

Climate Solutions Series, Session #2

Transcript: Decarbonizing the Electric Power Sector

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Four experts join Sarah Ladislaw (CSIS) to discuss how to decarbonize the electric power sector by 2050. They cover key themes for the power sector, including: managing a changing power mix, the importance of both deployment and innovation, and how wealthy countries can help low-income countries develop on a low-carbon pathway.

TRANSCRIPT

Sarah Ladislaw:

Welcome to this special online discussion, Decarbonizing the Power Sector. I'm Sarah Ladislaw, senior vice president and director of the CSIS Energy Security and Climate Change Program. This is the second event of the CSIS Climate Solutions Series.

Through this series, we're investigating the potential pathways to net-zero greenhouse gas emissions in different sectors of the economy. In this conversation, we brought together four experts to talk about the ways the electric power sector can achieve net-zero emissions, policies to drive decarbonization, challenges to creating low-carbon electric power sector in developing countries, and how the private sector contributes to the power sector's decarbonization.

I'm joined today by phone with Jesse Jenkins at Princeton University, Sue Tierney with the Analysis Group, Chris Shelton with AES, and Todd Moss, founder of the Energy for Growth Hub. I will start off with a 10- to 15-minute interview of each of our experts, followed by a set of questions to dive into some of the key themes and challenges for the electric power sector as it moves to decarbonize. First up, Jesse Jenkins. Welcome, Jesse. Thanks for joining us today.

Jesse Jenkins:

Thanks. It's good to be here.

Sarah Ladislaw:

Great. So in the first Climate Solutions Series that we did on deep decarbonization pathways, the electric power sector played a hugely important role in enabling whatever viewpoint you had on how to get to a deeply decarbonized net-zero environment. I thought because this is something you spend a lot of time not only working on in your research, but explaining to people in the policy community how to think

about parameters around which we are going to be decarbonizing the electric power sector, could you talk to us about some of the variables that come into play, whether it's technology cost or timeframes, and how you consider those in the work that you do?

Jesse Jenkins:

Yeah, that's a great question. Yeah, that's mostly what I focus on in my research is trying to understand the kinds of technologies that are needed to cost-effectively decarbonize the electricity system and reach a net-zero or even net-negative carbon emissions level from the electricity sector and the kinds of policies that might be effective in accelerating that, that transition since it has to be something that's directed and guided by policy. And what I found in my research is that, you know, sort of like a balanced diet for, you know, your health, what we need is a kind of complete package or a balanced diet of electricity resources, each of which play different roles in a low-carbon energy system, and if we have the right mix of those technologies, it's relatively, you know, affordable, cost-effective to reach a net-zero emissions electricity sector and even to expand the role that electricity plays in our overall economy, potentially increasing our electricity supply twofold by 2050 as we turn to clean, carbon-free electricity to power more and more of our energy needs, including in transportation, home and, you know, building heating, and potentially more industrial processes as well. And then that can help clean electricity displace emissions from fossil fuels in those, those sectors where it's harder to develop a low-carbon, drop-in fuel replacement.

So in recent research, the paper in the journal *Joule* that I published in 2018 with Nestor Sepulveda, Richard Lester, and Fernando de Sisternes, we classified a categorization of three different key classes of low-carbon resources that we were seeing show up across a wide range of technology cost and sensitivity analysis that we were looking at in our, in our modeling. And the first role is where wind and solar play their key and starring role, which is as fuel-saving variable energy resources. We described the variable renewables like wind and solar as fuel savers because at high penetration levels they don't contribute a lot of what we call capacity value. We can't rely on them for certain periods of time when the wind is dead across a wide area of the country and the sun is down at night or in the winter.

And so we sort of need the most firm capacity at the times when those resources are not available, but they provide a lot of energy value. So, you know, they have upfront capital costs but no fuel cost. And when they're available, they displace technologies with higher fuel costs like natural gas or coal or biogas or hydrogen in a low-carbon context. And that savings, you know, the fuel that is not consumed when we have wind and solar, is where those technologies deliver most of their value. So that's why we call them fuel savers. And then the second category we call fast burst or balancing resources. And this is where batteries like lithium-ion storage play a key role, but also demand flexibility—you know, choosing carefully when we want to charge our electric vehicles or heat up our hot water heaters, for example, and demand response or demand curtailment in response to very high prices of electricity. These are really useful sources of flexibility and capacity, but only for brief periods of time. You eventually run out of energy in your battery and you, you could defer charging your electric vehicle overnight, maybe, but not for a couple of days or a couple of weeks. And so those technologies are really best suited for providing flexibility on the kind of intra-daily timescale of a few hours to 24 hours.

And then that leaves a final critical category, which is kind of where I think we're seeing the least progress right now technologically and probably need a greater policy and technology, you know, focus, and that's on what we call firm low carbon technologies and firm technologies are technologies that

aren't weather dependent. They're not energy constrained. And that means that they can provide energy and capacity at any time of the year for as long as the system needs them to maintain reliability. And that includes technologies like geothermal and biogas—so renewable firm technologies—and also non-renewable technologies like nuclear and carbon capture on fossil fuel power plants. We rely on coal and natural gas plants for this firm role right now. And in the near term we can continue to scale up renewables and ramp down coal and gas and that will work fine. So this is more of a longer term question. What is going to replace coal and natural gas, you know, beyond the next decade as we transition, you know, hopefully rapidly towards a net zero energy system? “What's going to step into that from role without carbon emissions” is the key question.

Sarah Ladislaw:

Yeah, and I want to ask you about that in a minute, but I wanted to get back to something that you talked about in your second category, which came up in another series that we're doing on innovation, which is about sort of battery and storage technology. How do you think about the unknowns or the variables in the deployment of a technology like storage in how you forecast or try and model the options for deeply decarbonizing the electric power sector. What are the things that happen if you have more versus less storage capacity on a long duration basis? That certainly seemed to be, you know, for the folks in the national lab system who are working on battery storage technology, thinking about longer duration storage and the integration of storage technology into an electric power system is an exceedingly complex topic for which it's really hard to figure out whether the kinds of technology breakthroughs they're working towards will in fact come forward and over what timeframe. How does that affect the, how you're thinking about the variable outcomes of a, of a deeply decarbonized scenario based on whether you have those technologies available or not?

Jesse Jenkins:

So we spent a lot of time looking at energy storage both in the kind of 2 to 12 hour range, which is where most of the technologies that are available now are primarily suited, so, you know, lithium ion batteries, sodium sulfur batteries, most of the kind of vanadium redox flow batteries are even on that kind of time scale too, and pumped hydro, which is the vast bulk of the storage we have deployed in the country today. Most pumped hydro systems are scaled for kind of diurnal patterns to do some load balancing from overnight to during the day. And you know, what we find is those do play a really valuable role up to a point in the energy system and that lithium-ion batteries have fallen so much in cost and are expected to continue to fall due largely to demand for electric vehicle batteries, which will spill over into cost reductions for stationary storage as well.

That niches, I'm pretty confident that niche is going to be filled pretty well by lithium ion batteries over the next decade. And what that will mean is that we can integrate more renewables on that daily timescale. We can make better use of solar in particular by taking, you know, the solar peak which occurs, you know, around 1:00 PM and shifting some of that energy into the early evening, late afternoon time period when the sun is setting and demand is ramping up quickly in the evenings. And that'll help increase the value of, you know, and role of, of solar and wind in the electricity system. And some of that storage can displace the need for infrequently utilized peaker power plants like combustion turbine, natural gas plants or internal combustion engine peakers that run on diesel or fuel oil or, or gas. And that's great because those are, you know, dirty polluting assets usually and they are infrequently used. And if we can displace them with storage that not only provides that peaking but also

then throughout the year provides a lot of flexibility on a daily basis, that can be a really useful value add.

You know, the caveat is just like wind and solar's value falls as the, you deploy more and more of them, that's true for storage as well. As we deploy more and more storage capacity, the value kind of steadily declines can think of it at a high level. Storage is like an arbitrage opportunity. In any market you buy low and you sell high. And the challenge with that is that the more people who buy low, the higher the low price gets. And the more people that sell high, the lower the high price gets and that compresses the, you know, the profit margin that you're getting each time you cycle your battery. Plus you're probably using it less often because the opportunities to do that start to diminish. And so what we've found is that storage has a lot of value initially and that that value starts to fall and that kind of contains the ultimate role of lithium ion batteries to, you know, maybe on the order of up to 20% of peak demand in terms of capacity. So still a long way to go from where they are now. It's a big market, would be kind of on scale with combustion turbines today in the marketplace, but maybe not the kind of transformative role that some people envision.

Sarah Ladislav:

Yeah. Going back to your point on from capacity, the types of technologies that you were talking about that fill that, you know, need now, the low-carbon versions of those or something with carbon capture and sequestration and nuclear power and clearly sort of the deployment of those technologies is not going well, particularly in the U S context. How does that limit or is it too early to say that it limits the U S options for pursuing deep decarbonization along pathways that include those kinds of technologies?

Jesse Jenkins:

So the good news is that I don't think it limits anything over the next decade. We can really pursue full speed ahead the deployment of wind, solar and batteries and start displacing coal first from a carbon perspective, right? Cause it's you know, much more carbon intensive than gas. And then in regions that have completed that coal to gas transition to start ramping down the use of natural gas, at least the energy share, we may want to keep those plants around at a lower utilization rate to provide capacity and flexibility. But we're going to want to significantly reduce the amount of natural gas burn in the electricity sector over time as well. And wind and solar and storage are well suited to do that for the next decade and beyond that are going to be the stars of our low carbon energy portfolio. The challenge we have over the next decade is that we also need to simultaneously be improving and expanding the set of firm, low carbon technologies that we are going to need to scale up in the 2030s and beyond.

So the good news is we have some time to develop those technologies. We can continue making rapid emissions reduction progress without any scalable firm low-carbon options in the next decade. But we do need to be proactive. It took 20 years to make wind and solar cheap. And if we want to have, you know, low cost firm generation options available to displace gas over the 2030s and 2040s we need to get started yesterday. But you know, the second best time to get started is today. And actually we're not just getting started today. We've been started, you know, we've been working on these technologies for some time. Congress passed the 45Q tax credit for carbon capture sequestration and use last year. Treasury has finally issued its kind of guidance on that. And so hopefully people are going to be able to start claiming that tax credit for projects over the next several years. That's going to play a pretty important role in creating an early niche market for carbon capture technologies. The same way that the production tax credit or renewable portfolio standards did for wind and solar. And we we have a

production tax credit on the books that was recently expanded for the first six gigawatts of new nuclear power that makes it to market. There are efforts to cost share the licensing process for the next generation of nuclear reactors. There's a bill in circulation right now that would cost share the first demonstration reactors potentially at Idaho national lab. So you know, there's efforts going on along these fronts. There's a major push by the Department of Energy recently on enhanced geothermal energy systems, which could really make a lot of progress over the next decade and open up a lot more firm carbon free renewable generation potential, particularly in the American West. And the final big category are zero carbon fuels, which I kind of use as a catchall for both bio gas, you know, sort of methane derived from biogenic sources and hydrogen that could be produced from any number of carbon free options including renewable electrolysis, natural gas, steam methane reforming or auto thermal reforming with carbon capture to, to reduce the CO2 from that or even nuclear aided electrolysis. So high temperature, nuclear aided electrolysis could also provide that. So we have several different pathways to produce hydrogen and in many ways these zero carbon fuels are excellent technological economic complements to wind and solar because they have high fuel costs but can be used in, you know, low capital equipment like combustion turbines or combined cycle power plants. Even some potentially retrofitting our existing plants to run on, on higher hydrogen blends or even a hundred percent hydrogen blends over time. And that actually could work quite well as a complement to wind and solar, which have all upfront costs and no fuel but are variable, you know combustion turbine running on hydrogen is low upfront cost, very dependable when you need it. And has a high fuel cost so they kind of form a nice portfolio or a nice balanced diet in that sense.

Sarah Ladislaw:

That certainly points out the positive things that are happening on innovation and deployment agenda that are necessary to achieve deep decarbonization. Thank you so much for joining us today, Jesse.

Jesse Jenkins:

This has been great. Yeah, thanks.

Sarah Ladislaw:

Next I chat with Sue Tierney at the Analysis Group. Thanks so much for joining us today, Sue. To start, I was hoping you could provide some insight based on your experience into how much policy compared with market forces and the sheer competitiveness of low carbon energy technologies is driving decarbonization now versus in the past.

Sue Tierney:

Great question. I think that in the recent past and perhaps going forward for much of this decade, I think market forces are extremely powerful and the drive down of costs of solar and wind would be a perfect example of that. Those of course were driven by policy originally and then scaling those things up in markets has really helped to deploy them. I think solar was 40% of that new capacity added in the United States in 2019 so it's, it's a big deal. I think of course the effect of low gas prices has been monumental in terms of driving down carbon emissions and shifting coal from where it was half of power supply in the United States to a quarter of the power supply and natural gas and those renewable technologies filling in the space. So I think market forces have been extremely powerful. I think they continue to be powerful and I would even add into that the market forces associated with corporate action, the presence and scope of the buying power of many of the corporations who feel that this is part of what they need to do from a business point of view, from a branding point of view, from a save

the planet point of view. I count those as market drivers as well. So policy clearly has played a role in every one of those things, of course, that I just mentioned. But I think policy will have to take a big pivot by internalizing into prices the effects of climate change, changes in the financial markets which may be driven by regulators to account for climate risk in a much more deliberate way. So I think there's a lot of additional policy drivers that need to occur.

Sarah Ladislaw:

I love the big pivot. Right. I mean cause I think in the past we've been thinking about climate related clean electricity policy being about driving low carbon generation into the system and now it's really about sort of the incorporation of those resources into the system and and sort of the next phase of decarbonization. Right. Which is a lot about that incorporation process. Do you view the presence of those policies in the places where they exist as being sort of real key drivers to sort of the next wave of decarbonization or on balance is the lack of our ability to do that so far a barrier? What's the policy environment around this? Like how many places that you work get what needs to be done next versus are sort of stuck in this middle ground where they don't know how to do some of the pricing things that you were talking about?

Sue Tierney:

There is a broadly shared view about what needs to be done and I say that from interacting with climate experts. Some of the others on this podcast included. I say that as also a reflection of what I read in the literature, so from a techno economic point of view, I think that there is a very strong shared view about what has to happen of course associated with cleaning up the power system, but then at switching fuels in the other sectors. How that happens, how those other sectors really get cracked. I think that's where people are stuck. I think there are lots of ideas about what you would do, but how you get there is really the tough piece. How you really without draconian policies that are politically intractable. I think for example about so many great studies about what needs to be done in the building sector.

Of course the transportation sector is the next biggest, I think after the power sector has diminished from the, the leading greenhouse gas emitter, but the building sector, you can picture all of that building shell, the efficiency actions, the fuel switching. You can imagine that set, but actually how you do that in a way that resonates with people's behaviors, their traditions about what, what kind of fuel they like for cooking. I think policymakers are stuck except on really very blunt instruments of how to get going on that. I mean the, the mandates about no new hookups of gas I think are acceptable in a number of very liberal communities. I think they are very, very third rail issues in a, in a bunch of other communities. So all of us are stuck on being creative about how to create the incentives to get people to move in, in the other sectors.

Sarah Ladislaw:

It's interesting because one of the reports we had put out recently was a comparison of the sort of U S de-carbonization and the electric power sector conversation versus what's happening in the EU in maybe some places in the United States like New York and California and Hawaii are thinking along the lines of what you're talking about, which is not just decarbonizing the electric power sector, but then thinking about how other sectors electrify and how they decarbonize as well. And what I found was really interesting is the EU in earnestly pursuing a deep decarbonization scenario found it really hard to talk about sectors in isolation. And I think it's funny because in my reflection, I wonder if you agree with this is in some places in the United States we are still very much talking about this on a sector by sector

basis and in other places. If you're having a whole of economy de-carbonization discussion or even just the whole of the energy sector de-carbonization discussion, it kind of leads you to think about these things differently. It strikes me that the sort of a failure to do that in the U S might be holding us back in terms of some of the considerations that policy makers and regulators might be needing to think about

Sue Tierney:

As usual, that's a great question and I want to align with the all of the above ways to think about this. And by that I mean simply yes, we absolutely need to think about more deliberately the whole economy approach and what policy instruments are key for that. And as I mentioned that that might be about reforms in financial markets, that might be about pricing risk. It might be about pricing carbon in various ways so that it can permeate. But those things will not be enough I think even if they were to happen. And that's going to be a hard pull. And the sectors really have very different sets of decision makers both in the markets and in the policy arenas. So you think about, well, I'll go back to the building sector and you think about the building codes. You think about the development community as decision makers. You think about the appliance manufacturers that are going to deliver millions of appliances into homes and commercial buildings and so forth. The millions of decision makers whose behavior needs to change in the building sector is really different than the types of decision makers and really the, the much smaller set of decision makers say in the electric industry, you know, you could count the number of people on boards of publicly owned in investor owned utilities, you can count the number of regulators and so forth. And so I think that thinking about the things that are barriers or opportunities in sectors also helps think about fashioning different policies that may work in one sector but have, you know, they're completely off the wall in another.

Sarah Ladislaw:

A question that we got. We solicited questions from Twitter for this session because we weren't going to be able to have a live audience. And one of them that we got that I thought we'd be perfect for you was about how well or ill suited our federalist system of energy policy making was working. You all did a very good job addressing the MOPR issue in particular on a recent resources for the future event on this topic. I mean, rather than go through that, which is a super complex conversation, what do you think this is going, the lack of sort of federal direction in deep de-carbonization has led to this patchwork and hodgepodge approach for various States in regions? I mean, are we going to just keep hitting these threshold issues that we have to work through, or is it becoming more contentious in a way that there may be some sort of breaking points in organized markets? I mean, how do you think about the gauntlet that we're kind of running through in the federalist system? Or is this just the, is this just the tension that exists in the system and that, and that's okay and we'll work through these types of things. How do, how do you think about that?

Sue Tierney:

Oh, let's talk for a couple of hours here because everybody's going to have lots of time on their hands to do so. Right now, I feel very strongly that the long standing centuries old constitutional federalist framework that we have is one in which there are situations where states currently today can move and do move and resist interstate things. And I think that's just a lens, unfortunately or fortunately that we have to deal with. So I say, you know, it's, it's double-edged. On the one hand we have, you know, the RGGI states stepping out many years ago developing a program that worked for them and individual states are now joining that group. That's a great thing. That potential downside of that is that those states are very interested in that particular model of a carbon price or a car capita cap and dividend program and would not be excited, I wouldn't think, about something that came from the federal

government that was intended to displace that. And I'm talking literally about the hundreds of millions and literally billion plus dollars that have flowed through the state's offices to implement a variety of things, including a lot of energy efficiency. And that comes from the RGGI program.

So that's an example where it's great, but "we like what's invented here" approach is tough for companies, for example, that have markets that are across the United States, not to mention global markets, but it makes it tough when you have these state by state policies and of course the issue of the distribution of federal versus state authority over the power systems and different aspects of it from reliability at the federal level to transmission at the state level. Those are really hazards that people have to navigate through when they try to think about a workable set of climate programs that will lead to really deep decarbonization. I think that until people believe that we have such a climate crisis, of course many people do believe that, but certainly not enough and certainly not in many policy-making circles, but until that becomes, you know, central these States' rights, federal rights tensions are going to be the reality through which people have to make a decision. Yeah.

Sarah Ladislaw:

One of the big questions I have left for you is what is the policy movement that you see right now, whether it's at the state or at the federal level, you know, whether it's a mechanism or a certain genre of policies that make you feel most positive about making progress towards a decarbonized electric power system. Is it, you know, as carbon pricing, is it a clean energy standard? Is it some package of innovation? Like where do you see things that you think are really important and should be prioritized by some of the folks who will tune into this and, and when I think about you know, what they should watch that matters in this space.

Sue Tierney:

I think that as a starting point, the establishment of targets and timetables by in law or in pretty firm policy is really important because it then begins to set a framework for where things need to go. My strong preference is that those policies are about zero carbon or reflect carbon as opposed to a particular technology so that there is room for innovation on fossil. There is so that there's innovation on nuclear and so forth. As part of the pathway to meeting those very, very strict targets that people are beginning to roll out. And then I think it's a multi strategy. I do think that where there is not a price on carbon, then you are making it so much harder for companies and decision makers who control budgets to actually get in the right direction on state policy. So I think there has to be some form of pricing on carbon economy wide is probably a tough nut to pull in most places and that's why people are tending to try to pick off different sectors.

But as I have said in writing in New York, I think that that is a state with an enormously aggressive and affirmative goal to decarbonize and to get rid of all carbon from the the power sector. And until there is a carbon price, it's like you're only clapping with one hand at the moment. So I think pricing carbon is key and you could align that with a clean energy standard. I know they are different in the way that they operate in the economy, but a clean energy standard could be an alternative for those places that just can't stomach a price on carbon. And we know that there is a greater appetite for that kind of standard approach. People have done it on renewables and appliances and so forth. And then I do think a package of the innovative innovation policy is really key. We don't have very many States that fund research long-term research. California and New York are really notable, notable in that regard. And so that one feels to me like it needs to be a continued part of federal support, but in state actions, I just

think there's a lot of different strategies and you can think about the different domains in which carbon is emitted or greenhouse gases are emitted from activity. And you can begin to think about, well, so what is the agricultural policy in that state look like? What is the vehicle of course, vehicle and public transit policy and so forth. So there's a lot of different things in all of those things are going to be needed to attack this problem in the end.

Sarah Ladislaw:

Thank you Sue. That's incredibly helpful and thanks so much for joining us today.

Sue Tierney: Likewise.

Sarah Ladislaw:

To get the private sector perspective. I talk next with Chris Shelton, chief technology innovation officer at AES and president of AES Next.

So both AES' activities and your role within the company affords you a great position to comment on some of the things that we're interested in in this climate solutions sort of deep decarbonization series that we're running, particularly with regard to, you know, the opportunity set for achieving decarbonization in the electric power sector. I'm just wondering in your experience, you know, where is the new deployment of zero carbon energy as competitive on fossil fuels on an apples-to-apples comparison, not just on sort of an LCOE basis, but really thinking about what it contributes to the electric power system or, or how do you think about the competitiveness of some of these new low carbon opportunities in the various places where you're looking to make investments around the world?

Chris Shelton:

Sure. This is a great question. We have spent a lot of time over the last five years analyzing this and about five years ago we really saw that the trends that have been happening that didn't seem like they were going to slow down in the scale of solar and energy storage and to a lesser degree wind were causing continued cost declines. So where do we find ourselves today is that every market around the world that has a solar or wind except the United States, renewables are competitive on a new build basis. So that includes any capacity requirements you might need around that with energy storage, let's say. And the source of energy which would come in the form of the wind or the solar, you know, there's sort of a phase change, right? Like that's like the change from ice to water in terms of the amount of demand that you see, right?

Because you now are looking at wind and solar as least cost and everything starts to flow once you realize that. So the policy side is not as much about encouraging the wind and solar to come in. Now it's dealing with the fact that it is coming in. And so that is a shift that we're seeing in markets. You know, one of the markets we're in Chile is quite interesting in that regard because they have a massive oversupply of capacity right in the form of like peaking oil units that they've used and that allows the renewables to come in, frankly. So it's, it's a bit of an experiment. So the renewables keep coming in massive amounts. So how are they coming in or is the new build needed? No, what's really interesting is they're just coming in to produce energy to take away all the molecules that were coming in, in the form of coal or oil into that system. They don't have a ton of gas there. So it's, it's really a shift. The way to

think about it is you have all of these molecules of coal and oil and gas going through all this built infrastructure and renewables are competing with those molecules. They're not competing with the built infrastructure. That's how we think about it. And that that framing is very important because you might say, well, if we don't need any new build, we don't need any renewables. That's just not true. What you're competing with is all that flow of energy that's going through the built system.

Now a couple of other interesting things about that. One is that the power plants that are already there are critical to that happening because they provide the capacity and reliability that you need for that conversion. And so the purest view, sort of the white paper version of de-carbonization is always seeking 100% but I think in the way the AES has been evolving, this is we really need to focus on getting the fuel burn in those plants down, but keeping them around for the transition because that's the way to make the area under the curve of the emissions, the lowest possible. Because if we have to wait for the perfect 100% stuff and all the policies that you would need and some of the inefficiencies that might create, we're going to have more emissions. Yeah, so I think the other thing I would say is batteries. If you do have new build need and you have solar, a combination of wind, solar and batteries is now competitive with new build as well. Yeah, and I did give an exception. I said the US- it's not, I mean when you have the shale gas below \$2 in the US and it's, if it's not an expensive state to build a power plant in, those might still make sense in a couple of places, especially if they're supplanting coal. Yeah. I think it also makes sense in Asia where you're avoiding coal so that you had this freight train of coal coming in Asia. If you want to divert that freight train and say that should be gas. That makes a lot of sense.

Sarah Ladislaw:

Yeah. Yeah. As a technology officer, are there any sort of significant innovations that would, you know, really change the playing field for you guys? Both from a commercial opportunity perspective but also in shaping your view about systems operation? You talked a little bit about storage, but you know other things like a, a different sort of economic reality for nuclear or significant push on CCS. I mean, are there any things like that that you guys are paying attention to that would really change the outlook for you?

Chris Shelton:

This is sort of taking a step back from the question, but I think it's worth emphasizing, can't emphasize enough this idea of the experience curve. We have this kind of, you know, somewhat nonlinear thing happening in relation to solar and led and battery, right? So for the first hundred years of the electric system, everything was driven by the economy of scale of size, right? So the bigger you made something, the more central you could make it. And this was, this was enabled by AC transmission obviously, but as soon as you could do the AC transmission, it's just economies of scale of size, make these massive things and get the cost down by doing that and then spread it out with the transmission. And the LED was first and then solar and then battery. Once you started making things in a factory. And this was the first time, massive amounts of the electric system we're kind of factory made getting on to Silicon based economies of scale of volume.

So here the economy of scale is volume not size. You know, that's the game changer for me like that, that's bigger than anything else I see right now. And you can't, we can't focus on that enough in my view because it, we don't deal with that type of curve well as humans. So we run some model today and the model says it's uneconomic, but you could run that same model in nine months and it'll be economic because the experience curve, you can know that now you don't have to wait nine months to know that, you know, you just, you run the experience curve and you know when it's going to happen and it's a

near certainty. So what, what messes up the experience curve? It's volume. You know, if the volume is lower then the costs will be higher. If the volume is higher, the cost will be lower. And then you have tariffs, right? And things like that set up. But those aren't that complex. And you can kind of figure out and do sensitivities around changes in volume, changes in tariffs, and then really know where you're going to be. And you can bet on those things. So that's first. I would say, you know, that gets us to this 80/20 world. The 80/20 world is right there. It's baked into the experience curve. We could solar, wind, battery, you put the right combination in each market that has that solar and wind and you can get to the 80/20. It's not every single corner of the earth, but it's where a lot of the load is. Right. so the second thing, the other 20%, so looking for the game changers, I would say one of the most important things that we could do is find a way to use the carbon from the other 20%.

So if we're 80% renewables by 2030, then how do we get that other 20% to be carbon efficient? You know, I said like we can try to turn down the plants. You could run that to the limit, right? And have the least burn possible, you know? But now the question should be, can we use that carbon again? So if we use it once to make electricity because we didn't have any other option, what else can we use that carbon for? So think of an idea of maybe gas plants, you build them so that, or you upgrade them so that you can get the carbon out clean. You put it into some process to make liquid fuels using renewable electricity to make liquid fuels and maybe you make jet fuel from that carbon. So something like that- I think that to me is kind of the next most important thing because people are fighting 80/20, they don't like it. They want 100% or they want 99% or something. So we've got to deal with that other 20%. But, but there's nothing on the table right now that, that economically does that. And it's hard to imagine that this incumbent system that's burning this is going to deal with this. So what do you need there? You need policy? Yeah. So we have some policy in the U S and the tax code. So that example I gave, let's make some jet fuel from the clean carbon from a power plant. If you did that right now in the US you'd get a 12 year tax credit for \$35 per ton. So that's a good start, right? So sort of mimicking a carbon tax to help us move those things. I don't think that's a hundred percent type solution. That's a 20% 10% 5% type solution, but it helps move us to the a hundred percent reduction and to solve a really hard thing like jet fuel, which we don't see any solutions for anytime soon.

And then I'd say the third thing would be a seasonal storage solution cause that then lets you get rid of that second thing, right, eventually and reduce the costs. If you can get a lower cost seasonal storage, I think then that second case, which would only need to be temporary during a transition, then you could completely get off of fossil because of the experience curve. The renewables would be insanely cheap. You know, say a decade from now or a decade and a half from now, then now you've, you know, your main cost is just going to be whatever that storage solution is, that seasonal solution.

Sarah Ladislaw:

Can you talk a little bit about whether and how AES views opportunities for public-private partnership on things that lead to those types of innovations? I mean, are there places where it's easier for you to engage in that kind of activity than others? And are there some examples that you can sort of bring forward that talk about ways in which you're doing that?

Chris Shelton:

I mean, we worked directly with the department of energy. We've done that in a couple of, in a couple of different ways, like our solar storage solutions that, that we've scaled up. Yeah, we originally tested for more than a year at NRELs lab in Colorado. And so bringing all the expertise from all the scientists

and having the lab environment with all of the testing we were able to kind of push that forward very rapidly, validate it and then scale it into Hawaii for KIUC on the Island of Hawaii. That to me is a great partnership with government in terms of scaling something. I think the private sector largely does a good job. Once you validate something in the right context, right? With the quality structure in a market, then you, there's no trouble bringing private capital to scales and things. So where I would want the, the government to play is in creating a quality environment, right? Like that's where we want the focus on that policy. I think if we have a modest carbon tax, you're going to start to see innovations like the one I was talking about where you can reuse carbon because you can afford to pay to reuse the carbon and then it accelerates the, you know, the, the transition, you know, that tax code is decent. It's a 12 year stream of cashflows at \$35 of benefit. Right? So like, you know, we need more than that, but it gives you an example of that type of policy that attention by the government is I think much more leverageable. Right? Because the private sector will chase that. Right. We've seen that in renewables, the way people chase policy around renewables has been dramatic.

Sarah Ladislaw:

Switching gears a bit, Chris, we've been talking a lot about the deployment of renewable energy technology, but that's not the only thing that grid planners have to think about. There's all these other considerations like resilience and cybersecurity and other things like that. I was just wondering, you know, how much in your work do you see those other considerations perhaps hindering or shaping the way in which the electric power sector might be able to achieve deep decarbonization?

Chris Shelton:

I mean, there's a bit of bias in this, but in my early career I was a systems architect and I, I think that's the architect's problem. And a well architected system can embrace change and actually get better and as part of the process. And that is a challenge for the, for the U S sector. That's not really centrally planned anymore. But we have to drive standards. We have to, the industry itself, it's kind of incumbent upon us to come up with these architectural shifts that policymakers can embrace that allow change to happen faster, right? If we come up with standards for solar, let's say for their cyber risk or their dispatch, you know, of their inverters or whatever, and we can push those than we can, we can encourage more rapid adoption and then get more resiliency as a result, not less resiliency.

Sarah Ladislaw:

Great. Thanks Chris. That's really valuable perspective. I agree. I mean, I think that you're starting to see a lot of planners starting to incorporate more strategies for building resilience into electric supply system that's changing rapidly and a distribution system that's changing quite quickly as well. Well, we could talk about it a lot more, but I want to just say thank you very much, Chris, for being on the show and providing your valuable perspective on the work that you're doing.

Chris Shelton:

Thank you. We appreciate the opportunity.

Sarah Ladislaw:

Lastly, I chat with Todd Moss of the Energy for Growth Hub. Todd, thanks very much for joining us today.

Todd Moss:

Great to be with you, Sarah.

Sarah Ladislaw:

So a lot of the work that you've done has focused on energy development in developing countries. And this series that we're doing focuses on the question of de-carbonization and you know, it was observed by many of us thinking about this particular conversation that a lot of times we think about de-carbonization in a developed country context first and then sort of think about how that applies to a developing country context. How has this work sort of effected the work that are doing and how you think about sort of the developing country context for thinking about decarbonization?

Todd Moss:

Yeah. So in, in one way it's, it's been amazing in that people are really thinking about what kinds of energy systems do all societies need in order to be prosperous and successful. And how do we use new technologies to make sure that everybody gets the energy they need in an affordable and sustainable way. So that's been, I think, a hugely positive step.

But I do think that there's some big differences when we're talking about the future energy systems and de-carbonization a place like the United States or Europe or even in, in China relative to some of the other regions. And I, you know, my whole career has been working on sub Saharan Africa. So I try to view things through, through the African lens and when we start talking about energy and de-carbonization in frontier markets, like in East Africa or West Africa, I think there's some pretty big differences in terms of goals and objectives that often get lost in the conversation. And the big part is that, like, for instance, in Africa, there's actually no, there is no short term climate mitigation play here. The electricity system, certainly the power system is just far too small. So just to give you an example, in 2018, global electricity consumption grew by about 900 terawatt hours. But the total electricity consumption in all of Africa that year was just a hair over half of that. So we're really talking about just vast differences that, you know, the African power sector is less than a rounding error in global emissions. That I think point that it's so small raises some big questions about fairness. And you know, Nigeria is a big country, 200 million people. Does it make sense for Americans to ask Nigerians to focus on decarbonizing their power system when the average American is emitting, you know, 33 times as much as the average Nigerian? I think the answer that's probably no. So you know, the energy agenda in most of these emerging and frontier markets is just not right now. It is not about transitioning from high carbon to low carbon power systems as much as it is about just building that energy infrastructure in the first place

Sarah Ladislaw:

When the sustainable energy, you know, for all and the energy poverty alleviation goals were first raised. I remember exactly the conversation you're talking about, which is the amount of emissions you get from connecting the world's disconnected populations to energy resources and even their growth trajectories are just such a small rounding error. In the broader question of decarbonization on a global basis. But from there the conversation gets kind of tricky, right? So there's this concept of leapfrogging and you know, along with that this idea of infrastructure and technology lock in, right? And this is where I think it gets to be a more complicated conversation, which is yes, connecting communities in the way that we've always connected communities through centralized and maybe fossil based energy resources is something you on a an equity basis certainly wouldn't want to not allow in these developing country communities. But there is a question of at what point do we just sort of lock in old dirty systems? What is the capability of leapfrogging and quite frankly, what's the benefit of trying to leapfrog in some of these countries that we can learn about new business models? How, how do you think the development

community in particular and countries that you work with closely, how do they try and grapple with all of those dimensions of this?

Todd Moss:

Yeah, you're right. These are a complex set of issues and they're economic, they're social or political and they're ethical. But look, they're kind of two separate leapfrog conversations going on. So one is by leapfrog, do we mean that countries can use new technologies, new renewable energy technologies, lower carbon technologies and not be fossil based for that question? I think that the answer is yes in some cases. But let's not oversell it. So for Africa, can they do better than we are doing? Absolutely. Are, you know, are they going to exploit wind and solar far more than we are? Yes. And in many ways they already are. If we look at a country like Kenya, they're already getting a majority of their electricity from geothermal sources. Country like Ethiopia is going to be mostly a hydro. But I think it's also important that getting the energy that these economies need is nonnegotiable.

And that means that cheap and reliable. And in many places that is going to mean gas. Countries like Ghana and Nigeria have a lot of gas- they're are exporting it. Mozambique maybe even Tanzania, they're going to be exporting some of this gas and the question is whether they're going to use some of that at home. And I know that the idea of gas infrastructure in Africa is making some investors and policymakers nervous for climate reasons, but I'll give you just one little perspective here. So again, what we're talking about on on mitigation is in Nigeria a country of 200 million people. They currently have 18 power plants running on some kind of fossil fuel. The number in Tanzania and Senegal is 11. They each have 11 power plants running on fossil fuels. In Kenya, it's eight. In the United States we have 3,323 power plants running on some kind of fossil fuel today. So this idea that we're going to argue with Kenya or Nigeria over, you know, single digit numbers of power plants just, it absolutely makes no sense. So I think we need to be especially cautious.

Part of that is, you know, these decisions about what kinds of infrastructure are we willing to support or finance is going to be made in our city, in Washington DC. And you know, the World Bank and the U S Treasury Department are powered by a company called Pepco and last year Pepco is 94% coal, gas and nuclear. And if you are a country going to the US Treasury or to the World Bank to get finance for infrastructure, it's virtually impossible to get coal or nuclear and gas is becoming really difficult. So the, the opportunity for just horrific rank hypocrisy is like, it's on the table there. That's the kind of technology leapfrog.

And there's another leapfrog that people often talk about in Africa, which is leapfrogging the grid. We're already seeing all kinds of new business models to deliver energy services in new ways. The PAYGo solar and there's all kinds of captive power models that are happening. But the question is, will off-grid models change everything in a place like Africa? Do they even need a grid? So the answer to that is kind of yes and no. So th the differences, are we talking about rural homes or are we talking about Africa's mega cities and industrial future industrial parks? So for many households that are low income, they want basic lighting, cell phone, charging, maybe a fan in those environments. And for some very small low-power businesses, yes, these off-grid models make sense. They might be in a place where the grid will never arrive. And this provides an alternative.

But for heavy industry, for most commerce and for the cities, and keep in mind, by 2050, two thirds of Africans will live in cities. You know, the economies of scale still apply. And, and that is going to mean they're going to need large scale power that's delivered through what's going to look mostly like a traditional grid, at least for those segments. And where SDG 7 I think made a crucial mistake is that the ambition of SDG 7 is absolutely wonderful, right? It's access to affordable, reliable, sustainable, and modern energy for everyone by 2030. But the metric of how we're tracking that is the residential electrification rate at a very, very low level. So if you're able to have a couple of light bulbs in your house, it's considered success. But development is not about lighting at home. Everyone should have a modern lighting at home. It's a very important lifestyle issue. It's good for human welfare, it's good for communities, but for development you need power systems that can drive factories and data centers and farms and all and all of that. And that is not captured in a low level residential electrification. Right.

Sarah Ladislaw:

One of the questions in, in sort of the, between the nexus of your identification of the World Bank and other development sort of organizations and this question of whether or not we're targeting the right thing in these broad goals like SDG 7 and others is around the question of two things - one, what role do these development institutions play in energy infrastructure investment, particularly in places like, you know, Sub-Saharan Africa and, and some of the places where you've worked, you know, the majority of your career. The other question is to the extent that a lot of these development institutions are thinking in a post extractive industries kind of way in a circular economy kind of way, in a leapfrogging, in the sense of we're going to try and think about development in a post industrialization framework. Is that what you're identifying as being harmful to the development agenda in those parts of the world? Cause I find that just the conversation about can you create low carbon power generation opportunities in these countries? The answer is absolutely yes. The question is, is there a development model that doesn't have sort of an industrialized component to it that we've been able to figure out that is more along the lines of you know, what people are thinking about from a circular economy standpoint and that seems to be a much bigger open question to me and the world that development institutions are headed into, whereas I'm not sure that that same thing is true of the countries and where they're working.

Todd Moss:

Right. Look, those are two, two excellent, excellent questions. Let me take them in order. So look, the multilateral development banks, especially the World Bank where I've worked, they're involved in all kinds of infrastructure planning and financing. They're really a pivotal influencer in a lot of the frontier markets. And they do have a very important role in assisting countries to find the best low cost, environmentally sustainable options for creating the energy that these economies will need. And particularly the energy they will need for job creation. And the Bank I think has a very clear role, not just on the planning side but also in, in utilizing public finance, maybe sub market finance to subsidize the really hard parts. Things like transmission infrastructure. You know, generation infrastructure is a lot easier to get private capital. It's much tougher on transmission and some of the last mile distribution can be the kinds of things where, where the bank and low cost long-term finance can make a big difference.

But the World Bank is owned by 187 or so countries. And it's a political entity and I think it's important that this serves not just, you know, Northern European shareholders but also the low income shareholders. By not being overly limiting in the technology options, taking things like gas, advanced nuclear and large hydro off the table, which in the case of nuclear, it's absolutely off the table. Gas and large hydro are getting increasingly difficult if not close to impossible through some of these institutions

that's not really gonna help mitigate carbon emissions. It will absolutely hurt people and economies. And there's some real big ethical questions there. So I do think the range of technology options matter a lot and the Bank should be a bit more forthright about that. In terms of a kind of post extractive post-industrial world, look, I, you know, it depends, you know, these regions are not monolithic. Is Ethiopia going to build an industrial model that looks something like the East Asian model? It looks like it. Are all countries in Africa going to do that? Probably not.

But even if we think about a services driven economy post sort of heavy industry, if every country is not going to have steel mills every country is going to have an information economy. And what does that need? That requires data and data centers and functioning infrastructure and data centers are not low energy. Servers require a ton of power. They have to stay cool. A data driven economy is not a recipe for a low energy economy. So I think regardless of the path the different markets choose, we're still talking about orders of magnitude more energy being used in, in these economies. The effects of climate change, which actually suggest that countries like in Africa are going to need far more energy, not less.

And I'll give you just three examples. If we think about the effects of climate change being extreme weather, rising risks of drought and rising temperatures, each of these suggests rising energy demand. So for extreme weather, what do you need? You need resilient infrastructure that's mostly steel and concrete for drought rescue, you need pumped irrigation for agriculture. And a lot of countries are going to need desalination and rising temperatures. You need industrial cold storage and a lot of people are going to need air conditioning if not everyone. And if you, you know, steel, desalination, and air conditioning are just hugely energy intensive technologies. So the climate adaptation agenda is really a high energy agenda.

Sarah Ladislaw:

That's an excellent point. I mean I think a lot of times we are thinking about the sort of cost and minimization of decarbonization pathways, but don't always think about building their sort of resilience with an eye towards climate impacts but also communities energy needs in the context of a changing climate. I think that that's a good point.

This has been great. Thanks so much again for joining us Todd.

We were able to cover a lot of ground in our conversations with Jesse, Sue, Chris, and Todd. There were a few common themes and questions that popped up multiple times in our conversations. Here's some of the discussion on those recurring themes and questions. Please note this content has been edited for clarity. So Jesse, how well and at what level do you see policy makers and investors thinking about the kind of de-carbonization pathways that you're talking about? Is it really only at the state level where you've got deep decarbonization targets coming out that you start to see policymakers really thinking about this in the right combination of ways? And do you think people are getting smarter about thinking about managing these issues on a policy basis?

Jesse Jenkins:

I am optimistic in that front. I think we've seen a pretty dramatic expansion of understanding about the sort of need for a complete toolkit here and the important role of firm low-carbon options over the last really just, you know, two or three years. And that's partly due to the, you know, the work of the

research community and really trying to apply that systems thinking. I mean that's our job, right, to do that and run these models and try to provide robust insights. And so there's been an expansion of the body of work there that I think provides a strong and clear intellectual foundation for those policy efforts. And then there have been many groups, NGOs and utilities and you know, research organizations that have been, you know, consuming that and seeing how things are playing out in their real, in their regions and you know, that are leading the way on, in renewables integration and other issues.

And I think the need is coming into, into clear relief that wind and solar and batteries are going to be star players on our energy system, but we need to complete the team and support them with other technologies. So I've had a number of conversations with utilities, many of whom have recently announced these, you know, net zero or carbon neutral or deep decarbonization commitments. And all of them now clearly understand that to get to those goals we need to complete the low-carbon toolset. You know, they have the confidence to make those commitments today because they know they can keep making rapid progress on emissions over the next decade or two and they are confident that if we are proactive over the next decade, we will have the rest of the toolkit available when needed. And I've seen that focus shift in, you know, the investment portfolios of DOE and ARPA-E, which is, you know, ARPA-E spun up a number of programs that are effectively targeting this kind of a technology need.

And you know, I've spoken with principals at Breakthrough Energy Ventures for example, who are organizing much of their investment portfolio around a need for low cost firm low carbon generation. So I think there's, you know, there's reason for optimism and as policies expand that are ends-based policies, you know, that focus on carbon free electricity standards or low carbon goals at a state level that I think is an important change as well because it's shifting from the kinds of means based policies like renewable portfolio standards, tax credits that specify kind of a specific narrower set of tools or means to an ends based policy that says, look, we need to complete this job of transitioning to a low carbon system. We're flexible about what technologies contribute to that. We know renewables are going to play a big role in that, but maybe not the exclusive role. And so we want to be open to contributions from a variety of technologies and that's generally been the trend across most states and utilities that are making these commitments lately. And I think that's certainly encouraging sign as well.

Sarah Ladislaw:

So it strikes me that even though sometimes we take for granted that we're going to decarbonize the electric power sector, we actually have a number of sticky wicket issues to deal with particularly when it comes to thinking about how to keep certain technologies in the market or deploy brand new technologies into the market. I know that you follow very closely the policy environment on something like nuclear power where these issues really come up a lot. Is that discussion been moving in a positive direction or has it been moving in a less positive directions for the purposes of deep decarbonization?

Sue Tierney:

On nuclear in specific - Uh I think that there are two sets of discussions. One of them is the near term discussion about retention of the existing fleet. As long as it is safely operating and as long as it is even with a price on carbon, if it's economical to keep them in place, then I, I think that that's one conversation. Where you're hitting a third rail on that one is tension between the mechanisms that states have used as they've tried to grapple with the absence of federal policy to put a price on carbon that that can retain those resources and then the wholesale markets in which they operate. And clearly

the recent action by FERC with regard to the PJM mitigation policy, just to be a little wonky here for the moment, is the poster child for that very extreme tension between state policies on nuclear and not to mention renewables and others, but also the wholesale market designs. So I think that's still a work in progress or process. Then there's a whole other discussion about the research portfolio and regulatory reforms and business model reforms that are going to be necessary for the hoped for ability of a different kind of nuclear fleet to begin to operate eventually. And I do think that that is probably in the chapter of the 2040s, but those things, those reforms and the research budgets have to begin. And then I, they are beginning. I mean I think that there's an interesting conversation in, in Congress that is bi-partisan about the innovation agenda. And so I do think that there is an opportunity for that plowing of ground for eventual fruits to play off when we really need it. I agree very much with the, the way that you've framed this in the question, to me it's almost different chapters and in this chapter we have a lot of room to introduce a variable generation, variable demand and so forth. But we really do need some new suite of technologies to help us out there in the long stretch and the very difficult time to get from say 80 to 90 to a hundred percent carbon free in the electric sector.

Sarah Ladislaw:

Chris, are there systems level changes that policy makers are making that you think will help push this transition to a decarbonized power sector? What other changes do you think are necessary?

Chris Shelton:

I think people are starting to move in that direction. And you know, I think for the first part of this, which is if I'm going to let renewables compete, right? It's, it's the molecules to metal thing, right? So I'm going to convert the fuel burn that I have in my system to renewables. The first thing you have to do is let that happen. So you, you know, policy-wise and most states in the U S have finally started to do this. You have to allow all source competition. Yeah. Whoever's doing the procurement, if it's a utility, they need to be focused on the best solution and not come with some pre-baked expectation of some combined cycle, let's say, or some peaker gas plant or whatever. That's largely been happening. Now, you know, PURPA was allowing folks to bring renewables into even every corner of the United States to try to do this. I think there's been a lot of pushback on PURPA, so, you know, we'll see what happens there.

But the idea that you know, if you have a least cost source of energy, you want to supplant the expensive fossil that you're, that you're paying for, you should just let that happen. On the system wide basis, I think the most critical thing is figuring out how power plants... two things. One, how they're remunerated for helping the transition, right. And then second, how to encourage them to drive their dispatch lower. Right? Because if one thing people may not realize is either power plants that are owned by utilities or power plants that are on tolling agreements, the operator, many times of those plants could be completely indifferent to the dispatch of that plant. They really don't care because they don't make any more or less money, right. Based on the dispatch of the plant. So I think we have to think about that and say, how do we, you know, continue to, to fine tune the dispatch of the fossil plants to get to this kind of 80/20 world. Because I think the storage and wind can easily get us to the 80/20 yeah. You know, I think five years ago that was was a dream. Yeah. I think today it seems relatively inevitable. So that's very exciting.

Sarah Ladislaw:

You know, a lot of times we hear people talk about renewable energy is now cost competitive with new generation. Are there places where renewable energy additions are going to be cost competitive with

existing generation? And what does that do to the business model for existing generation? And there's certainly not enough focus on the transition from adding additional renewable energy generation today to what is the business model for existing fossil energy? What does a natural gas peaker in a 80/20 world, what is their business case look like? And how does the regulatory environment have to adjust to take that into consideration? And I think that's interesting that you're thinking about that.

Chris Shelton:

Right. And, and I, I think a lot of it is muscle memory. Yeah. No one's really trying to fight it. It's just Hey, when people run a power plant, they run it at 45%. Yeah. They don't think about trying to run it at 25%. Cause it's just easier to run it at 45%, but it may be uneconomic to run it at 45% for the system. It's a system wide uneconomic decision to run the plants at 45%. It should be run them at 25%. So that kind of thinking that's a physical that really isn't based on engineering. It's just based on, you know, the way people have always done things.

Sarah Ladislaw:

Sue, what are you hearing from some of the public power providers and utilities that are not necessarily being heard by policy makers and regulators? I'm thinking of, you know, things that those utilities and public power providers would be very willing to do in the right circumstances and they feel like are technologically or economically possible, but they need just a more certain investment environment or longer term signals that there's going to be an opportunity to demonstrate some of these projects in new areas.

Sue Tierney:

I think that there is a surprising growing body of opinion among leadership in a number of the public and private utilities that they are committed to eliminating carbon emissions by a certain timeframe. And they I think would, would wrap their arms around something that was a reasonable pathway. So you and I might agree that there needs to be action today about a whole lot of different things, but there's lots of reasons like equity considerations, like financial stranded cost considerations and so forth that may call for a pacing of action so that we really have a sustainable transformation of the, of our industries and I, many in the utility industry would like to see different phases of this rather than saying, you know, by 2025 you have to do X, Y, and Z, which is almost impossible and then creates situations where there has to be conflict.

So if there were agreement on yeah, we are on this trajectory and what we need to do today, say on innovation to get us ready for the 2040 to 2050 period. That's part of the pathway of what we need to do today. But actually eliminating natural gas from the power system today would not be, would not be a productive strategy for keeping the lights on. I think there's actually growing interest in getting a common perception of yeah, we are working to get this and we're not dragging our feet. It's just the realities of different chapters of this work that we need to work on.

Sarah Ladislaw:

I often tell people that I have every confidence we could decarbonize the entire energy system over a period of many decades, but doing on a time scale that's relevant for climate purposes is really fast by most people's measures. Are there barriers that you see, whether they're physical or technological or business case barriers that prohibit us from doing this as quickly as we need to? Certainly being able to

get to net zero environment, which would probably mean having a deeply electrified energy system in a shorter timeframe than that. Chris, what do you think?

Chris Shelton:

I think the limit will be largely NIMBYism or and or transmission, which are kind of interchangeable. So if you need to build renewable resources near highly valued land, whatever's causing it to be valued. But let's say, I mean the obvious one is near where people live, you know that slows progress. So how do you deal with that? I think you could build transmission, that's what Texas did, right, with CREZ. So you know, it worked. How long did it take them to course correct. You know, because the wind resource was where it was. You can't move the wind. And so you build the CREZ and you have this massive growth and wind and you know, they have the highest penetration of renewables right in the story, you know, continues. That's how we think about it. So if it happens, it's probably a hiccup. You know, you can modify the NIMBY ish pressures with, with transmission, but solar is kind of unique cause it's kind of everywhere and as it gets cheaper, it can encroach on being closer to load, you know, elevates the NIMBY issues. Solar has a particular opportunity that then introduces particular challenges. But I think they're, they're not insurmountable. I mean, I think as the costs continue to come down, that cures all ills,

Sarah Ladislav:

Really infrastructure challenges, whether it's transmission lines or people not liking solar next to their house, those types of things, they do hamper the ability to have a quick transition. Sue, is this one of those areas where you feel like the federal and state policy or regulatory process might be able to be helpful down the line in facilitating the building of this infrastructure more quickly?

Sue Tierney:

I do, and I'm ducking my head under the table as I say that because it's, it's a pretty tough area. Interstate delivery infrastructure is really, I think what we're talking about. Yeah. And you know, ironically we have now and have had for decades in effect federal preemption over a gas pipeline citing and add to that LNG and so forth. And, and states are mad. Many states are mad about what that means for them and their ability to shape a portfolio of energy resources broadly consistent with their state policies on decarbonization of their economies. I mean, New York would be the archetype example of that. I'm not saying all states are, are mad. I live in Colorado. There's a lot of people in Colorado who think that the fact that pipelines can have eminent domain is a really important thing. And then that it is a federal decision about the ability to condemn land basically or pass through to certificated pipeline companies that authority to go to court. And yet that's what we're thinking about that might be needed on electric transmission. So the, the, the very states who might like to see multi-state transmission lines and corridors and opening up a bigger regions electrically so that you really can take advantages of diversity of supply that the timing of sunshine and, and dusk and the different times in which economic activity occurs across a region. I think there's a lot of people on the, let's get serious about climate. Who thinks that there needs to be much better work now, we may need to get more creative so that we go back to governor's compacts or some other kind of way to get around. What will probably be a very difficult bill coming out of Congress to give the federal government eminent domain and a preemption over transmission. But again, it all depends upon how bad things get in people's awareness. Could you imagine that people would live with the kinds of changes that people are absorbing in real time as the coronavirus goes out? And that's because of the shared sense among policy makers and people that we are collectively at risk. Until that kind of urgency happens, I think we have to be creative about this

federal state hybrid system that we have over infrastructure, but we really do need to talk about infrastructure more. So I agree with Chris.

Sarah Ladislaw:

Jesse, another important issue to consider is the difference between de-carbonization pathways in developed versus developing economies for the purposes of fighting climate change. It's obviously important that both developed and developing economies reach a low emissions pathway, but the way to get from where we are today to that pathway is likely quite different in developed versus developing country contexts. How do you think about that issue?

Jesse Jenkins:

I think this is absolutely critical and it's a really key part of how we need to think about our decarbonization strategy in the United States or in other wealthy countries. Because for example, say we could over the next 10 or 20 years dramatically eliminate CO2 emissions from our energy system, but we did so in a way that drove up the cost of energy substantially and failed to drive down the cost of climate solutions because we were in such a hurry that we're not really focused on driving innovation and we just, you know, throw enough money at it to get the job done, which you know, we would potentially have the means to do as well as the countries that would eliminate our emissions, but it would fail to make the kind of progress that we need to drive down the global trajectory for CO2 emissions. The biggest lever that we have to affect the international trajectory on emissions isn't just our role as leaders, you know, sort of putting on, you know, our hair shirt or doing the right thing and encouraging others to do the same.

It's in doing a decarbonization policy in a manner that makes clean energy and climate solutions cheap enough for widespread adoption across the world. If we can use our wealth and our technological expertise and our willingness to act early to drive down the cost of technology the way we have with wind and solar and batteries, that has an enormous implication for the, you know, sort of political willingness of other countries to follow in our footsteps. So I think that we've done that successfully. I mean, not in a necessarily in a coordinated or focused way, but you know, uncoordinated you know, somewhat accidental, a series of effective partnerships between different countries, subsidizing the growth of wind and solar and subsidizing the industrial base, et cetera over the last couple of decades has succeeded in making wind and solar cheap enough that many developing countries are excited to adopt those technologies now. And I think EVs and you know, not just four wheelers, but two and three wheeler electric vehicles are following a very similar trajectory where these are now very attractive mobility options for a lot of the world. We have to do the same thing with the full suite of low carbon technologies, whether that's nuclear or CCS or electrolysis or direct reduction of steel with hydrogen. You know, so we can do that without coal. You know, there's a whole suite of those technologies that are still immature and costly. And if we invest well and, and structure innovation policy and industrial policies in the Western countries or the wealthy countries, well we can make those technologies cheap also. And that will have an enormous ripple effect across the world. It's really the biggest lever we have to affect the course of global emissions.

Sarah Ladislaw:

Todd, would you agree? What are your thoughts?

Todd Moss:

Yes. I mean I look, I think as you've characterized it is right. I hope that we're not generating electricity in 20 years in the exact same way that we're doing it now. So there is definitely a role for continued innovation and particularly to push the cost curve down. And that's what's really going to drive adoption and deployment of these technologies in all markets. But especially in, in low cost markets where people are very price sensitive. If you're running a small business in Nigeria your power cost is going to be one of your most expensive line items. We organize, we organized, a workshop in Abuja last year and there was actually a line for diesel for the backup generator to make sure that the lights in the air conditioning stayed running during our, our workshop. So every industry in certainly African markets has to deal with high cost electricity and unreliable electricity, which makes it even more high cost because you need a redundant backup system.

So the more that we can drive costs down through technological innovation and business process and new technologies the better it's going to be. And if you want to replace all those diesel generators and if you eventually want to push coal and gas out of the energy system, the cost is, is what's going to drive that. I often hear people misuse the, you know, the LCOE estimates and kind of treat very low cost solar LCOE costs as equivalent to the same from a more baseload style power system. And I think that's something that people need to be a bit more transparent about, about comparing apples to apples.

Sarah Ladislaw:

Todd brought up the LCOE or levelized cost of electricity. Jesse, you have an interesting way of highlighting the fact that cost is not the only metric used to measure a balanced diet of generation technologies.

Jesse and then Todd, could you elaborate on your analogies for the various generation technologies in the energy system?

Jesse Jenkins:

Yeah, so I, I use that analogy in a lot of my talks to point out that it will start with the good news, which is that wind and solar power have fallen dramatically in cost over the last decade. Basically 90% cost reduction for solar PV and a, you know, 70% reduction for wind. And we've seen similar, you know, 85 even close to 90% reductions in the cost of lithium ion batteries as well, which provide a, another key tool in the low carbon toolbox. So that's great news. And what that has led a lot of people to comment on is that wind and solar are now in many cases the cheapest energy source we have or for new electricity and much cheaper than many other low carbon options, including geothermal energy or nuclear or bio gas or the low carbon technologies available. The complicating factor though is that when you compare those technologies, you know, one to one another on cost alone, this is where the analogy comes up.

It's a little bit like comparing the cost of a banana to the cost of a burger when you're trying to decide what you want to eat, right? It's good to know that the banana is cheaper than the burger. That's useful information. It's good to know that solar and wind are cheaper than bio gas or geothermal or nuclear. But you know, the two kind of classes that technologies play very different roles in our low carbon diet. Just like you don't want to eat only bananas and you don't want to eat only burgers, you know, you need a balanced diet. And similarly to the banana/burger analogy, you know, the first few bananas as you eat are great sources of potassium and that's good for your diet. But if you eat too many of them, the value

of that additional potassium, you know, basically falls to zero. And that's true for the electricity sector as well, where wind and solar are very valuable and when they start to scale up in the energy system, but as they fill their sort of niche or role in our energy diet, their value starts to fall and other things become more relatively valuable.

Todd Moss:

I think about it as analogous to a transportation system. So like my bicycle is definitely the cheapest, lowest impact way to get around my neighborhood. And I love to bike around. But if I need to haul cargo to California from Washington DC, my bicycle is, is literally useless. So you need a transportation system to do all kinds of things. We need an energy system to do all kinds of things. And me just saying, Hey, my bike is cheaper than a diesel truck is actually not that useful. If you're not thinking about the services that that provides.

Sarah Ladislav:

No, absolutely. That's a good analogy as well.

Well, those were definitely two great analogies for us to end our conversation on today. I hope you enjoyed today's virtual event about exploring pathways to achieving net zero emissions in the electric power sector. I want to say a big thanks to Jesse, Sue, Todd and Chris for joining us and for sharing their expertise. This was the second session of the CSIS Climate Solutions Series.

We want to thank JP Morgan Chase & Company for supporting this series. I also want to say a big thanks to my colleague Stephen Naimoli for his research and work to make these events successful. I want to thank my other colleague, Mary Margaret Allen, who helped with the formatting to make this virtual programming a success. Check out [CSIS.org](https://www.csis.org) for the first event in our Climate Solution Series and keep an eye out for the second discussion, which will be coming up in May when we're going to explore lowering emissions in the transport sector. Thanks for listening.