Kathleen Hogan: Well, hello everyone, and welcome to the 2021 Better Buildings Better Plants Summit. I'm Kathleen Hogan, the Acting Undersecretary for Science and Energy at the Department of Energy. And thank you for joining us today. We really have a wonderful session for you, fantastic speakers, which I will introduce in just a moment. But first, I want to run quickly through how this session will work.

Attendees, you, will be in listen only mode, meaning your microphones are muted. And certainly, if you experience any issues, audio, visual, please send a message in your chat window at the bottom of your Zoom panel. But this will be an interactive session. We want your questions, we want your feedback, and we'll be using an interactive platform called Slido for question and answers, polling, and session feedback. So please go to slido.com using your mobile device, or by opening a new window in your Internet browser, quickly find today's event code, #DOE, and after that select today's session title in the drop down menu in the top right, that session title being Emerging Trends and Technologies from DOE-s National Labs.

And if you have questions for the panelists, please submit them in Slido at any time. Just get them loaded in there, so that we can be ready to go. And we will answer these questions a little later in the session, about halfway through. And again, if you have any issues, please message Tech Support by using the chat function in your Zoom panel. And finally, just so you know, the session will be recorded and archived on the Better Buildings Solutions Center.

So onward. I really am delighted to be here with you today as part of this panel. This session is always one of the highlights of the summit, and we're glad all of you can be here with us. As we all know, we've got very ambitious goals in the coming years for energy efficiency, clean energy. And here in this session we can look toward the future and the possibilities that it holds.

Let's just think about some of these goals, net zero carbon economy by 2050, carbon free electric grid by 2035, deeply de-carbonized buildings, transportation, and industry, with a strong, U.S. competitive, clean energy manufacturing effort, good quality jobs, and providing benefits to all our communities, really emphasizing equity and justice. To achieve these big and really critically important goals, we need leadership, leadership everywhere we look, leading examples, so that … and that is why we're all excited to be here with you, exploring what we can do together, and exploring what you can do, as well, as you continue to define and showcase your leadership.

So now we're gonna talk with three leaders from three of our national labs, and we will ask them to talk about several things, two or three, that they're most excited about, and how these things have the possibility of being game changes for you, your organization, and the way we use energy in our buildings, homes, and manufacturing plants, really throughout our economy.

So this is gonna be hard for each of them. We're giving each of them only seven to ten minutes to do these … to present this really great information, but we really also want to leave time for your questions, too. So again, please make sure you use Slido and become part of that conversation.

So without further ado, I will introduce our first panelist, Martin Keller. Martin Keller's the Director of the National Renewable Energy Lab where he's been since 2015, where he applies private sector best practices to achieving game changing scientific outcomes. His strategy for driving NREL's work, along with his leadership team focuses on three key initiatives, integrated energy pathways, the circular economy, and electrons to molecules. Martin, you're on.

Martin Keller: Thank you, Kathleen. So, thank you to all of you, wherever you are, and I'm glad to walk you through what we want to talk about in the building sector. But I just want take one, the key message away at the beginning, and you see this already also in my presentation in the slides, so buildings will be vital to achieve the 2035 clean energy goals. So we cannot do without buildings, and I hope I can explain this to you, why. It's, from a research perspective, super exciting what's going on in the building side.

So the next slide, you're seeing just a couple of highlights about NREL, just in case you don't know us. So we have about 3,000 people. We're having a very nice facilities. We are in Golden, Colorado, and focusing on energy efficiency, renewable energy, and achieving energy transition.

So the next slide shows you the so-called megatrends. So what I want to show, I think you … yeah, perfect. Thank you. So there is things like cyberthreats, electrification, and so on. I just want to highlight a few of them which are also critical for the energy transition, especially related to buildings.

The next slide shows you this so-called population growth. We all know we're dealing with a big population, 2050. We have about 9.4 billion people. We're using much more resources than our planet provides. And again, a lot of these people, as you can see on the next slide, are moving into an urban setting. So every week, 1.5 million people move into a city. So the question is, how do we keep this city livable? How do we provide the resources to the cities? How do we create energy, the water, the food, and so on? So a big challenge, a lot of good opportunities also to increase our infrastructure needs across the planet, but also cities will be the big focusing on the energy transition on the change.

So the next slide shows advanced mobility. And again, this is now where it's getting very interesting because suddenly, historically transportation was always uncoupled from buildings. And now we the electrification of our transportation, now suddenly all this morphing together, and you also will see how this will change our grid architecture because of this.

So the next slide shows you how our electric power system is changing. So currently we have a large central station, synchronous generation, a central control point. We have dispatchable generation, which follows the demand. The future of the power system will be much more variable, more power electronics, more information, and more distributed. So when you see that, for the decarbonization, we will see an increased level of wind and solar and variable power electronics on our grid. We see the digitization, I will come back to this one, is run through big data and information. It will be much more distributed and interdependent. And again, this would bring a lot of challenges to the grid of the future.

So the next slide shows you that there now where buildings come in. And especially behind-the-meter solutions will be an integral part of the future energy solutions. So that's where we move into, that everything will be integrated. We have our electric vehicle, we're charging them, we have our battery storage, we have thermal storage, we have solar panels on our rooftop, all this behind the meter will be … so the grid on the edge … will be key for the future system, and how we're integrating all this together.

So the next slide shows you just one slide to see that the grid interactive, energy efficient buildings research at NREL. We feel that this is very, very critical and vital again to reach our 2035 and 2050 goals. So we are working on developing building technologies and controls that reduce energy consumption. We're developing new thermal energy storage materials. We're developing trans building construction methods, and so on. And especially very important also, the skilled workforce. This will be a big challenge, I think, for us in the future. How do we train the people who will actually will keep all this function operational, not only from the installation, but also from the service sector side. So this will be a very, very large challenge for us in the future, I think, here in the U.S., and I think also globally.

So the next slide shows you now how all this is tied together. So historically we work on single buildings. We put smart thermostats in our buildings and we managed the load and energy consumption within our buildings. But now we're moving this out to neighborhoods, from there into community and towns, and from there into large city. All this will be interconnected, which will be a great opportunity, but it's also a challenge how we accomplishing this. So the community scale solution is where we're now moving into this connecting different homes together. To go from some individual homes and family, then we're connecting them together with what we call here the community aggregator, and certainly 500 homes roughly will be connected. And this will be a tremendous opportunity to manage the building loads, and help the utilities also to manage the loads on our grid. The key is also the challenge, how to integrate all this together from one building with smart meters, thermostats, water heaters, battery storage, distributed PV, from one building and connect non-elective communities, like 500 buildings within a subdivision together to then go and correlate all this up to the big cities.

The next slide shows you where this will go. So, what we call autonomous energy grids. The future of the grid will be so complex, and will be so many controllable devices on our grid that the traditional way of controlling our grid will not work anymore. It will be autonomous. It will be done by machine learning, by smart algorithms. And this is the challenge, again, how do we develop the algorithms to do all this and also how do we keep it safe? How do we keep the bad actors away, where they come in through a solar panel and turning our lights off? And this is where cybersecurity will play a major role in the future grid architecture for us.

The next slide shows you, when you look at just right now, the Bay Area. And this is, again, what we modeled and simulated in one of our high performance computer, and asked the question, so if everybody in San Francisco Bay Area has a TV, a storage in batteries, electric vehicles, smart thermostats, smart appliances, and so on, alone in the Bay Area, we're talking about 10 to 20 million controllable devices. So 20 million. When you talk about this, the current grid, the eastern grid, is controlled with about 10,000 control points. So alone, the Bay Area will have 10 to 20 million controllable devices. This is where the challenge will come in. This is where we need new algorithms, new ways how we actually control the grid architecture in the grid of the future.

So the next slide, so I think you're a little bit behind. So if you go to, yeah, one further, please, to the ARIES slide. So now the really interesting thing is how do we connect all this together? How do we bring the modeling, the simulation, and then how do we take all those devices through emulations where we take live data from different equipment and bring this together that we can actually check and make sure that the new … the algorithms we develop in working on devices work. And this is what we're working on, the so-called ARIES platform. So this is bringing together our energy systems integration facility, which goes up to 2 Megawatts, will basically can simulate different appliances, electric charging vehicles … you can see on this picture there. And then this goes up to AIRES, which is then 20 Megawatts, where we have wind turbines and solar panels, and battery storage and electrolyzed, produce hydrogen. So you can take all this together through emulation where you then can model and simulate this live data from different equipment to a size which is behind a substation to be ready for the utilities to then roll this technology out to the market. So we are very excited about this new investment ARIES will bring to NREL, because this will be the platform to integrate all these different technologies together.

So the next slide, please. Shows you one other big thing, what we have done lately, and you might have seen this. And if you have not seen this, I encourage you to look at our website under the LA100 study. This was a big study in Los Angeles, where Los Angeles came to us and said, "What will it take to go to 100 percent renewable energy? What can we do?"

So this study, where we did over 100 million high performance computing simulations, where we modeled every rooftop to see if it can take solar panels on there, where we modeled the transmission lines, where we modeled electric charging station for cars, coming to this conclusion that yes, we have a couple things where we still have to figure out how we doing this, but there is a path in LA to 100 percent renewable energy.

And what was also very interesting on this study and this is also working very deeply with the communities … and we'll come back to this one in next slides … but also brings up cost to the consumers. So by going through all the different scenarios, we also can now predict what the cost would be actually back to the consumers. And it also will have into the models, the kind of resilience of power grid, what will happen by having this more distributed system with wildfires and so on.

So I encourage you to look at our website. This was once a lifetime study which is very interesting. And now the question is, how can we role this type of implementation plan out across the whole United States?

So the next slide shows you now the big thing which also the Biden administration and Kathleen brought this up, to see how we're doing this in the energy justice? How do we bring everybody around in this energy transition? Historically, when you look into research development moving to demonstration to deployment, a lot of times we are really not doing this demonstration, deployment, and the research with a focus of underserved communities. And this is, again, where we need to do a better job right now to also look into these communities, work with these communities to bring them along in the energy transition.

So the next slide shows you one of the so-called trickle down energy research what we normally do. A lot of renew research we're doing shows a new subdivision where we're looking into the kind of people who are first out there to see, wow, whether they want to have solar panels on the rooftop or they want to have a new thermostat in the house. So a lot of times, when you're focusing on the research, on the first adopters of some of this technologies.

But we also need to look into the historically marginalized communities and work with them, and design research and experiments also for these communities, because it's very different if you have a new subdivision to make the transition, or if you're going to underserved community and ask them about the energy transition. So this is something where we really have to put much more focus on, to bring everybody across this energy transition.

And then the next slide shows you the Clean Energy Transition Implementation Plan. So the key is we see how do we do what we learn from LA, what we learn from our work for some of these different communities in rural settings or also in the cities, we have to do stakeholder engagement. We need to work with the people and bring them along, and then have to integrate this with analytical insights, models, and tools. We have to create solution and technologies to bring the cutting edge technology there. We have to create action plans and implementation plans, again what I also showed you on the LA100 study. It's not enough just to do some of the modeling, we also have to create this into an actionable plan. And then we have to do a community driven national impact.

So this is a big challenge. I think that's also what Kathleen said, it's very ambitious goals. I'm very optimistic. I think we can achieve this, but it will take everybody. It take all people on deck to get this done, from all communities across the United States.

And the next slide now shows you that partnering with industry is in our point critical to accomplish this. The next slide shows you that this is in the transition, this is where we can create great American jobs, we can boost the U.S. economy, and we also can strengthen our energy security. But it has to be in new teams. We have to form new public/private partnerships to really accelerate the energy transition.

So the next slide shows you a couple of our big partnerships. As you know, we have a lot of partnership at NREL. I think they are critical. I talked about the LA100 study, which was a wonderful partnership with LA to accomplish this. So we have a very encouraging partnership with Dallas/Fort Worth International Airport, which also goes towards electrification, the connectivity of new airports and transportation systems. We're working with companies such as Eaton, which are actually now located at our facilities. And we're also working with companies like Wells Fargo to do some incubator space. And again, I apologize, I switched the two texts between Eaton and Wells Fargo.

So, I want to give it back to Kathleen, so in the next slide I want to say thank you. So we have a lot of things ahead of us, so we have to get going. Time is of essence, but I am very optimistic we really can do this. And again, I want to say buildings will be the centerpiece. They will be the integrator of bringing all these technologies together. So thank you. Kathleen, back to you.

Kathleen Hogan: Martin, thank you. Fabulous job. I think I have time for one question here of my own for you. You spoke about a very different world, a different, a changed energy grid with these buildings at the center in this country. And you talked about something that … where we would be going in any number of years. But what is it you think people should really be focused on today, as they get ready for this rapidly and very dynamic changing space?

Martin Keller: Yeah, I think you said it's changing rapidly, and it's very dynamic, and it's very fast moving. So I think for everybody in this industry, I think it's really important to keep up where the technology goes. So I think it's very, very important that we … through meetings like this, honestly, is where we are building the network, we'll be knowing where the technology goes, where we're starting to transition our buildings, that we're having this in mind that they all will be connected, that we are starting to bring this technology into our buildings, and there is so-called low hanging fruits, and we'll talk about this to make it more energy efficient, and be moving this along. And I think that's very important.

But then we also need to prepare our buildings on the side to be able to accept some of these new technologies from a smart thermostat to, for example, charging stations, especially if you're working in the industrial sector. Every, sooner or later, maybe if we have, let's say, a shopping mall, there will be charging stations linked through this. It will come. So what can we do right now to really prepare for this transition? Because everything what we are seeing is that this is accelerating and, for example, when we talk with companies such as Eaton Corporation, or Siemens, or Schneider, to name a few of these players in the sector, this is super fast moving. And I think we need to be alert what's coming down the pipe, that the people in the sector know where the technology goes, being informed, training our people to accept some of these new technologies, and getting our buildings ready to start installing some of these new devices, because, as you all know, what you've seen in the transportation sector, the electrification will go pretty rapidly.

And so, we in the building sector, we have to be ready to have our customers who want to charge their cars in front of our buildings, as an example. Or, if you build a new subdivision, it will be a lot of … the houses will be electrified. So it is coming. It's coming fast.

Kathleen Hogan: Well thank you. Let's move to our next speaker, and that is Angela Becker-Dippmann. Angela is the Director of the Pacific Northwest National Laboratory Energy and Environment Director, its Program Development Office. And here she evaluates policies and programs to help insure the most impactful outcomes for the lab. She's been with PNNL coming up on a decade, with a little time out in the middle to serve as the staff director at the U.S. Senate Committee on Energy and Natural Resources, a committee that had jurisdiction over many of DOE's programs, as well as U.S. Department of Interior. Happy to have you with us today, Angela. Take it away.

A. Becker-Dippmann: Alright. Well thank you. Thanks, Kathleen, for that introduction, as well as to the Better Buildings team who invited me today to talk about some of the cool things we're working on at the Pacific Northwest National Lab.

So, I think, first off, Martin laid out a really very compelling vision of what the future likely will look like. And we very much share much of that vision at PNNL. So I want to spend a little time describing the way we're partnering with industry to operationalize some of these smart, integrated building concepts for the commercial sector on the ground. I'll also touch briefly on a couple of other concepts, more and more central to building operations, namely resilience, cybersecurity, and also what we're learning about viral transport in buildings, on the heels of COVID, as we consider not just efficiency, but health related outcomes in the built environment. So next slide please.

So in the Pacific Northwest, we've got a pretty rich policy driven policy history of energy efficiency savings as the resource of first resort. And today, enabled by advances in building materials, sensors and controls, and again, a supportive policy environment, we're taking the next step toward grid optimized net zero energy and zero carbon buildings.

Here you can see an illustration of the South Landing Ecodistrict in none other than beautiful Spokane, Washington. It's been developed through a joint venture between Avista Utilities, the local utility, and McKinstry, which is a Seattle based construction and engineering firm. The South Landing development is, at present, comprised of two commercial buildings, of just about 200,000 square feet, combined. The larger, five story Catalyst building, is gonna be occupied by Eastern Washington University students come this fall, alongside commercial tenants. The smaller, four story Hub building is gonna have the least space, but also the central energy plant, pooling and distributing energy to Catalyst, and eventually to other buildings as the site is more developed.

So, from the outset, the vision's been to lower the carbon footprint at every stage in its development. First off, the developers took some different construction approaches, rethinking supply chain management, basically. And in terms of building materials, every effort was made to replace … to lower embodied carbon by replacing steel and concrete where possible, and replacing it with locally and sustainably sourced cross laminated timber, for both structural materials as well as factory fabricated tip-up panels.

In terms of on-site energy management, which is the stuff that gets PNNL researchers and Martin's researchers at NREL super excited, the project relies on solar PV, and both battery and thermal storage, along with managed EV charging capability. It's also leveraging high performance air handling systems that can be configured to meet fluctuating demands from occupants.

For our part, PNNL researchers, in partnership and with the support of DOE's Building Technologies office, are demonstrating new, integrated and interoperable control approaches for the systems within these buildings. Those approaches are designed to coordinate the systems to respond to the needs of the local distribution system. We call this transactive control, which is a new approach we've developed on our own campus, and in connection with other DOE grid modernization projects in the past. I guess transactive control is sort of a fancy term, but at its heart it reflects the merger of economic theory and control theory, to manage building systems to deliver more comfort, operational efficiency, reduced operating costs, while enabling automated response to a incentive signal from the local utility. And the idea here is to move from traditional demand response paradigms to autonomous demand management. And our ultimate goal is to design control approaches that are gonna be turnkey solutions, broadly available, as opposed to the custom jobs currently require for this sort of functionality.

And then, in this particular case, the eventual plan is to extend this grid responsive capability to the neighboring community served by the same substation as the South Landing development. And that's gonna include two economically disadvantaged neighborhoods in Spokane. And Martin talked earlier about connecting residences. For our purposes, we plan to start with commercial and light industrial loads, in terms of being able to access more flexibility.

In addition I'd mentioned we're working with the State of Washington through its Clean Energy Fund, essentially to examine rate and tariff structures and different use cases to explore different potential services this shared energy model will provide, and importantly how best to properly and equitably value those services. So we're really excited about the potential future for this model, especially if we're successful in doing this at cost on par with the market for commercial development, which is the goal.

So, I also just want to mention a couple of other areas where we're making advances with respect to refining buildings operational strategies, so next slide, please.

One is resilience. In trying to better understand and quantify the cross cut between efficiency and how it can contribute to resilience building operations. Today our building codes put a value on things like fire safety. So the question we're assessing and asking is can we put a value on measures that enhance both resilience and efficiency? So we're exploring the kinds of trade off analyses that may result in better buildings at lower cost … that are lower cost to operate and more resilient to events, including high water, high winds, and flooding. Next slide, please.

As we're evaluating these evaluation metrics, we're also, in collaboration with the Federal Energy Management program, or FEM, developing a suite of tools to help assess risk to a site's critical functions from disruptions in energy and water utility disruptions, essentially. Then we can use this assessment to help prioritize solutions that reduce the most important risks. And again, so far we've piloted these tools on our own campus, and we had plans to do this at six different federal installations last year, but we were pretty limited in that by travel, so those efforts have been mostly virtual, so far. So as this suite of tools matures, we really do hope to work with the Better Buildings community to exercise them in the commercial context. Next slide, please.

In a very similar vein, we've been working on developing methods for assessing cybersecurity in buildings and the systems within them. This goes hand in hand with the use of sensors and data to automate building controls. So we started with best practices that had already been developed by NIST and ASHRAE, and frankly, the Department of Defense. And we created a framework that provides a sort of heat map for a facility or installation that points toward the kind of cybersecurity considerations you might want to prioritize.

And from a federal perspective, it allows agencies to compare themselves to other agencies, or compare buildings across their portfolio. And again, in the case of the cyber and resilience goals, we probably, honestly, have another year or so of ground truthing, but they're both areas where we hope to work with the Better Buildings community, and would love to know your thoughts on how to make these tools most accessible and valuable to commercial building owners. So next slide, please.

And then finally, in this day and age, where would be without mention of global pandemic? As it turns out, factors impacting the ways viral transmission can occur in the built environment, were not all too well understood at the outset of the COVID crisis. And interestingly, it's one of those areas where national labs were uniquely positioned to help make a crash course effort to help figure it out. In our case, in particular, I can say we had a former epidemiology professor working down the hall from buildings engineers and HVAC experts.

So in addition, in the first month of COVID, we definitely heard tell of utility bills on the upswing due to spending on added air flow on campuses and buildings, even as they were mostly basically vacant. So our initial modeling, though, tells a bit of a more nuanced story, really. While outdoor air circulation and filtration provided expected benefits, it turns out vigorous and rapid air exchanges withing multi-room buildings are perhaps not always a good thing. And the study suggested, this modeling has suggested that these rapid air exchange can quickly spread a virus from a source room into other rooms at high concentrations. Basically, like how second hand smoke spread from one room to another back in the day, which is actually kind of intuitive.

COVID particle spikes in adjacent rooms could occur within 30 minutes, and remain elevated for up to approximately 90 minutes. So we're working with Berkeley and Argonne National Labs on some more experimental studies to help complement the modeling. And so more to come on that. But certainly it underscores a growing understanding, really, of the link between health in the built environment, which is a trend we expect to see continue through our work and partnership with the Department of Energy and the Better Buildings community. So, I'll leave it there for now, and thanks for the invitation, once again. And I look forward to the discussion.

Kathleen Hogan: Great, Angela. Covered a lot of ground there. A lot going on, and let me just follow on with the health thread. As you said, it's really so important right now. So what would you say mangers of buildings and plants across the country, what should they really be paying attention to with the health concerns in our built environment, and how can they get started today on a good foot.

A. Becker-Dippmann: Yeah. I think certainly there is the issue of viral transport that has been incredibly important over the last 14, 15 months, for sure. And another factor we've been thinking about here on the west coast in particular is, air handling, in the context of a changing climate and forest fire, and understanding the nexus between air quality and air handling and efficiency, where I think we've probably got more work to do in collaboration with the commercial building sector to understand all those dynamics.

On a more optimistic note, I guess you could say, one of the areas we're really excited about is the work we're doing on advanced lighting solutions, and essentially the health and productivity related impacts of tuneable LED lighting, where we're beginning to understand the physiological and psychological benefits of tuneable lighting solutions. And again, the solid state lighting program at DOE has been central in beginning to understand the connection between these factors. So that's an exciting area as well, I think.

Kathleen Hogan: Absolutely. Well thank you. So let's move on to our third panelist today, Tom Kurfess. Tom is the Chief Manufacturer Officer at Oak Ridge National Lab. From 2012 to 2013, while on leave, he served as the Assistant Director for Advanced Manufacturing at the Office of Science and Technology Policy at the White House, where he coordinated federal advanced manufacturing R&D. He was president of the Society of Manufacturing Engineers in 2018, and is on the board of the governors of American Society of Mechanical Engineers.

So his work spans digital manufacturing, additive and subtractive processes, and large scale production enterprises. Tom, … mute. You're …

Thomas Kurfess: Like we haven't done that before, right? Thank you, Kathleen. Anyway, so thanks very much for the intro. I'm gonna talk about manufacturing. And really, the title of my talk, it depends on how you want to look at it. Punctuation's critical. My kids tell me that, so just look at the sentence, let's eat Grandma, or let's eat, Grandma. These are critical things. It's the same thing with manufacturing the future. Manufacturing, the future, or manufacturing the future. And it's really about insuring both prosperity and security in the United States.

So, let's take a look at, first of all, I want to thank some my colleagues, Dr. Tom Feldhausen, Dr. Kyle Saleeby, Dr. Vincent Paquit, so we're really bring together, we're gonna be talking about hybrids, so this is both additive and subtractive manufacturing, digital and security. So you heard about cybersecurity, we'll mention a little bit about that. And then a lot of the AI. So a lot of the digital stuff really drives a lot of artificial intelligence machine learning. So … And, of course, thanks to our colleagues over at the Department of Energy for funding the laboratory.

So, in terms of our operation, we're really about … our unofficial mantra is innovating faster than the competition can copy. And really what we're about is taking whatever the latest and greatest technologies are that are out there. And there maybe very nascent, so maybe bench top type technologies, and working with … and this is very important. We're working with a partner, whether an industry partner, or government partner, to take that technology and scale it so that it's at production level. So if you're familiar with the technology readiness levels, going to about a TRL 8, which is something like a pilot plant, but really taking technology, scaling it up rapidly.

And I'll talk about our plants, but I will … I know this is Better Buildings. I'm thinking about better plants here, but I will talk a little about some building stuff, as well. So that's coming up. So the bottom line is, with not these connected factories, but they're looking a little bit different than what we had before. And the connected factory really has a backbone and it's using commercially available communication capabilities and so forth. So the machines might be connected up. In fact, machines that are even produced five or ten years ago with state of the art controllers, they will have capabilities like MP Connect, which is a communication standard, or OPCUA communication standard, and they can be connected to the network and get all sorts of information out. In fact, really, the experiments that we might have run 30 or 40 years ago, where we put sensors on machines and then ran experiments and analyzed it … and this would have happened over months … those sensors are out on the machine. And so those data are freely available. You just have to tap into them, and then make use of it.

And then you have things like Google Cloud, and so forth, or Azure, and so forth, that are easy to get to. Some of them, if you think about Google, you've got 15 GB free. So there's a lot of capability out there that people can tap into. And we'll talk about how you might use some of that.

So, let me give you a really simple example. This is a company we're working with, and they produce turbine blades. They don't make a lot of turbine blades at once, it's just a replacement blade. So maybe one or two of the same blade, and that may happen once or twice a year. And so one of the things they were curious about is, well, how long does it take me to make the blade? So we said, "Lookit. There's a plot of your spindle RPM. And that's just coming directly off of the machine. And that spindle RPM just tells you, yeah, the machine is running. So while it's running, I'm making the blade. While it's not running, I'm not making the blade.

So in this particular case you see two different blades being made. And that'll tell you the production time for the blade. And so, over the course of a year, we might have made 10 or 15 or 20 of these blades, and we can get an average and standard deviation for those blades. Well that's great. And so now we have information on production capacity. So what's really interesting is I looked at that blank space between two blades, and that tells me the setup time for the second blade. Turns out the setup time is the bigger amount of time in this particular instance. And what we found, actually, when looking at the setup time for an individual blade is the standard deviation, the variation of that setup time was all over the place. It was really big. And, look. Hindsight is 2020. What we learned is if those two blades are similar in nature, then the setup time is small, because they don't have a lot of tooling changeover. If they're very different, the setup time is big, a lot of tooling changeover. And again, hindsight is 2020. So that's fantastic.

But the company didn't think about this, because you'd never really looked it in this fashion. But the data were there. They were free, they were there, they were available. We saved them 17 percent downtime on their systems by taking a look at this. By the way, if those machines … and those are relatively new machines, maybe five years old or so … if those machines were legacy, we could have just put a little accelerometer, like on your smart phone, and that's a few dollars for the accelerometer.

So the machine's vibrating, making a part. The machine's vibrating, not making a part. And the cost of that smart sensor … and, by the way, we would have something like an Arduino in there and the whole bit, and just to calibrate you, putting Neil Armstrong and Buzz Aldrin on the moon, 8K of RAM. Not 8 Gig, not 8 Meg, but 8K of RAM. So these systems today that you're get today for 10, $20 that your kids are programming in junior high and high school, much more powerful than what it took to put people on the moon.

So anyway, so the sensor plus the processor, so a smart sensor, battery, and an enclosing box, probably about 30, 40, $50. In fact, the most expensive part of that whole smart sensor setup, just vibration testing and then sending the information out, is the box. So not the sensor, not the processor, but the box. So these are the types of things we think about.

Let me go a little bit further, because they said, "Hey, talk about additive manufacturing, so 3-D printing." I'm gonna talk really about hybrid. So think about a machine tool now where I can print the material down … in this particular case we were putting down a weld bead, so you can see they're kind of rough looking. And then we're gonna machine them nice and clear. But what it allows us to do, if you take a look at this on the picture on the left, this is a five axis machine, so we're printing this propeller. We don't need any support structures, because we can rotate. You'll see in the videos, in the next one, really how we're printing some of these out. But we can print it out, and then we can machine it to the final shape. Really saves a lot of energy, because now I don't need a big block of steel that I had to create. I can put the steel down just as … in the areas that I need, and then machine it to get my final finish.

So if we take a look at the next slide, so here you can see that's just a simulation of printing it … but we're printing this paddle wheel, and you can see that our fifth axis is actually rotating, so we can print without the support structure. But there are a couple of things we need to think about. For example, if you take a look at that picture right next to it, you can see the trajectory, or the slicer and so forth. When you're on the inside of that curve, you have to print less material.

So again, it's not thinking exactly like your little home printer. It's a little bit differently. And, in fact, I'm gonna show you a picture, you can see that little, what we call the little loving cup over there. It's got the curved surface. Instead of slicing it in planes, we're actually slicing it in arcs. And as we go to the next picture, we'll show you actually printing that particular curved surface. So this is now a thermal image. So we're printing with thermal imagery as opposed to visible imagery. And you can actually see how we're rotating the entire part to make sure that we're printing straight down, so that molten steel doesn't drip off anywhere. And this is how you would print a part.

The other cool thing about this is we're spinning around. So we're printing it up in terms of a spiral, as opposed to back and forth in terms of how people think. But the neat thing about this now is we can do some pretty interesting things. So one of the things that we've really learned is we've said, "Well, hey. If you do a lot of printing, it generates a lot of heat." And so the deal is, okay, if you have too much heat, and you can see all the way on the far left, that's particular one is just printing that … it's a wall, but we're really, it's a surrogate turbine blade, we're printing turbine blades. That's a printed, functional turbine blade that spin in a hot gas path. If you print it, it gets too hot, the blade, and then the wall starts to fall over and so forth, and it doesn't look particularly good. So what we do is we actually measure the temperature. We've got a thermal camera there we're integrating. And this is using standard technology that's available today. We're integrating it, and basically when we print a layer, if it's too hot, then we have a little bit of a lag. We actually don't print the next layer until it cools down. So you can see now, you can see that second image on there, that it's printing much faster, and then it slows down.

Now, of course, people get upset because they're saying, "Well, that's inefficient." So, in fact, the good doctor Saleeby turned around and said, "Well, hey. Look. If one blade's too hot, let's just print two blades at the same time." So what you see in the picture over on the far right is basically we're printing very rapidly. When one blade gets too hot, we go and print a second blade. So now we have complete utilization of the machine for really … to optimize our process. But again, these are systems that are commercially available, but we're integrating more advanced sensors.

Now, as I mentioned, I said, "Well, hey. Look. This is the Better Buildings program, so I'm gonna show you SkyBAAM. SkyBAAM was just 3-D printing with concrete. But now, instead of using a big gantry, what people have seen in the past, what we're doing here is, if you think about Skycam from a football game, the bottom line is, is instead of a Skycam that's cable driven, we're actually driving the concrete printer. So we're pumping concrete into this printer, and we're actually printing this wall. This wall is actually cool, it was a Department of Energy project. You can see, actually, the red there is where heating and cooling going through the walls. We have sensing in the walls so we can tell what's going on with the temperature and so forth.

And it's very environmentally sound. You're putting forward a really nice concrete wall, and looking to put in carbon capture, carbon dioxide capture with these types of walls and so forth, but again, very flexible. Takes about a half an hour to set this system up out in the field, which is great. And where we get our … here we're using an overhead crane, but we're partnering up with one of our partners, Oshkosh, to use a sky crane, actually, to support this out in the field. So about 30 minutes to set up.

So, look, before I wind up, one of the things I do want to mention, and this is a question that often comes to me is, hey, all this automation, it's the robot and the dishwasher. Where do we get the robot that's gonna load and unload the dishwasher? I gotta tell you. People are not going away. If you've worked with robots before, and you're a Better Plants person and so forth, I would not trust that robot with my fine china. And so that robot, so stacking and so forth … and so again, robots sometimes have a hard time putting a round peg in a round hole. You want to stack the dishwasher. This is difficult. For I want to inspect the plate, yeah. Do I need to pre rinse it, and so forth. So people are awesome. You're not gonna replace people. So you're gonna get rid of the nasty job of washing the dishes. And that's the key thing, here. So it is about workforce development and training.

So just a couple of key points as we start to wrap up in terms of big picture. And, by the way, what I'm showing here is Medusa. So this is a three robot system. There are three robots going, and then you gotta big turntable down there at the bottom, and you're actually printing a very large part. We can print parts that are a couple of meters in diameter, and several meters tall, and so forth, with this one. So, again, some really crazy, next generation type of systems.

But the bottom line is that those systems, they can get the data out, and we can get latest and greatest information to the systems, digitally connected. You've got to do it in a secure fashion. I haven't talked about linking securely, but it is important that you like securely. We have an entire, new institute, CyManII, the Cybersecurity Manufacturing Innovation Institute, supported by Department of Energy, that really talks about how do you make sure your plant is secure.

Now, what the digital thread what you're seeing is to rapidly deploy the latest, greatest technology. Not only the technology to the plant, but also to the people using it. So we're looking at things like augmented reality, virtual reality, and so forth, and really leveraging that whole Cloud and Fog and Edge. Edge is processing right there at the machine. Cloud is, of course, I think people know that. And Fog is where the Cloud touches the Edge. But again, highlight. We've got to weave in cybersecurity. And this will make sure that we can protect our proprietary information. And we really do need to support … and that does support the overall ecosystem. So this is good, not only for the big players, the primes, but all the mom and pop shops that make the nuts and the bolts that go into every airplane and every car that is out there.

And so, what I'd like to do here is basically just to close with my favorite statement from a twentieth century philosopher, because it really is about our workforce, and that is, it's by Eric Hoffer, "In times of change, learners inherit the earth; while the learned find themselves beautifully equipped to deal with a world that no longer exists." And I think that that's really important. It's not just about next generation workforce, but it's about keeping that current generation workforce well tuned, so we can continue support U.S. manufacturing.

Thanks very much for your attention.

Kathleen Hogan: And thank you, Tom. Again, a lot of ground that you just covered there. But let me just ask you one question, 'cause we're talking about technology, and again, rapid change. So what do you see as the largest obstacles to the rapid deployment of some of the technologies you're highlighting, and what are we gonna do to break these obstacles down?

Thomas Kurfess: I think the two biggest obstacles, one is gonna be cybersecurity. And that is, we just have to make sure that we're secure. And again, it's not just thinking about, "Well, let's put up a wall … well, first of all, you can't say now I'm gonna unplug everything. We're not gonna plug stuff in. Imagine your life without a smart phone today. It's just not gonna happen. So, you gotta be plugged in, and it's not an issue of putting up a wall, but you've gotta … just like I said, innovating faster than the competition can copy. On the cybersecurity side, we have to stay one step ahead of our adversaries. And, by the way, just to point out, 30 percent of all cyber attacks in the United States are against manufacturing facilities. And most of those cyber attacks are not to break in to machines and destroy machine or mess with processes, but to steal intellectual property.

The second thing that I really think we need to look at is to make sure our workforce is really spun up. And what we're talking about, in terms of technology, is not just training the next generation workforce, but making sure the current generation workforce fully utilizes these systems. To give you an example, think about it. You want to go out for lunch. My mother, she's 82 years old … probably shouldn't have said that to 8000 people … but look. She can bring up her smart phone. I'm gonna go to lunch, bring up my smart phone, and see if I need to bring my umbrella. She is accessing a constellation of satellites generating terabytes of data that are integrated with other terabytes of data from ground based Doppler radars into our latest super computing models running super computers to give you that weather map that says, yeah, bring the umbrella or no. And so look it, if she can do all of this type of stuff, we should be able to put together the right type of training and apps and so forth so that our current workforce can really leverage what's out there. And I think that that's it. Making sure that we really match our workforce with our capabilities, whether it's next generation or current generation. And that's gonna keep us at the leading edge, and keep us dominant in advanced manufacturing.

Kathleen Hogan: Thank you. Thank you very much. And actually, thank you to all three of our speakers, our panelists this morning, for kicking us off here, and sharing your insights today.

So, we're gonna turn right now to our attendees, and give you a little bit of a challenge before we move to question/answer. So, we're gonna have a quick poll, and do this poll. Can you tell us, what are you looking to next, as a promising new, decarbonization effort? Now remember, we're doing this on slido.com. So go to the event code, #DOE, and to the room Emerging Trends and Technologies, to join this poll. We can't … very interested to see what's gonna come to the top here.

[Silence from 0:49:48 – 0:50:52]

Well, great. We have technology, we have policy, we have supply chains, we've got an incredible set of things. I think you just look at all the things that you all are looking to next, and there really is tremendous reason to be optimistic about the pace of change we're all gonna be working on together. So fabulous.

So thanks for everyone for participating. Now we're gonna move to our live Q&A. So, if you haven't, again, already gone to Slido, do that now. slido.com, #DOE, Emerging Trends and Technologies. Submit your questions, or up vote existing questions you'd like the speakers to answer, and let's go ahead and get started.

So I think … got some questions coming in. One is following up on the topic we've addressed a little bit, but can certainly see now important it is to everyone, and that really is the issue of an equitable transition. So, one of the questions is, how can we insure the clean energy transition is truly equitable? And can our speakers, our representatives from the national labs speak a little bit about how they're engaging with stakeholders and other experts to ensure that what we're doing is inclusive? So who would like to go first on that one?

Martin Keller: I can start off. Thank you for the question. It's an excellent question, because again, what I tried also to highlight in our slides that I think we, as the scientific community, I think can honestly do a better job, I think, in bring and talking to these communities. And what we learned from two events again, from the LA100 study is, and also perhaps on a different area where we're doing with the Cold Climate Housing Research Center in Alaska, Fairbanks, were our folks up there are very, very engaged with the community. They, for example, talk to some of the tribal leaders there. As you all know, this is an area where, so climate change this whole village has to be removed because there the sea ice is moving further out, and now suddenly the waves are really eroding the coastlines. And through the permafrost changes, that means their sewer systems are not working. So it's massive changes happening up in these communities.

In order to learn this, it's very important that you bring these communities at the forefront into some of the design of the new buildings. We have to have them engaged. And the same was true for LA when we talked about the change to 100 percent renewable energy, we had to make sure that we talking and taking the time to sit down with these communities, listen to them, and with them, bring them along. And historically, I think we have not done this so well. And I think this is where we are very excited also with the current administration where DOE now puts a lot of emphasis onto this to make sure that we are not leaving these communities behind.

So the concern, I have to be honest with you all, is that that's very hard to scale, because it's a really … it's time consuming, it's super critical, but it is something where we need to find a way how we bring these people with us, bring them along, talk to them. This will take some resources, but I think it's absolutely critical for the energy transition. And for me, the key answer there is to really go and make the contact. So take the time and sit down with these communities, to understand what the problems are, and then we can incorporate these issues into our research portfolio.

Thomas Kurfess: I think I'll just add onto what Martin said, and I can focus on the manufacturing perspective. So you have the OEMs, so let's say the automakers, like a General Motors or Ford, that they're going to have to comply to certain new regulations. And so forth. And some of them have already committed to, "Yeah. We're going to completely electric vehicles," for the personal transportation sector. And so, what is happening there is, they're working closely with their supply chain, because really they have a lot of the engineering know-how, working closely with the supply chain. But then the national labs, for example with Oak Ridge and our manufacturing demonstration facility, are also partnering with them to make sure that we're moving in the right direction. And really what this does is it helps to de risk some of the more advanced technology, and to help it deploy in a more rapid sense.

So really it's leveraging the capability, and Martin would say the same thing, in terms of what's going on with the environment, really we're targeting … and I either Angela would say the say the same thing … we're targeting some of the high risk areas to really make those technologies more cost effective and viable, so that they are easier to deploy. But not only that, but working, whether it's community or with the manufacturing community or manufacturing supply chain to make sure that it's not only great in the laboratory, but it gets deployed out to society or to the supply chain.

A. Becker-Dippmann: Yeah, and I'll hop in here just briefly maybe, just to echo what Martin and Tom have said to a certain extent is that it absolutely starts with listening, and engaging communities that haven't necessarily been part of the discussion heretofore. And I think observing some of the policy development that's happening out here on the ground in the Pacific Northwest, there's definitely a capacity building need to have communities engaged in these conversations. And Martin's also exactly right that when we're talking about the climate crisis, our need to engage at the community scale is somewhat in tension with the speed at which we need to address the crisis. So again, it takes dedicated and intentionality around those engagements.

I would also say that it's not just technology innovation that we need to be investing in. It's also the financial and the regulatory innovation. I mentioned in the South Landing example, how we're working with Washington State through the Clean Energy Fund, to look at different rate and tariff structures, such that if you're engaged with, say, small businesses in a disadvantaged area of Spokane, like a low margin dry cleaner, family owned dry cleaner or something like that, and they're helping provide additional flexibility to the grid, because they have grid connected capability. But what are the financial models by which they can share in the economic benefits of defraying infrastructure upgrades that the utility might otherwise need to make? So what are the financial models by which we also share the economic benefits of this transition more broadly than historically has been done in the past?

I think those are very interesting … set of integrated challenges. But exciting to be able to work on them, to partnership with the Department of Energy and our national lab colleagues.

Kathleen Hogan: Perfect. Another theme through a set of the questions here is really, it's the research to the markets. It's a question you'll always get. How do you get the great work that's going on out into the markets more quickly? And so, a little bit of what you're doing in that space, to get the research out. And there's a variety of questions that are really focused on how we can work to more rapidly benefit small-ish manufacturers, small businesses, smaller manufacturers, and giving them access to either the capabilities of the labs, or getting, again, technologies out to them like smart manufacturing. What can we do to help. So, maybe we'll start with Tom this time.

Thomas Kurfess: Alright, and I remembered to unmute, so we're good.

So the reality here … and it's a perfect question. I can go back to my smart phone. This is the beauty of it. So if you think about your car, you used to pay all sorts of money for this navigation system. Now you plug your smart phone in, and when Google or Ways or whomever, they update, or Apple they update their navigation on their phone, it comes to you, it comes to you free. You are paying something for it, because you're giving them data. But now the navigation system on your car is also being updated. And I think this is really the same type of approach, is how do you get that type of update out? And the machines that are out there, when a company buys a new machine, it's pretty much state of the art. And the real question is, how do you use … I grew up in a machine shop in the 1970s, and a lot of these shops are still operating in the same way. Instead of using pay to play, they're plugging in a USB key. And, by the way, I should say, cybersecurity warning. Don't plug in a USB key. That's always a dangerous thing to do. But the reality is, we're already using this type of technology to get that information out, via the digital thread. So a secure connection really allows you to get it out there. And then making a really nice human user interface, HMI, that allows you to easily use the technology. So it's there, the pathway is there, and getting there, the biggest stumbling block I think is cybersecurity. So we have to be very aware of that.

Kathleen Hogan: Anyone else? Research to markets.

Martin Keller: I can chime in on this, perhaps a little bit, and look at the next thing question. We're always trying to come from, when you look historically, and always, here at NREL, we use solar as an example. It took 30 years to go from the idea of a solar panel to now being one of the cheapest way to produce electricity. And for some of the new technologies, we don't have 30 years. When you look at the, take the 2050 goal and calculate backwards, what you also take to get it into the market, we have about 10 years to get technology ready. And this means that we need to be much more … we have to be faster in scaling technology.

And this is, again, something where we also, to be honest with all of you, are having a lot of discussion right now also with DOE to see how can we, as an organization, as the whole national labs system as a complex, how can we scale up faster? How can we take the great ideas from universities, from other fundamental national laboratories, and how can we work with this and then scale it, scale it in a faster time line, bring it to market faster? And this, again, comes back what I think also what Tom alluded to and what we at NREL why

I also highlighted that the importance in industrial collaborations, because I think when you de risk some of this technology and work fast and earlier with industry, then to take it into their hands to then scale it. Industry, a lot of companies are wonderful and excellent in scaling technology fast, and getting deployed. I think this is a strength for them. But I think we, from the federal supported research, in my opinion, we have to be fast in de risking technology, building new partnerships in early way. That's why I feel that public/private partnerships for the energy transitions will be so critical to really accelerate the time to market.

And still, sometimes, national labs are kept secret. Sometimes, especially for smaller companies, it is too hard to work with us. So we need to make it simpler. We need to streamline the process. I'm a scientist, so I can say this, but as soon as all the lawyers are getting involved, this is where it's getting complicated, and this is where it's getting very long time lines. So we have to be much more agile. We have to be faster. We have to increase the speed to work with industry. We may have to make it simple, that we can … because look, we find a way to make it very simple, to make sure academia to bring students to bring students and post docs into our organizations. Why not do the same with industry? Why not making it simpler. And this is something I think we have to protect, or otherwise we cannot scale enough to make the 2035 and 2050 timelines a reality.

Kathleen Hogan: Well said, well said. Angela, you want to jump in?

A. Becker-Dippmann: Yeah, sure. I'd echo a lot of what Tom and Martin have already said. I think that there are some programs that exist that have been on life support for the last four years, but are making a comeback. Like small businesses voucher program, and things like that, that strive to make the capabilities present in national labs more accessible to industry, for sure. And I would just also remark that understanding the needs of industry up front is what make us more effective at our job, in terms of understanding the more intractable technology challenges. We spend a lot time in the national labs trying to understand what is the level at which we must demonstrate something, like a new energy storage material, to make it interesting to industry to pick it up and run with it. And that differs across different sort of technology verticals. So it's not uncomplicated, but that's what makes it fun.

Kathleen Hogan: Great. Actually, Angela, another question for you, people are interested in drilling down just a little bit more on the resiliency topic that you brought up. So a little bit more on some of the metrics around resilience, and then how to get access to some of the tools that you mentioned.

A. Becker-Dippmann: Yeah. Happy to follow up through the Better Buildings folks on access to those resilience tools. As I said, we're in the process of doing the trade off analyses for different sort of … how the intersection of efficiency measures and resilience defined loosely as continuity of operations under a variety of different conditions, are related. And there may be some efficiency measures that accelerate resilience, and there may be some efficiency measures that don't necessarily. And so that's what we're trying to understand right now.

For purposes of work in the code space, those are the trade offs we're trying to understand. In terms of some of the resilience work we're doing with FEB we're also building in things like forest fire and other threats to the building stock. And so, like I said, it's an analytical challenge we're working on right now, and happy to follow up to the Better Buildings folks on those trade off analyses and that suit of tools that we're trying to mature.

Kathleen Hogan: Terrific. So let's talk about buildings a little bit more. A variety of questions talking about electrification of buildings. So what are the biggest challenges to electrifying our buildings? But also another question coming in, knowing that it's not just an issue of what fuel goes into our buildings, but how do we get ahead in designing buildings that use the absolute least amount of energy, so whatever it is that's going in is the least you need to have a nice, workable, livable space? So, electrification, and how do you design efficiency in from the get go?

Thomas Kurfess: I can kick off because … and I won't take too much time here … but the reality is, we do think about those. When you're looking at 3-D printing the walls and so forth, okay, this is a whole different way of putting it all together, and really thinking about. So one of the things we can do is we can actually print the wiring directly into wall. And so we think about, how do you put this all together? You think about your LED bulbs that you have, or your light bulbs. They used to screw into an Edison socket. Well, that's no longer the case. I have LED bulbs, so I can actually distribute them around and so forth.

So the … One of the things we didn't … I showed you some of the software tools, an so forth, but there's a whole new generation of software tools that's gonna let people think completely outside of the box. 'Cause right now, you think about, I'm gonna put up a structure, and this is what I'm gonna do, and I'm gonna put wiring up, and so forth. But the reality is, it's gonna be completely different. Even think about switches. Do I really need to run copper switches to all of my switches and so forth? Or, do I just have … I'm putting up my light bulbs over here. Do I just have light bulbs that are Internet capable? That Wi-Fi chip is pretty cheap, so do I really need to have all this connection and all this copper running through my building when I can use Wi-Fi?

Now, I'll say that, and I can tell a few people are cringing out there, because you also have cybersecurity issues. And so this was just really punctuated by the recent issue with the Colonial Pipeline. So I think it's a double edged sword. We really have a great opportunity to be much more efficient, actually even on … I'll just say this … on aircraft they have all these LED lighting now on the aircraft. Why do they do that? Part of it's energy efficiency, but now I don't have to have all the wire in there. I can have really thin wire, and that saves unbelievable amounts of weight there.

So there are tremendous opportunities, not just in terms of energy savings, but in terms of construction cost saving, and overall material savings. So it's really gonna drive things forward. But you're gonna have to think about things a little bit differently.

Kathleen Hogan: Great. So it is wonderful when you find these win/win/wins. And, of course, that is part of what is a new world. So Martin, challenges with electrifying our buildings?

Martin Keller: So I think that, in my opinion, it all comes back to all of us. So this is where I want to start, because as you all can hear, being from Germany, when you look at how homes are being treated in Germany, it's fundamentally a little bit of a difference than perhaps here to the United States, where you are willing, if you're building a house, to invest from the beginning into some of the energy efficiency side. As you know, German houses are, in general, built in a way where they are putting so much efficiency measurements in there that sometimes they have inequality problems that they're so insulated that you have to open your windows certain time to get the air flow going. So they are sometimes going into the extreme. But this said, I think it takes all of us to take a path forward that this is important to us for living in our homes.

And I'll tell you what, coming back because when you talked about the pandemic, what I'm seeing is that through these horrible times we had during the 15, 16 months, I think a lot of people are also now looking into their homes in a very different way. Using myself, I'm still sitting here in my home office for now for 15 months. So I'm starting to enjoy my house in a very different way than perhaps even before the pandemic. And I think this is a great opportunity for us, to really realizing that we putting some of these new measurements into our homes, that we are seeing this more as an active environment where we're spending a lot of times, that we're investing into some of this new technologies coming that we be taking pride in having efficiency in our houses, which, the question is absolutely correct. Every electron you save is a double win. So we need to put efficiency into our homes.

So, and then, frankly, what I see on the electrification of our homes, one of the biggest challenges what I'm seeing is some of our customs. I, personally, our family, we still love to cook with natural gas, and I love to have a flame and then saute my little onions. And changing this to electric is … I grew up in Germany with an electric stove. But of course, now, how do we go back to this in this case? How do we change our behavior? And again, this is why a lot of these things, I think we need to put more emphasis onto the social science aspect.

Sometimes we, as scientists, we just looking technology, but we forgetting to work on the social side to see how this is adapted at NREL I give this example. When I moved from Oak Ridge into NREL to my office, where, of course, at Oak Ridge I was able to plug my coffee maker into my office. And then, at NREL, they told me, "No, no, no, no. You can't do this." "What do you mean I can't do this?" "No, because we have a net zero office building."

So I had to learn to adapt, that we had … we've done it differently. So I had to go through a central kitchen to take my coffee. So you need to adapt. You have to adjust to some of these new kind of measures. And this is why social science, I think, is so critical, that we showing this, that we understanding what do the consumer want. How to direct technology which is then also adapted and implemented to our homes. And sometimes we uncouple the two, and I think this is what I say looking forward, in my view, the most important element, to combine the two together.

Kathleen Hogan: Marvelous. Angela?

A. Becker-Dippmann: I'll add a few things to the mix. In terms of commercial buildings in particular, we're running an experiment out here in the Pacific Northwest. The Washington State legislature passed a Clean Buildings Act in 2019, which is a set of incentives which will ultimately migrate into mandates, for commercial building owners to participate in performance based building program. And so making that shift to performance based operations rather than proscriptive this measure and this measure and this measure, is the 45 degree turn in the commercial building space we're trying to execute in Washington State.

I would add that, on the question of electrification of appliances and systems, part of it is insuring we're manufacturing the kinds of appliances and systems that consumers want to buy, to Martin's point about natural gas. We've made those market transformation related mistakes in the past where, performance of the appliances isn't necessarily up to what the consumer demands, which doesn't end up well for anyone. So there's more to be done, I think in that space.

Finally, and this is based on really n=4, based on my experience with doing things in my own home. Workforce is a non-trivial challenge in terms of boots on the ground to install my … the common wire from my smart thermostat and my heat pump technology in my own home. The workforce challenges are real, and really deserve a lot of attention, I think, because it's one of, sort of, the soft factors that are gonna make or break this transition, I think, in terms of having the workforce that knows how to execute on these new technologies and making sure we're, again, as I said, intentional about ensuring that we're skilling the workforce appropriately for this.

Kathleen Hogan: Great. So let's talk a little bit more about manufacturing, and some of those better plants, or the intersection between some of the manufacturing and homes. We have a question about the cement, and cement being such a CO2 intensive material. Can you speak to how you see the future of cement in this country, Tom? And a related question, what are some of the other fuels out there that you see being part of the de-carbonized manufacturing sector?

Thomas Kurfess: Certainly, one of the things we look at in terms of cement is, is there cement, or is there concrete out there that actually absorbs the CO2, so you actually have a negative CO2 footprint, as you produce it? And so these are the things that we do take a look at. The, can you put it down? Can you make use of it? Can we actually use it as a surrogate material, even in replacing … we're not building machine tools, for example. And instead of having a steel base, where you've gotta cast the iron and there's a lot of heating that goes on there, we're actually using concrete as the base. One would think, "Oh, concrete. Is it a very good base?" It turns out yeah, it actually works out pretty well. One of the things you don't want your machines to do or to ring. If you ring a bell, it's made out of metal, it rings quite nicely, vibrates quite nicely. If you hit same bell is made out of concrete, you hit it, you get a thud. So, I think there are a lot of opportunities. So we're working with a number of our partners … like Quickrete is one of our partners … in terms of designing the concrete appropriately.

The other really nice thing about it is really you produce concrete at a local level. So you don't produce it here in one part of the country and then ship it all the way across to another part of the country. So you get rid of those transportation costs.

One of the things that we are looking at … maybe this is something a little bit further down the road … is can you recycle? So can you grind it up and reuse it? And what about the aggregate, using it in terms of an aggregate? So I think that there are a lot of good opportunities in there.

What was the … I'm sorry. I got so excited about concrete … By the way, I gotta tell you, if you go to Home Depot, take a look at concrete, at the cost of concrete, and take a look at the cost of a bag of topsoil, and you'll find out that concrete's cheaper than dirt. So it's a pretty good material, an again, if it's absorbing CO2, life is really good.

What was the other part of the question, Kathleen?

Kathleen Hogan: The other part is, as you look at a deep decarbonization of manufacturing, what kind of fuels do you see that sector moving toward?

Thomas Kurfess: I think Martin did a, given the National Renewable Energy Laboratory, I think Martin will probably have some great comments on that. NREL, you can see right on his shirt. But the reality, actually is we do see a lot of … the manufacturing sector, a big chunk of it, at least on the machine tool side is driven by electricity. So things like wind power, things like solar are gonna be great for us. Now, of course, wind's not always blowing, sun's not always out, so you've got batteries. A lot of work that's going on in the transportation sector with automotive is also gonna be very useful on the manufacturing side and the home side. Once these batteries in these cars are not quite … they don't quite give you the same full charge, can we use them somewhere else to store that electricity?

And, of course, one of the really big things we're looking at are small, modular reactors. So can we produce small, modular nuclear reactors, completely different than what the current reactors look like. Everybody's afraid of nuclear. We know what happened in Chernobyl and Three Mile Island. These operate completely differently. And we're actually making these things, using 3-D printing technology. So 3-D printing a small, modular reactor, which allows us to make them much more cost effectively, much safer, and that use completely different designs so they don't get really hot. So things like meltdowns can't possibly occur. And so I think that there are a lot of good opportunities there, whether it's how we're gonna use things, how we're gonna make things, or how we're gonna make next generation things using the latest technologies are really gonna make a big effect on that. But I'll defer to my other two colleagues to talk a little about there thoughts here. I can see some smiles on the other end or the line there.

Kathleen Hogan: Sure, Angela?

Martin Keller: Go ahead, Angela.

A. Becker-Dippmann: In terms of fuel sources for manufacturing, as Tom was saying, a number of us are looking at electrification and different metals process heat, extrusion processes, which hold a lot of promise, working with the Advanced Manufacturing Office and Vehicle Technologies Office, for example, and joining of dissimilar materials and how we can use different electrified manufacturing processes on this. I think … and Martin will probably elaborate on this, given the electrons to molecules work that NREL's engaged in … everybody's looking at hydrogen and its role in the manufacturing sector, and how we would understand the scale required to produce those fuels I think is at the forefront of the need to know right now, as we look at decarbonization the industrial sector. So Martin …

Martin Keller: You brought up a lot of good points. When you look at industry, I think we have a good path forward on the electrification side. We have different ways to create electricity. So I think is, right now, already wind and solar is many areas cheaper than even a combined natural gas cycle. So I think this trend will continue. The problem still is the so-called process heat, because there's not so many technologies to really create very high temperatures. And a lot of industry processes require significant process heat. And this thing will be very interesting, how we develop and create these processes. So we could go into hydrogen. Again, that's … Angela talked about this where we're using what we call electrons to molecules, where we very likely probably could take a renewable electricity and go through electrolyzers to create hydrogen. And then the question is, will hydrogen then be transformed into other hydrocarbons? Or will it stay as hydrogen? That's one question we still really don't know where the technology will go.

The other interesting element from process heat, you could say that you could use concentrated solar, potentially, especially if you combine this with geothermal, could be very interesting for process heat. And Tom mentioned small, modular reactors, which also could produce nice process heat. There is another very interesting field developing, and this is again, I saw there was one question there to see what other technologies other countries are doing, especially also in Europe, especially also in Germany, and there is a lot of new emphasis put into this high temperature heat pumps. And this is something which, again, we also starting to check into this, because this could interesting element, to take heat pumps towards producing process heat. I would say that, from a technology perspective, they are very early in development. But the key is overall, how do we produce process heat in a sustainable way, and not using natural gas.

Or, if you need to have natural gas, can you decarbonize our gas pipelines. So we're working on processes where you could us electricity through hydrogen, and we're having a process this so-called gas that we producing methane in carbon neutral way through a microbial process in this way. So there is other ways potentially to decarbonize our natural gas system, which will be very interesting, because our natural gas pipeline is a tremendous storage opportunity for energy, if we know how to decarbonize natural gas.

But overall, especially in certain industries, like steel and others, process heat is a big issue. We still have to work this.

Kathleen Hogan: Great. And still on the manufacturing topic, there's some questions on manufactured … site manufactured homes. The intersection for a new generation of homes that are manufactured. So what's the thinking on that front?

Thomas Kurfess: I'll just kick it off again, since manufacturing. I think there are a couple of things. People like to think about 3-D printed homes. And I think that that's fine. What you see out there in general are these big gantries that you gotta set up and so forth. You've got something like SkyBAAM now, where you could set up … you just set up four corners of the box and put the crane in there, and they you can print it that way. And so you can print a complete home. But the other thing really that we're seeing in terms of manufacturing is a lot of prefabrication. So if you look at a house today, many of the beams will even come, or even sections of the house will come … if you look at your roof structure, your framing structure … will come. And we can even think about, we might 3-D print the brackets that hold it together, or we might actually 3-D print the dies that you stamp the brackets out of them.

So, it's not a just, well, we're gonna go from building a stick built house to a 3-D printed house. I think that there are different levels that you can go after, and really look at scaling it up. That being said, I think that there's also something to be said, since we're talking about a digital manufacturing capability, you could really look at point of consumption manufacturing. So that basically means I can produce these elements, whether it's an entire framing structure, or just brackets that I use to put things together. I can print all those and get those together locally, and make use of it.

And the last thing I'll talk about is, we have some large polymer 3-D printers where we take the plastic, and the really taking about recycling two liter bottles. You could take the plastic, mix it in with what they call wood powder. It's really sawdust. And so now you're capturing that carbon. You've got fairly good material. In fact it lowers the cost, 'cause the sawdust is cheap. And you could actually print out things like 2x4s. And they're pretty indestructible to the weather, so they're not gonna rot and so forth. And that actually could save you in terms of Wolmanized or pressure treated wood. You don't have to go in that direction.

So there are a lot of things that can happen, just to get you to a house that has 3-D printed components in it. You could even 3-D print your 2x4s, if that made sense. And, by the way, it can make sense. We're 3-D printing telephone poles for use out in hurricane stricken areas where you've got a bunch of scrap wood. I can grind it up, mix it with the plastic, print the poles out, and I don't have to bring the poles in. So, these are a lot of things you could think about in terms of construction.

Kathleen Hogan: Fabulous. Martin, Angela?

Martin Keller: So I just want to highlight one project, and this comes back to the environmental and energy justice. One project which really took a lot of my attention is what we have done through the Cold Climate Research Center in Alaska, where they hat worked with this community and said, how can we change when we have whole villages have to move to new location? How do you bring these buildings up to the next standards? And the path they took up there was very interesting. It's a little bit hybrid, I think of what Tom just described.

They started to design their homes where the inner, the expensive parts of the house, what is … it's the kitchen, it's the bathrooms. And a lot of the plumbing assigned to this. So they decide, with this community, these modules where you basically, in a container, bring the bathroom, the kitchen, clumped all together. You can easily ship this. And then the local communities build the house around this kind of inner cell, which then the communities can build based on their needs. Some of these tribes want to have very specific meetings there, is where the family comes together. They want to have the bedrooms aligned in a certain way. So they want to have specially with all the winds blowing around, so that you go, when you have an entrance, which is where you take your clothes and your shoes off.

So basically you bring the local community where you very easily can teach some of the folks to build the structure around these modular cells, which are the expensive parts. So then you can build these in a manufacturing, a bigger place. It's easily to batch them, to ship them into these areas. And then you use a local workforce to develop the homes around this. And this concept is not just an interesting concept for Alaska community, but also, for example, talk about FEMA. If you have hurricanes destroying whole neighborhoods, you easily could then develop this where the centerpiece can be manufactured, even be prepared ahead. And then, people can customize their homes for how they want to have houses around this. And this is, I think, a very new way of building, where you bring the energy efficiency and the expensive components. You will make them in a manufacturing place, and then you have these custom built homes with the local community. You're not making all of this in a manufacturing place. You custom build it, but you still have the centerpiece designed to create the most energy efficient way, and the best way to get the plumbing and electricity done.

Kathleen Hogan: Fabulous. Angela? I think you've got the last minute here.

A. Becker-Dippmann: Manufacturing components and assemblies out of new material is central to what we're seeing terms of the net zero, zero carbon, building experiments we're running out here. And cross laminated timber, in particular is of interest, given the resource we have here in the Pacific Northwest. This is a case where frankly, we're learning from industry about better managing their supply chains, where a lot of savings can accrue as well.

Kathleen Hogan: Fabulous, fabulous.

I think that really is all we can fit into today, and we did cover amazing territory, with a lot of really good questions. So let me thank our audience, and let's also thank you, of course, to Martin, Angela, and Tom for being part of today's session. It's really been great.

So, as you can see, there is a lot of very exciting work going on at the national labs, and some terrific people thinking about that, and what's coming next. So before we close, we do want to remind you that through the Better Buildings Solutions Center, there are more than 3000 solutions to help you find proven and cost effective strategies, and to help you reach your goals for energy, water, and waste reduction. So please check out this this video to learn more.

[Video]

Great. One other thing I want to highlight to you all is to invite you to attend the Better Buildings summer webinar series, starting in June. Through this series, partners discuss some of the pressing topics they're facing. They share their best practices, and the new approaches that they're using for sustainability and energy performance. And it's easy to register at the Solutions Center by clicking on Events and Webinars.

So let me just close, again, by thanking our panelists, very, very much for taking the time to be with us here today. We have launched a short feedback survey in Slido and ask that you please take a couple minutes to give us the feedback on the session. It is certainly through your feedback that we can keep providing to you really great sessions as part of the Better Buildings summit, as well as the other Better Buildings events. So the poll will be open until tomorrow morning. And please send us your information.

So again, thank you all, our panelists and to you, especially, our attendees today.

[Music]

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