, anyways.

*Bruce Hedman:* Okay, can you hear me now?

*Thomas Wenning:* Yep.

*Bruce Hedman:* Okay. I think I remuted after that automatically unmuted. Again, thanks, Gavin, for teaming me up and thank you, Tom, for that introduction earlier.

We wanted to end this webinar with a topic that the TAPs and DOE CHP program headquarters have really been thinking about for a while and one where we're getting more and more questions about, and that's where does CHP fit into a decarbonized world. Gavin shared that close to 77 percent, I think, of existing CHP capacity is natural gas. I think we all know that natural gas is coming under scrutiny in many areas of the country and it puts some questions and pressure on CHP.

Where does it fit in? How can CHP fit into the future? What's the role of CHP in a path to decarbonization? Can CHP be part of the solution? And I'm sure there are questions if I invest in CHP today, is that going to be a stranded asset in 10, 15, or 20 years?

So start some slides. We've got seven or eight slides we put together that talks a little bit about where we think this might be headed. Marissa, next slide, please? Thank you.

We do think there's an important role for CHP in in decarbonizing the US economy and US industry, in particular. And that's in particularly if you're using low or net carbon zero fuels to provide energy services to markets and processes that don't lend themselves easily to electrification. And this is sort of our thinking on this approach and I'll go through these points, but I've got a slide or two on each of these just to document what we're basing some of this thinking on.

I think first, it's important to note that CHP is fuel flexible. Yes, 700-plus percent of existing CHP capacity is fueled by natural gas and that's really because of gas' historic availability, ease of use, low emissions criteria emissions, relatively low carbon compared to coal and oil, and low price. But you'll see that the CHP currently also uses renewable fuels, low carbon waste fuels and hydrogen, where available, and CHP technologies will be ready to use higher levels of biogas, renewable natural gas, and hydrogen in the future, and all the major manufacturers, turbine manufacturers and engine manufacturers, are working on 100 percent hydrogen capability prime movers.

Secondly, we'll show you that CHP is the most efficient way to generate power and thermal energy through combustion. And because of that, CHP provides some significant reductions of CO2 emissions now compared to the electricity that it displaced from the grid, and we think it will in the future, as well, wherever marginal grid generation is based on a combustion technology, be that fueled by natural gas or some renewable fuel.

And again, CHP fueled by renewable natural gas, low to no carbon, hydrogen fuel, can decarbonize thermal end uses in industrial and commercial facilities that are going to be difficult to electrify, or in some cases, extremely expensive to electrify. Renewable hydrogen fuel CHP may be a more economic and just as effective path to decarbonizing those operations.

Similarly, renewable hydrogen-fueled CHP can decarbonize critical facilities, hospitals, places of refuge, police, things like that that need a dispatchable onsite power for long duration, resilience, and operational reliability. Gavin talked a lot about the resilience benefits of CHP and those advantages, those benefits can still be there based on low to no carbon fuel.

And finally, because of CHP's high efficiency, it can extend the supply of these renewable, low carbon, zero carbon, and hydrogen fuels in the future, which all promise to be a great benefit, but are going to be limited supply, and especially initially, costly. So using them with the highest efficiency has to have great benefits for the system.

In the next slide, please, I'm going to start with fuel flexibility. Now Gavin showed you the total kind of look at the CHP commercial and industrial, but just looking at CHP in the industrial sector, and this is a broad definition of industry. It includes manufacturing, agriculture, mining, oil and gas, waste water treatment, things like that. But currently, on the pie chart on the left, 15 percent of existing industrial capacity, CHP capacity in terms of megawatts, is fueled by non-fossil resources such as biomass and wood, biogas, processed waste, and waste heat. And again, this is driven by really the availability of these fuels to the site and the price or the cost of cleanup of those fuels.

This might not seem like a lot, and I guess it's not, in terms of capacity, but note that if you look on the number of installations, the number of industrial CHP projects in place on the right, 44 percent of existing industrial CHP is fueled by non-fossil fuels, by biomass wood, by biogas, waste heat, and process off-gases. So there's an enormous track record and experience base for CHP operating on renewable and other non-fossil fuels, and it certainly bodes well for the future of CHP as the fuel infrastructure decarbonizes. I also want to note that just looking at biogas and landfill gas, the orange part of the pie chart there, 440 industrial CHP sites are currently operating on those fuels, so there is quite an experience-base.

The next slide, please. I want to talk a little bit more about CHP being the most efficient way to generate power and thermal energy. This chart shows you that CHP has a higher net electric efficiency than state-of-the-art marginal natural gas generation. What the chart has in the green bar are the net electrical efficiency of CHP options. The first three to the left are 20-megawatt industrial gas turbine unfired and with various levels of supplementary firing in the heat recovery steam generator. The middle green bar is an 8-megawatt industrial gas turbine, and the two green bars on the right are a 1-megawatt and a 100-kilowatt recip engine CHP system.

And this is the net electrical efficiency based on a credit for thermal energy provided in determining the fuel chargeable to power in the system. And you can see that the net electrical efficiencies are quite high compared to state-of-the-art central station power generation that is now really the base of most marginal generation in the United States, natural gas combined cycle and simple cycle gas turbine.

And again, because of that higher efficiency, that higher net electrical efficiency, natural gas CHP systems today have a lower net greenhouse gas emissions than the marginal natural gas generation that's on the grid on a kilowatt-hour basis. And in addition to that, you also have to remember that on average, there's a five, five and a half percent T&D loss in getting central station power to the point of use that is eliminated when you have onsite CHP.

So there are some significant efficiency benefits to CHP now and those benefits will go into the future. And because of those, again, benefits, natural gas CHP can meet these grid loads more efficiently, these marginal loads, and with less emissions, and those advantages will remain as low and no carbon fuels come into the system.

In the next slide, I just want to show really just sort of demonstrate that concept about the benefits of CHP's higher efficiency. Again, one of the key concepts to remember is that CHP, because of its high efficiency, saves significant carbon emissions today. And when you consider that CO2 stays in the atmosphere for over 100 years, I think that is an important benefit.

So to illustrate the savings of CHP today, this chart compares the electricity output and annual CO2 emissions savings of a 20-megawatt industrial gas turbine CHP system. This is one of the markets we see growing in the US. To the required capacities of the utility scale solar PV and utility wind system to have equal CO2 savings on an annual basis. Each of these technologies will be displacing marginal emissions as they're deployed. For this calculation, we used, at EPA's recommendation, the avert uniform energy efficiency CO2 emissions factor on a national basis, which was about 1,550 pounds of CO2 per megawatt hour.

And the key to the chart is looking at the annual capacity factors, which are the first line. You can see we've got a typical – the second line, I'm sorry. We've got a typical 90 percent capacity factor for industrial CHP versus the national average capacity factors for 2020 from the US Energy Information Agency of 24 percent for solar PV and 33 percent for wind.

And in that first row, the table shows that in order to have the same CO2 savings on an annual basis, you would have to need to install more than twice the capacity of solar PV than CHP and 50 percent more wind capacity than natural gas-fired CHP to generate the savings in today's electric system. Again, this advantage is fundamentally driven by the annual capacity factors of the three options, while CHP generation is based on a fossil fuel, meaning that its savings per kilowatt hour are not as great as solar and wind. The fact that it runs so many additional hours in a year and generates so much more electricity that your annual savings, your annual CHP savings today, are indeed larger than the same capacity of solar and wind.

The next slide, please, looks at the cumulative impact of this kind of savings, and this is a demonstration of both the near term and midterm cumulative CO2 reduction benefits of, right now, natural gas CHP. This is an analysis that was done by Sterling Energy of a major electric utility in the Southeastern part of the US. It compares the annual CO2 reductions from, again, a 20-megawatt industrial natural gas CHP system to 20 megawatts of utility wind and PV over a 35-year period based on that utilities long-term resource plan. The marginal generation, again, was estimated based on their long-term dispatch modeling of their regional resources and based on their integrated resource plan as filed with the state PUC.

It's probably hard to see for everyone, but in that text on the bottom left, the marginal generation for this utility is 95 percent fall in Years 1 to 4, 55 percent fall in Years 5 to 11, and then state-of-the-art natural gas combined cycle from Year 12 forward. And the analysis shows that based on this utility situation, and it's gonna vary all over the country, but their situation and plans, it takes 35 years for the 20 megawatts of solar PV to save the amount of CO2 that the 20-megawatt CHP system saves in the first six years. And the savings from CHP continues to grow even as the grid gets cleaner.

And again, this is sort of a demonstration that CHP is an important and critical part of saving CO2 now, and the question is what's its role in the future. And I think that comes from decarbonizing natural gas supplies for renewable natural gas, and for the longer term, hydrogen. And the next slide, just a little bit of background on that. So again, natural gas is a tool to produce significant CO2 reductions, natural gas CHP now and in the midterm. The question is what's the long-term role for CHP and decarbonization. And again, we think that role is using load and no carbon fuels to provide efficient and reliable energy services to markets and processes that don't lend themselves easily or cost effectively to full electrification.

And the chart on the right is from a 2019 report released by the American Gas Association Foundation that evaluated the potential for renewable natural gas, and in this case, they define renewable natural gas as a digester gas, biogas gasification, and green and blue hydrogen. And it looked at what could cost-effective resources, the amount of potential resources be for that combination of low and no carbon fuels in the future, again, focused on those three feed stocks, looked at the corresponding greenhouse gas reduction potential, and the estimated cost of bringing this RNG on the system.

Again, they considered RNG production from nine feedstocks in these three areas, anaerobic digestion, thermal gasification, and power to gas renewable, and green and blue hydrogen. Blue hydrogen, again being hydrogen produced from methane reformed with carbon capture. And I'll get into their results in a second, but to reiterate, current CHP projects, products currently operate routinely on biogas and hydrogen blends. Gavin mentioned the packaged e-catalog before.

Almost all these CHP systems that are in the e-catalog can operate as they are on up to ten percent CHP hydrogen. There are a couple of systems in there by providers that can operate currently, commercially available systems, engine systems, that can operate up to 40 percent hydrogen blend. And all the major manufacturers of both gas turbines, micro turbines, and engines are working on 100 percent hydrogen capable systems to be introduced in around 2030, plus or minus a couple of years.

The next slide, again, is sort of that AGA look at the resource potential for RMG in the coming years, and they focused in on 2040. And they looked at three cases, a low resource, a high resource, and a full technical potential. And looking at the high resource scenario here, you can see that in that kind of light blue bar in the center, about 4.5 TCF of renewable natural gas. That is enough gas that they saw as potentially available at competitive prices compared to other carbon mitigation approaches in 2040 and that 4.5 TCF represents about 60 percent of current industrial natural gas use, which is 7.6 TCF. So there is the ability to have a significant supply out there.

In a similar report, all right, in a report that the World Resources Institute introduced at the end of last year, they actually compared the AGA estimate to two other studies that were done earlier, and they were sort of in line. So there is at least the promise or the potential for significant resources in terms of RNG and hydrogen in the near future that could supply, again, critical infrastructure, industrial processes that might be difficult to electrify, and being a way for CHP and the efficiency of CHP to be an important part of the solution to decarbonization.

And particularly when you look at the efficiency of CHP and the ability to extend these sort of what certainly will, in the beginning, be limited resources, but being able to extend these low carbon and no carbon fuel resources because of its efficiency. I think that could be an important benefit and an important driver for CHP in the future.

I'll end with the next slide, please, which is just to show that DOE is active in this area. It is looking at where CHP can fit into a decarbonized future there. This is an example of an R&D project that was recently announced from DOE's advanced manufacturing office. It's a project with Caterpillar, National Renewable Energy Laboratory, and District Energy St. Paul, and it's demonstrating a two-megawatt flexible natural gas hydrogen CHP system at the municipal district energy generating station.

And the objective for this project really is to demonstrate the ability of the engine to accommodate varying blend levels of hydrogen in a commercially operating environment. It's to identify what are some of the technical issues, if there are, what are some infrastructure issues, operating issues of incorporating high levels of hydrogen blends into a CHP system and into a district energy system.

And this is just an example of the kinds of things that are going on not only at DOE but with major manufacturers in demonstration sites around the world, of gas turbines, engines, micro turbines, operated in real-world situations on higher and higher blends of hydrogen and natural gas, hydrogen and biogas, and 100 percent hydrogen that I think it really leads the way for a pathway of CHP providing CO2 savings, significant CO2 savings, not only today but well into the future, and providing, again, maybe more cost effective and with less difficulty ways of decarbonizing industrial processes and critical infrastructure as we move forward.

With that, Gavin, I'll give it back to you to next steps, in summary. Thanks.

*Gavin Dillingham:* All right. Thank you, Bruce. That was a great overview of some of the slides. The first time that I've seen them. Exciting to see all the work that's happening in the CHP and decarbonization space. If we go to the next slide there, we talked about the summary, and just to sum things up, I think one of the key takeaways here is really that CHP can be that low-carbon resource, it can help with decarbonization efforts. If your company has some specific ESG goals or climate emission reduction goals, CHP is really kind of able there to play a part to ensure both resilience, as well as emission reductions there.

And then overall, CHP waste heat to power can really be that resource that provides improved efficiencies, lower operating costs, and it really, in some cases, allows for greater improvement to the resilience of your power system or of your site to reduce those power disruptions that are happening there.

Next slide. Next steps. So key what we always like to discuss and point out is the resources that the CHP TAP can provide, and one of our key resources is providing no-cost technical assistance, and those qualification screenings, and really helping end users better understand what opportunities are available. We really work in at that very front stage, that very first stage when thinking about, "How does CHP potentially help me with operating cost reductions or how does it help me with resilience."

And you have a wide group of experts around the country leading these TAPs that can really help you better understand that piece. And you can really learn more of that when you go check out the July 1st webinar on seeing how CHP TAPs can support your work. I think that'll be a great way in which you can better understand the resources that are available and brought to you from the DOE there.

And so I think that's everything that we had to cover today and I think our next bit is Q&A. So open to questions.

*Thomas Wenning:* Okay, just as a reminder, folks, if you haven't gotten into slido, go over to slido and try to get your information or questions populated in there. We did get one other question that doesn't show up here, but it was sent in through a chat. The presentation and the recording for this will be up on the DOE's Better Buildings, Better Plants Solution Center, okay. So about a week after this, you'll get an e-mail and you'll be able to get access to the slides that Gavin and Bruce were showing today.

So we only have a couple minutes left here, so we'll try to knock out a few of these questions. And before I even jump into the questions, I will reiterate that the CHP TAPs, since you have about two minutes, we do have a handout if you look at the go-to webinar stuff. There's a nice little two-page fact sheet handout covering the CHP TAPs that Gavin was discussing, a really good opportunity for you.

All right, so first question here. Is there a calculator or tool available to calculate the carbon reduction potential when switching to combined heat and power? Gavin or Bruce?

*Bruce Hedman:* Yeah, I'll take that. EPA actually has a tool. If you Google EPA CHP CO2 savings tool, or CO2, or emissions calculator, it'll pop up and it's quite easy to understand, and straightforward, and it'll walk you through the process, if you're considering a CHP system and calculate the savings. DOE's Packaged CHP eCatalog (https://chp.ecatalog.lbl.gov/) has resource pages that will connect users to a number of DOE and EPA tools for CHP screening and emissions calculations.

*Thomas Wenning:* All right. Excellent, Bruce. Thank you. We'll just go down in order here for a little bit. So this one is in regards to the Texas grid going down through extreme weather and its impact on the natural gas supply and generation infrastructure. Gavin, I think you were talking about the resiliency aspect here, so how much of that, just a one-time, maybe a freak accident, versus something that needs to be considered elsewhere around the country?

*Gavin Dillingham:* Right. Well, that was just kind of an embarrassing event for Texas. We all know that natural gas systems can operate in extreme cold temperatures, compressor stations can operate in extreme cold temperatures, so that was a lack of winterization and preparedness by the state. It does not reflect the ability of the technology to be able to provide resilience to provide a resilient natural gas infrastructure there. There was some legislative action that took place in our last legislative session and just wrapped up in Texas that is going to require winterization and weatherization of key natural gas compressor stations that feed the power system.

One of the other things with a lot of that natural gas compressors there is a lot of it wasn't cut off to the end users, or to just smaller generators, or the CHP. A lot of that essentially was cut off to the large power plants, and so we had no issues with CHP operations that we're aware of in the state of Texas. It was mainly impacting the larger power systems that were out there.

*Thomas Wenning:* All right, excellent. Thank you, Gavin. And maybe one more question here. I want to cherry pick one of them so we can close up on time. How do we determine the preliminary analysis feasibility of CHP at our facilities before engaging with the CHP TAP? Is there a checklist? Are there screening tools? Bruce, you mentioned the EPA tool. Are there other open resources that you guys can recommend?

*Gavin Dillingham:* Would you mind if I get that one, Bruce, or you want it?

*Bruce Hedman:* No, go ahead, Gavin.

*Gavin Dillingham:* Yeah, so Bruce talked about the emissions calculator and that's definitely a piece that we actually run that for folks or people can run that themselves. But what the TAPs really act as is that kind of that first no-cost step. So before engaging the designer or engineering firm and MEP, people come to the TAPs and we talk through, okay, so what are some of your goals, what are some of the attributes of your site. And then we gather just real high-level information, some 12 months of utility and natural gas and electricity data, some operating parameters of your site.

And then within a few days, we can turn around a report there that essentially says, yeah, this is worth pursuing or not worth pursuing, and this is the economics that this site looks like. And we really kind of help with that very early stage piece so people don't have to go take the time and figure it out themselves or pay someone to figure it out themselves in that early step.

Once it looks like it's viable and something worth pursuing, we then can help guide them to find who's the appropriate engineering company, or the appropriate MEP firm, or designer, or provider that can then help them kind of work through the rest of the process there. So there is a site survey that we share that can kind of give an idea of what information you need to gather and what you need to be thinking about, so that's one thing we do typically before we do the analysis, and sometimes that helps people figure out what's most practical or not. But yeah, we're kind of that first step. We're here to really make it easy and simple to determine if CHP is a good fit or not.

*Thomas Wenning:* All right, fantastic. Excellent plug for the CHP TAPs here. I love it. Marissa, let's jump back over and close this thing out, and as we do that, I will mention that for the questions that were not answered or covered today, we will include those in the transcript at the very end. So we'll try to answer those and get those posted for you all, okay?

All right, so Gavin has mentioned this multiple times, and rightfully so. We have another really good webinar coming up here July 1st. Again, it's on combined heat and power. It's an extension of today and answering maybe some of the questions that were coming in here, so please take the time. It's on the DOE Better Buildings Solution Center. You can find that out there. I'm sure DOE will be blasting this out multiple times ahead of time.

So with that, Marissa, I think we can close out with the last slide here, which is really a thank you, and if you have additional questions, please feel free to reach out to Gavin, Bruce, myself, or the Better Buildings, Better Plants team at large. We want to help you on this journey. This is an important area for DOE. As hopefully you've seen, there's a lot of opportunity.

So with that, thank you, everyone. We appreciate you spending your time with us today. Take care and we'll see you all later. Bye-bye, now.

*Bruce Hedman:* Thanks, Tom. Thanks, Marissa. Thanks, everyone, for the time.

*Gavin Dillingham:* Yeah. Thank you, everybody.

# *Additional Speaker Q&A:*

*Better Buildings does not endorse or recommend any product or technology provider. The answers in this document are solely the opinions of the speakers based on their professional knowledge and experience.*

## Additional Questions

*Audience member*: Does the calculation of the carbon reductions account for methane loss in the mining of natural gas or just the on-site usage?

*Response*: The calculation included in the presentation is based on combustion emissions only for both CHP and displaced grid power and is the standard EPA approach used in calculating emissions impacts of renewable and energy efficiency projects. A full life cycle emissions analysis would need to include emissions from production, transmission and distribution in addition to final combustion for natural gas CHP and similarly the full life cycle emissions for all fossil fuel (coal and natural gas) on the margin for displaced grid electricity.

*Audience member:* With the long lifetimes of CHP, how do they fit into the mix if we are to decarbonization the economy completely by 2050?

*Response:* Existing CHP saves significant amounts of CO2 emissions now wherever fossil fuel generation is on the margin. Looking forward, there is growing interest in decarbonizing the natural gas infrastructure by developing renewable natural gas (RNG) resources and injecting this into the natural gas supply in increasing percentages over time. RNG is essentially the same fuel quality as pipeline natural gas so the efficiency and emissions advantages of current CHP systems will remain as RNG levels increase in the gas transmission system. For the longer term, transitioning the pipeline system to mixtures of RNG and hydrogen is an option to further decarbonize industrial and commercial facilities that will be difficult or extremely expensive to electrify or that need dispatchable onsite power for long duration resilience. Providing required energy services for these facilities through efficient CHP systems will extend the supply base of these future fuels. Most current CHP offerings can operate on hydrogen mixtures of 10 to 40%, and all major gas turbine and engine manufacturers are developing products that will operate efficiently on higher levels of hydrogen up to 100%.

*Audience member:* With some modifications the natural gas turbines should be able to convert to green Hydrogen. Is this already in preparation? What is the timeline for the transition?

*Response:* All of the major gas turbine manufacturers are developing 100% hydrogen capable models with most having a target date of 2030. There are numerous gas turbine systems currently operating on fuels with high hydrogen content (e.g., coke oven gas), and a number of 100% hydrogen demonstration projects underway (see https://chpalliance.org/webinar-hydrogen-fueled-combined-heat-and-power-systems/).