WHITNEY BELL: Hello and welcome to the National Transmission Planning Study webinar. I am Whitney Bell with ICF and I will be your host today. First, a few housekeeping items for today's webinar. This WebEx meeting is being recorded and may be used by the US Department of Energy. If you do not wish to have your voice recorded, please do not speak during the call. If you do not wish to have your image recorded, please turn off your camera or participate by phone. If you speak during the call or use a video connection, you're presumed consent to recording and use of your voice or image. All participants are in listen only mode. If you have any technical issues or questions, you may type them in the chat box and select send to host. We are not taking questions today, but you still may submit questions throughout the event using the chat function. All questions received will be used to inform the FAQ on the National Transmission Planning Study website. If you need to view the live captioning, please refer to the link that will appear in the chat shortly. Finally, we will post a copy of today's presentation on the National Transmission Planning Study webpage by

Tuesday. The recording of today's webinar will be available in about 2 weeks.

To kick off today's meeting, you will hear from Maria Robinson, the Director of Grid deployment Office here at DOE for her keynote remarks. So let's go ahead and get started. Maria, welcome.

MARIA ROBINSON: Thank you so much and welcome everyone here today. Good afternoon or good morning depending on which part of the country you're in. I wanted to take this opportunity to express my appreciation for all of your input so far, and all of your input moving forward into the National Transmission Planning Study as well as make sure that everyone is familiar with the newly created Grid Deployment Office and the work that we're doing here. So, if you move to the next slide.

The Grid Deployment Office is one of the new offices developed in the Department of Energy as a result of the Bipartisan Infrastructure Law with an increased focus on deployment in addition to DOE core mission of research and development. We separate out into three main functions, primarily. The Power Generation Assistance Division, which focuses on nuclear power and hydropower, and maintaining existing assets. Our Transmission Division, which supports a variety of financial and planning efforts around transmission in addition to permitting and risk analysis. And then finally our Grid Modernization Division, which oversees a number of activities relating to reliability, resilience, outage prevention and overall look at how we can continue to develop a 21st century grid.

So all of these activities live here within the Grid Deployment office. And in addition to that, we're going to dig down today a little bit into what is happening in our Transmission Division. The Grid Deployment Office, as a whole, is working on a number of different financial programs relating to the Bipartisan Infrastructure Law and now, of course, the Inflation Reduction Act. And if you'd like to learn more about some of the efforts happening on the grid side relating to those financial programs, both loans and grants, I encourage you to take a look at our Grid and Transmission Conductor Program which lays out the different requirements and expectations associated with each of these different programs, and we're also happy to take any questions that you might have through the inbox that is linked to within that page about specific programs and what financial assistance efforts might be best aligned for your particular program. Going to the next slide then.

Within our larger Building a Better Grid Initiative, which encompasses all of our work relating to both transmission and distribution systems, we're focused on not just those financial planning and assistance related programs, but we are looking more largely at how these systems would operate in the 21st century and doing a significant amount of work around permitting, R&D, and general stakeholder engagement. As a part of this, we have a significant amount of our portfolio is looking at both short term and long term planning at a variety of different scenarios and specifications. For example, we have an Atlantic Offshore Wind Transmission Study and hope to perform similar studies relating to offshore wind in other regions of the country moving forward.

We have our congestion related study, which is the Transmission Needs Study that I'm sure many of you are also actively involved with. But then we have this landmark National Transmission Planning Study, which we're here to talk about today, which goes down to a much deeper level of modeling work than any previous National Transmission Study and really looks at what the requirements of our system will be moving forward under a variety of different scenarios, whether we are looking increasing AC lines, DC lines, going for a macrogrid, and allows us to determine how best to use some of our resources moving forward, considering the changing nature of the electric system as a whole and what kind of grid is needed in order to support it.

So we really appreciate your input into the National Transmission Planning Study, acknowledging that all of you who are participating today and have been participating in other workshops have been able to provide a regional local viewpoints that will allow this study to really be a truly comprehensive look and assist in our overall modeling towards our goal of ensuring clean, secure, affordable electricity. So with that, I'm going to turn it back over to the team who will walk you through the great work that's going on in this study.

WHITNEY BELL: Thank you Maria. We now welcome Carl Mas and Hamody Hindi from the Grid Deployment Office to provide updates on the National Transmission Planning Study. Carl, I will turn it over to you.

CARL MAS: OK, so once again I want to extend a warm welcome to everyone for our second webinar on the National Transmission Planning Study. As was mentioned before, my name is Carl Mas and I'm Senior Advisor with the Grid Deployment Office here at the Department of Energy. Next slide.

So we have a full agenda today. We plan to review for you our study objectives, which will serve as a reminder from our discussion earlier this year, we will provide a quick review of the public engagement processes and then spend the bulk of our time on the overall analysis of our scenarios. It will be valuable to revisit the actual modeling framework and our approach to the sensitivity analysis as it has evolved over the past few months based on public engagement and then next we will present our early findings. It's important to note that this project is built upon an iterative modeling process which will not be complete until the end of 2023 and we therefore stress that the numerical results will change over time in part based on future detailed modeling that we will be exploring later this year and going into next year. We do, however, think that there are valuable early insights, and that's what we want to share with you during our hour today. Next slide.

So, as described earlier this year, this project is being conducted by a joint National Laboratory team, NREL and PNNL. Support and direction is being provided by the Department of Energy where the project was initiated by the Office of Electricity and has since moved under the direction of the Grid Deployment Office, where we find ourselves now. While the analysis is new and modeling tools are being improved as part of the process, this work builds from many years of work and important foundational studies that have been completed by our national labs, and we've highlighted two studies here. One was a recently published study examining the effects of 100% clean electricity system, another one is a foundational work on the North American resilience model which has really built foundational tools for this project. Next slide.

So we have a number of objectives for this work, including the development of specific modeling outputs, and we'll be sharing some of those early insights later today, but equally important from what we look for to this project is the beginning of a process that will serve to advance our energy system goals. So through this work we're looking to identify interregional and national strategies to accelerate cost effective decarbonization, as mentioned by our director earlier today, while maintaining system reliability.

In addition to exploring deep decarbonization scenarios, our study will produce insights into the potential impact of the Inflation Reduction Act. As the preliminary analysis will show, the IRA is potentially game changing if we can unlock the scale of clean energy deployment that our models show could be achieved. So those will be some new insights that we can bring. Our analysis will also include detailed models and which are also used by transmission planners across the country. So in this way we're going deeper into reliability than past national level studies have been able to accomplish, and we are looking to develop a list of robust expansion options that deliver high value across many future scenarios that take into account some of these much more detailed modeling outcomes from our tool set.

We will seek to inform regional and interregional transmission planning processes, particularly by engaging stakeholders in dialogue. This is not a replacement for existing regional planning processes, but we do hope it will help to reinforce and expand on early examples of interregional collaboration that's already ongoing throughout the country. And we really feel like those early models are examples that we can build from and help to facilitate those types of discussions across the country. And our goal is not only for individual regions to engage with DOE, but also for each region to engage with each other.

We have already had broad discussions from a diverse set of participants representing every region of the continental US. We've heard that this is an ambitious scope and that there is substantial hope that this exercise will produce actionable results as well as new methods and new tools. And I'll unpack a little bit more of what we've heard as some of the early stakeholder engagement. And we don't view this as a one and done study. We see long term value from repeated national level planning and we're interested in supporting studies in the future that explore implications for each region. And then finally, as was mentioned earlier, we anticipate that this work will inform future DOE funding opportunities, a number of which were discussed as part of our overall Building a Better Grid initiative. Next slide.

Okay, so we just wanted to make sure and highlight what we see is in the study and actually what the study will not be trying to focus on. And so and as we've as we've mentioned before, we are looking to accomplish with new tools and new activities, linking several long term and short term power system models and we went into some detail at our last webinar on what the nature of those models will be. We want to be able to test transmissions options that are outside of the normal content and focus of current planning processes, and we're looking to provide a wide range of economic, reliability and resilience indicators. Some of the catch phrase for this is multi value analysis and that's, again, what we're looking to bring that's new to this study.

We are not looking to replace existing regional or utility planning processes. We are not going to be siting individual lines. We are focusing on looking at where is the opportunity for increased transmission capability between different points in the system. We will provide results that are granular, but not as granular as what some of our utility studies will do. So and again, we see this as complementing that work and we will not be developing detailed plans for service. Next slide please.

OK, so I'm going to take a few minutes to walk us through some of the public engagement and then we'll shift gears and talk about our scenario analysis. So next slide. As we introduced in the first webinar, we have a four pillar or four aspects of our engagement. The first is gaining public input, and that's a two way street, so we are sharing information through public webinars we have. On our website we have a form that welcomes input and I'll be sharing some of the insights that we've already gained through that structure, and we'll be gathering your thoughts and questions in the chat and we'll be reading through those carefully and adjusting our website to address questions through our FAQ and also to pull insights into our technical team.

Our second pillar is with our existing convener groups and we have a couple of their logos here, so that includes organizations that represent the public utility staff around the country, NARUC, as well as state energy office representatives through NASEO. There also are convening groups for the regional planners, EIPC in the east and WIC in the West. So we've been actively engaged with these organizations and with their leadership team, we want to thank them for that engagement. We've leverage organizations like NARUC and NASEO in order to help us to conduct surveys of the state energy office and utility commissions to be able to better inform our input assumptions.

And really the objective there is not to reinvent the wheel, but instead leverage some of our existing ways to communicate and share information, but also gather feedback. The third pillar, which has been very active this year and is the core of our input, is through our Technical Review Committee. You see a number of logos representing just a sampling of the types of organizations we have. We have utility planners from regional transmission operators. We have utilities, we have representatives from both PUCs and energy offices, we have folks representing NGO's as well as some private sector transmission developers and generation developers, we have expert academics who have volunteered to join our group, and we've had two public TRC meetings and we hope that you've been able to join those. We've published those scheduled meetings on our website and as I'll show later in this slide, we will continue to leverage the work of the TRC to give us detailed technical input along the way. And finally, to round out, as sovereign nations we've also done direct outreach to tribal nations, and we've already seen a number of tribes stepping forward and showing interest. We've been gathering their input along with the rest of our stakeholder community. Next slide, please.

So just to talk through a couple of the themes that we've heard from you all through our forums and through the chat from the previous webinar, we have broken it down into three categories. First, around modeling, we've heard specific recommendations on reports that we should leverage and other online resources, and we really welcome those, and we encourage you to use our forum to share with us what you think are some of the seminal studies that may be outside of the kind of core literature that we've already been leaning on. We've heard encouragement to leverage existing corridors and infrastructure and also to not just focus on the bulk system, but think about grid enhancing technologies that can happen both for our existing transmission lines as well as at the grid edge.

We've heard a call through both our technical experts and through general public engagement of a need to look at climate change impacts on the system. When we look out in 20 years, we've heard from a number of voices that we need to run additional sensitivities that look at what might be the impact of a changing climate, and I do have a couple of slides that will speak to how we want to, in the future, in the next round of analysis look to address those requests. We've also heard from you all of that distributed energy resources are key drivers, and as important in load as thinking of the actual level of over electrification of our buildings and transport. And so we have added sensitivities and have been further exploring sensitivities around broader deployment of distributed solar.

Also looking at how peak shaving could be increased through new distributed energy resources and so we are exploring those through new sensitivities. And then it's kind of a general catchall on modeling, we've heard reinforced that we're looking for actionable results, actionable tools to come from the work. We want the methods and the actual plans to come out to be focused on what would be actionable. There was a call for engagement at the regional level, which we're doing both through the existing convener groups, but also to make sure that our Technical Review Committee has representation from all regions of all planners. And then to maintain a feasible scope and so what that speaks to is it's a large and ambitious scope, and we recognize that we're going to have to focus and prioritize along the way and to really seek how can we have actionable outcomes from the work?

On the policy side, we have received specific information on how to interpret existing policies and we were encouraged to work directly with states to ensure state policies are up to date and to that end, while we have representatives on our TSD from regions representing different state voices, we've also done direct survey work to our states, and we've seen a great response and folks being able to help us fine tune how our modelers can interpret individual state policies. We also took note that folks wanted us to -- benchmarks to other models, they feel that some of these non-binding incentives and goals that are in states will also influence outcomes. While we will be hard coding in firm state policies into the modeling work, we will be benchmarking to other models in order to think about how goals that are maybe not codified in law may influence outcomes.

And then finally, some themes around land use environment. It was reinforced that permitting and siting challenges are important to both recognize and incorporate, and then to think about, for example, as we look at more nodal detailed analysis on how we can be informed by and inform decisions around how existing rights of way could be better leveraged, and so we've heard some of those calls clear that using existing rights of way, for example, will reduce local opposition. And then finally, we've heard inputs and interests around exploring issues around equity, both in terms of energy justice and environmental justice, and so we're working with the labs now to think about how we can incorporate that given the scope, and we absolutely want our final report to be able to speak to some of these important issues around both the participatory processes and how we can engage our communities in an equitable way, as well as thinking about how the specific modeling outcomes might be informed by equity concerns. So that rounds out some of the themes, next slide, and I think at that point we'll pivot to the scenario analysis and I'll turn over the mic. So thank you very much.

HAMODY HINDI: All right, so. So now we're going to dive into the scenario analysis. First, I'm going to revisit the framework, including some important updates that Carl alluded to and then we'll jump into some of these preliminary takeaways we've seen from our early work so far. And really, the scenario analysis is the heart of this project and where we're focusing the most effort. And what we're looking at here, we're asking the question, what are the different ways the power system could evolve going into the future? It depends on a lot of factors from the cost of generation and siting challenges to things like load growth and other factors that we'll go through.

And we're saying as we adjust those different factors and different system constraints, how might the system evolve? And what are the transmission expansion options we see coming up in all, if not most of those future scenarios that provides a lot of value? And we want to come away from this project with a prioritized hierarchy of transmission expansion options that provide value, again, in most if not all of those future scenarios.

So let's dig in here first to the framework itself, and then we'll get to the results. So this slide here shows all the different types of modeling we're using. As Carl mentioned, we're going after the multi value of transmission, so it's important each different type of model demonstrates a different type of transmission value. So we've got on the left here are our model inputs. So again, generation data, the transmission network itself and then assumptions on electrification with vehicles and in building assumptions, not all will feed into initially our capacity expansion model. And that model co-optimizes generation and transmission capacity, both the capital costs and the operating costs ranging from starting in 2020, going out to 2050, into the future.

And as we vary the inputs and constraints, the capacity expansion model will produce different future power systems. And feeding into that, of course we have a distributed energy model and the forecasting model that also feeds into that. And to make, we've analyzed about 200 scenarios and I'm going to go through some of those. But the follow on work here, the most compelling scenarios we see we're going to then downselect to do more detailed analysis. And that's represented by the green models here, so we'll do things like production cost modeling, first at a zonal level consistent with the capacity expansion model, which by the way is 134 zones for the entire country, just to give you a flavor of the spatial granularity of the capacity expansion model.

Anyway, we'll do production cost modeling at that same zonal level and resource accuracy modeling at that same zonal level. And then we'll dive even deeper and downselect again to convert over to nodal models, which are in line with what industry uses to do their utility studies, as Carl alluded to. And we'll do additional production cost modeling analysis, resource adequacy analysis, and power flow analysis. And through all that work, we're again trying to identify what are those high value expansion options that perform well in most, if not all of the future scenarios that we're analyzing.

And again, it's a starting point for a conversation and we want to work with regional planners to then take those identified options to the next level of development to ultimately try and get steel in the ground where appropriate or, as Carl also mentioned, upgrading existing corridors with appropriate technologies. Alright, so I'm going to keep going here and let's dive a little bit more into the scenario framework.

How do we get to 200 scenarios? That's a lot. So first, as Maria sort of mentioned at the beginning here, we're looking at several different transmission paradigms. So I'm going to go through them here. The first on the left, we have what we're calling a limited transmission expansion paradigm. And here what we're doing for the model, we're constraining transmission expansion to just be within each FERC Order 1000 Region. So no cross regional transmission between those 134 zones in our capacity expansion model. And we're actually adding an extra limitation in this first paradigm to limit the total amount of transmission growth to be in line with the average growth rate over the past 10 years. So that's an additional limitation to this limited paradigm, so that's a constraint on one set of scenarios.

Second transmission paradigm we're living in is what we're calling an AC paradigm. And that will allow for any AC expansion to happen within each interconnect. So Eastern interconnect, Western interconnect and ERCOT [phonetic] interconnect, but no cross-interconnect transmission expansion. So you do have intra-regional, just not across the interconnects. The third paradigm we're looking at, we're going to give a shorthand named of LCC which stands for a line commutated converter, and in that paradigm we are allowing expansion of the transmission system across the interconnects, but just through point to point to terminal HVDC, that's the LPC moniker as a shorthand for that paradigm.

And then the last paradigm we're looking at is really the most progressive paradigm. It's what we're denoting with a shorthand as VSC, standing for voltage storage converter. But in this paradigm, the options we have are all the previous options, plus we're allowing the model to have multiterminal HVDC. So that will overlay the existing power system or other types of expansion, including the AC expansion, sort of that's what is also known as a macrogrid concept, and so we are studying that paradigm as well. So those are the four transmission paradise that will govern our scenarios.

And then moving on, so again, how are we getting up to 200 scenarios? So we have the four transmission scenarios. Then we're going to look at two different demand paradigms, a low demand paradigm and a high demand paradigm. And I'll talk a little bit more how we're choosing those later. And then for each demand paradigm, we're looking at three different carbon targets or decarbonization targets. The first is if we live in a world where we want to use existing policies for decarbonization, so that'll capture stated goals and also the Inflation Reduction Act, and I’ll talk a little bit more about that. That's sort of the most conservative decarbonization future.

Then our middle of the road decarbonization future here is this 90% by 2035, followed by 100% by 2045. So that's kind of a medium paradigm. You might remember in our kickoff webinar we did back in March, our middle of the road decarbonization target was actually 80% by 2035. Then when the IRA passed last August, we did some quick analysis and found there's a range of decarbonization that might happen in current policies with IRA and part of that range got somewhat close to 80%, and so we thought it might be more informative to have our middle of the road be bumped up to 90%. As I'm sure many of you know, the last 10% getting from 90% to 100% is really challenging and still quite a big leap. And so we thought having both 90% and 100% would provide a good diversity of interesting scenarios to look at.

And so that takes us to our highest decarbonization feature, the 100% clean electricity system [unclear] by 2035 and of course, that is the Biden administration's goal. So those three decarb paradigms plus the two load paradigms, so that's four times – So that's 24 core scenarios. And then to get us up towards 200, we're doing additional sensitivity analysis on a subset of those core scenarios. So for the current policies, low demand scenario or the 90% decarbonization high demand scenario, and for the 100% decarbonization by 2035, a high scenario, high load scenario, we're going to do these additional 14 sensitivity analysis.

So I'm going to walk through these here and there's another slide that recaptures this in more detail, but the first sensitivity will look at increasing transmission costs by a factor of 5. Now in our default assumptions, transmission cost varies across the country based on region where you are. So we already have that variation where for our high transmission cost sensitivity we're going to overlay that to a multiple of 5 for all transmissions across the country. The second set of sensitivities here, we're doing both a high gas price sensitivity and a low gas price sensitivity, and again, that was in response to a lot of feedback we've heard from public input. So those are two sensitivities.

And then we've got a PV and battery low cost sensitivity. So that's sort of speaking to, you know, what if storage cost gets decreased significantly, wow will that impact the expansion options that might come up in our futures? This next sensitivity here is a low wind cost sensitivity and then the siting sensitivity, limited siting here that refers to wind and solar siting limitation, so not other types of generation and not transmission sighting but wind and solar in particular, so that sensitivity. Then the next we've got a high distributed generation sensitivity. And I'll point to some numbers there in a few slides.

Then, as Carl mentioned, we're doing a demand response sensitivity, such as peak shaving sensitivity. Initially we're looking at shaving 40 hours, the top 40 hours for each half of the year, both the summer half and the winter half, and then as the sensitivity, high sensitivity is now doubling it to 80 hours for each half of the year. So the next sensitivity is a high hydrogen cost and a low hydrogen cost, as we see that as a potential flexible resource in the future so that the sensitivity to price is important for how a power system evolves.

And so this next sensitivity, here is an interesting one, this is looking at non renewable technologies. We're doing both a high non-renewable technology paradigm and a low non-renewable technology paradigm relative to our default assumption. So this top one we're adding for nuclear, so not only extending existing nuclear plants, but adding new small modular reactors nuclear, as part of that high non-renewable sensitivity and then also adding direct air capture as part of that high non-renewable technology sensitivity. And then likewise, we'll do the opposite and do a low non-renewable technology future where we have no carbon capture or no DAC and also new nuclear, so two sensitivities there.

So this climate sensitivity, this is an interesting one, we got a lot of good feedback on this one, for the climate sensitivity, we're basically looking at, you know, the ambient temperatures might increase going forward into the future, looking at impacts on hydro generation, so both reducing the energy availability of hydro generation in this climate sensitivity and also reducing the capacity credit of hydro plants. As well as for thermal plants, reducing their capability, their nameplate capability down to 85% compared to our default assumption due to higher ambient temperature.

And then the transmission system itself, right, transmission line ratings depending on ambient temperature. As that goes up, where we're saying, well, let's derate the transmission transfer capability by 5% going out to 2050. So that reflects what we're capturing in our climate sensitivity. And then this many challenges sensitivity is really a combination of the sensitivities I've already talked about all rolled into one sensitivity. So what the many challenges sensitivity captures is limited solar and wind siting, a high hydrogen price, no carbon capture and no new nuclear, and then these climate sensitivities that have those transmission and resource derates that I was mentioning.

So for those sensitivities, that's four transmission paradigms times the three different load and decarb targets times the 14 sensitivities and so that gets us 168 future scenarios. So adding those to our 24 core scenarios gets this up to pretty close to 200 there. So again, we're exploring those future scenarios using our capacity expansion model, which is really a starting point for the conversation. Let me talk a little bit more before I get to the results about some of these modeling adjustments that we've made since this study kicked off.

OK, so first I'm going to talk about policies. So again, we're looking at three different decarbonization policy paradigms, the most conservative being existing policies. Our lab teams that have worked really hard, and I think done an excellent job of very quickly incorporating the

Inflation Reduction Act, which again just passed mid-August, so very recent. So we are reflecting that and I'll go into more detail in the next slide for that. And then of course, our 100% by 2035 paradigm and our 90% by 2035, 100% by 2045 middle of the road paradigm.

And again, these carbon constraints in the model, our national targets, so for example, in our 90% scenario it potentially we could have certain states be above 90%, with others being less than 90%, it's a national constraint. And so we went through state by state and took a careful look at the policies and we also, we first reviewed the Lawrence Berkeley Labs update. They monitor state policies and make updates every year based on what they're seeing. So we started there and then, as Carl mentioned, we've been engaging with our experts on our Technical Review Committee in existing convening groups, so NARUC and NASEO talking to the state energy offices and utility commissions and having them review our spreadsheet of assumptions we had for state policies and asking them, look, are these state policies we have here for our model reflective of what's the latest available to your knowledge?

And so we've got good feedback there as well. It's looking at things like not only clean energy targets in renewable portfolio standards, but things like coal retirements and nuclear retirements and offshore wind targets that individual states may have, so those would be reflected. And in all of these, you know, our modeling is reflecting what's enshrined in law so far. And so we do want to acknowledge there are other non-binding incentives and goals that states have that might facilitate decarbonization. And so our model are not reflecting all of those voluntary and non-codified options, and so we want to acknowledge potentially more decarbonization could potentially occur then what's directly captured in my model here and it's important for us to note that.

All right, so let me dive into the Inflation Reduction Act here. So again, what we're modeling in our model is the production tax credit, so we've got $28.00 per megawatt hour for bio power, for land based wind, and for utility photovoltaic. And we've got the investment tax credit modeled for batteries, for concentrating solar, for geothermal, for hydro, nuclear, offshore wind, and pumped hydro. And then lastly, we've got a captured carbon incentive of $85 per ton for bioenergy, CCS, and for fossil CCS. And we don't have any equivalent transmission tax credits modeled.

And the last thing I want to speak to on the IRA is there's a couple different ways these tax credits could expire, they were written into the law. And the first is that they could potentially expire in 2032. But secondly, they could expire once we reach 75% decarbonization from where we are today, which is quite a deep level of decarbonization. And so the law is written, so whichever of those two things happened later. So we decided, let's be conservative here and go for this 2032, assuming our model may expire in 2032. And the reason we chose that conservative target is we didn't want different scenarios having the tax credits drop off on different years because it made it more difficult to do comparative analysis between the scenarios, so we went ahead with this conservative assumption of, well, let's assume these tax credits all go away in 2032. It's acknowledging they'll likely go beyond that based on the other provision. OK, so that's the Inflation Reduction Act.

Let me talk a little bit more about our demand and electrification assumptions. So again, we have a low demand growth assumption. By the way, this plot here is looking at energy growth in terawatt hours over the course, going from a about - Yeah, well, the 1990 out to 2050, but again our study is going from today out to 2050, so you can see historically what we've got in terms of energy and then our low demand growth on this grade curve, so .9% per year. And then the other side of our envelope is this high demand, so 2.4% per year energy growth across the country.

And let me talk a little bit more where these are coming from. So for the low demand scenario we're looking at really two sources here, the first is Evolved Energy Research’s Annual Decarbonization Perspective. They sort of have a baseline scenario that captures business as usual energy growth and then that's also benchmarked against EIA's Annual Energy Outlook, which again forecast out business as usual growth, so benchmarked our low demand scenario against that as well. And then for the high demand scenario, we're looking back at this the Evolved Energy Research’s Decarbonization Perspectives, what they're calling their Central Scenario, and so that scenario is energy based on achieving a net zero economy by 2050, and so that that lines up with what we're using for our high demand load growth scenario.

And of course, we've had feedback and adjustments from TRC and state experts so far. And I think going forward, we want to dig into this a little bit more with the regional planners. And in terms of load, we've heard feedback that a lot of planners are seeing growth in industrial point loads and the data center point loads as well, and that's been a major challenge for them, and so going forward we want to try and look a little bit deeper into this and see if there's further adjustments we might want to make in terms of load growth assumptions.

Let me keep going here, so this is a little bit more about load. This is looking, rather than energy, looking at actually peak load, so this shows for the entire country peak load over the course of a year for today and then the yellow is by 2035 and then the black is by 2050. So you can see that the load growing, particularly growing this summer, and I'm just zooming in here to the New York area looking at annual peaks between 2020 out of 2050, you can see the winter peaks on the blue line. The winter peaks go - this is for the higher demand scenario where we have high electrification. So today it's a summer peaking system, but that'll be overtaken by a winter peak as gas gets converted to electricity in the high demand scenario.

And I've already talked about our sensitivity on the demand response assumption. So we keep going here. And then I've already talked about these sensitivities, these 14 sensitivities, but here they are written out explicitly. On the right is our default assumption for most of our scenarios, and then on the middle column here is the variation we made for the sensitivity challenges, say for our high distributed PV case. Our default assumption, we got 181 gigawatts across the country by 2050. For our high scenario ,we got about double that to 363. We've heard feedback that, you know, can we do our energy transformation just with high amounts of distributed resources? Do we really need all this transmission?

And what we've seen and it's true in these preliminaries results so far, we need more of both. It's not an either or, it's all of the above. And again, the climate challenges I talked about, the numbers are listed there and then there are many challenges that you see are a combination of the previous. So I won’t go through each of those, but I'll leave those for folks to explore afterwards. when we post these slides. Alright, so now onto the findings here.

So our preliminary finding, number one, I do want to emphasize these are early results, again, just starting points for conversation, and we're actually going to do another set of runs mid next year. And then we've got, of course, our more detailed analysis using other types of models to follow up, so these are really just based on these early capacity expansion modeling results for these 200 early scenarios. So, but firstly, I want to focus in on this current policy world. The most conservative of our decarbonization futures, right? Even in this most conservative set of futures we're seeing a large amount of decarbonization happening, again, in large part driven by the IRA, but it's not enough to get to zero, and even if you have existing policies plus a lot of interregional transmission development, although it drives decarbonization down, that plus economic optimization alone won't get you there. You're going to have to have other drivers to get to 100%.

The other thing I want to point out on this chart, this is decarbonization going out to 2050 for a range of our scenarios, the uncertainty in how much decarbonization happens can vary quite a bit. It varies from 65% to 90% decarbonization in our modeling here, so that that's quite a large window. Okay and let’s see, so going on to our next finding. There's really notable growth in renewable energy and storage, and this is even still staying in this current policies and low demands world, so really, the most conservative of our set of futures. Even in this most conservative set, you can see the large amount of growth in solar and wind and storage that's happening against, solar is increasing to well above 400 gigawatts.

And each of these colors, by the way, are the different transmission paradigms, so the limited, the intra regional, the intra interconnect, and the macrogrid. You see it varies depending a little bit on which transmission paradigm you are, but really all the transmission paradigms, even for this current policies and low demand, it's quite a large amount of nameplate increase, and so a lot of infrastructure that we're going to have to be adding to do this energy transformation. And here on the left is how much how much transmission gets added. So it ranges between 20% increase to 70% increase based on about today's transmission system, depending which paradigm, even, again, for this conservative set of futures.

OK, and I will say in this load low demand and current policies world, we do see even getting out to 2050 that, again, fossil fuel plants without carbon capture remains. So again, economics alone is not going to be enough to drive to that to zero, so I don't have the capacity [unclear] here, but today we're around 700 gigawatts-ish and it's still even by 2050 remains in that similar range. All right.

So finding number three, so now shifting away from the current policies, low demand world into looking more at our high demand world in 90% or even 100% decarbonization, so the more progressive of our futures. Here you're seeing really a huge increase in the nameplate capacity of resources, so this is gigawatts here going out from today out to 2050, and the different colors represent the different types of generation. Today we've got about 1,100 gigawatts installed on our system and by 2035 that could double or more than double and then by 2050 that could triple compared to what we have today. So again, it's just a huge amount of infrastructure build. And now the transmission system you see from 2020 going out to 2050, basically a doubling of the transmission system capacity here for these high demand futures and decarbonization futures.

OK, so now I'm going to shift away from capacity and talk a little bit about energy for our fourth preliminary finding. So in this case, what we have here looking at our 100% by 2035 decarbonization, for high demands and then the AC transmission paradigm, so that includes interregional transmission. What I've got here is the energy production for a future year for 14 of our sensitivities for this base scenario. And so you can see over the course of the year how much energy is produced by each type of generation by the different colors and these are sorted from top to bottom based on how much of the energy is coming from wind and solar, so the blue and the orange, and this percentage here at the end says what percentage of the total energy produced is coming from wind and solar.

So what this basically is saying, they're sorted from lowest to highest, so in our lowest wind and solar producing sensitivity, that would be high transmission cost sensitivity, but even there 70% of our energy in that year is coming from wind and solar, so that that's quite a large chunk. Then maybe a couple of others I’ll point to, even in a world where we have high-non renewable technologies, so small modular reactor, nuclear, and direct air capture, we're still seeing 78% of our energy coming from wind and solar. And then at the other end of the spectrum, where are we seeing the most wind and solar energy providing [unclear] you really need? So that's the no carbon capture and the no new nuclear scenarios where you're getting the most, but really in all of these futures it’s quite a large chunk of our energy from the year coming from wind and solar. All right.

Then my last finding here before I pass it back over to Carl to wrap things up here and talk about some future work, we have our preliminary finding number five and this is getting into the spatial distribution of the new transmission expansions that we're seeing based on this early modeling. So here again, I want to focus on this 100% by 2035 and high demand scenarios, so fairly progressive. So first, these four pictures of the country over here show the transmission expansion that happens in the limited transmission paradigm, the AC paradigm where you have intra-regional without going across the interconnect, and then the point to point DC, and finally the red and the macrogrids.

The thickness of the lines basically represents how much new capacity is being added of transmission, and it's a little tough to see, but there's a reference point of 10 gigawatts thickness in black there. So most of these you can see are bigger than 10 gigawatts, really most of the pictures you're seeing. And then for this AC scenario, if we look even across all those 14 sensitivities I was talking about, it's pretty clear across the sensitivities we're seeing transmission reinforcement needs in the same locations geographically, and what you're really seeing is from the center of the country, so the windbelt basically to deliver to those eastern load centers, that's where the most transmission reinforcement need is showing up across the country.

And again, going forward going to try and dig a little bit deeper into these and get more granular. And of course the amount of capacity varies depending on which sensitivity, but at least the locations seem to be fairly, fairly well consistent. OK, so I think with that, I'm going to pass it back over to Carl and he'll go through some next steps and then we'll wrap this webinar up.

CARL MAS: Thank you, Hamody. That was a great overview of the early findings and some of the framework by which we arrived at them. So I'm just going to wrap up today by talking about some of our next steps. So we're going to take these candidate scenarios, where we now have on the order of 200 different scenarios across those 14 different sensitivities, and begin to look for early draft thinking around some of these high priority transmission options and that Hamody just highlighted and some of those early opportunities that we're seeing on the previous slide and really again, that's just our starting point of our conversation as we dig into the, to the more detailed analysis.

And so what will come next will be a down selection of our scenarios, we won't be able to analyze, nor would it be a prudent use of time to analyze all 200 with our more detailed models, so we'd be going through a process this fall and winter of down selecting to some of the key scenarios and then running those through our production cost modeling and resource adequacy models at the zonal level. So, as we mentioned earlier, they're on the order of around 100 different zones in our capacity expansion modeling, and we'll first run some of our more detailed models and look at resource adequacy at that geographic scale.

Once we've learned from that, we’ll then be looking at the more nodal analysis where we’re looking at hundreds of thousands of nodes and do production cost modeling and power flow analysis, again, that's aligned with some of the tools and approaches that utility planners use across the country. It's really with that much more detailed modeling that we'll be able to focus in on where are these transmission opportunities? Where might we see additional value proposition that our zonal model hasn't shown us? And then with that output and information, we’ll be able to do the more detailed economic analysis and I'll speak to a little bit of our objectives there, which we're just kicking off now in terms of focusing on what would be the right methods, as well as our resilience analysis and looking at some extreme weather.

And bring some new tools to the table that we think will really help us to more fully understand what is the value of interregional transmission. We'll have then completed that more detailed analysis, and we'll do another look at our capacity expansion modeling, so that's this iterative nature of the work and why I mentioned at the beginning that all these numbers we've shared today are preliminary, and we can guarantee that they will change in some way. And so we will rerun our capacity expansion modeling next year based on the insights that we've learned from the more detailed analysis. And we'll also be able to fold in updates as we develop them, and so we've highlighted today some of the high level rules that we've used, for example, looking at climate change impacts, we're actually, and I'll speak to a little bit more detail, we'll look at some more detailed climate modeling and be able to inform some of the input assumptions that we'll be doing in the second round.

We'll also do any updates to our demand forecasts and anything else that we can learn along the way from our more detailed modeling and feedback from our stakeholders. And again, we think, while it's a significant investment of effort and time, this iterative approach is really what's necessary to be able to do both the kind of high level zonal analysis and then iterate with our learnings from our overall nodal analysis. Next slide.

So for the economic analysis, I'll just speak for a minute just to, but to remove doubt, we are keenly interested and we've heard substantial feedback on the importance of the economic analysis to really enumerate what are the multiple values that would come from interregional transmission? We're looking for this work to inform transmission planning and potentially cost allocation down the road, so that's not the focus of the work right now. And as we see the objectives, we want to evaluate how transmission benefits, how they occur today, but then as the system evolves, we recognize that that economic valuation will change over time, and that's something new that we want to bring to this type of study that hasn't been looked at in the past.

So the types of activities, we’re going to be identifying new methods and, again, leveraging the work that's been done by some regional planners already looking at multi-value, but building from that experience and from the literature, building from some of the comments and some of the work that's been happening during our FERC NOPR [phonetic] process that we've all been taking part in and really look at what does multi-value analysis look like and what are the appropriate methods to look at benefits associated with transmission development? And so we're not only looking at methods, of course, but we're looking at what are the actual disaggregated economic benefits?

And so traditionally this type of work, to look at national models and national overall benefits, and we've heard loud and clear that in order for this work to become actionable, we need to disaggregate those economic findings into regional values and so that'll be an important piece on new activity which other studies have not done in the past. And so outcomes, as I've mentioned, there’s both methods, and so how do we develop methods and tools for disaggregation that can be used by others as both in their own regional analysis and as we do future iterations of the work? And then what are the numerical outputs for the distribution of transmission benefits associated with interregional lines?

And so that will be actual numbers that will come from our various scenarios to be able to demonstrate what those values are. And obviously we hope that the insights that we draw from this on how - we can show how transmission benefits that are anticipated to change over time and to help inform future planning. Next slide, so I have two slides here.

Just unpacking what we see as the next iteration of our climate analysis. We previously mentioned, Hamody mentioned that there’s heuristics that have been assumed as part of our early sensitivity. What we want to do is actually take the actual output from the global climate models and be able to downscale those into our work, and so this lower box shows our existing model ecosystem, so production cost modeling and our capacity expansion modeling and our resource adequacy modeling happening at different scales of zonal to nodal.

Right now we feed that with several inputs, including the renewable energy resource databases that existed in rail, so wind and solar resources. We put that through an existing tool called Rev which looks at what's the, how do we translate the potential of wind and sunshine into actual energy that can be used in the grid? We also take existing load data that we've described, and we see through these dashed lines that we can inform through the global models how wind and solar will vary in the future and also how temperature will bear and that affects load through higher heating degree days, actually in this case, and then in lower heating degree days and in higher cooling degree days. And so how will climate models affect temperatures into the future which then affect load? Next slide.

And so the key question here, which our labs are actively working on is, how do we do this downscaling? Our global climate models operate on a geographic scale on the order of 100 kilometer grid resolution and look at daily averages. And for the type of modeling that we need to do, for the type of datasets we have, those are to inform mesoscale datasets. We need to take that down to a 2 to 4 kilometer grid resolution and look at hourly data to inform load, potentially down to 5 minutes for power flow analysis and for some of the variation in our wind and solar resources.

And so what our labs are actively doing now is leveraging some of the machine learning techniques that we've used in other areas and apply that to this downscaling where we can translate global climate models into very detailed analysis of how climate and weather and temperature will change in the US and leveraging our computing power and some of those computational tools, we will be able to execute that work this winter. Next slide.

And so just to round out, I think it's important to talk about our timeline, where we've been and where we're going. So what we see is we had our kickoff meeting earlier in the spring, where we are today in October, we had our TRC meeting and this public webinar, we've concluded our initial scenario modeling, and we're now pivoting into that more detailed nodal analysis going from the hundreds of zones to the hundreds of thousands of nodes. And we'll be planning to come back in the spring and share some of the findings we have from that more detailed nodal analysis. And then we'll look at round two scenario analysis in the summer and going into the fall and looking at wrapping up the project with final discussion with you and with all of our stakeholders towards the end of next year.

We also mentioned last time that there is some baseline analysis looking at what's possible with our existing infrastructure and adding in projects that we see in the pipeline. And so we've been bringing back some of those insights as well as they become available. And that wraps up the focus of our talk. We have one more slide, so next slide just to talk a little bit about - Thank you all for what you've contributed so far and how you will be contributing in future.

What we have on our website, on our Natural Transmission Planning website is part of our GDO family or online ecosystem is we publish information about project news and milestones. We will be publishing this webinar as well as previous webinars, both the PowerPoint as well as videos. We have linked there to our online mailing list. And so we encourage you, if you haven't already joined, please do, so we can send you updates. We have details in our TRC, when we have public meetings in the future, we've also listed the roster of our TRC members and the charter or the mission of what the TRC is trying to accomplish.

And then finally we have a public comment form where we would love for you to go and to submit information, both questions as well as comments on the work that we're doing, and so with that I'll turn it back to our moderators and thank you for your time and attention today.

WHITNEY BELL: Thank you so much, Carl and Hamody, we really appreciate it. That wraps up today's webinar.

As Carl was mentioning, thank you for submitting your questions. We'll use those to inform the FAQ on the National Transmission Planning Study webpage, it's there on your screen, it's also in your chat. As he also mentioned, a copy of today's slides will be available up on the site on Tuesday and the recording will be up within two weeks. Thank you to Maria, Carl, and Hamody for joining us today and thank you to all of our attendees for participating. Take care everyone and we'll see you next time.

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