Transmission Planning for a High Renewable Energy Future: Lessons from the Texas Competitive Renewable Energy Zones Process

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Webinar Panelists

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Speaker Hello, everyone. I am Katie Contos with the Clean Energy Solutions Center, and welcome to today's webinar, which is hosted by the Solutions Center in partnership with the United States Agency for International Development, the National Renewable Energy Laboratory, and the Electric Reliability Council of Texas. Today's webinar is focused on the transmission planning for a high renewable energy future: lessons from the Texas competitive renewable energy zones process.

Before we begin I'll quickly go over some of the webinar features. For audio you have two options: You may either listen through your computer or over the telephone. If you choose to listen through your computer, please select the "mic and speakers" option in the audio pane. Doing so will eliminate the possibility of feedback and echo. If you choose to dial in by phone, please select the "telephone" option, and a box on the right side will display the telephone number and the audio PIN you should use to dial in. If anyone is having any technical difficulties with the webinar, you may contact the GoToWebinar's help desk at 888-259-3826 for assistance.

Finally, one important note of mention before we begin our presentation is that the Clean Energy Solutions Center does not endorse or recommend specific products or services. Information provided in this webinar is featured in the Solutions Center resources library as one of many best practices resources reviewed and selected by technical experts.

If you would like to ask a question, we ask that you use the "Questions" pane, where you may type it in. If you're having difficulty viewing the materials through the webinar portal, you will find PDF copies of the presentations at cleanenergysolutions.org/training and you may follow along as our speakers present. Also, the audio recording or presentations will be posted to the Solutions Center training page within a few days of the broadcast, and will be added to the Solutions Center YouTube channel, where you will find other informative webinars, as well as video interviews with thought leaders on clean energy policy topics.

Today's webinar agenda is centered around the presentations of our guest panelists, Nathan Lee and Jeff Billo, who have joined us to discuss an overview of the CREZ process, including the regulatory, procedural, and technical considerations that were critical to a successful implementation in Texas. The webinar will also introduce a renewable energy zone toolkit developed through a USAID and NREL partnership and intended to guide other power systems in adapting elements of the CREZ approach to their own power system planning processes.

Before we jump into the presentations, I'll provide a quick overview of the Clean Energy Solutions Center. Then, following the panel's presentations we'll have a question and answer session moderated by Ilya Chernyakhovskiy of the National Renewable energy Laboratory where the panelists will address questions submitted by the audience. At the end of the webinar you'll be automatically prompted to fill out a brief survey as well, so thank you in advance for taking a moment to respond.

The Solutions Center was launched in 2011 under the Clean Energy Ministerial. The Clean Energy Ministerial is a high-level global forum to promote policies and programs that advance clean energy technology, to share lessons learned and best practices, and to encourage the transition to a global clean energy economy. Twenty-four countries in the European Commission are members, covering 90 percent of the clean energy investment and 75 percent of the global greenhouse gas emissions.

This webinar is provided by the Clean Energy Solutions Center, which focuses on helping government policymakers design and adopt policies and programs that support the deployment of clean energy technologies. This is accomplished through the support and crafting and implementing of policies relating to energy access, no-cost expert policy assistance, and peer-to-peer learning and training tools such as this webinar. The Clean Energy Solutions Center is co-sponsored by the governments of Australia, Sweden, and the United States, with in-kind support from the government of Mexico.

The Solutions Center provides several clean energy policies, programs, and services, including a team of over 60 global experts that can provide remote and in-person technical assistance to government and government-supported institutions, no-cost virtual webinar trainings on a variety of clean energy topics, partnership building with development agencies and regional and global organizations to deliver support, and an online library containing over 5500 clean energy policy-related publications, tools, videos, and other resources. Our primary audience is made up of energy policymakers and analysts from government and technical organizations in all the countries, but we also strive to engage with private sector, NGOs, and civil society.

The Solutions Center is an international initiative that works with more than 35 international partners across its suite of different programs. Several of the partners are listed above, include research organizations like IRENA and the IEA, and programs like SEforALL, and regional-focused entities such as ECOWAS Center for Renewable Energy and Energy Efficiency.

A marquee feature the Solutions Center provides is the no-cost expert policy assistance known as "Ask an Expert." The "Ask an Expert" service matches policy makers with one of more than 50 global experts selected as authoritative leaders on specific clean energy, finance, and policy topics. For example, in the area of renewable energy policy and policy purchase agreements we are very pleased to have David Jacobs, Director of International Energy Transitions serving as one of our experts. If you have a need for policy assistance in renewable energy policy and power purchase agreements or any other clean energy sector, we encourage you to use this valuable service. Again, the assistance is provided free of charge. If you have a question for our experts, please submit it through our simple online form at cleanenergysolutions.org/expert. We also invite you to spread the word about this service to those in your networks and organizations.

Now, I'd like to provide brief introductions for today's panelists. First up is Nathan Lee who is a Postdoctoral Researcher with the Integrated Decision Support Group at NREL. Nathan's research and work concentration is in energy system and power system planning with a focus on generation and transmission systems.

Following Nathan we'll hear from Jeff Billo, who is the Senior Manager of Transmission Planning at ERCOT. In this role he oversees the near-term and long-term transmission planning efforts at ERCOT, including both steady-state and stability analysis.

And our moderator for today's question and answer session is Ilya Chernyakhovskiy. Ilya is a co-author of USAID and NREL's Greening the Grid toolkit. He serves as the lead for NREL's Scaling Up RE in Central Asia project under USAID's Power the Future initiative.

And with those brief introductions, I'd like to welcome Nathan to the webinar.

Nathan

Thank you, Katie. As Katie noted, I'm a—this is Nathan Lee. I'm a Postdoctoral Researcher here at the National Renewable Energy Laboratory. And today I'll be presenting an introduction to the renewable energy zone—or REZ—transmission planning process, as well as some introduction to the resources that we have available here at the National Renewable Energy Laboratory for practitioners who may be interested in this REZ process.

A quick outline for my presentation: We'll start with just an introduction to what the renewable energy zone transmission planning process is, give an overview of the steps in this REZ process, as well as a quick introduction to the REZ toolkit and some of the resources we have available here to help those who may be interested in finding more, finding out more about the renewable energy zone's process.

So, just to start off: What is a renewable energy zone? A renewable energy zone is a geographical area that enables the development of profitable, cost-effective, grid-connected renewable energy. So, in essence, when identifying a renewable energy zone we're looking for a couple of key criteria, and these are high-quality renewable energy resources such as wind and solar, suitable topography and land use designations—so, identifying those areas where it is possible to develop these resources. And then, finally, demonstrated interest from developers—so, making sure that we have that private sector interest in developing in these zones. So, all of these criteria of course support cost-effective renewable energy development.

So, how do these zones tie into the actual REZ or renewable energy zone transmission planning process? The REZ transmission planning process is really a proactive approach to plan, approve, and build transmission infrastructure connecting these renewable energy zones to the power system. The REZ process really helps to increase the share of solar, wind, and other renewable energy resources in the power system while maintaining reliability and economics as we scale up renewable energy resources. The REZ process also helps to focus on large-scale wind and solar resources that can be developed in sufficient quantities to really warrant transmission system expansion and any upgrades that are necessary. And when we're talking about wind and solar we're looking at these variable renewable MG resources as they're really similar to large hydropower just in the fact that transmission systems need to be brought to the location of that resource to connect them to the grid. So, they're somewhat site-constrained.

Other renewable energy resources such as geothermal or mini-hydropower are of course important to many planners, but they're seldom found in that sufficient concentration to really warrant consideration as a renewable energy zone. But when we're—when these supplementary resources such as geothermal or mini-hydropower are located within a designated zone, or REZ, these supplemental renewable energy resources may provide additional value to a designated renewable energy zone.

The REZ process that we're presenting here really applies to these renewable energy expansion activities that are constrained by the lack of existing transmission systems. The REZ process may not be as applicable in situations in which other reasons limit renewable energy development, or if the existing transmission system already has the capacity to accommodate new renewable energy development. In these cases, more traditional planning practices or processes may be beneficial, and a REZ process may not be as applicable. So, in the graphic here I'm just showing that the REZ process really wants to identify these zones, shown here as these kind of hubs or circles in different colors representing the amount of capacity inside of each hub, and these lines that are connecting them, or these transmission system options, for expanding and—for expansion and enhancement connecting zones to load. This is from specifically a western renewable energy zone's initiative here in the western area of the United States.

So, why are we interested in this different renewable energy zone—or, this different transmission system process, planning process? Why is the REZ process really advantageous to us? We've seen that traditional planning processes don't really accommodate the scale-up of renewable energy very well. These traditional planning processes may not align with the development of RE and the decisions needed to be made well in advance of RE generation.

So, we see in the graphic here this kind of time scale misalignment. At the top, renewable energy projects may just take two to three years to plan and construct, whereas traditional thermal plans may take five to ten years, a bit longer. And transmission systems may take anywhere from 10 to 20 years for planning and construction, at least here in the US. So, historically, transmission has been developed to really interconnect these large, conventional, thermal power plants. It takes approximately 10 to 20 years, at least in the US, to permit and construct these new transmission lines, which is compatible enough with this 5 to 10 year timeframe for developing conventional generation. However, it takes much less time to develop wind and solar power plants, as we see here: possibly only two to three years.

And this really brings us to the second reason that the REZ process is advantageous, in that it helps us overcome this circular dilemma that arises from this time scale misalignment. So, if we look at the top right on the slide, we see that RE generators really need financing to implement their projects and get constructed. However, if we follow this circular dilemma around, we see that financers really need to see existing or planned transmission near that proposed generator site to ensure that that plant will be interconnected and utilized and would be profitable. But then, if we move around the circle another step, we see a problem arises if there's not already transmission near that proposed renewable energy generator. And new transmission lines to access this resource need regulatory approval, so we need more regulatory approval to build transmission lines to access these resources. And then, kind of completing the circle or going back around to the top, we see regulators really need to see come committed renewable energy generators in order to sign off on the construction of these new transmission lines, which brings us back to the renewable energy generators needing financing.

So, the renewable energy zone really helps us to overcome these two difficulties in traditional transmission planning processes: the time scale misalignment and this circular dilemma.

So, how does the renewable energy zone process really overcome these two difficulties in traditional planning processes? Well, it overcomes these in a number of steps to make sure that we identify the best resources, that they're attractive to private developers, and that we identify an attractive transmission expansion or enhancement plan.

So, here is an overview of the REZ process, and this was recently posted in the document at the bottom of the screen: the "Renewable Energy Zone—or REZ—Transmission Planning Process: A Guidebook for Practitioners." There's a link there, and I invite you all to go and read this in more detail. I'm gonna go quite briefly through each of the steps now, and in this document you can find each of these steps in more detail and some of the considerations that practitioners such as yourself may need to consider in implementing the REZ process.

So, the first step is really this process design—so, taking the general process that we described here in the guidebook and applying it to the specific system or context where it's going to be used, and developing a vision statement. So, really identifying the boundary of application or the scope of the REZ process. What resources are going to be considered? What geographical area are you looking at? And who will be involved in this REZ process?

So, in this step stakeholder engagement is very important to the REZ process. And on the left here we see kind of a general REZ process organization structure, with a lead entity at the top that really initiates and oversees the planning activity, followed by a technical advisory committee, which is a group that really guides and reviews the technical work and outputs of the two working groups. And two working groups are shown here—of course, this could be adapted to each specific context. But the first working group is of course the zone identification and technical analysis working group. So, these are really responsible for—the groups involved in this zone working group are responsible for the identification of the study areas—so, where are the really good resources located?—and candidate zones—where are developers really interested in developing renewable energy projects?

And second here is the transmission and generation modeling working group. It's really responsible for defining and analyzing these new transmission and generation expansion and upgrade options. And we will discuss where—in which steps these working groups kind of come into play in the next slides. But in all of these working groups and the technical advisory committee there are decision makers that really have the legal authority to make these binding decisions, and these may include the Ministry of Energy or other energy agency officials, other ministries that are relevant, regulators, planners, but also transmission system operators, depending on the context.

Also really important here are the stakeholders that may not make the binding or legal decisions but really have valuable input to all the steps and activities of the REZ process, and that could include renewable energy project developers, utilities, interest groups, as well as non-governmental organizations in the context—and of course, this would be changed by the context of this application.

Step two: identifying the renewable energy resources. So, here we conduct an assessment to really select the areas with the highest resource and technical potential. So, where can we technically develop wind and solar? And an output here is really a map of where these study areas are and understanding how much generation is available from each of these areas. So, a supply curve showing how much generation we can get at what levelized cost of electricity.

With this renewable energy resource assessment we can move to step three, which is a candidate zone selection. So, identifying those zones that actually have the highest probability for actual development. And the output here is a candidate zone map that shows where these zones are and how much capacity—and supply curves that would also show how much generation we could get from these zones.

So, why do we identify these candidate zones? Well, the output from step two really identifies where the best resources are, but these resources and these areas may not be attractive to private developers at this stage. So, at this step developers really demonstrate their interested in the screened areas to ensure that the candidate renewable energy zones are commercially attractive for development. And these examples of commercial interest could include pending or signed interconnection agreements, leasing agreements, interconnection studies by a transmission owner or grid operator, or any other indication that would be deemed appropriate in this specific context of the renewable energy zone application. So, the regulatory authority or other relevant authority would have to really identify what indicators could be taken as commercial interest.

So, after step three, moving to step four, we start to look at how we could connect these zones that are—that have great renewable energy resources but also have signs of commercial interest. How do we connect these zones to load? So, we start to look at transmission options for expansion and enhancements to the transmission systems. And the outputs here are really a cost-benefit analysis, some transmission planning studies that may include a dynamic stability analysis, production costs, and reliability analyses.

So, once we've looked at a number of these transmission system options, possibly three to five really attractive options, we select the option that is most attractive according to a set of preset criteria that would identify that transmission system option that has the enhancements and expansion options that would be most attractive and would allow us to make a final transmission order.

So, here in step five the appropriate authority would really designate the final transmission plan to be implemented. And this designation would really include a geographic description of the renewable energy zones. So, where are these zones located? What resources are contained in them? And what generation can we have in these zones?

This designation also identifies those major transmission system improvements that would allow cost-effective delivery of this electricity to load. It would also identify who would pay for these improvements—so, how would we implement this transmission system enhancement or expansion? Also, it would update any estimates on the maximum generating capacity in the zones. And shown here on the right is an example of the zones that were identified and the new transmission infrastructure to access these zones and really export this power to the load. And this example is from the Texas competitive renewable energy zones initiative, or the Texas CREZ, which Jeff will be discussing in more detail in the next presentation. But it really just shows the steps here: Really identify these zones, and then identify transmission system enhancements and expansion opportunities or options to connect those zones to load.

So, the final step of the REZ process is really the transmission system upgrade—so, implementing that final transmission plan. And this last step may take different—varying amounts of time depending on the context, as well as the cost of that final transmission plan.

So, feel free to check out this guidebook that we have the link for below to go into a little bit more detail for each of these steps.

Also, if—as a practitioner, if you are interested in this renewable energy zones process, we are in the stages of developing a renewable energy zones toolkit that is meant to provide practitioners with knowledge and expertise on the REZ process to really implement this integrated renewable energy and transmission development, following what has been identified as really those best practices. So, the REZ toolkit is an online platform with information and tools to aid practitioners in really successfully deploying the REZ process around the world. Right now it will be hosted on the Greening the Grid site you can see to the right. We invite you to check out the Greening the Grid site currently, but in the coming months we will also include this renewable energy zones toolkit.

The toolkit will include a number of resources for practitioners, including the process guidebook which I've gone into some detail during this presentation about, and you can find that guidebook at the link shown there. In—before we actually launch the toolkit it is available. The REZ toolkit will also provide technical assistance for the REZ process. So, we can help you navigate questions about when this is applicable, what considerations are necessary for the REZ process in your specific context. So, please feel free to reach out with that technical assistance when it's open. We also have some learning and training sections to help you learn about the REZ process and get more familiar with the steps involved. We also include some topical quick reads and in-depth resources to understand some of the different components of the REZ process in more detail. And we also will include some tools and templates and exercises to help practitioners such as yourself really take this general REZ process and apply it to the specific application that you're interested in.

As I said, the REZ process guidebook, or "A Guidebook for Practitioners," is available now at the link that we've shown in the previous slides and also on this slide. And this guidebook is really for policymakers, planners, and system operators around the world. The REZ process has of course been used in different variations to chart the expansion of transmission networks and overcome barriers to traditional transmission planning processes, but with this guidebook we really want to help power system planners and key decision makers, stakeholders such as yourselves apply the REZ process in your specific contexts. So, the REZ process gives kind of a general organizational structure for an effective stakeholder-inclusive REZ process, as we discussed. It also details each step of the REZ process, from identifying a vision statement all the way through to transmission system upgrades. So, as you know, we went quite briefly over each of the steps to give an overview of the process today, but with this document you can go into—you can dive really deep into each of these steps and see what is necessary to advance through the process according to best practices or a general approach that could be adapted to your context.

So, this REZ process is adaptable, but it's really based on this Texas competitive renewable energy zones—or CREZ—initiative that Jeff will go into more detail in the next presentation about. But our REZ process can really be modified based on each country's or application's unique circumstances, so it is flexible. So, I invite you of course to download and read this document if you'd like to know a little bit more about each of the steps and—in the REZ process.

So, some quick takeaways for today's presentation on the REZ process and the REZ toolkit. Of course, the REZ process is really a transmission planning process. It's not a mapping exercise, or not just a mapping exercise to develop an RE resource atlas for country applications, or just to identify resources that are quite close to existing transmission systems. It's really meant to support this integrated transmission planning and renewable energy generation development.

Two, successful implementation of the REZ process really enables this integrated development that I had just mentioned on transmission systems and renewable energy generation development to of course scale up renewable energy generation, but also to harness the best and most developable renewable energy resources when scaling up, and deliver the lowest cost—or lowest possible cost electricity from this renewable energy generation.

The REZ toolkit which is coming soon—however, the guidebook is available—is meant to offer resources and technical assistance to help you practitioners understand and implement the REZ process. So, I invite you all to visit the Greening the Grid page but also to read the REZ process "Guidebook for Practitioners."

So, thank you all for your interest in the REZ process and on the work we're doing here. I invite you all of course to reach out with any questions you have, either after—at the webinar we have some time, but also feel free to reach out to the e-mail address shown here if you have questions on the REZ process after today's webinar.

And I guess now I will hand off to Jeff Billo from ERCOT, who will take a deeper look at the Texas CREZ initiative. Thank you.

Jeff

All right. Thank you, Nate. I'd just like to say up front I am really happy to be on the webinar today and glad to share the story of the Texas competitive renewable energy zone process.

So, up front I'd like to go over just a couple of key takeaways that I hope you get out of the presentation this morning. The first is, as Nate said, this is really a transmission planning process when we're talking about the renewable energy zone process and the Texas CREZ process. I hope that you understand that this is really a transmission planning process.

And the second is that there are a lot of technical details that go into planning for renewable energy zones, and we certainly had a lot to consider as we went through the CREZ process here at ERCOT. So, I hope that you get a feel for some of those technical considerations that need to be taken into account.

And lastly, this is a—this is really a stakeholder-driven process where you really have to get all of your stakeholders aligned and working together in order to take on a project such as a renewable energy zone project like the Texas CREZ project. So, again, those are sort of my key takeaways up front that I hope if nothing else out of this presentation that you get those takeaways.

So, before I get into the story I want to give a little bit of context on ERCOT and what ERCOT is and kind of how the Texas market and regulatory construct is set up. And the first thing I want to say is for those that don't know, there are three interconnections in the United States. There's the Western Interconnection, the Eastern Interconnection, and then the Texas or the ERCOT Interconnection. And in Texas we are somewhat unique in that we are the only grid that is wholly contained within an entire state. And what that means is that there are some—I would say we have less federal oversight than maybe the grid in the Western Interconnection or the Eastern Interconnection. And so, we have this Public Utility Commission which really acts as the regulator for the state of Texas. And ERCOT the company is overseen by the Public Utility Commission of Texas, and the Public Utility Commission has authority to set kind of broad policy objectives as well as the siting of transmission lines and the approval of transmission lines. ERCOT's role is—we were set up by the Texas legislature. ERCOT's role is to really oversee the grid from a reliability perspective as well as from a market perspective. And we have both a wholesale market and a retail market, and it's ERCOT's job to make sure that the system is running reliably and efficiently. ERCOT is a nonprofit and we are not a government organization. We are overseen, like I said, by the Public Utility Commission, which is a government organization, but we are not a government… And also, we don't own any generation or transmission. We have market participants who own all of the generation and the transmission in the ERCOT system, so ERCOT's role is more of the air traffic controller making sure, as I said earlier, that the system is running reliably and efficiently.

Also, somewhat unique to ERCOT is our deregulated construct. We have separated—this goes back to the 1990s—we separated generation from transmission distribution from retail electric service. So, for example, if you own transmission, if you own the wires, you are not allowed to own generation. And so, those are separate companies. And where this is important as we talk about CREZ is that the generators are all competing. They're all owned by private companies and they are competing on the Texas grid to serve the customers on the Texas grid. And again, those are different companies, and so they're all—there's a separation there. So, the generators are competing with each other to serve the retailers, but the transmission itself, those wires, that's really the only piece that is still regulated. The rest of it, it's just purely market-driven.

A couple slides to give a little bit more context on sort of the technical details, the numbers behind ERCOT. As I said, Texas has its own grid. ERCOT doesn't actually cover the entire state: We cover about 90 percent of demand. We had a peak demand last year of about 71,000 megawatts. We have over 46,000 miles of transmission lines. And as far as wind generation goes we set a wind generation record on Christmas Day of last year: We had a little over 16,000 megawatts of winds. We also, from an instantaneous perspective, we surpassed 50 percent of the demand being supplied by wind generation in March of this year. We went over that 50 percent from an instantaneous standpoint.

And we are also, I would like to point out, we are also not synchronously connected with any of the other grids in the United States. We have some AC—or, I'm sorry, some DC or asynchronous connections to the both—we have two to the Eastern Interconnection and three to the Mexico system. But those are really relatively small connections, so we are really an island system, if you will.

And the last slide I really have on context is just our generation fleet. I really wanted to—I'm just going to show we have a lot of wind generation and we're also blessed to have a lot of gas in the state. So, really, a lot of natural resources in terms of natural gas and wind in the state. So, those really sort of dominate our system. And for our historic, I'm going to start in 2003—so if you look in 2003 and sort of where we were at that time, we had about 1000 megawatts of wind generation at that time, and of course a lot of gas generation. And I really want to tell that story and how we got from 2003 to where we're at today in 2017, really focused on the wind generation piece of that, where we've gone from about 1000 megawatts of wind generation in 2003 to now we have over 19,000, and by the end of this year we'll be over 20,000 megawatts of wind generation capacity on our grid.

I'd like to start this story in just kind of explaining the geography somewhat of Texas. So, the map on the right, that is the NREL map that shows sort of the average wind speed for the different parts, the different areas of Texas. And if you'll notice on the left, it's the—kind of the purple and the red, those are the really great wind resources. A lot of average wind—there's a lot of wind energy there. In that part of the state there's not a lot of people, not a lot of—not a large population in that area. And to give you some context—so, I mentioned earlier our peak demand is about 70,000—a little over 70,000 megawatts. In that part of the state that I have circled on the left there's about 2000 or 3000 megawatts of demand. Now, on the eastern part of the state, that is really where most of the population resides, and that side of the state in context is tens of thousands of megawatts of demand.

So, if you go back to 2000, the early 2000s, there just was not a need for a lot of transmission out in the western part of the state because there wasn't a lot of demand to serve in that part of the state. So, what we had at that time was really just a little bit, I would say, a little bit of transmission, and it really was designed to serve the design and not really move power from the western part of the state to the eastern part of the state. And as we had these wind generation developers that were building these wind generation plants in the windy part of the state—of course that's where they want to locate—they were running into transmission constraints, being able to get that—being able to transfer that power from the western part of the state to the eastern part of the state. And as Nate mentioned, we sort of ran into that circular dilemma where transmission is built for generation once that generation is committed to build, but the generators couldn't get the financing to build their plants until they had some commitment that there was going to be transmission so that they knew they would be able to get their power to the load centers in the eastern part of the state. And Nate did a great job of explaining that dilemma.

So, in 2003 we had an area known as the McCamey area. There's a town in the western part of the state known—it's the town of McCamey and it's known for a lot of wind generation resources in that area. A really good wind regime out there. In 2003 there were 750—about 750 megawatts of wind generation that had been built in that area, but the transmission system in that area could only really handle about 400 megawatts of generation. And so, ERCOT worked with our stakeholders, we worked with the transmission utilities in that area, and we came up with a plan, because not only were there the 750 megawatts but there was several thousand megawatts of interest in wind generation development in that area.

And so, we came up with this plan where we did some kind of short-term fixes immediately to raise that 400 megawatt limit, but we also, recognizing that there was this interest out there, we came up with a plan that said, "Okay, if generators—if wind generation developers, if you will commit to building 1500 megawatts of generation in this area, then we will build this new 345 kV line out of the McCamey area and to the east. And then, if that—if you go to 2000 megawatts of commitment, then we will build another 345 line out of the area to connect the McCamey area to the north." And that sounded like a great idea at the time because we were essentially saying, "If you build this wind generation, then the transmission will come."

But the problem was that it didn't work. And why didn't it work? Well, the reason it didn't work is because even with that commitment that that transmission would get built if the generators would commit to coming, they—the generation developers did not want to tie up financing and wait for the four or five years it was going to take to construct those transmission lines. And they also didn't want to go ahead and build their generators knowing that they would be constrained. They didn't want to put the turbines on the ground knowing that they would be constrained for the four or five years it took to build the transmission facilities. And so, we really never got that additional commitment, never had a single megawatt of additional generators that would commit.

And I'd also like to point out at that time the wind generation sites were a lot smaller than what we see today. Today we see on the ERCOT grid these 300 or 400 or 500—or in some cases larger—megawatt facilities. At that time they were sort of the 40 and the 80 megawatt facilities, and really less than 100 megawatts. And nobody wanted to be that generator that was going to be the next one to sign up, hoping that somebody else would sign up as well. And so, we got into this situation where we had a lot of interest in developing in the area. It was very economic from a wind regime standpoint. But the transmission system was really limiting that development.

So, fast forward two years. In 2005 our state legislature stepped in and passed what was known as Texas Senate Bill 20, which was this law which required the Public Utility Commission of Texas, the regulatory authority over transmission in Texas, to designate competitive renewable energy zones. And as I mentioned earlier, the "competitive" is that these—all generators in ERCOT are competing with each other. And at that time, when we were talking about renewable energy it was mainly wind. Solar at that time was not really competitive and couldn't compete on a cost basis. And as Nate mentioned earlier, the zones are really these areas that have high renewable potential.

And so, the law required that the PUC was going to have to designate these zones and that they were going to have to develop a transmission plan to deliver the power from those CREZ zones to the consumers. And there's more details in that bill that I'm sort of leaving out here, but one key I did want to point out, and this is maybe a little bit unique, is that there wasn't really any discussion about—in the bill it didn't specify how many megawatts they were to include in these CREZ zones, or where the CREZ zones were to be located. So, they really—the legislature really left that up to the regulators to decide that.

So, in 2006 the PUC—PUCT asked ERCOT to work on this problem and to determine where the zones would be that would be the—would have the best wind potential. So, ERCOT contracted with a company known as AWS Truepower—I think at the time they were AWS Truewind—to determine where's the best wind resources in Texas. And what AWS did is they looked at the state and they had a lot of field data, and they took that field data and came up with these zones that had a certain amount—I think they had 4000 megawatts of potential wind generation development in each of the zones, and they came up with 25 different zones, and they ranked them from 1 to 25, where 1 had the best wind resources from an energy, total energy standpoint and 25 had the least amount.

And so, that was 2006, and ERCOT did some preliminary transmission analyses that looked at transporting power out of each of those zones to the load centers. And in 2007 the Public Utility Commission took that information from AWS as well as the transmission analysis, kind of that preliminary transmission analysis that we performed, and then they asked the wind developers, wind generation developers, "Where are you interested in building wind plants? Where are the best locations from your perspective?" And based on all of that information they came up with these five competitive renewable energy zones, two up in what we call the panhandle, which is sort of the northern part of the state, and then three zones in sort of the western part of the state—the central west, central, and the McCamey areas.

So, in 2007 the PUC identified those five zones, and then they also asked ERCOT to develop what became known as the CREZ Transmission Optimization Study, and they gave us four scenarios to study. And I think that I'm going to start with scenario three. Scenario three was as they asked the wind developers, "Where are you interested in?" the developers came back to the PUC and said—each one said, "Hey, I want to build a 150 megawatt plant here or a 250 megawatt plant here or a 150 megawatt plant here." And they took all of those numbers and they added them up in each of the zones, and that's how they really came up with that scenario three, was "This is everything that a wind generation developer has told us they're interested in." That was sort of how they came up with scenario three.

Scenario two was really a subset of scenario three. It's smaller because I think there were definitely some cost concerns that it was going to be too costly to develop the transmission system to handle that amount of wind generation. And then, scenario one was, again, another subset of scenario two. And then, scenario four was another look at that same sort of looking at the interest in the zones, but they really—they took that scenario three megawatts and they said, "Well, what if we didn't go all the way to Panhandle B," which was the northernmost part of the—or, the northernmost zone. And the reason they did that is because that zone from a load perspective, a demand perspective, is not served by ERCOT's system today. And so, they looked at sort of spreading those megawatts out in the other zones. And so, that's how they came up with the four scenarios.

And so, they asked us to look at each of those four scenarios and develop an optimal transmission system plan for those, for each of those scenarios. And I also want to point out that these numbers were in addition to what was already existing on the transmission system and what was already committed and planned. And at that time, that was about 7000 megawatts of wind generation that was already existing on the system or was committed to be built in the near future. So, if you want to get the total amount of megawatts, then add 7000. So, as an example, in scenario three, even though it was incrementally about 18,000 megawatts of wind generation, that would be about 25,000 megawatts total wind generation on the system.

So, as ERCOT looked at the scenarios, right away we recognized that this was really an unprecedented amount of wind generation to incorporate on our system, and it was going to be moving just an enormous amount of power. And we really started off by brainstorming different approaches to getting that power from the western part of the state to the eastern part of the state. And as a couple of examples, we looked at just taking our existing 345 kV network in that area and just sort of incrementally adding to that network. We also looked at options such as higher voltage transmission facilities such as 765 kV. We also considered high voltage DC. And we had all of these different kind of brainstorm options and we started developing each of them individually to see what that would look like. And the primary tools that we used were production cost modeling, and what we found was that just in general it wasn't economic to develop the plan in order to get 100 percent of the wind generation out of West Texas. And the reason is that the wind just doesn't blow that many hours. It doesn't blow such that you're getting 100 percent of the energy out of a given plant or given plants in an area.

So, what we came with through some analysis was that really optimal was going to be about a two percent wind energy curtailment, that there would be some hours where you would not be able to get all of the wind generation out of the system. But that was going—that was okay. That was actually economically advantageous to do that. And so, our objective as we were developing this transmission plan was to come up with a system that would have no more than two percent annual wind curtailment. And we did the production cost analysis to really look at congestion patterns and where the transmission system would be limiting, and tried to come up with transmission lines and solutions that would get us to that objective.

And then, the second important piece was stability analysis. And we found that when we were moving that much power on the system then stability really became the limiting factor. It wasn't the thermal capacity of a transmission line; it was really the stability of the system to handle that amount of generation moving from one area to another area. We were moving the generation hundreds of kilometers across the state, and so stability really became the most limiting factor. And those were our primary study tools as we went into the analysis.

And just for fun I included some of the early maps that were kind of the conceptual ideas. In this particular map the red is 345 kV lines and the kind of the purplish lines are 765 kV lines. And the idea in this concept was that you would have sort of these 345 kV collector loops, and then you would transport the power across the state using 765 kV lines.

We had another option here that was—this was actually—the concept was that you would have a separate 345 kV—in this case, the purple lines are 345 kV, and this idea was that you would have a separate 345 kV system that was not connected to the existing system on the western part of the state but that would be just used to move that wind power from the western part of the state to the eastern part of the state, and really only has connections to the existing grid on the eastern part of the state. So, these were a couple of the existing—or, the early concepts that we had.

And really, what we did is we took all of those ideas from the initial kind of brainstorming and we did sort of proof of concept on each of those and developed those ideas, and we took the best of those ideas and came up with the hybrid approach for solving the transmission needs for integrating the wind generation. And they hybrid approach of sort of those best ideas, we really came up with that plan and finalized that plan in April of 2008. So, total study time was about six months from beginning of study until we issued our CREZ Transmission Optimization Study in 2008.

So, in—later in 2008 the Public Utility Commission selected scenario two, which was sort of that middle scenario, which would accommodate in total about 18.5 gigawatts of wind generation on the system. And the total cost ended up being about $6.8 billion, and it added approximately 3600 miles of new 345 kV transmission to the system.

So, that was 2008 when they made that decision, but there were still a lot of things that still had to be decided even in 2008. And the first was that they really didn't know who was going to—or, what companies were going to build the CREZ transmission lines. And you can imagine with 3600 miles of transmission they really didn't want just one transmission provider to be responsible for all of that. There were also a lot of—there were reactive needs on the system that we hadn't really fully studied because it was such a compressed time period. We did that entire analysis in six months, and there were really a lot of reactive needs that the system, we recognized, was going to need. And so, we really had more study work to do on that.

As part of the design we also incorporated series capacitors onto the system, and we really found that that was an economic choice to make. And with series capacitors you have this resonance phenomenon where you can have resonance between the capacitors and generators, and so there were additional studies that needed to be done to make sure that we weren't causing any sort of reliability issues by introducing the series capacitors.

And then staging. I think it was recognized early on that 3600 miles of transmission, you're not going to put that in place all at once, and that there were going to be some lines that were going to be more important than others, and we really wanted to—I think the PUC really wanted to explore which lines should go in first, which were the priority lines. And so, that was all things that were decided over the next couple of years.

So, in 2009 the Public Utility Commission decided to sort of spread out the building of the transmission lines to two different transmission service providers. And there are a number—so, each color on this map represents a different transmission service provider that would be responsible for constructing those lines. And that was something they decided to do in order to make sure there was no one transmission utility that was overwhelmed by the amount of work that had to be done—and it's not only construction but it's also the, you know, going through and working with land owners and doing environmental assessments on the land that was going to be used for the transmission facilities. And they really didn't want to overwhelm any one entity, and so they decided to sort of spread that out among many different—the transmission providers.

I mentioned that there were additional stability studies and those kind of reactive studies that needed to be done, and so those were completed in 2010. And then, in 2010 to 2013 it was really the construction period, and the goal was to have all of the facilities in place by the end of 2013. And I think it was a tremendous accomplishment that that nearly happened. It was—I think the last facility went in in January of 2014. So, if you think about all the possibilities of construction delays due to weather and all of the coordination that had to be done with taking outages on the existing system in order to construct the facilities and get the facilities in place, I really think that was a tremendous accomplishment that was—it nearly happened; for all practical purposes, they were able to meet that goal.

So, I wanted to share some lessons learned, and I'll start with technical lessons learned. And the first is this idea of a weak grid—and that term, I know, is kind of offensive to some people, but I think that's sort of the term the industry uses, is it's this idea that these inverter-based generators such as wind turbines or even the solar inverters, the technology today is that they really need a strong synchronous signal. And what we found is that when you incorporate a lot of these generators, these inverter-based generators such as wind turbines in an area that is far away from synchronous generators—your conventional gas plants or what have you—then the inverters have a hard time finding that signal and maintaining that 60 hertz signal—in ERCOT's case, 60 hertz signal—in order to maintain stability. And you get this—and I've included a graph that illustrates what happens when you don't have that strong synchronous signal, is you get the inverter sort of hunting around and oscillating to find that signal, and it creates a lot of oscillations on the system. And in many cases the inverters, the generators will just trip off the grid.

And so, that's something that if you're developing a renewable energy zone, if you're developing a plan, I would really recommend that you look into that issue if you're incorporating a lot of these generators on your system that are inverter-based. There's a C-grade paper that I think came out last year. There's also—the North American Reliability Corporation is—they had a draft report that came over the summer, and I believe they're trying to finalize that report on this issue later on this year. So, I encourage you to look into that. I think it's something that most planners—your software, kind of your standard stability software doesn't really recognize this phenomenon, and so it's important to really look into that issue more and understand that and if your system may have that sort of limitation.

And I mentioned earlier that stability really became the most limiting factor on our—when we were doing our studies. If you go back and—I'm going to go back a few slides here. If you look in that kind of northern panhandle region, you see there are a number of transmission lines in that area. From a transmission line capacity standpoint we really only needed two lines out of that Panhandle A and Panhandle B region, and all of the other lines that you see were really added for stability. And so, it's important to do those stability studies up front. And I think if there's one thing that I would like to go back and change from the process that we did back in 2007 and 2008, it's that I would begin our stability studies earlier in the process. I think it probably would have saved us a lot of heartache and headaches later on because that really became the most limiting factor.

I also wanted to mention grid code. I didn't really touch on that earlier in the presentation, but what we found is that when you are incorporating just—in our system of our size, when we had a couple hundred megawatts of wind generation on the system it wasn't really that big of a deal. But as we started adding thousands of megawatts of wind generation it became a big deal for the turbines and the inverters to support the needs on the system. And that includes needs such as providing reactive power, low voltage ride through, high voltage ride through, and even frequency response. When you're incorporating that many megawatts on your grid it's important that the turbines and inverters be able to support the needs on the grid. And thankfully, as the technology has evolved the turbines are able to do that; the inverters are able to support the needs. And so, it's important to think about that before you really get a lot of those generators on your grid because it can be really difficult to get those generation developers to go back and retrofit after those turbines or inverters are already installed on your system.

I mentioned earlier the economic curtailment, that we really found that it just really wasn't optimal to plan for 100 percent generation output. And again, in our system we found that about two percent annual curtailment was economic, and the generation developers were willing to live with that amount of curtailment. And I should mention that that's really—that two percent is really system-wide. It's not a specific plant. There may be some plants that are in areas that may see a little bit more than that, and there are some plants in areas that may see no curtailment. But system-wide that seemed to be a good number for ERCOT. But I would say in general I would not recommend planning for 100 percent wind generation output because there's going to be many hours—most of the hours of the year that—there's going to be—your transmission facilities are not going to be utilized to that extent.

And some policy-related lessons learned. We really were able to successfully integrate—where we're at right now is over 19,000 megawatts of wind generation. And we did that by eliminating that transmission bottleneck issue that we talked about earlier, that the McCamey was a great example and they had a good explanation of that sort of circular dilemma where transmission really becomes limiting to that generation getting developed. And so, we were able to do that through the process that was developed here. And I will say it's successful because it's operating today reliably and efficiently. So, as an example, in 2016 ERCOT had our lowest ever average wholesale price of electricity. And that's probably partially due to natural gas prices, but it's also partially due to the fact that we've integrated a lot of low cost renewable energy onto our system. I mentioned earlier that in Texas it's really—the generation is competing. And when you have resources that have, in ERCOT's case, 40 or even 50 percent capacity factors, these wind resources, then they are able to compete and they do lower the cost for consumers on the ERCOT grid. And so, that I think has been a success story here. Now, there are of course other factors as well that have contributed to the low prices, but I think that the—that amount of low cost renewable energy on the system has contributed.

One thing that was a little bit controversial was the transmission provider competition, in that when the Public Utility Commission assigned the transmission facilities to different companies to construct and to operate they really didn't pick just one or two or even three transmission providers; they picked several transmission providers, and some of them weren't even previously in the ERCOT system. And in doing that they really sort of incented those transmission providers to compete, and it really became this thing where nobody wanted to be the company that was the reason that the facilities were going to be delayed. Everybody wanted to—they had this incentive to try to get the facilities in by the end of 2013. And so, that I think is part of the success story.

From an operating perspective, that can be challenging sometimes because you have areas on the grid that if you're trying to coordinate your reactive devices, then that can be sort of challenging in that the operators are having to coordinate with multiple transmission providers. So, if your area is thinking about doing something like that, I just wanted to kind of point that out, that that's something that needs to be considered as you're thinking about what transmission providers are going to be building these facilities.

And then, lastly, the stakeholder collaboration, I think this process really worked because all of the decision makers and all of the stakeholders and interested market participants were aligned. That doesn't mean that everyone always agreed. Of course every company had their own interests. But really, the decision makers were aligned, from the legislature to the Public Utility Commission to ERCOT to the generation developers. Everyone worked together—and I should also mention the transmission service providers—everyone worked together to make sure that this project was successful. And everybody really focused on that goal of getting the system in place and making sure it was reliable and efficient.

So, where we're at today—I mentioned that we have over 19,000 megawatts of generation on our system and it appears that we're going to be well over 20,000 megawatts of generation within the next couple of years. Now, I just wanted to point out in 2009 we had 17 percent of the wind energy on our system was curtailed because you had generation developers that were putting their turbines on the ground, but really they didn't have enough transmission capacity, and so it was sort of limiting that generation that was getting constructed. And so, if you see in the early part of this graph, in the 2000s we had this tremendous run-up, but then it sort of stalled in 2008 and 2009. We really didn't add a lot of megawatts of wind generation until after 2013, and then we started adding the thousands of megawatts, kind of those chunks again, after that transmission was added to get that power out of West Texas. And so, in contrast, in 2014, even though we had a lot more wind generation on our system in 2009, we only had a half percent of wind generation curtailment that year. And so, I think that that sort of speaks to the success of the transmission plan and the process that went into that.

So, with that, that is all that I have. So, I thank you for your time, and I'll leave with you—this is sort of that map that we submitted in 2008 of that scenario two plan of building new transmission to get that power out of West Texas.

Katie

Great. Thank you so much, Jeff. I'd like to thank both Jeff and Nathan for these great presentations. As we shift to the Q&A I just want to remind our attendees to please submit any of the questions that they may have using the question pane at any time. So, with that, I will turn it over to Ilya to moderate the question and answer session. Ilya?

Ilya Thank you, Katy. So, hi, my name is Ilya Chernyakhovskiy. I'm with the National Renewable Energy Lab and I'll be moderating the Q&A session for this webinar. So, thanks, Jeff, and thank you to Nathan for the great presentations.

The first question that I'll start with is for Jeff, and it has to do with the competitive market that Texas has and whether a REZ process or a competitive renewable energy zones process like what was conducted in Texas would be applicable to a market that is not competitive or to a vertically integrated utility.

Jeff Sure, yes. I think that yes, it can be. Really, I think the applicability of the renewable energy zone process, it really has more to do with do you have a system where transmission is constraining the generation of renewable energy that would otherwise occur? I think that's really the key question. I don't think that the market is as much of a factor, although I would say that one of the things that made it successful in Texas was that you had all of the—the decision makers were all aligned. So, in our case we had just one Public Utility Commission. In other areas where you have more stakeholders or regulators that you have to get in alignment, that can be challenging. But I really think that that's—the key is having all of your stakeholders and all of your decision makers aligned in the goals that you have.

Ilya Thank you. And that leads me into my next question, which is for Nathan. So, you mentioned that the REZ toolkit will have a guidebook for implementing a REZ process. Will that guidebook include some guidance on bringing together stakeholders? And can you speak a little bit about that stakeholder process and what stakeholders would be necessary in order to successfully implement a REZ process?

Nathan Thank you, Ilya. Yes, the REZ process guidebook that we discussed in the presentation today of course discusses—goes into some detail about that organizational structure and how to make it a stakeholder-inclusive process. So, when we're talking about stakeholders, maybe it's good to define, going back to my presentation, decision makers are of course important and they make a lot of those legally binding decisions, but stakeholders are really involved as they have a lot of important input and can support the process throughout the activity, just as Jeff noted that it's really important to make sure that we include them in all the steps, and those relevant stakeholders. So, the guidebook discusses who those stakeholders and decision makers may be and how they could support the different steps of the REZ process as well as how they would fit into that maybe general organizational structure. And of course, this would have to be adapted to any specific context. So, in the future the REZ toolkit will provide some tools and resources really to help that those—that lead entity or those actors or practitioners involved in adapting the REZ process to their context know how to do that, how to apply that general structure and approach that we presented in the guidebook to their specific context of application, whether it's a country or region or maybe possibly multinational group looking at a REZ process.

Ilya Thank you, Nathan. So, we have some great questions coming in from the audience, and I do encourage you to use the question pane to submit questions if you have any. This next question is for Jeff, and it's regarding the costs of the transmission development and who bears the cost. So, for example, is it on the side of the private developers to pay for the new transmission, or is it somewhere else?

Jeff Yeah, so in ERCOT the way that the transmission cost is, the way that it's paid for is by consumers. So, that is sort of what we call a postage stamp rate where that is spread out across all of the consumers in Texas. So, in ERCOT the developers really aren't responsible for any of the transmission costs. They do have to put up some security once they commit to build their generation facility, really to ensure that if they don't come, then the facilities, the transmission facilities that have been invested to support their plant, the consumers can recover that cost. But really, once they start putting power on the grid they don't really have to pay for any of the transmission costs.

Ilya Okay, thank you. So, this next—it's a follow-up question and it's for Nate. More generally, does the REZ process in assigning renewable energy zones consider transmission costs in assessing the zone?

Nathan Hi, Ilya. There are a number of approaches out there to the REZ process. And the REZ process that we're describing here in the guidebook and in today's presentation, in—identifying the renewable energy zones does not take considerations of transmission system costs into consideration at that stage. So, the idea in identifying those zones at the early stages is really identifying where you have the best renewable energy resources. So, where do we have really high technical potential for wind and solar? And then, identifying: Is that—are those resources attractive to private renewable energy project developers or other project developers for renewable energy? And that's how we identify those candidate zones. At that stage we do not take into consideration the cost of extending transmission to those zones to rank zones or any of those kind of actions.

I think the transmission zone—the transmission system costs are considered at a later stage when we're looking at transmission system options to connect those zones. Because we really want to make sure that we don't limit ourselves to resources that are only close to load only in specific regions. We really want to identify and harness the best resources wherever they be and then identify how we can connect those best to the load.

Ilya Thank you. That was a really helpful explanation of the zoning process. So, these next couple of questions are for Jeff. First, does this renewable energy zones initiative in Texas—would it only work for wind or do you see it being applicable for solar as well?

Jeff No, I think it could work for solar as well. The—I think the only difference that—different approach I would take for solar is with the wind generation we assumed that you could do—have that two percent annual curtailment, and that was going to be fine. I'm not sure that that would work for solar because you have—solar generation tends to be—when it's on it's generating at 100 percent output most of the time, whereas wind is rarely generating at 100 percent output. So, I think that that would probably be the only difference, is you may come up with a little bit different criteria when you're looking at what is economically optimal. But I think the process overall, I think, would work for solar.

Ilya

Thank you. And the next question is also about Texas and why was the REZ process so successful in Texas and we haven't seen something similar across states in other parts of the United States? Can you speak a little bit to why things moved quickly in Texas, and maybe some lessons learned out of that?

Jeff

Sure. Yeah. I think it goes back to what I said earlier. The decision makers in Texas were all aligned, between the legislature and the Public Utility Commission. I think everyone was aligned in the goals that we were trying to achieve. My just understanding and talking to colleagues around other parts of the United States anyway is that they have maybe started some similar initiatives but they don't have all of their decision makers aligned. And part of that is due to the fact that in other parts of the country the transmission facilities would have to cross multiple states and it's hard to get all of the decision makers in all of the states to be in agreement on what the goal is that they're trying to achieve.

Ilya

Great. Thank you. And another question about the results of the CREZ process in Texas. So, are there—have you seen cross benefits outside of being able to integrate large amounts of wind power and move it to centers of load?

Jeff

Yeah, that—absolutely. I think what we didn't really know at that time in 2008 as we were developing that plan but certainly have seen is that there have been a lot of reliability benefits to having those transmission facilities in place. The transmission facilities themselves, they don't look at the electrons that are flying across them and say, "Okay, yeah, I can only have wind electrons." I mean, the laws of physics say that the power that's going to flow across those transmission facilities is going to go from wherever generation is being developed, wherever demand is consuming that power.

And what we've seen, especially in the western part of the state, we've seen a lot of development and industrial development related to oil and gas exploration activities, and those facilities have actually been very beneficial in supporting that industrial development, the demand that's been added on the system. And that's just one example where we've seen that these facilities—yes, they were constructed to support wind generation, but they've also been very helpful in reliably serving the demand and the consumers.

Ilya

Thank you. That was great commentary for—especially for policy makers who are thinking about the benefits of a REZ process. This final question is also for you, Jeff, and it's about the sizing considerations that ERCOT used in developing the transmission lines. So, was there a wind target? Was there a target megawatt capacity or penetration for wind that was used to size the transmission that was ultimately developed? Or, was there some other consideration?

Jeff The main consideration was that the Public Utility Commission had given us these scenarios with certain megawatt targets for each of those scenarios, and we really developed the plan and sized the transmission based on those scenarios. Now, we also—as any good transmission planner would do, we looked at future expansion capability and looked at areas where we may be planning for a certain amount of megawatts at this time but recognize that there's a lot of potential in this area. And so, we did have an eye towards "Well, what's our expansion path? What's our next transmission system upgrade after this one?" And that went into sort of sizing the facilities. We had many facilities that were constructed where we maybe only needed a single circuit in place in order to meet the CREZ objectives but we recognized that there could be future expansion, and so we really "specced" out the facilities to be double circuit capable, so that when needed we could go back in later and add the second circuit on those towers. And we've actually already done that in a couple of cases where we've gone in and seen the need to add in a second circuit, where maybe in CREZ there was only one circuit needed initially.

Ilya Great. Thank you. So, I think that wraps up our questions unless there are any other questions from the audience—please submit them into the questions pane. If we didn't have time to address your question, we'll get back to you by e-mail.

So, now I just want to remind you and encourage you to visit greeningthegrid.org if you are looking for additional resources on grid integration topics, including renewable energy zones and other topics including ancillary services, forecasting, balancing area cooperation, et cetera. So, please use the links that are provided on this slide, and thank you for joining the webinar.

Katie All right. Thank you, Ilya. We only have a few minutes left. Nathan and Jeff, do you—either of you have a final thought in these closing minutes? Nathan, we'll start with you.

Nathan I'd just like to say thank you for everyone who joined the webinar today and your interest in the REZ process and invite you all to take a closer look at the Greening the Grid site, the renewable energy zones planning process—the link is onscreen—to find out a little bit more about that general process that we presented, and invite you to reach out with any questions you have.

Katie Thank you, Nathan. Jeff, do you have any final thoughts for today?

Jeff I'll just echo what Nathan said. I just appreciate the folks joining us on the webinar today, and I was happy to share some of our experience.

Katie Wonderful. Great. Thank you again. On behalf of the Clean Energy Solutions Center I'd like to extend a thank you to all of our expert panelists and to our attendees for participating in today's webinar. We very much appreciate your time and hope in return that there are some valuable insights that you can take back to your ministries, departments, or organizations.

We'd also like to invite you to inform your colleagues and those in your networks about the Solutions Center resources and services, including no-cost policy support through the "Ask an Expert" service. I invite you to check the Solutions Center website if you'd like to view the slides and listen to the recordings of today's presentations as well as previously held websites. Additionally, you'll find information on upcoming webinars and other training events. We are also now posting webinar recordings to the Clean Energy Solutions Center YouTube channel. Please allow about a week for these recordings to be posted.

And finally, I'd like to kindly ask you to take a moment to complete the short survey that will appear after we conclude the webinar. Please enjoy the rest of your day and we hope to see you again at future Clean Energy Solutions Center events. This concludes our webinar.