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Greening the Grid: Implementing Renewable Energy Zones for Integrated Transmission and Generation Planning

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Webinar Panelists

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This Transcript	Because this transcript was created using transcription software, the content it contains might not represent precisely the audio content of the webinar. If you have questions about the content of the transcript, please contact us or refer to the actual webinar recording.

Sean Esterly

Hello, everyone. I'm Sean Esterly with the National Renewable Energy Laboratory. Welcome to today's webinar which is being hosted by the Clean Energy Solutions Center in partnership with USAID and the National Renewable Energy Laboratory. Today's webinar is focused on "Greening the Grid: Implementing Renewable Energy Zones for Integrated Transmission and Generation Planning."

And 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's resource library as one of many best practices resources reviews and selected by technical experts.

And before we begin, I just want to go over some of the webinar features. You do have two options for audio. You may either listen through your computer or over the telephone. If you do choose to listen to your computer, just go to the audio pane and selecting the "mic and speakers" option. Doing that will just help eliminate any feedback and echo.

And if you choose to dial in by phone, simply select a telephone option and it'll provide you with a phone number, access code, and audio PIN that you can use to dial in. And if anyone is having technical difficulties with the webinar, you may contact the GoToWebinars Help Desk at 888-259-3826 and they can help you out.

And if you'd like to ask a question at any point during the webinar, and we do encourage everyone in the audience to do so, we ask that you use the "Questions" pane where you may type in your question and submit it there. And if anyone is having difficulty viewing the materials through the webinar portal, we will be posting PDF copies of the presentation at cleanenergysolutions.org/training and you can follow along. We'll also be posting the audio recording of the webinar to the Solutions Center training page within a couple days of today's broadcast.

And just a reminder: we're now adding audio recording to the Solutions Center YouTube channel where you'll find other informative webinars, as well as video interviews with thought leaders on clean energy policy topics.

So today's agenda is centered around the presentations from our guest panelists, Daniel Getman and David Hurlbut. Jennifer Leisch has also joined us today to help moderate the question and answer portion of the webinar. Today's panelists have been kind enough to join us as part of the recently launched greeningthegrid.org toolkit, a USAID and NREL collaboration designed to support countries in integrating renewable energy into the power system, and to introduce the renewable energy zone or REZ approach.

Now, before our speakers begin, I'll just provide a short informative overview of the Clean Energy Solutions Center initiative; and then following the presentation, we will have the question and answer session where panelists will address questions submitted by the audience.

And this slide provides a bit of background in terms of how the Solutions Center was first formed; and the Solutions Center is one of 13 initiatives of the Clean Energy Ministerial that was launched in April 2011, and it's primarily led by Australia, the United States, and other CEM partners. So an outcome of this unique initiative includes support of developing countries and emerging economies through enhancement of resources by policies relating to energy access, no-cost expert policy assistance, and peer-to-peer learning and training tools such as the webinar you are now attending.

There's four primary goals for the Solutions Center. The first goal is to serve as a clearing house of clean energy policy resources. The second goal is to share policy best practices, data, and analysis tools specific to clean energy policies and programs. Third, the Solutions Center strives to deliver dynamic services that enable expert assistance, learning, and peer-to-peer sharing of experiences. And then, lastly, the Center fosters dialogue on emerging policy issues and innovation from around the globe. And the primary audience for the Solutions Center are typically energy policy makers and analysts from government and technical organizations in all countries; but then we also strive to engage with the private sector NGOs, and also civil society.

And this slide provides on overview of one of the marquee features that the Solutions Center offers, which is this no-cost expert policy assistance knows as "Ask-an-Expert." The Ask-an-Expert program has established a broad team of over 30 experts from around the globe who are each available to provide remote policy advice and analysis to all countries at no cost to you. So, for example, in the area of renewable electricity policy, we're very pleased to have Paul Komor, Energy Education Director at the Renewable and Sustainable Energy Institute serving as one of our experts. So if you do have a need for policy assistance in renewable electricity policy or any other clean energy sector, we do encourage you to use this service. And, again, it would be provided to you free of charge.

So if you have a question for our experts, please feel free to submit it through our simple online form at cleanenergysolutions.org/expert. Or, to find out how the Ask-an-Expert service can benefit your work, please contact me directly at Sean.Esterly@nrel.gov or at 303-384-7436. We also invite you to spread the word about this service to those in your network and organization.

So now I'd like to provide brief introductions for today's panelist. Our first speaker today is Daniel Getman who leads the Geospatial Analysis Team in the Strategic Energy Analysis Center at NREL in Golden, Colorado. Mr. Getman has over 15 years of experience in spatial analysis, spatial application development, and geoinformatics working in environmental engineering, defense, and for the U.S. Department of Energy at both NREL and Oak Ridge National Laboratory.

And following Dan, we will hear from David Hurlbut, a senior analyst with the Strategic Energy Analysis Center at NREL. He also led NREL's technical support to the Western Governors' Association for the Western Renewable Energy Zone Initiative, which identified renewable energy resource zones throughout the western United States.

And then finally to moderate our question and answer session today, we will have Jennifer Leisch. Jennifer is a Climate Change Mitigation Specialist in the USAID Office of Global Climate Change. She supports the U.S. Enhancing Capacity for Low Emission Development Strategies program, and manages the USAID Greening the Grid partnership. She also directs agency work to account for greenhouse gas emissions reductions as a result of USAID Clean Energy programs.

And so with those introductions, I'd like to now turn things over to Dan.

Dan Getman

Thank you very much, Sean. So I am Dan Getman and I'll be presenting with David Hurlbut. We are incredibly pleased to have the opportunity to talk about renewable energy zones with this audience. We're going to start off by giving a very brief description of what a renewable energy zone is; and then I'll be doing the first part of the presentation to talk through some of the logistics of the analysis to figure out where opportunities are in renewable energy, to go from having a resource assessment for an entire region or a state or a country, and narrowing that down to the places that really make sense to begin thinking about investment or opportunity development in renewable energy. And then I'll be transferring the presentation to David and he'll be talking about much more concrete example of renewal energy zones, specifically focused on the Texas Competitive Renewable Energy Zones process.

So to start off with: "What is a renewable energy zone?" This is a map of the resulting renewable energy zones for Texas. To be very brief, the idea of a renewable energy zone is focusing on a specific area with the intent of making it very appealing for the development of renewable energy. So focusing developers into a place where we have goals that we want to accomplish, like development of transmission or provision of energy, or we can reduce environmental impact. Essentially, making sure that development happens in places where we can maximize the investment; and that allows local government, state government, national government to ensure that development happens in accordance with their longer-term plans for transmission development. So I'm going to talk a little bit about some of the logistics for doing the analysis that leads up to renewable energy zone development in trying to identify opportunities for renewable energy based on resource and exclusion areas.

So it all starts here with this idea of renewable energy resource. What you're looking at in this map is a direct normal irradiance for the North American continent: some of Canada, Central America, and South America. This is direct normal irradiance which we'll be referring to as DNI in the presentation. But what this means is irradiance that is perpendicular to a PV panel or a CSP installation. And so this is the highest irradiance that you can get.

We also talk about global horizontal irradiance, which is essentially irradiance that's reflected throughout the atmosphere and off of other objects. But the idea is that these data alone, just understanding where we actually have solar resource, requires a lot of modeling. In this case, this particular dataset is four kilometer spatial resolution and half-hour temporal resolution. So when you look at map like this, we're looking at an average. But you can imagine that the dataset represents a value for every single half an hour for an entire eight-year period. So it's very large dataset, and we need that to really understand what happens with, in this case, solar resource over a long period of time so we can really estimate how much production we're going to get from particular technologies.

If you can think about this for wind, it would be a similar type of thing, except for instead of irradiance, we're talking about wind speed, and those would be at different tower heights—so 30, 60, 80, 100 meters—and we would have the same kind of dataset that would be a time series dataset where we have values for every minute or every ten minutes or every half an hour for years at a time. So very big datasets that help us understand where we actually have the resource to think about, initially think about where we might be able to have an opportunity for renewable energy.

So the resources is obviously a starting point. But even dealing with the resource and trying to start to think about where we might be able to have an opportunity for a particular technology, there's a lot of complexity, even in that first part, and so I want to talk very briefly about that. I've got six maps up, and so I apologize they don't have a bit more detail directing you around. But if you look at the top two maps, we're talking about a particular kind of technology called a fixed tilt technology. What this means is—and we'll be focusing more on PVs and wind at this point—but these things apply. The fact that the technology drives—understanding of the technology really drives the analysis.

So in this case, with regard to PV, we have this first technology type which is fixed tilt; and essentially what that means is the system is bolted to the roof and it isn't moving. And so the top two maps are representing on the left variability of energy production with fixed tilt; and on the right, the capacity factor for a fixed tilt system for the whole of the United States. If you go down to the second two maps, we're talking about a system that actually tracks the sun. And so the panel itself moves from east-to-west and changes its angle so that it gets as much direct normal irradiance as possible during a day. And then the bottom two maps are talking about an even more advanced technology that's to access tracking where the position of the panel is even better able to get direct normal irradiance for a longer portion of the day.

And so the reason that I'm showing you all of these things is to talk about when you're looking at resource data and thinking about where you have opportunities, it's very important to be thinking about what kind of technology you're actually looking at and what the limitations of that technology are. And so in this first step, you can see—looking at the fixed tilt systems at the top—you look at the capacity factor map on the right: as you go from fixed tilt to one-axis tracking to two-axis tracking, the map gets more red and orange as you go through those technologies. And what that means is, the one-axis tracking and then the two-axis tracking are better able to take advantage of direct normal irradiance until you get more energy output from those systems.

But the down-shot is, if you look on the left, you're looking at variability of the resource. And what I mean by this—just to set an extremely simple example—is if you have a PV panel and it's getting direct normal irradiance and it's generating energy and a cloud goes over it, it drops significantly, and then it comes back up when the cloud passes. And so the idea is weather patterns increase or create variability in the energy production. And the challenge is that lots of variability can cause issues in grid integration, and so we do a lot of things to make sure that that gets mitigated.

But you can see that as you go from fixed tilt to one-axis tracking to two-axis tracking, you get more and more and more variability in the energy production. And that's one of the issues that we need to be thinking about when we're talking about, "How do we identify areas we have a really good opportunity?" You can see from these two sets of maps that finding those opportunities is actually very dependent on which technology you're talking about.

And so what we do when we talk about opportunity assessment is we take an area that looks like the map—a dataset that looks like the map on the left where we've got all of the resources, that in this case would be very good for concentrating solar power, because this is direct normal range. We take all of the resources and say, "We've got all of these places where we think the technology could work," and then we take it to a map on the right where we say, "Now let's get rid of all the places where we actually don't think the technology would work for a myriad of other reasons," and I'll talk about how that process plays out. But, again, the purpose of showing you this is to illustrate this point that we're actually very much focused on developing a capability that lets us find these opportunities that are actually going to have a good cost benefit where we put an investment in and they actually create energy, and it's at a price that we can actually leverage. And so that's the reason why we're looking at these things.

And it's a complicated process, and so we have a pyramid to describe it. On the bottom section of the pyramid it's got the word "resource," and in this idea we're saying, "What is the potential for a particular technology?" The very first thing you look at is you look at the resource, which is what we've been talking about so far. And this has the actual resource, and then the physics constraints of the system: "Is it sensitive to temperature? Is it sensitive to aerosols?" How do we actually make sure that we know, based on the particular technology, how it's going to behave solely due to the resource?

And then when we find the areas that the technology can be successful because we have the right resource, we then go into the next step which is looking at some of the technical—potential of the technical limitations, the potential, and that's where we start to talk about, "Where do we have land use constraints?" and "Where do we have topographic constraints?" because there's too much variability in the slope, and things like that that really create some pretty obvious problems or pretty obvious costs associated with renewable energy development.

As you start to go further up this potential pyramid, we get into the economic potential, and this starts to get into, "What's happening with technology costs and how are those going to change?" "What's happening with fuel costs?" you know, "What is the distance to transmission lines?" All of these sorts of things really start to get into, "What are the other costs associated with development?" And the last part, this peak of the pyramid, market potential, is really where David's going to be talking in economic and market potential.

But in market potential, we're talking about, "What is the impact of policy?" and "What is the impact of changes in the regulatory environment?" and "How are investors going to respond to certain things that are happening?" and "How do you predict that?" And as you can see, this gets more and more sort of nuanced as we move up the pyramid. We're going to start with the first two, and I'll outline those, and then David will take over and talk about economic and market potential.

So this is the world I live in. I'd like to introduce you to spatial analysis for identifying renewable energy opportunities. You're looking at a map on the right which is intended to demonstrate the potential for utility scale PV across the United States; and what we do in order to generate data like this and maps like this is we start with the resource and we say, "Okay, let's look at the technology, let's look at the resource, let's really try to understand where we've got opportunities for a particular technology," in this case, large utility scale PV, "and we figure out all the places where it costs a lot, or it's problematic, or you actually physically can't do an installation."

And so this is a very sort of brief subset of this. There's actually sort of hundreds of things that we look at when we do this kind of analysis. But to give you an idea about what we're talking about: we take the map of the resource and then we take maps of things like water features in urban areas and wetland where it's obvious you can't put a big utility scale PV system when we exclude those areas from the available land. And then we say, "Well, now that we've got the rest of the available land, where are the places where we have a very low slope so we don't have to do a lot of earth moving?" and "Where are the places where we know we can actually get a big contiguous area, big enough to have the entire plant? Where are we going to have issues with federally protected lands and environmental concerns and things like that?"

And all of that sort of reduces the total available area down to the places we actually want to think about investing. And what this does—hugely important in the process—is that it lowers the risk and it lowers the cost, because if you're going to invest a significant amount of time or money in doing all of sort of the more detailed or more nuance work to understand, "What are the actual implications of building or developing in a certain area?" it's best if you can reduce the area you were actually going to look at as much as possible first so that you can make sure you're spending your money on the sweet spot. And that's really what this is about is finding these sweet spots.

And so there's plenty of other things to consider. I wanted to toss out a few more examples; and I apologize that these are smaller maps.

If you look at the map on the upper-right, the areas that are dark blue and dark green and green are indicating places where we have a pretty good wind resource, and the areas that are gray are indicating places where we're not really thinking wind because it's too populated. So this is the idea of public acceptance of large-scale wind. And so we exclude those areas because it would be too expensive or too costly to deal with that.

On the left map at the top, you see all of these gray areas, including this nice big swath right through the wind resource in the United States where we're dealing with habitat issues. So there is a big migratory bird path, there's lot of species protection that's happening in the United States. And so we need to consider that when we're trying to find these really good opportunities to do cost-effective wind development.

The same thing is true for radar, for example, which is the bottom left-hand map; and you can see all of these little circles that are grayed out indicating these are places where it would be problematic to develop wind because of the interference with radar. And so what we wind up with is an analysis that looks like this chart on the right.

So this is a blow-up of that; and the idea is, if you look at the line on the far right, the bottom axis here is capacity in gigawatts and the axis on the left is cost or LCOE. And so if you look at the line on the right, the black line is indicating without any exclusions at all, "What's our capacity for wind at difference cost points?" And then we start to remove these areas that we're talking about: these wildlife areas, radar installations, public acceptance. All of these things sort of move that line over to the left and we wind up with less capacity available nationally at a particular cost, but that capacity that we're identifying is capacity we know we can do something with, and capacity that we should be looking at how to develop.

So I'm going to walk very quickly through this process because I think it's important just to show it visually. And this is an example of going through this step-by-step process for concentrating solar power in the southwestern part of the United States; and I'll walk through what each of these steps are.

So this is the resource for the southwestern United States. Again, this is direct normal solar radiation, and so this is what we would be looking at to assess the potential for concentrating solar power.

I'm just going to add transmission lines on for reference. We're actually not reducing the available area based on the location of transmission. The reason is that in many cases, we see that there's a very good opportunity to build transmission, and so we certainly want to consider that in the available area that we're looking at.

So the first step is we get rid of all places where the resource isn't good enough to really just immediately be cost-effective with the technology we're looking at. And this doesn't mean that those areas can't be developed, it just means that we're looking for the really sweet spots in this particular study.

So in the next step, we actually look at removing all of the places where we have known issues with environmental concern or land use exclusions to make sure that we're not setting up these projects to deal with lots of permitting issues and things of that nature.

And then we remove three percent slope, because in doing that, we actually have one cost point. And this is still relatively expensive to deal with the earth moving associated with creating a nice flat place for this technology to exist. But we're actually going to take one more step in this vain and we're going to lower it down to a one percent slope, because these are the places where you have to do very little preparation in order to be able to do the kind of development that we're talking about with these large-scale CSP.

And so what we wind up with, this map on the lower right is actually the same one we were looking at a moment ago, but it's got typography and things like that on it. This is very important to be considering when you look at a number, for example, in this one table at the top where we say, "The total available land area that you can develop for concentrating solar power is 13,000 square miles," or "The total solar generation capacity is 4 million gigawatt hours."

When you look at numbers like that, it's very important to understand that these are not numbers representative of the total possible solar resource; these are numbers that are actually very carefully thought through to say, "If we make all the right decisions and we're really smart about where we put things and everything's cost-effective, what is the actual potential for a particular technology in a state or a region or a country?" And so when you look at these numbers on the left and you see these big numbers for solar generation, it's important to keep in mind that the actual areas we're talking about are the areas on the right that are really right for investment.

And so this is—when I think of the process that we just went through, this is a really nuts and bolts, pretty straightforward process of finding out where we've got things that are cost-effective, and where we've got areas that aren't necessarily as cost-effective. And this gets very interesting when we start to add policy into play.

So these are very old maps; and I wish I had updated versions of this, so please keep in mind. I think this is from 2008. But the idea here is that we're looking at how long: "How many years does it take to pay back a PV system in the United States? If you get it on loan and you use the money that you make, or the money that you save, to pay for the system, how long does it pay for itself?"

And at this time when we ran this with the technology that we ran it, you can see that green is 0-5 years, and yellow is 20-30 years, and red is greater than 60 years. So we've made some significant improvements there. But the situation is similar in that when you add policy into this calculation, you can see the entire situation changes.

And so if you look at the map on the right, the map on the right is number of years a PV system would take to pay for itself with incentive included—and I think this is just federal incentives. And so you can see all of a sudden whole states sort of show up as green are being very low number of years to pay back, including places like New Jersey and Michigan, because the policies there are all about promoting the technology so that we can get past this gap where we start to have a benefit from the level of adoption really starts to reduce cost, which is the intent of these incentives.

And so that's a transition in talking about this policy piece where we start to really go from technical potential into that next section of the pyramid, the economic and the market potential, where David's going to take over and start to talk a little bit about how all of those things apply in the Texas Competitive Renewable Energy Zones.

David Hurlbut All right. Thanks, Dan. And what I'd like to do is to shift gears a little bit. Dan has been giving a really good overview of the "how" involved in identifying renewable energy zones. I wanted to get into a little bit of the "why" and basically how this concept arose, and I'll be focusing on how the concept developed in Texas in the Electric Reliability Council of Texas, the grid operator there, for a couple of reasons. This was really the first of its kind type of transmission policy. Texas is where the idea originated, and is also an example of how it was executed to its fullest extent. But also it's something that I had a lot of involvement in before I came to the National Renewable Energy Laboratory.

I was a Senior Economist with the Texas PUCT, and basically oversaw the implementation of the CREZ process. So I can kind of take you behind the scenes in the things that we dealt with and the issues that we had to confront in coming up with renewable energy zones. But also I think it might provide a little bit more insight as to just why this concept arose in the first place, and how does it differ from traditional methods of transmission planning.

So, basically, the competitive renewable energy zones in Texas arose because of the peculiarities of renewable energy. In many respects—setting aside emissions—renewable energy performs differently on the grid than a coal plant or a natural gas plant, and that has implications for transmission planning. There's a mismatch in time between how long it takes to build a wind farm, for example, and how long it takes to build a transmission to serve it. It takes five to seven years to build a high-voltage transmission line; it takes five to seven months to put up a wind farm. So there's a mismatch in time that I'll get into a little bit more detail later.

But the bottom line was that it confronted ERCOT with a dilemma that had limited the development of wind power in the most productive areas, and the competitive renewable energy zone concept came out of staff discussions with stakeholders to try to come up with an out-of-the-box approach to solving the problem. But even after we had developed a concept, it really couldn't go forward until certain laws were changed at the state level. So that was really what the impetus was behind competitive renewable energy zones was the need, but also the recognition in policy and the authorization in law to proceed with this new model.

So a little bit of background to sort of set the stage for how this concept arose. In 2001, the ERCOT, the Texas wholesale power market was restructured to allow more competition and to split the traditionally vertically integrated utilities into three components: a generation component, transmission and distribution component, and then a retailing component.

Transmission ownership, by being separated from generation, the transmission owners were essentially indifferent to which generators used their systems. So they really didn't have any stake in whether or not the electrons flowing across their system came from a wind farm or it came from a coal plant.

The transmission part of restructuring was the only one that remained regulated by the state of Texas. The others, cost were determined by independent generators, or prices were set in an auction process operated by ERCOT, retailers determined their own rates that they charged their customers; but the in-between piece, the wires piece—that was regarded as an essential infrastructure needed to make both of those markets work, and so those remained regulated by the state.

The most important part of restructure with respect to renewable energy development was open access to transmission. This is a principle that is involved—that's part of all major market restructuring in the United States and elsewhere in the world. The idea is that if you have a generation project that you _____ [audio fades out] has sufficient financial backing and can get out of the market, all you have to do is really get a transmission interconnection agreement with the grid operator and demonstrate that all the reliability issues would be addressed. But there's no need to demonstrate to regulators that you have an off-taker.

So this open access basically allowed a lot of development to take place. So at the time the wind market really took off in Texas—I mean Texas really was not unique in the types of resources that it had or the incentives that were available. There was a federal tax incentive for wind power, but that was available anywhere, not just Texas.

West Texas has exceptionally good wind, but then so do many other states in the west. So Texas was not unique in this; and yet at the same time, a lot of the development came to Texas mostly because of open transmission access and the restructuring of the new market. It opened up new _____ [audio fades out]. So this really led to the wind industry really focusing on Texas for its first phase of development.

The problem was wind responded too much. West Texas is where the best wind resources are located, but it's also where the existing transmission infrastructure was located. And the interest in developing wind in Texas was so great that it overloaded the existing transmission system in the place where the best wind resources were located.

The maximum transfer capability out of this area was about 400 megawatts. By 2002, just one year after the market was open, 760 megawatts of wind power had been installed. And it was leading to a number of problems: local congestions, local costs. And in some cases, equipment was damaged because a wind gust would come up and all the wind resources would go to 100 percent at the same time, overloading transformers and other equipment in that area.

As a result, there were regular operator ordered curtailments because of the transmission limit, and that essentially degraded the effective productive potential of wind as shown in their capacity factor. The capacity factor is an indicator of how much energy is produced over a typical year based relative to the total capacity of the equipment being used.

So the engineers at ERCOT and at the transmission utilities all knew what the answer was. It was basically to upgrade the transmission path from West Texas to the parts of Central Texas where the large loads were. The wind industry was also looking forward to additional development. So they were looking for a transmission solution that would not only solve the existing problems, but avoid the same problems arising in the future with additional development that would occur.

The problem was that the transmission utilities could not advance plans for building new lines until there was demonstration that the generation would be there to use it. And this is where the collision between old precedents and old practices came into conflict with the new realities of renewable energy development. Transmission historically had been built in conjunction with a new coal plant or a new natural gas plant, which would take about the same amount of time to build and bring online as the transmission serving it would take. With renewables, that time table was thrown out of kilter because of the short time it takes to build a wind farm and the long time it takes to build the transmission to serve it.

So the dilemma is circular and very hard to break if you just focus on the precedent that we were working with at the time. In order to build transmission, the transmission would need approval from the state that it was needed for serving customers. But in order for the regulators to give that approval, they needed to see the generation, they needed to know what was going to be connecting to it. But there would be no wind farms that would be on the queue to connect to it because they couldn't obtain the financing necessary to assure that they could go ahead with their construction. And the financers, the financiers and lenders would not provide the capital unless they saw that the transmission was there. So round and round and round, and the bottom line was no transmission was built.

And this is where we came up with the idea of competitive renewable energy zones; and there are three principles behind the development of zones. First, is to use the most productive resource. You want to direct development into those areas where you know that the productivity per dollar of capital invested is going to be the highest. So you look for areas with the highest capacity factors, and that means a higher utilization, not only of the generation assets, but the transmission assets as well.

You also want to build as few lines as possible; that means big lines, a few lines. Higher voltages for the lines have lower line losses, and they're more economically efficient for delivering the amount of power. It also means that by reducing the number of transmission corridors you have to build, you're reducing the amount of environmental damage. If you were to have the same capacity over a proliferation of a smaller line, you'd have a much larger footprint that you'd have to build over, increasing the amount of environmental impact. This also means that there are fewer proceedings because you're having one large proceeding for one large line instead of five or ten for a bunch of smaller lines.

And then, thirdly, a very important concept that we wanted to build into the competitive renewable energy zone process was competition; and this, at the time, was fairly unique to Texas because of the nature of how the wholesale power market had been restructured. It was all built around competition. It was built around allowing generators to enter into the market and compete with one another to provide the best service at the lowest cost. So we wanted to fold that principle into the competitive renewable energy zone process by letting the market decide which developers and which projects were most economically and advantageous.

By selecting renewable energy zones and building transmission to those zones, you're directing _____ [audio fades out] the development into those areas where competition is going to be the hottest. And the idea also is to not make all of the developers comfortable. Even though you might be able to _____ [audio fades out] an additional 1,000 megawatts of transferred capability out of there ideally, there should be 4,000 megawatts of potential competing to get to that line. That enhances the incentive to bring the projects on quickly and to bring them on with the greatest efficiency and at the lowest cost.

So here are the basic steps of the CREZ process that we followed in Texas, and this is really the idea. And as I said at the beginning, this is really—the Texas CREZ process is an example of the full utilization of this process. You start with the renewable energy assessment that Dan described in his part of the presentation. You look at where the resources are and where the best ones are. And then the second step is that you screen these resource areas. You look at the quality, you look at the develop-ability, and you look at the density.

It's not enough to have really good high-quality, high-class wind resources. You want to make sure that there is enough concentrated in a single area that if you were to put a 500-kV substation in the middle of an area, you could fill it four to five times over with high-quality, high-capacity factor renewable energy potential.

Once those initial areas are identified, you want to ground truth it. So the third step is to conduct an open season, and basically invite the developer community to indicate which of these areas they are really seriously interested in, serious to the extent that they would have some financial skin in the game, so to speak, and to provide some demonstration that they're really serious about developing in the area.

Once those high-quality, high-interest areas are identified, then you conduct an economic analysis of the zones. You look at the production cost involved. So if you were to add 1,000 megawatts of wind in this particular zone and connect that to the rest of the grid, how would that change production costs over the entire grid? And in the case of wind and solar, generally the variable cost of production goes down because you're offsetting a generation that have natural gas fuel costs or coal fuel costs. And then you could do a cost-benefit analysis of all the costs and all of the benefits to see which scenarios are the best.

Once you have the analysis in-hand, then you designate the actual renewable energy zones. And in Texas, designation of the zones carry legal and financial weight because it was directed by the state legislature and the PUCT had authority and, in fact, a direction to approve a transmissions plan, designations of the zones meant that transmission was going to happen in these areas. So that was a very clear signal to all the lenders and all the financial institutions that this was going to be a reasonable bet for transmission and for renewable energy investment.

And the final step is to develop and approve a transmission plan to connect the renewable energy zones to the rest of the grid. And this is where you need to decide, "Do you build just as much transmission as you need to meet your renewable energy zone, your renewable energy goal? Do you supersize it to allow plenty of surplus development or something in-between?"

So as I mentioned, the economic analysis of the CREZ scenarios will involve production cost modeling. Production cost modeling is essentially simulating the dispatch of the entire network on an hourly basis, or perhaps a sub-hourly basis, to see what the most optimum utilization of generation is with respect to the variable cost of transmission. And this can tell you what the total variable costs are over a test year. It can show you where the congestion issues are likely to arise and how much those congestion costs are; and congestion could increase or decrease in different areas of the grid. There are local costs of power that you can identify from production cost modeling. This is the sort of social benefit analysis that goes into identifying a renewable energy zone scenario. Once you have that, you fold in the cost of new transmission and other benefits and other costs to do a cost-benefit analysis; and you can use the result of that analysis to compare the relative social benefit of different assemblies of zones, or different magnitudes of development for the zones.

The step of identifying commercial interest was a very important step in the Texas CREZ process. At the end of the technical analysis, we knew where the good wind areas were, and we knew where wind could provide exceptional benefit for the system as a whole. For example, wind along the Texas coast fits the low profile of Houston and San Antonio and these large urban areas much better than the daily production profile of wind in West Texas. So that seemed to be a really interesting area. But we needed ground troop that by looking at whether developers were really interested in areas such as this. So the issue is, if there really is no specific interest in a project, how can regulators know that market demand is really robust enough to get the competition that we were looking for in developing a zone?

So there was an open season, and this open season provided developers with an opportunity to bring in their evidence of their interest in each of the zones. They could do this in a number of ways. They could demonstrate existing renewable projects that were in those zones as evidence that they are already familiar with the attributes of the zone. They could provide pending or signed interconnection agreements with ERCOT demonstrating that they've done the studies necessary to interconnect. They could show leasing agreements with landowners, options for developing on areas.

They could also provide letters of credit, you know, post letters of credit with the PUCT where the funds would be used to develop projects later on. And they also had an opportunity to provide other types of demonstration; and all these came to the PUCT. They evaluated all these demonstrations and basically ranked them—you know, ranked zones based on the development that had been demonstrated.

So the implementation of the CREZ itself, it began with a 12-month study that was conducted by ERCOT, going through most of the steps that Dan described earlier in his presentation. Now, remember, this was back in 2005, and the tools that we had for this sort of analysis were not nearly as sophisticated and detailed and high-quality as they are today. But from those zones from that analysis, ERCOT was able identify a number of initial study areas.

There was an open and informal stakeholder process—and this is very important to any renewable energy zone initiative wherever it's done: you want to make sure that the developer is there so that the assumptions that you're making about the renewable technologies pass the laugh test with industry. You also want to make sure that all the environmental interests are there. This is really where their most effective input is found. If there was an area that's going to be off limits because it says "Sensitive Habitat," this is where we need to know. And that can be screened; that can be accounted for. But it's important for the stakeholders who have that knowledge to be part of the process as well.

The study areas were then aggregated into scenarios. The production cost modeling was used to sort of do a first cut at what the cost and benefits might be, and then the final report was delivered to the PUCT at the end of 2006.

This shows the initial study zones that were identified by ERCOT in their initial zone. These were the zones that were taken by the PUCT and carried forward into the open season for demonstrations of developer interest.

And as it turned out, there really was not a lot of demonstrated interest in these wind zones along the Gulf Coast, at least not at the time. The strongest interests were in the areas where wind development had already taken place, areas 5 and 9 on the map here; but also in the Texas Panhandle and in the north area, areas 1, 2, and 4 shown in the map here. There was significant demonstration of commercial interest there. So these were the zones that the PUCT selected as final CREZs for transmission development.

Once the zones were identified, the final step for the PUCT was to determine what the size of the transmission buildout would be. The final decision turned out to be about 2,400 line miles. The estimated cost was about $5 billion, actual cost was in the neighborhood of $7 billion, and the final element was completed in 2013.

Now, in the case of taxes, the transmission plan was really a network plan. It was a series of three 45-kV double-circuit upgrades. So it wasn't one single line going from one zone connecting it to the rest of the grid; it was really a series of network upgrades. So not only did this open up really high-quality wind areas, the network improvements also addressed other reliability issues that were already existing in that part of the grid, independent of renewable energy development. So there were a number of reliability benefits that came from the CREZ transmission process as well.

So the big question: "Did it work?" Well, Texas was kind of slow with respect to wind development. In 2000-2001, the amount of wind capacity on the system was negligible. Within a five-year period, Texas had come to surpass California as the state with the largest amount of wind development in a very short period of time. But at that point, development slowed mostly because of transmission. As these CREZ elements came online, you can see the increase in actual development over time starting in 2009 and 2010, then really accelerating in 2014 and 2015.

Now, a really important point here in looking at the development trends is that wind development has basically literally blown away the state's renewable energy requirement. The RPS goal really isn't a driver anymore because it's essentially history. There was also a non-binding renewable energy planning target that was for 2025. We're basically double that right now in Texas.

So the opportunities opened up by the CREZ process, and the fact that they are cost-effective, combined with the reductions in cost we've seen in wind, and now that we're seeing in solar, basically means that under the right circumstances, wind and solar are economically competitive with natural gas and the other conventional resources that are on the grid. Now, this means that there are other operational issues that need to be accounted for. But the important takeaway is that ERCOT is now addressing those issues. Cost is not the issue right now, it's integration.

This shows where the wind development has taken place. The red lines on the right show the network upgrades that came from the CREZ process. And you see that wind development has really followed those CREZ processes—the zone, as well as the transmission. But there's also been sort of a collateral affect with the fact that the wind market for Texas has improved because of CREZs. There have been a lot of non-CREZ wind development taking place as well, even in those areas that initially there was no developer interest in when the PUCT solicited interest in 2007. So the development can take place in places outside the CREZ. There's no requirement that they'll even be in a zone, but it creates sort of a critical mass of economic opportunity that really sweetens the entire market.

This shows how the effect of zones have increased the overall efficiency of the wind generations. If you look at the initial projects that were built in 2002-2003, the capacity factors at the time were about 26 percent, and that was using the old technologies. But also it was low due to the lack of transmission availability in the regular curtailment. Now those capacity factors for the same equipment, the same turbines, are up to 30 percent; and for the new equipment, the capacity factors are even higher. What's really significant is that the new areas opened up by the CREZ process in the Panhandle area of North Texas. These are really high-capacity factor areas, around 45 percent, where products are coming in at a very, very low cost per megawatt-hour.

Wind is now about 10 percent of the total generation ERCOT, up from less than 1 percent in 2001. And this shows a recent day where the capacity impact are pretty much for the entire day for the entire plate was around 30—wind was providing about 35 percent of ERCOT's electric generation throughout the day.

Now, the Western Governors launched an initiative to do something similar for the entire western United States. This was a little bit different from what was done in Texas, mostly because there was no direct link to any statutory authority for approving transmission. This was really more a planning exercise, something to kind of focus planning into areas that were known to be the most efficient, with respect to interstate delivery of renewable energy.

Also unlike Texas, most of the interest—most of the result from this planning has been looking at high-voltage DC ties that would go from one area with a high concentration of low-cost renewables to a large load center. There's been a lot of interest in moving wind power from Wyoming, which has the best wind resources in the country and a very high concentration of those wind resources, and delivering those to California. Wind capacity factors are above 50 percent. But getting from Wyoming to California crosses several jurisdictions. So this is something that these jurisdictions are using in their planning.

So going back to the pyramid that Dan showed earlier in his presentation: competitive renewable energy zones are at the apex of that triangle. This is where everything comes together—economics, the technical potential—brought together under proactive policy that intentionally directs development to those areas that have the highest potential for social benefit: benefit in terms of the least cost to customers and the least environmental impact.

Just the takeaways for applying the CREZ model elsewhere: Keep in mind that the development always follows transmission; and if transmission goes to suboptimal resource areas, well then the renewable energy development is going to be suboptimal because that's where the transmission is going. The intent of the CREZ process would change that by diverting—by putting transmission into those areas where the cost per megawatt hour would be lowest.

Ideally, the authority to build transmission should come before the process of identifying the zone so that the question going all throughout the analysis is not whether to build transmission, but where to build it. And part and parcel is that jurisdiction was easy in Texas because there was only one jurisdiction, if you're looking at several countries or different states. And those states need to be able to coordinate their regulatory _____. [Audio fades out]

So that is kind of a firehose version of what we do in Texas and it's applicability elsewhere. Other states have tried this model with various changes, which certainly we can go into more detail at another time if anyone would be interested. But before I turn it over for questions, I just wanted to let people to know that you can find more information about renewable energy information at the Greening the Grid website, and the URL is here. And please check back frequently; there will be more information posted as it develops. So thank you very much.

Sean Esterly Thank you both Dan and David for the excellent presentations; and we will turn things over now to Jennifer who will be moderating the question and answer session. So, Jennifer, go ahead.

Jennifer Leisch Thank you, guys. It sounds like we've heard all about the process of developing a CREZ from starting with resource analysis all the way to transmission planning. And we've had a few questions come in, and maybe a very quick one we can ask David that came in is, "What is the LCOE for wind in Texas right now? Or, how has it evolved through the CREZ process?"

David Hurlbut Well, when we began the CREZ process, the capital costs were a bit higher—we're talking 2007—and the investment tax credit was 30 percent, and it was a very important part of the pro forma or a project at that time.

Right now we're seeing projects come in at a levelized cost of three to four cents per kilowatt hour, or $30.00 to $40.00 per megawatt hour. And that's comparable to a lot of the marketplace—location of marketplaces—but the prices that are clearing the ERCOT auction.

There's been a rush of development to get projects online to take advantage of kind of the residual production tax credit. That's been sort of in limbo for quite a while. But there's still a lot of project planning going on beyond that. So development hasn't really slowed. But those are the prices that we're seeing in Texas right now.

Jennifer Leisch Great. So we've had a bit of questions come in with regards to data, so maybe, Dan, you can give us a few answers on this. And this is multi-parted. Folks are really interested on where a lot of this resource data comes from, where they might find it if they're outside of the U.S. for their country, and what type of analysis tools are out there and are available.

Dan Getman Yeah, that's a question we could spend an afternoon talking about, so I'll give a brief answer. The brief answer is it really depends on what you're doing, because the resolution of the data is what makes it more or less available. So low resolution data whereas, you know, instead of being a four-kilometer-by-four-kilometer grid cell, we're talking about tens-of-kilometers grid cells. And instead of being half-an-hour data, it's more like monthly data.

Those data sets are available in several places. There's SWERA, an application that we have. There's the IRENA Global Atlas for Renewable Energy. There's lots of resource data that's available, lots of ancillary data that's available at what I'll say are median flow resolutions.

The answer for resource data for this kind of work, the high-resolution data is that NREL generates solar irradiance data through models for some countries, for the U.S., India, and some other places; and the challenge with that is the modeling is actually pretty straightforward. If the validation of the models requires ground truth, and so you have to have ground truth stations in country that have a relatively long period of time where they've been taking measurements so that we can actually validate the model against the ground truth.

And the same is true for wind as it is for solar. The modeling isn't too bad; it's the validation that requires sort of time investment and equipment investment. There are companies that do that in several countries; and also NREL produces some of those data.

Jennifer Leisch Great. And what type of tools might folks use to do some of the geospatial analysis that you're talking about?

Dan Getman Yeah, that's a very good question, and the answer is there is a bunch of them. So the very short answer is most of what we do, we do using—we write software that does analysis using Python. We use the R, which is an open-source statistics package. We do a lot of analysis on—some analysis in ArcMap, but usually that's actually a pretty limited version of it because the data are so big. It's actually hard to use a traditional software package, and so we have to write codes because the data will wind up being quite large.

Jennifer Leisch We actually had a question on very specific set of data—and I think this is of interest in a lot of countries where earthquakes are an issue—is, "Do you at all, if at all, take fault lines in consideration when you're doing this analysis?" and "Are there other things with regard to maybe climate resiliency or anything else that should be taken into account?"

Dan Getman That is a really good question. And I think that in some cases, we do take just natural hazards in general into account when we're talking about what the cost is. But I think what we wind up doing is I think of these things in phases—and you can think of the things that we've been talking about today in phases.

The first phase is: where are all the places where it's worth investing additional funds in doing detailed analysis? And then into the second phase is where you're actually buying more expensive data, you're doing surveying, those sorts of things; and I think in that second phase is where a lot of the, "What is the actual risk of natural hazards? What's the actual cost of strengthening wind turbines, for example, to deal with tornados or whatever the hazard might be?"

I think that's where those costs go into this sort of economic potential piece. But we do consider then some of the work that we do; but I think that's really more of siting problem where those things wind up being considered.

Jennifer Leisch Great. Maybe something that we can do is switch a little bit more over to David and discuss the CREZ process, maybe what it could look like outside of Texas. So there are a lot of folks who are really interested in what other countries outside of the U.S. are currently implementing an approach similar to this, or even some of those where it might be a good thing to begin thinking about.

David Hurlbut Well, I'm not aware of other countries that have actually implemented renewable energy zones. A lot of my personal focuses have been in the United States and U.S. more. But there has been a lot of interest. I've discussed renewable energy zones with China, Chile, Mexico. So they're looking very closely at this idea.

There seems to be a relationship between countries that are proactively expanding their electric infrastructure. They want to fold this in kind of at the front-end to—you know, I guess one other way to think about it is to avoid the mistakes that were made in the United States by transmission structure being locked into conventional generation. But there are a number of questions that any country would need to look at in looking at zones.

First and foremost is whether or not there are opportunities for additional efficiency and cost-savings by partnering with neighboring countries. Politics are amenable to that sort of thing. Generally, the larger the footprint you have for planning, the better it is to—or the easier it is and lower the cost of integrating renewables into the system as a whole. But that also means sort of getting the jurisdiction issues sort of clarified at the front-end.

Another issue is that the role of private capital and private ownership in plans for expanding the electric grid. If infrastructure is a state enterprise, I mean that sort of defines the decision process in one way. If it's private, then that defines it another way.

So, generally, this same idea applies regardless of the type of market that you're looking at and the countries that you're looking at. The idea is to use transmission to direct development to those areas with the highest social benefit; the mechanisms doing that will change from country to country though.

Dan Getman I maybe have something onto that that I certainly neglected to say from the tools and data discussion, which is in trying to do that to try to find these places where you've got the best benefit and the best resource. I mean dealing with those data can be complicated because they're very distributed. Lots of different organizations have them, and one of the things we've done at NREL is to produce the geospatial toolkits, whereas actually for many countries to gather as much data as they possibly can together in one place and then provide it in some _____ [audio fades out] for doing this technical potential kind of analysis; and so to get those first few steps out of the way to look for places that have high potential to have that maximum benefit. I think those are really good places to start for countries that we've already done that for.

David Hurlbut Yeah, and another—there are a couple of examples in the United States that I think would be really applicable along those lines.

The eastern inner connection, the eastern part of the United States, the eastern grid had an initiative a few years back basically to identify renewable energy zones. And a big part of that was putting all that data into a mapping platform, mapping tool that anybody could access. So there's a very, very strong value in having a visual tool—the kind of visual tools that Dan is talking about—available to all of the stakeholders at the different jurisdictions so they can start to see visually where the best opportunities might lie. That sort of takes a lot of issues out of the abstract where they can be kind of quite possibly volatile, and sort of bring them down at least one step closer to reality where they can start to discuss where are the most cost-effective options.

Jennifer Leisch

And maybe something I can even mention is that if you do check out greeningthegrid.org, there are links to the existing geospatial tools that NREL has developed on there for over 20 countries, I believe.

Another question has come in—and it's something I'm very interested in—is how the actual construction of the transmission lines in the Texas CREZ process was paid for. And maybe you can discuss a little bit more of really who bears the risk of the transmission lines being under-utilized, if the building of the new transmission resulted in higher electricity tariffs for end-users, how the cost was recovered.

David Hurlbut

Yes. So I'll talk about Texas specifically first, and then talk a little about how it is in other places.

As I mentioned in the beginning of my presentation, the model of the Texas restructuring effort was to separate utilities into different components. The generation component was set to be competitive. The retail service section was set to be competitive. That part of the middle transmission remained a regulated utility. And part of that is that all of the cost of transmission and distribution involved with it—but let's focus on transmission—all of those costs are essentially pooled together and then distributed across all of the area on a low-ratio basis. So everybody pays the cost of the same transmission infrastructure.

And the CREZ lines are no different from any other line with respect to the degree of utilization. Sometimes they're fully utilized, sometimes they're not utilized; so that goes up-and-down. But any transmission system is that way. You build it to the peak; but by building to the peak, that also means that for most of the year, there's going to be some degree of non-utilization on any different information line. So the total cost, $7 billion, when you essentially socialize that across the entire market, it has a cost _____ [audio fades out] not really acceptable cost impact, and certainly one that is offset be the reduction in production costs.

So costs in the ERCOT market are determined on an auction basis every 15 minutes. That's based on the marginal costs of all the units that are available, and what the level of demand is for that particular moment; and that's what the auction solves for. By having more wind and solar resources on the system, those come in a zero marginal costs. Those are basically more capital cost investment. So what that does—and we looked at this very, very closely in Texas as part of the CREZ process, that the reduction in generation costs can be $2.00 to $3.00 to $4.00 per megawatt hour, depending on how much wind you have and how much solar you have on the system, because that's going to crowd out the more expensive resources on the system.

Now, in other areas, for example, the Western United States, the outcome of the renewable energy zone process is really helping inform planning for independent transmission providers. For example, there are two or three projects looking at how to move wind power from Wyoming to California, but those are all independent transmission projects. So they'd be dedicated as part of that process, and those transmission costs would be folded into the cost of the delivering wind power utilities in California. So in that case, the risk is born by the independent investors who were behind the transmission project. So I mean the method of paying for transmission can vary depending on the regulatory context.

Jennifer Leisch Seems that developing a CREZ is a very complex and lengthy process. Are there some key stakeholders that other countries should be considering when they do this process to ensure that it's very inclusive and will develop well?

David Hurlbut So remember that the goal of the CREZ is to direct development to places that have the greatest social benefit. So the two stakeholders that you need—that you really need in the process are, first of all, the developer community. So if you're looking at developing wind resources, you need to have wind developers as stakeholders. So you can make sure that all the planning and the technical modeling that you're doing accurately reflects the state of the industry at that time. If everyone is building wind turbines on 100-meter towers, you don't want to use data that's based on 50 meters.

The second stakeholder group, very important, are all of the non-governmental organizations that are involved in environmental and land use issues. You want to get them engaged in the process as soon as possible for a couple of reasons. One is that it is so you can make sure up front you're avoiding areas that are very problematic that might not show up in the technical analysis; but, secondly, it will be very important to have them onboard with whatever comes out of the process.

In the Western United States—Sierra Club, Natural Resources Defense Council, some of the leading environmental NGOs—were involved in that process from the very beginning. And at the end, they were very supportive of the zones that had resulted, mostly because they recognized that renewable energy development was a good thing with respect to things like climate change and reducing emissions. But also they wanted it done in a way that minimized the environmental impact of the transmission needed to accomplish those same goals. So in their mind, identifying renewable energy zones maximizes the amount of green energy that you can put onto the grid, while at the same time minimizing the land impact of getting that same amount of energy to market.

Dan Getman And they're also going to have a lot of the data that we need because assessing environmental impact and things like that are—there's a lot of overlap in the data required to find these opportunities, and so that's another reason to be contacting those folks who are there.

Jennifer Leisch So we have one last question, and that really involves, "What kind of modifications to the process do you think would be important in non-market or vertically-integrated systems?" which in many of the partner countries that USA works with is the case for the power sector.

David Hurlbut

You really don't have to modify it that much. Colorado, for example, had a similar project—similar initiative basically right after Texas had completed its CREZ process. In some ways, it's simpler because you've only got one grid operator, one generator. But in the United States, a lot of utilities, a lot of vertically-integrated utilities will purchase renewable power through power purchase agreements from third-party developers. So they use that in their own internal transmission planning process, essentially the same as ERCOT did, except that's done by the utility. And they integrate that more with other transmission development plans that they have. So really it's the same objective, the same inputs that you need for the analysis, even if you're looking at a vertically-integrated utility.

Sean Esterly

Great. Thank you, again, Daniel and David, and also Jennifer for the question and answer, and the great discussion in addressing the attendee's questions. We are coming to the close of the webinar; so before we do wrap up, I'd like to just kindly ask our attendees to participate in a brief survey we have for you.

I will display the first question up on the screen that is, "The webinar content provided me with useful information and insight." And the next question is, "The webinar's presenters were effective." And the third one is, "Overall, the webinar met my expectations."

Great, thank you. And two more: "Do you anticipate using the information presented in this webinar directly in your work and/or organization?" And finally the last one is, "Do you anticipate applying the information presented to develop or revise policies or programs in your country of focus?"

Great. Thank you very much; appreciate your answering our questions there. And on behalf of the Clean Energy Solutions Center, I'd like to extend a thank you again to our expert panelists, and also to our attendees for participating in today's webinar. We very much appreciate everyone's time, and thank you for joining us.

I do invite everyone to check the Solutions Center website. We have posted the PDF version of the presentation, so you can access those now. We'll also be posting a webinar recording within the next day or two. Just a reminder: we're also now posting recordings to the Solutions Center YouTube channel where you can check out other videos on clean energy topics. And we also invite you to inform your colleagues and those in your network about Solutions Center resources and services, including the no-cost Ask-an-Expert policy support.

With that, hope everyone has a great rest of your day and we hope to see you again at future Clean Energy Solutions Center events. And this concludes our webinar.