UPDATED STATE WIND RESOURCE ESTIMATES
February 26, 2010

Coordinator: Welcome and thank you all for standing by.

At this time I would like to remind parties that your lines are in a listen only mode until the question and answer session, at which time you may press star 1 to ask a question.

Today's call is being recorded. If you have any objections, you may disconnect at this time.

I will now turn the meeting over to Susan - I'm sorry - to Mr. Larry Flowers. Thank you, sir. You may begin.

Larry Flowers: Thank you and welcome everyone to this Webinar.

As many of you know, Wind Powering America has been involved in wind mapping the United States for the last decade. However, wind mapping actually has gone on even in the '90s with work that was done by Pacific Northwest Laboratories. And then that team moved here to NREL.

And we did a lot of work on the international area because in many cases, most didn't know what their wind resource was. And oftentimes the international data was poor. So they didn't realize they had a wind resource.

And of course, the most important single piece and the starting piece on any wind project or wind development is getting a good read on your wind resource.

So when Wind Powering America began in the year 2000, we became very active with our state partners in mapping, remapping, using high resolution modern mesoscale technology to provide states with a good idea of what their wind resource spatially looked like and quantifying it with the tools we developed with GIS and other databases.

We partnered up with AWS Truewind in the early 2000 - 2002 and began mapping the country. And we've now mapped 39 states with this high resolution approach.

And today we want to review some of the most recent work we've done as we have now moved from 50 meter maps to 80 meter maps and also have developed a different approach to quantifying potential wind resource.

So with that introduction I wanted to turn this presentation to our three presenters today - all well-recognized international experts in the field of wind, meteorology and analysis - Dennis Elliott and Marc Schwartz here at NREL, Dr. Michael Brower, AWS Truewind.

So Dennis, with that introduction lead us off. Thank you.

Dennis Elliott: Thank you, Larry. We'll proceed with the slide presentation now. We have a lot to cover here and a lot of the -going to be spectacular information and new products that hopefully everybody's had a chance to visit our Web site and get a - viewed this information already.

So this is, you know, the talk, as Larry said, is on the new wind maps and resource potential estimates for United States. I'll proceed to the second slide - see here - click on that. How to - let's see - why's it not moving to the second one? So - there we go. Okay.

You know, here's - this is an outline of the presentation today. We'll have three speakers - all prevent an - present an overview and then talk about the history of the wind maps and resource potential estimates beginning from the 1970s and '80s to the present time. This is with the work supported by the U.S. Department of Energy.

And then Michael Brower of AWS Truewind will talk about the methodology and their involvement with NREL in developing products over the last decade and, more importantly, this latest project.

And then Marc Schwartz will talk about the - NREL's validation of the AWS Truewind model data, this latest data. We have it for heights of 80 meters.

And then I'll take it back over and talk about the - how we develop the wind potential estimates, the data, the methods and then discuss the key findings, and then more importantly, compare it to the previous studies. You've probably seen news releases on that and it tripling and so forth. I'll explain what's going on there.

So go to the next one.

What is the major significance of this project? If any of you have been to our Web site and seen, you'll see we now have new wind energy potential estimates for the contiguous United States and each state at 80 and 100 meter heights. This is the first comprehensive update of the U.S. potential in almost two decades. That's quite significant. It's been a long time.

The new ones are based on very high resolution. I mean 200 meter - these are very small grid cells of wind resource data. What we're using now is what we call capacity factor, which is representative power output from large wind turbines instead of the old power classes that we used previously back in the '90s.

That was - they were essentially related to the theoretical energy in the wind. And as everybody knows, you really - most people, more important in wind energy, turbine production typically you get from a large scale wind turbine.

So this is what we used to develop the estimates. Also we excluded areas unlikely to be developed such as parks, wilderness, urban areas and so forth.

And the major products developed for - that you'll find on the Web site for the United States and each state are the mean wind speed maps at 80 meter height. We call wind potential charts at 80 and 100 meter heights. And we - those are shown in megawatts of installed capacity as a function of capacity factor which is not adjusted for losses.

We also present tables of the windy land area and wind energy potential at 80 and 100 meter heights for various capacity factor ranges. And this is - the wind potential is expressed in megawatts of installed capacity and (ango) generation and gigawatthours.

I've given the Web link where you can find all of this - most of you have already seen from the news releases. And these products were developed through a collaboration between NREL and AWS Truewind. And it was supported by the U.S. Department of Energy's Wind Powering America Program.

And we'll next - to bring up the next slide here - there. Let me pull down - there we go. Over it - okay. Well...

Larry Flowers: Push the Down button, Dennis.

Dennis Elliott: Down button there. Okay. There we go. There we go. Here we go.

This is the wind resource map of the United States - annual average wind speed at 80 meters. You can study this in detail on our Web site. These are the colors NREL chose. Truewind has the same map - different colors. But this is - I'll show you how to relate - use this later on in the presentation.

The next visual is the final product on the - showing the wind resource potential of the United States. You see on the bottom we've expressed it by capacity factor. And the scale on the left is - relates to the potential install for the United States. It shows gigawatts of potential installed capacity.

That's where you see these number far. So example, 80 meters is a red line at 30% capacity factor and above. This is cumulative. It's a little over 10,000 gigawatts installed potential.

If you go to 100 meters, due to the more land area at that given capacity factor, it increases to about 12,000 gigawatts installed capacity.

So you can see even at the higher levels out to, say, 35%, 40%, there's still enormous amounts of wind potential which is due to the enormous windy land area that's available in the United States.

Larry Flowers: Yeah, just let me make a point here. This is consistent with the 20% report that DOE published. But remember the DOE published that report with using 50 meter maps. So this is a consistent...

Dennis Elliott: That's correct. I think it was around 8000 gigawatts but at the higher levels it's - you go to 80 meters, there's more land at a given capacity factor which increases it.

So if you had a 50 meter line on there, you'd probably see it cutting through around 8000 megawatts.

But we'll jump to the next visual here. Let me pull this down.

What I want to do is just give you a - there's a lot on here. You can just read it but I'll just give you a brief history of the wind mapping and development of wind potential estimates for the United States.

The - this work began with the U.S. Department of Energy way back in the late 1970s - developed these - a set of 12 regional atlases. And then that was used to go out, do measure programs. And then that - where we got - finally we got some data from these 30 to 50 meter type towers.

We went back. We developed a comprehensive U.S. wind atlas, came up with a power classification system as everybody knows. And of course, at that time we were even pushing the technology to get the 50 meters.

And the spatial resolution - this was all done subjectively using more what we call primitive methods nowadays. But they were state-of-the-art back then - essentially the resolution at 25 kilometer spatial resolution, which is very coarse for today's standards.

And then in - we used the maps and data from the U.S. atlas in the early 1990s to produce the first (FETO) analysis of the U.S. wind potential. And we came out - and this is a landmark document where we came out with potential for each state as well.

There again, it’s based on the old atlas maps and landform classifications. We didn’t have all the detailed digital terrain and topography data we have today. So we used old landform classification maps to subjectively classify the information.

And then we had to digitize in areas of environmental lands and land use areas and then define the areas to exclude because we certainly didn’t want to include national parks and wilderness areas and urban areas and so forth.

So that was the first time any study like this had been done. And it was a ton of work back then to try to do all of this.

And then in the 2000s we began development of these high resolution wind power maps at 50 meters height. It was a lot of effort. We worked largely with AWS Truewind there.

And as Larry said, we ended up the - we finished this in 2008 and we ended up at about 39 state maps. And this work was funded by - through the W - when DOE’s Wind Powering America Program, cofunded by states and other organizations.

And then this last year we are - we’re looking at opportunities to try to figure out how we could team with AWS Truewind and produce new maps and wind potential estimates at heights of 80 to 100 meters since we’ve, you know, been working with them. And they had expanded this and - on their own and developed these additional products.

So we - that's the history of where we started from the '70s up to the current time where we've got these brand new products.

And then let's see - where are we here? What I'll do is just show an example of how the maps change in time.

You can see this is the - in the upper left this is the Kansas wind maps, how they changed over time. As you can see, these 25 kilometer grid cells here - very coarse maps we developed in the U.S. wind atlas. And then we updated it and it was one of the last states to get updated to 50 meter heights.

You can see the much more detailed analysis there. We had a lot more data. We had tall tower data. So we feel much more confident than the accuracy of the 2008 maps.

And then Truewind has gone ahead and produced information as well at heights of 80 meters. On the right you'll see the 80 meter wind speed map.

As I said, we ditched the power classification system. I'll explain later why we feel more comfortable using - showing wind speed maps than to do the power class maps.

But you can see the - how it evolved from the - over the last two decades to what we have currently as far as the wind maps.

And then that's it for me. I'm going to turn you over to Michael Brower. Michael will talk about the existing - about AWS Truewind's methodology and modeling to develop the wind resource datasets.

Michael Brower: Hello. Can everyone hear me?

Larry Flowers: Go ahead, Michael.

Michael Brower: Okay. So I wanted to start just with a brief overview of what I'll be talking about today. I'm going to present a timeline of how we came into this process so that you can understand AWS Truewind's role.

Second, there are some key points that I wanted to bring out that hopefully will - you'll take back with you after this presentation is over.

Then I wanted to discuss the methodology that we used in the wind resource modeling that Dennis has presented and in the estimation of the plant output - the capacity factors - and finally the validation and adjustment process that we followed.

First, just as an overview, AWS Truewind really came into being near the end of the 1990s when we developed a mapping technology called MesoMap, which was really the first method that had been developed at that time for producing high resolution wind resource maps using a combination of mesoscale numerical weather models and micro scale models.

And starting in around 2001 we partnered with NREL and with Wind Powering America to produce a bunch of maps for the U.S. states as well as some maps overseas. And in the end - by the end of that - process actually was still going on - we published maps for over 30 states. I think Larry said the number was 39 which is good to know.

There were nonetheless some gaps, particularly in the Central U.S. and the Southeastern U.S. So not every state was mapped.

In - around 2007 and 2008 we started on our own to remap a lot of areas and also to revalidate and readjust maps. And in that process we completed maps of the lower 48 states.

And in May of 2008 those new maps were released through a system we call Wind Navigator. And you see the Web site there which you're all welcome to visit. This is a online system for users to access wind resource data.

And then in the fall of 2009, NREL approached us about using the Wind Navigator maps to update the state level wind potential estimates. And that process started back in the summer.

So over the last - what is it close to - seven months now - we've been working with NREL to - both to - well we provided the capacity factor data and NREL then did its assessment of the windy land area. And we collaborated in this final release which occurred in February.

Some of the key points that I wanted to make - and before I get on to the methodology, which hopefully will help you to understand some of the context around these estimates - the first point is that the resolution, as Dennis mentioned, of the underlying wind speed and capacity factor data is about 200 meters, which is less than the spacing between turbines in a typical large wind farm.

And this is really certainly adequate to resolve most terrain features - hills mountains and so forth. But it's important to know that there is some smoothing of the wind resource on sharp ridge lines. That's an inevitable byproduct of this resolution.

So the wind speed and capacity factor estimates really represent the average resource over a 200 meter by 200 meter square at each point.

The wind resource and capacity factor estimates have been thoroughly validated by AWS Truewind and by NREL. However, inevitably there are still going to be errors. We don't claim, certainly, perfect accuracy. We'll discuss the uncertainty margin. But there is always some uncertainty in the results, of course.

And I don't want to leave the impression that these estimates are the end of the line, that this is the final result. There are going to be updates from time to time. That's something that NREL and AWS Truewind will have to discuss going forward. But I would - certainly as more information comes in, it's possible that these estimates can be updated in the future.

One important point to get across is that the capacity factor estimates reflect a particular turbine power curve, meaning a particular relationship between wind speed and turbine output.

And this power curve is - which I'll present briefly later - is a generic curve in the sense that it's really a composite of state-of-the-art commercial, large wind turbines. And the CF estimates also reflect - also represent the output at the two hub heights.

Now it's certainly possible that with different turbine models, different heights and so forth, you may get different results. So that's an important factor to keep in mind that these estimates represent one particular scenario of power production and there are certainly other turbine models that would have a different profile.

The last point here is that one of the key assumptions in the megawatt potential estimates is the assumed turbine density, which is 5 megawatts per square kilometer.

That was NREL's assumption and I think it's a good one as a rough average. But of course, there are variations in the actual density of turbines. In particular on ridge tops, you can get a much higher effective array densities.

So, you know, the numbers that are actually perhaps that are not sensitive to this assumption are the windy square kilometers of land area. So for a given windy square kilometer, you could assume a different turbine density and come up with a different potential.

So all of this is really to say that the megawatt potential estimates are - represent a snapshot of the energy potential from wind. But it's certainly - we wouldn't want to say that this is exactly how it would be developed or the exact amount that would be available under a particular - under all future conditions.

Larry Flowers: Michael, this is Larry. Let me just...

Michael Brower: Yeah.

Larry Flowers: ...elaborate on just that a second.

For those of you out there who have primarily ridge top resources, the numbers, because of this particular assumption, will underestimate your resource. Five kilometer - five of - the five number came from DOE - our analysis of average wind farms. And we want to be conservative in our estimates.

But clearly those states that are dominated by ridge top development, they're - we underestimate their total resource value. So that would be a correct statement, Michael?

Michael Brower: Yes. And, in fact, those of you who are familiar with the EWIT study - the Eastern Wind Integration study that AWS Truewind participated in - we used really the same maps or virtually the same maps. And in some of the areas in the East the number of megawatts that were modeled was considerably higher and - than are in these estimates. And that's because of that density assumption.

So moving on now. I wanted to touch on the process without going into too much depth - and I would welcome any questions you might have about this later. But this is a schematic of the process we use to produce the wind resource maps.

And starting from the left and moving across to the right, you'll see that we use data from a large number of sources. There are - there is geophysical data, topography, roughness and other kinds of information. And there is also meteorological data.

There's a dataset called the Global Reanalysis dataset and also Direct Measurements.

Now the reanalysis dataset is a model dataset but it is an assimilation of data from many different sources, including satellites and surface stations and balloons and so forth.

So all of these data are put into what is called a mesoscale model. Now that's just a term that describes a certain type of numerical weather prediction model - excuse me - or atmospheric simulation model. And these models simulate the development of conditions in the atmosphere using the full equations of motion, conservation of mass, momentum, energy. And equations of state and other parameters are part of that.

And in the particular application or manifestation that we developed, we model a - sort of a typical year that is sampled from 15 years and is run at a scale of 2-1/2 kilometers. So this is the scale at which the significant weather features are captured.

Then the output of that model goes into a micro scale simulation which is, obviously, a much finer scale.

We use a model called Wind Map which is a mass conserving model. It's quite simple but it does a fairly good job at basically adjusting the wind estimates that come out of the mesoscale simulation for the effects of local topographic and surface conditions. And that's where we go to the 200 meter resolution.

The final - the next step, and in some ways it's really the most important step, is the validation and adjustment of the wind resource maps. And here we compare the predictions from our maps to actual surface wind measurements. And if we see errors, which we always do - there's always going to be some discrepancies - then we make adjustments to the map.

And that was really the - one of the main things that we did in this process that led to the most recent estimates that you see - that you have now - was a completely new validation and adjustment of the wind resource maps across the whole country.

And from all that then we produce a combination of wind maps and wind resource databases of various kinds which, combined, can go into estimating the capacity factor or other kinds of information that you might want.

The map validation and adjustment process is described here.

The first step was to put together a database of roughly 1600 monitoring towers. About 550 of these are the standard surface map stations - the ASAS stations, which we believe to be the most reliable among the surface stations. We've deliberately excluded stations that use pre ASAS or older monitoring technology.

And in addition there are a little over a thousand tall towers. I put that in quotes because some of them may not be that much taller than a standard 10 meter tower. But quite a few of them are above 30 meters and some of them are 50 meters and 60 meters high.

From these - once we collected this database, each station was carefully assessed and the observe mean wind speeds were adjusted to the long-term conditions, meaning something like 10 - the past 10 or 12 years - and projected to the map height, such as 80 meters using observed or estimated shear information.

Now the shear is the rate of change of wind speed with height. So based on our experience or direct measurements of that rate of change, we would project the speed estimates up to a common height of, let's say, 80 meters.

Once that was done, we were then in a position to calculate a bias or error signal between the map - the raw map and each measurement. And from that we constructed a bias correction which was applied to the map. And that's what produced the final wind resource map.

Important to point out that this bias correction process doesn't eliminate the bias at every tower because there are always going to be local influences that you can't encapture. But it does reduce or eliminate those errors that are correlated or common over significant areas.

And in the final result, we came up with a raw deviation - standard deviation in the errors of about .4 or 5 meters per second which, after adjusting for uncertainties in the data, we - from - with that we derived an error margin of the final wind map of .35 meters per second.

The errors obviously vary depending on location. They tend to be higher in the West and in the East because of the complex terrain. And they are lower in the Midwest and Plains states.

These two plots just show you the scatter plot between predicted mean speed along the X axis and the observed wind speed projected up to the same height. And in the lower right you see the scatter plot that we have with the raw map. And in - the larger plot shows the scatter plot for the final map.

You can see, obviously, that it's a more - it's a tighter and more linear relationship between the map and the observed speeds. But there is still some scatter and that's an inevitable part of the - this process.

The final stage, which we - where - which led to the capacity factor estimates, was to convert all of the wind resource data that we had - the Wind Navigator system - to estimated turbine output.

And part of that process, the first bullet here in the chart on the right, is to construct speed distributions for each point on the map. And these speed distributions are - indicate the frequency of occurrence of wind speeds in those bins that you can see along the X axis there.

And the mean speed, of course, corresponds to the mean speed from the wind map. The distribution of speeds comes from a separate database called windTrends, which is developed by simulating weather conditions over the last 12 years.

These speed distributions are then run through the power curve that you see on the lower right. And this is what is - this is called an IEC Class 2 Turbine Power Curve, which is the kind that's being most widely deployed right now. It is suited to winds - to moderately strong and strong wind resource sites but not the absolute strongest sites.

So it is a composite of three different actual turbine power curves which we don't - we didn't want to use one particular turbine model because, of course, that would - might be subject to misinterpretation.

And now one of the consequences of using a Class 2 Turbine Power Curve is that we may be, say, overestimating the gross capacity factor at very windy sites where you would want to use a Class 1 turbine.

Conversely, at very low wind sites or relatively low wind sites, you could possibly get a better capacity factor by using an IEC Class 3 turbine.

So this is one of the consequences of choosing one turbine model or one turbine power curve.

And finally, we validated the speed distributions themselves separate from the wind map - the wind - mean wind speed map by predicting the turbine output following our process, and then comparing with what you would get based on the observed winds at ten locations across the country.

And this is a scatter plot showing that relationship. It's not perfect everywhere but overall the agreement is quite good. And so we feel fairly confident about that stage of the process.

The overall uncertainty as a very rough estimate in the capacity factor at any given location is roughly 10% based on the various validations that we've done.

And that concludes my part.

Larry Flowers: Thank you, Michael. Dennis?

Dennis Elliott: Okay. Yes. I had it on mute. Sorry.

Marc Schwartz is going to speak next. That's correct. Marc, are you there...

Marc Schwartz: I'm here.

Dennis Elliott: ...to talk about the validation - NREL's validation of the AWS Truewind wind resource maps.

Marc Schwartz: Okay. Thank you, Dennis.

I'm going to talk briefly about what NREL did in terms of validating the AWS Truewind 80 meter data. I apologize a bit for some formatting issues here. Microsoft is acting up again. But we'll proceed.

The purpose of NREL's validation was to identify gross disagreements between the model 80 meter wind speed and the measured data. And the model wind speed - they were provided to us by AWS Truewind for the validation. And the capacity factor estimates were not included in this analysis.

We validated the data in 19 key Wind Powering America states, three different sections of the country -- six Western states, six Midwestern states and seven Eastern states -- a good sampling from important regions of the country.

The way the validation was conducted is that the average wind speed from measurements from the towers were compared to the model wind speed values. The actual time series of the data - the individual measurements - was not looked at in our validation.

The information from the towers that was provided to us - 1600 sites from AWS Truewind - the information provided to us is - it's below - the three most important elements that Truewind provided to us was the approximate location of the towers, the estimated wind speed at 80 meters -- it was almost all cases of the winds were estimated -- and the shear exponent which helped us to judge how fast the wind speed increased with height.

Briefly - I just want to skip ahead briefly to - so if you're not familiar with wind shear and how we try to estimate it, the winds usually increase with height.

There's formulas that are used to estimate how fast they increase with height. The equation on top is called the Power law - is one formulation. And the N up there is called the wind shear exponent. And right now the graph shows that the wind speed is increasing in height using a 1/7 Power law. In other words N is equal to 1/7.

There are other exponents that occur in the United States. The higher the exponent - in other words if you have a high value like a 1/4, the more - the faster the wind speed increases with height.

So I just wanted to introduce that. Go back to the other slide.

Out of the 1600 sites - information that was provided to us, we defined a subset of about 304 in the 19 states would use the analysis. Almost all the towers were for proprietary sources.

Data from 45 meter tall towers and higher were analyzed, and the higher first to the highest measurement level. Twenty towers had measurement levels greater than 60 meters. And about 80 towers had easily identifiable periods of record of two years and longer.

There's always uncertainty in the model validation. The two sources basically are the tower data itself, which is the greatest source of uncertainty. And there is some uncertainty based on the regional analysis.

Towers - they were not evenly distributed among the 19 states. And they were tended to be clustered in recent wind prospecting and development regions of the states which sometimes made it difficult to extrapolate the results to other parts of the state.

Other sources of uncertainty - the short periods of record and again the shear exponents used estimate the 80 meter wind speed from the highest measurement level. I don't think the shear exponent contributed as much other - as the other factors.

The regional analysis - there is one factor that stood out. Shear exponents varied more widely in the Eastern states compared to the Midwest and the Western states. And even this was true for some towers in the same general area. So that was a source of regional uncertainty.

And what's the result of the validation? Happy to report there is no gross differences found between the measured and model 80 meter data that precluded using these data for the wind potential estimates.

However, there were regions where additional measurements are crucial. Two sides - two regions stand out -- ridge crest sites in the Northeastern U.S. and interior sites in the Western U.S.

And finally, if I may get up on my soapbox, I think we need a national network of measurements at turbine hub heights to estimate the wind potential with even greater accuracy.

So that's what I have on the validation. I'll turn it back to Dennis right now.

Dennis Elliott: Okay. Well thank you, Marc. We'll (unintelligible) here and figure out where we are - talk about the development of the - let me see if that's correct here because it's down to where the right slide is. I believe it's this one right here. Okay yeah.

Slide 14 - how we developed the wind potential estimates. You heard Michael Brower give the details on the modeling and the methodology. And that resulted in a national dataset of estimated gross capacity factor. And by that, we mean not adjusted for losses. And I mean typically, loss is 10% to 20%. I've heard numbers like 15% on the average is a good ballpark number to use.

As Michael said, a very fine spatial resolution of 200 meters - this was excellent to get - and heights of 80 and 100 meters. And again, it's land-based areas only, no offshore. And it's the 48 contiguous states.

I've talked to Michael and we have tentative plans to include Alaska and Hawaii before the end of this year.

So - and we use this - NREL used the gross capacity factor data to estimate the land area and wind potential as a function to capacity factor for each state in the U.S.

And then we had to make a decision. This is - well in the old days we used - we came up with this Power Class 3 and greater which was accepted. And so we spent some time trying to figure out how could we redefine the windy land area and wind potential by - of these ranges of capacity factor.

And finally after looking it over, it looked like about 30% gross capacity factor was the right value to use, which we considered generally con- suitable for wind energy development.

And if you want to equate that to a mean annual wind speed, areas with capacity factors of 30% and greater correspond roughly at sea level. Now it's going to be higher, say, here in Colorado and at - but about 6.4 meters per second and greater.

So if you're somewhere like Colorado, maybe it'll be 6.8 meters per second. When you get to 2000 meters, it approaches 70. You just - there's less - the area's less dense so you need slightly higher wind speed. And this is well known.

We excluded the sensitive environmental lands and incompatible land use areas. Details will follow on this. Donna Heimiller just showed up in my office. And when we get to the details, since she prepared these slides, I'm just going to let her speak to them.

The important thing for the wind potential - we assumed 5 megawatts per square kilometer installed - nameplate capacity. This is something we've been using over the last decade or so. We didn't - we used something a little different in the old 1990 study.

But then starting with the - in the - and how do we express potential - we - in megawatts - installed megawatts capacity. And also we took this and computed the (ango) generation and gigawatthours.

Let's go to the next one.

Okay. Donna's here. Donna Heimiller is - she's going to talk about the next few slides here. She's what we call a Geographic Information Systems expert. She wrote the software to input the - all the wind potential data and all the exclusion data to develop the final numbers - the function of capacity factor. So would you like to go ahead, Donna?

Donna Heimiller: Sure. Thank you, Dennis.

Well NREL has worked with industry for the last decade or more to come up with this list of exclusionaries that we apply to the resource data to try to get an estimate, on average, of what the wind potential is.

Now these are national level exclusions. And so we applied them consistently across the U.S.

We are also dependent though on having data that is available at a national level. So there are a lot of state and local areas that might be considered sensitive environmental lands. But if we don't have a representation of them consistently across the country, then we're not using that as a exclusion criteria.

Larry Flowers: Donna, you need to speak up a little bit.

Donna Heimiller: Okay. Sorry.

So the first category is the potentially sensitive environmental lands. And so there are a couple of agency administered land areas that we exclude categorically. That includes the National Park Service and the Fish and Wildlife Service.

Other federal lands are excluded based on whether or not the land has a specific designation of protection. So things like wilderness areas, national monuments, parks and wildlife areas are excluded from the federal side.

To get a sense of some of the state and private lands that could be considered in this category, we also use the Protected Area database that was produced by the Conservation Biology Institute using some of the gap analysis that was done to quan- to categorize lands as whether they're protected from conversion from their natural state.

So there is also a second dataset that we used to get at some of that national level, state and private land.

The next category is land use exclusions. And so we're excluding here areas - urban areas, airports, water and wetland features. And then for those first two categories, we also have a 3 kilometer buffer exclusion around everything but water, so that we're trying to account for any overlap or just a - nearness issues to some of these sensitive lands.

Finally, the last category is a more qualitative exclusion that's applied to U.S. Forest Service, Department of Defense lands and non-ridge crest forest lands.

I should actually qualify those first - the U.S. Forest Service and the Department of Defense is only non-ridge crest lands that were not previously excluded in - because of their categorization.

So there's a 50% exclusion applied to those lands.

And the next slide shows graphically what that distribution looks like.

And so in the tables that have been released, you can see that we report for the country and by state both the total number of windy land that is greater than

30% gross capacity factor and then the excluded amounts. So you can get a sense for what the percentage of land that is being excluded is.

You can get a sense from the map itself about what that distribution of exclusions is. But I did want to emphasize that since these are national level exclusions, they may not apply as well when you're looking on a state-by-state basis.

So additional analysis can be done to kind of customize the kind of scenarios that we're using to define these exclusions based on the states - state criteria.

And this next map for West Virginia, you can kind of graphically see again that the exclusions are very broadly applied to the state. Very little of the state has no exclusions.

The crosshatch area - gray area - on the map on the right is the area that's being 50% excluded. So we just - we're not excluding specific parcels of land there. We're just taking that total land area and dividing it by two when we're calculating wind potential for the state.

Dennis Elliott: Okay. I'll take over from here. This is Dennis Elliott again. Thank you, Donna. And we'll just try to wrap it up quickly here.

This is - just talked about some of the key findings. I think most people have already seen these. These are numbers you've probably seen in a lot of news releases that have been coming out from AWEA and others that have talked about this study.

You know, it's obvious that the wind potential from areas with a capacity factor greater than 30% is enormous. At 80 meters it's almost 10,500 gigawatts capacity, which corresponding to about 37 million gigawatthours of - per year. And at 100 meters it jumps up to 12,000 gigawatts and nearly 45 million gigawatthours.

Most of this potential comes from the windy central regions of the country. But many Eastern and Western states also have significant potential.

If you just want to look at 1000 megawatts of - at 80 meters, there's 35 states with - that's - and then at - you know, you don't get a lot more, but at 100 meters you get three more states to bring you to a total of 38 states that have 1000 megawatts or more.

But even if you look at the very high levels, you know, the 35% and the 40% and greater - you see the graph on the right. You have more than 8000 gigawatts at - in 28 states. More than - 8000 gigawatts total.

And 28 states have more than 1000. And at 40%, which is probably mostly the central region of the country, there's still - that's a huge number - more than 5500 gigawatts in 19 states with more than 1000.

Let's jump to the - what I'll do - I just wanted to show a few states here and examples.

Some of the states like Arizona probably would have more uncertainty than others around the - this - the 30%. Let me see if I can get the marker on here. There we go.

If you see around 30%, this - see - this is the line for 80 meter height. It's a very steep slope here and, you know, about a half meter per second difference in annual average wind speeds corresponds to about a 5% change in the capacity factor.

So if there's only - let's say there's a - the data's only off by maybe a couple tenths meter per second or so, which is entirely possible especially for a complex state like Arizona - and, you know, it could vary anywhere from maybe 20,000 to 5000 megawatts.

So, you know, I think one could easily justify if you wanted to - 20,000 instead of 10,000 for - at 30. And then if you go to 100 meters, it's, you know, considerably more as well.

So that's an example of how to interpret this. The - you can't really - you know, there is some variation in some of these states on the wind potential.

Another good state with a lot of variation around that 30% is the - is Ohio. And you can see here that it's very - it's steeply sloped here. And so there's quite a bit - about, you know, almost 60,000.

But if you just like - a couple tenths of a meter per second variation in the accuracy and you're anywhere from maybe 20,000 up to 80,000 and more.

So this is - keep in mind that we need to take more measurement data, more shears, more, you know, the - because there's a - where you have the steep slopes like this, there's a lot of variation that could happen in these numbers.

And over here, let's look at the map on the left. Well most of that potential here at 35% and greater is coming from these little red areas here - that's the 7 meters per second greater.

Six-and-a-half meters for - per seconds correspond roughly to the areas of 30% and greater. So that's where much of this 50,000 megawatts comes from are the areas that are colored orange on this map here.

So that's the way you can relate the maps to the wind potential numbers.

And then we'll jump down, show one more state and we'll finish it up.

This is North Dakota. And you see North Dakota - over here is 30% greater. It doesn't - there's no variation whatsoever at 80 meters or 100 meters. The reason for that is that corresponds to about 6-1/2 meters per second and greater resource.

If you look over here, that's the orange and better, so almost the entire State of North Dakota, except for tiny little areas - probably over 90% of the state has wind potential greater than 6-1/2 meters per second. And so that's why you don't see much variation.

The big variation in North Dakota comes out here around 40%, 45%, 50% where you correspond to these high levels of 8 meters per second and above.

Let's jump to the next one. Okay.

Larry asked me to talk about the comparison to previous studies. I'll - you can read this but I'll just try to summarize it very quickly.

You see numbers - when the releases by we and others saying that - how the numbers have tripled since the old studies from the 1990s. There's a lot of reasons for that.

I mean we're - one of the reasons we're using capacity factor at 80 meter height right here instead of where the old ones were Class 3 at 50 meter heights. That's one of the reasons.

You know, when they went for 37 - three times the old estimate, 11 million. And the land area is about twice. One reason you get three times is because the wind turbines are much more efficient now than the old technology using.

This next one shows that. The old technology - we didn't really use wind turbines with that studies. We used very conservative assumptions at 25% efficiency, 25% losses. Also we used much more restrictive land use exclusions.

For example, we excluded 30% of the agricultural lands. And that was based on these coarse resolution maps from the old '80s atlas.

And if you jump here, the new maps are, you know, very fine resolution. We feel the U.S. is much more accurate.

As Michael Brower said, it's advanced computer modeling and 1600 measurement sites. So it's not just muddling along. It is validated and revised with high-quality data from a lot of measurement sites. And we used the new technology composite power curves and the - and now the GIS data.

What - importantly here, we exclude- we updated the exclusions for what we used in the 90s, we brought in in the early 2000s. We were trying to figure out how to do this.

We brought in national experts from federal agencies, such as the Forest Service and VOM and all these - and this - and we came to the agreement of what to do. And one of the things we decided, why are we excluding any agricultural lands? So we threw that out. We aren't doing that anymore.

So there's a lot of reasons that are summarized here.

So the main differences, too, the power class represented theoretical energy in the wind. And now the capacity factor represents power output from large wind turbines. That's a big difference.

So we're essentially talking about apples and oranges here. There's a lot of reasons the differences for the - but we feel the methods we're using now are much better than the old methods and also the products and amounts as well.

You know, and obviously 80 meters instead of 80 meter - 50 meters - with the big increase in height.

So let's go down to - what I'm doing, just for your purpose, I've showed, you know, relationship between capacity factor, wind speed and power. This is - I won't go through this much.

Weibull K refers to the shape of the wind speed distribution. These are different shapes of the wind speed distribution you can get throughout the United States.

That's why on the power density for giving capacity factor varies enormously from what we call Class 2 to Class 4 and 5 for giving the capacity factor. That's why it's not reliable to use energy - theoretical energy in the wind because it doesn't really represent that accurately how much power you're getting out from today's modern wind turbines.

Whereas speed is much closer. If you look over here on the left, you'll see that there's very small variations in wind speed, maybe only a couple tenths meter per second for a given capacity factor even if your wind speed distribution varies a lot.

So that's why the wind speed maps can be used much more reliably to relate to turbine power production and potential than the old power class numbers.

So let's see here. Where are we here?

This - I'm just - this - I just said I want to show a good example. This is - shows that examples where you have different areas of the U.S. and where the capacity factors with the new method are almost identical here. You know, 35%, 36% for 7 meter per second wind speed.

But if you look at the power class you'd get from these areas with the different Weibull K values, they vary anywhere from Class 2 to Class 5.

And so you do you land area, you're going to get enormous differences between these two methods. And so that's why we abandoned the power classification system.

So the conclusions essentially will say - well - I won't spend any time on this. I think we'll jump on to questions. But this is - gives a quick summary of - we did this and here is essentially the - what the final results were.

So I think that's it for me. We'll open it up to questions, if that's - unless Larry wants to say a word or two.

Larry Flowers: Yeah. This is Larry. I just want to make two comments.

First of all, thank you to our partners - to our technical partners, AWS Truewind, but also our state partners. U.S. DOE contributed in many cases half of the funding for these state wind maps. And the states had to generate the other half. So this has been a real cost-shared effort between DOE and the states. And a great technical collaboration between AWS Truewind and NREL.

And I also want to mention to the state folks that if you want to have a specific presentation on your wind map and the implications and discussion of exclusion areas and this new idea of capacity factors, that's all something that's available through Wind Powering America and the state Wind Working Group. So if we want to have a much further detailed discussion about your particular state, let us know and we can do that.

And with that, operator, let's open it up for maybe 10, 15 minutes of questions.

Coordinator: Thank you.

At this time if you would like to ask a - just please press star 1 on your touch tone phone. Please unmute your phone and record your name clearly when prompted so I can announce you when we're ready for your question.

If you question has been answered, you may withdraw your request by pressing star 2.

Once again at this time, if you do have a question, please press star 1 and record your name. One moment please.

Our first question is from (Brian Miles). Your line is open.

(Brian Miles): Hi. Thank you for the very informative presentation. I'm wondering if there are any plans to make GIS data available to Wind Powering America state programs as these data are very useful in our extension efforts. And I just wanted to know about that firstly.

Larry Flowers: Dennis?

Dennis Elliott: (Brian) - I mean - let's see. I have Donna here but Michael - it's probably more appropriate for Michael Brower to answer this. Are you on, Michael?

Michael Brower: Yes. I'm here. The answer is yes, the data are available through our Wind Navigator system in addition to the, you know, the PDF maps that have been released through NREL and the tables of estimates that you've got.

You can get access to them in a GIS environment through Wind Navigator. There - it is a commercial site. There is a free browser available which you can use to get access to the information at one level. And then to go beyond that an obtain prob- the more detailed wind resource data, there are various subscription levels that you can take.

(Brian Miles): Okay. Thank you. I guess I - take that up with our state energy office because I think we had purchased the data in the past from you all. So something like that might be in order then.

Michael Brower: Sure. Yeah. And just to - so you know that these are completely new maps. They're not the same maps as were released before. In many states they are quite similar but in many other states there are significant changes based on the new validation and adjustments. And in some cases states were actually remapped.

So depending on where you are, the previously published information may be quite good or quite close to what was used in this case. And in other states it might be quite different.

(Brian Miles): Thank you.

Coordinator: Thank you. The next question is from (Nathan Wilson). Your line is open.

(Nathan Wilson): Hello. I was wondering - you don't say that a lot of the data is collected from net towers at 10 meters and 50 meters. But a lot of the wind turbines have hub height wind monitoring.

So I was wondering in the states with higher installed capacity, is any of that data used in the modeling? Or if not, why not?

Michael Brower: Sure. So I guess you're asking about the anemometers that are installed on the turbine themselves?

(Nathan Wilson): Yes.

Michael Brower: Right. Those data generally aren't available because - for proprietary reasons. The owners of the wind power projects simply don't share the information.

There are also issues of accuracy. Because these are measurements that are taken in the middle of a wind park, they are influenced by - both by the - in the cell that that they're mounted on and the blades that pass in front, but also by other turbines in the array.

So they're not really a suitable source of data for the - they're not as accurate - put it that way - as the kinds of wind measurements that are taken for preconstruction energy studies.

Larry Flowers: Michael, the - please clarify. This is Larry. We didn't use 10 meter tower information for this validation.

Michael Brower: Well some data are. There were 550 ASAS stations in the validation dataset but that was - so that was about 1/3 of the stations were 10 meter. But the rest were taller than that.

Dennis Elliott: Yeah the data that Marc Schwartz and I used in the independent validation, we only selected, as we said in the presentation here, the towers and heights of about 50 meters and greater.

So no, we did not use any of the low level data because we just felt that was too much adjustment.

(Nathan Wilson): Okay. That makes sense. Thank you.

Coordinator: Thank you. The next question is from (Jenny Allen). Your line is open.

(Jenny Allen): Hi. I'm from Arkansas. And we've been discussing doing a tall tower wind measurement study because we've yet to see any commercial wind developers follow through on any projects which makes trying to convince our legislators that there is commercial viable wind in the state somewhat difficult.

I'm wondering if what you guys have been doing with these maps though makes, I guess, the usefulness of a tall tower study maybe less so if it's still worth pursuing?

Dennis Elliott: This is Dennis Elliott. No we definitely need tall tower measurement data, especially in areas of complex terrain like Arkansas. These mounts aren't intended for siting, micro siting.

So we encourage everyone to continue to do their measurement programs also for this data to be used for any wind farm development that you're required to have at least one year of high-quality data at your hub height levels.

Michael Brower might be able to speak more on this.

Michael Brower: No. I think that's quite accurate. Yeah.

Marc Schwartz: And I just want to add - this is Marc Schwartz speaking - that any data from tall towers can help judge the accuracy of numerical model output and will lead to better modeling in the future. So there are a variety of purposes that tall tower measurements are needed for and they're quite valuable.

Larry Flowers: (Jenny), this is Larry Flowers. We are pursuing taller towers in some states in cooperation with some of the modeling needs. To do a, you know, complete U.S. tall tower validated effort is a multi-million dollar effort.

But clearly in Northwest Arkansas where you have, as I said, significant terrain features and lots of trees and so forth, a tall tower would be a very good thing to do to verify what your resource is.

(Jenny Allen): Right. And I guess I'm also just curious in terms of when I get up and present these maps in front of, you know, policymakers and people who are somewhat critical of the idea, can you give me an assurance that I can say, with at least some level of confidence, that these are fairly accurate estimates for a state where you don't have any tall tower data to help with the validation process?

Larry Flowers: (Jenny), let's talk about that offline because...

(Jenny Allen): Okay.

Larry Flowers: ...have in - we have in some cases testified when requested by energy offices to some of the regulatory and legislative bodies about the accuracy and methodology of these maps.

(Jenny Allen): Okay great. Thanks, Larry.

Coordinator: The next question is from (Brandon Levin). Your line is open.

(Brandon Blevins): Yes. This is (Brandon Blevins). For those of us working primarily in ridge top states, how would you recommend when approaching agencies, organizations or utilities who may not consider wind due to the underestimation of the resource that we just went over? Is there going to be something we can point to where this going to be documented, let's say?

Dennis Elliott: Tough one. Well, you mean the underestimation in some of the states? Which area - which particular areas are you talking about?

(Brandon Blevins): I work mainly in the Tennessee-Kentucky, but then also due to some partnership work, in North Carolina-Virginia-West Virginia.

Dennis Elliott: Yeah. It's a possibility. There's two things going on here - I think we touched on it - is that - yeah, we're - this - we used just a very conservative 5 megawatts per square kilometer for the whole U.S. and also the - as we've indicated or Michael maybe indicated - you can do maybe up to 10 to 20 on a ridge line. So the potential could be greater.

And also in the EWIT study, I think, the potential is greater what we came out with here.

So you're right. In this particular one, since we treated everything, you know, normally as possible, the estimates are low in the - some of the Appalachian areas.

Larry Flowers: (Brandon), this is Larry. Let me give - put a thought out there for the folks on the call. I noticed some North Carolina folks as well who are ridge top dominated states.

I think there is opportunity here, not necessarily to adjust the map or the information posted, but to do a - to put in a TAP request to do a state specific estimate based on what we know are higher density wind applications on ridge tops.

Michael Brower: And this is Michael Brower. AWS Truewind would also be happy to at least provide advice on how estimates might be different in a particular state or the impact of these ridgeline estimates. So that's something we could discuss as well.

(Brandon Blevins): All right. Thank you all.

Coordinator: The next question is from (Steve Guy). Your line is open.

(Steve Guy): Thank you. Thank you all very much for doing this. I had two quick questions.

The first one just to reconfirm what I think I heard, and that is that this data was used in the EWIT study.

And the second one is that - regarding the - what you found in the areas that have tended to be viewed as high wind resources and whether or not there was a change in that, I heard a lot of discussion about the expansion of areas that are viable at 30%.

But what about the areas, such as in Western Kansas and up through that corridor and down through Texas, that have been considered high capacity resources? Did those numbers go up or did they change in the study?

Larry Flowers: (Steve), this is Larry. Let me preamble the comments from our technical experts. But when they - when we did this, one of the things that didn't change was the - the Top Ten states of wind capacity, they changed in order. But the Top Ten states that had the best wind resource from the older mapping are still the Top Ten states with the new mapping.

(Steve Guy): Yeah.

Larry Flowers: So we didn't - it wasn't as if all of sudden there are a whole bunch of states came into the Top Ten and all of a sudden we have to rethink our whole regional and national wind map.

(Steve Guy): Right.

Larry Flowers: So with that sort of general comment, I'll pass it to Dennis for more detail.

Dennis Elliott: Yeah. And for the reason I said in that one slide, they went up in those states as well particularly because the - even - no matter what level you look at, the winds are stronger at 80 meters than 50 meters. And also we have the technology is much better than the old technology.

(Steve Guy): Yeah.

Dennis Elliott: For those two reasons alone, they went up as well. Then also the - you do get - what we found based on our studies that in the Great Plains and Midwest, there's lots of strong shear. So they increased more there than they did in many other areas of the U.S.

(Steve Guy): That's actually what I was trying to get to. That's helpful. I want to follow up, Larry, if I could sometime with that.

I'm looking - I was interested in the delta of the change between those areas that might have been viable before but on the fringe and those areas that were clearly very attractive.

So if I could do that sometime, that'd be great.

Larry Flowers: Absolutely.

(Steve Guy): Thank you.

Coordinator: Thank you. The next question is from (Mark Sullinga). Your line is open.

(Mark Sullinga): Yeah. Hi. I had a question about the way you calculated your power capacity factors using, as I understood it, a wind speed distribution from the windTrends simulation.

So first just a question - is that a simulation that's of similar resolution to the ones you used for your high resolution wind maps?

Michael Brower: This is Michael Brower. No, the windTrends simulations are done at a coarser resolution, about 20 kilometers. That's because they cover 12 - well now 13 years for the whole country rather than the typical single year of wind mapping run.

And that's exactly why we did the validation of the capacity factor estimates. We wanted to make sure that they were reasonably accurate. And you'll recall the last slide that I presented showed the scatter plot for ten sites across the U.S....

(Mark Sullinga): Right.

Michael Brower: ...where we compared exactly that issue.

So our conclusion from that was that the uncertainty in the overall capacity factor estimates is dominated by the uncertainty in the mean wind speed and that the possible errors in speed distributions stemming from the use of this windTrends dataset was a secondary factor.

(Mark Sullinga): Okay. Did you ever look at the wind speed distribution from the - say, from the windTrends versus your 366-day, 2 kilometer simulations and - I mean are they very different or do they look kind of the same or?

Michael Brower: Well they're actually very similar in almost all parts of the country except for certain areas such as a windy mountain pass in, say, California or Washington State where you can get quite different speed distributions. And so that's a source of additional uncertainty in those particular states.

Even so, we concluded - that was - that we had some data in a couple of those passes in the samples - the ten sites that I described. And even so, we felt that the uncertainty was acceptable and smaller than the uncertainty in the wind map itself.

In terms of - really the - now that comparison really looked at actual observed data, which is the appropriate comparison here.

The EWITS data were also validated separately against observations and compared very well. But that just covered the Eastern U.S. where, in fact, the windTrends data does pretty well as well.

It's really in these areas - if you want to know the technical term, you know, where there are mesoscale circulations that are significant where you get some discrepancy.

(Mark Sullinga): Okay. Thank you.

Coordinator: The next question is from (Hugh Turnbow). You line is open.

(Hugh Turnbow): Hi. I was just wondering if you're going to make available online the recording of this presentation as well as the PowerPoint?

Larry Flowers: Yes.

(Hugh Turnbow): Awesome.

Larry Flowers: It'll be posted on the Wind Powering America Web site in about a week.

(Hugh Turnbow): Thank you.

Coordinator: Thank you. The next I believe is from (Pete Larsh). Your line is open.

(Steve Marsh): That's (Steve Marsh) from Michigan actually. I've got a quick question on how you accounted for variation in wind speeds, particularly on a annual basis?

We have, for example, data from 25 years at 60 meters. And we also put that through a wind power analysis and the capacity factors varied as much as 30% across that 25 years.

How did you - how's your data deal with - is this an average for what you think it would be over a ten year period?

Or in a related question, when you had a tall tower data for one year, how did you know it wasn't one of the top years or one of the poor years in terms of your calibration process?

Michael Brower: Sure. It - the - it is probably best to think of this as a ten year average output. There are certainly going to be variations from year to year and they could be, in extreme cases, as high as you've seen.

But we used a speed distribution and a wind mapping process that produces what should be a pretty good estimate of the ten year mean.

Regarding your second question, for each of the tall towers - well for most of them, I should say, where - those where we had access to the data, we performed a correction for the - between the short-term wind - the period of measurement and the long-term historical climate using, in most cases, the nearest ASAS station that's more correlated with that tower.

So we're quite comfortable with those as representative of the long-term conditions. These are sites - in many cases, we know them very well from work we've done with clients.

There are some towers - tall towers - in the dataset where we didn't have access to that information. And we tried to, you know, we filtered out stations that were short period and we thought would be unrepresentative. There wasn't anything we could do about those.

The ones that remained though, that's just one of the uncertainties in this process.

(Steve Marsh): Okay.

Coordinator: Thank you. Again if you would like to ask a question, please press star 1 and record your name.

We have one more question from (I. B. Pemsey). Your line is open.

Larry Flowers: And let's make - this is Larry Flowers. Let's make this the last question. We're running a bit over.

If you do have additional questions, please email me or Dennis Elliott. Dennis.Elliott@NREL.gov. Larry.Flowers@NREL.gov.

Michael, why don't you give them your email so they can - if they have a technical question, they can ask you as well.

Michael Brower: Sure. It's MBrower - that's M-B-R-O-W-E-R at AWSTruewind.com.

Larry Flowers: So last question please.

(I. B. Pemsey): Yes. Thank you very much for the information. Very enlightening.

Question is with the capacity factors of greater than or equal to 30%, which I would assume, you know, would be equal to the 10,500 gigawatt capacity. How much is realistically retrievable or can be produced?

Larry Flowers: Let me address that a bit. This is Larry.

That's a good question that we've talked about. This is really more of a theoretical potential. We do do the exclusions that are very significant to take them out of consideration. We do take out 50% of non-ridge crest forests.

So if - it's clearly much greater than ever - possibly would be developed. We didn't take into consideration, for instance, how close it was to transmission lines or transmission capacity or how it matched local loads.

So there are lots of sort of economic questions that this does not address at all. It's specifically about potential.

We chose the 30% gross at 80 meters because, in fact, that resource is being developed in parts of the country. So it is a practical minimum, although in many cases, for instance in the Dakotas or other - Wyoming - resource -

capacity would actually be much greater than that and they won't really develop their low capacity factor resource at least first.

So it is a technical capacity, I think, with reasonable exclusions. But it's certainly not the economic - economically appropriate capacity because there's nothing in there about transmission or competitive markets.

So...

(I. B. Pemsey): Thank you.

Larry Flowers: ...with that comment, thank you very much.

We had over 90 folks listening in. And we look forward to following up with some of the state and regional questions as they develop. Thank you for your attention. And good afternoon.

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