RENEWABLE ELECTRICITY FUTURES STUDY

August 15, 2012

Coordinator: Welcome and thank you for standing by. At this time all participants are in a listen only mode for the duration of today's conference. If you should need assistance about your call please press Star then 0 to reach the operator. This call is being recorded if you have any objections you may disconnect at this time.

I'd now like to turn the call over to Mr. Charles Newcomb. Sir you may begin.

Charles Newcomb: Thank you very much and I'd like to welcome everyone to this month's installment of our monthly Wind Powering America webinar series. And I wanted to give a shout out to Jonathan and the folks at the Department of Energy headquarters for their continued support of this program. It's a valuable venue for sharing what's happening in the industry and what's important to all of our stakeholders.

So today what we've got coming up is a report or presentation on the renewal energy futures study. I guess I should forward the slide, shouldn't I Corrie? There we go, I apologize for that, I hope everyone out there is doing well. We were just talking before we joined the call about how hazy it is in Colorado and it's coming from fires up in the Pacific Northwest and other areas. So our visibility is down to about 10% of what it normally is out in Colorado. It's kind of a strange day out here.

So again, back on topic, today we have a presentation from Trieu Mai, who is one of our PhDs at the laboratory. Who will be talking about the renewable electricity futures. And the way we like to look at the futures study in context of wind powering America and wind deployment in general, is that there's a

lot of short term chatter if you will and issues that very much impact the industry on a day to day and seasonal and annual basis. And cause concern and alarm at different degrees depending on who you are. And what I think is on everyone's mind is the production tax credit and seeing that become part of the debate in this upcoming election is of course exactly what industry would like to avoid. They'd like to keep it out of the political arena as much as we can.

So in stark contrast, to the sort of, near term and immediate pressures that the industry gets buffeted by. It's occasionally nice to see a very long range, sort of future's horizon type study that says, "Hey, it's all going to be okay long term." That's one perspective.

The other perspective is that when you have an opportunity to influence something, such as an incoming meteor, you want to affect that thing early, because you can have the greatest effect. So as you listen to Trieu Mai and you learn a little bit more about this study, keep that in mind. That as we go forward how do we make sure that as the future does seem to be bright, how do we, as constituents and stakeholders, affect the ultimate horizon? And by engaging early, engaging strong, engaging consistently that we can actually have some sort of an impact, a lasting impact.

So with that I'd like to give you Trieu Mai, he's again, one of our PhDs here. He's the section supervisor for the Strategic Energy Alliance Center that looks directly at electricity modeling. And he's also one of the lead authors and analysts for this study. So with that, Trieu I hand the phone to you.

Trieu Mai: Great, well thank you Charles and thank you everyone for spending this afternoon. Our futures report, which I'll go into some detail during this hour long presentation but definitely not complete summary of the report as it is

over 850 pages and was released just a couple months ago so I encourage you, if there's interest after this webinar to contact myself to ask more questions. Or to delve into some of the report material which I'll have some pointers to the Web Site later on.

Charles Newcomb: Trieu, if I may interrupt already, in my excitement to hear from you. I forgot to cover a couple of the ground rules and so if I may just take a moment and remind people that the top of your screen there is a Q and A button that you can highlight. Which allows you to ask questions of the speaker. Those questions will sit in a queue and I will look through them and paraphrase them and ask them of Trieu on a periodic basis.

Also, Trieu's presentation will be available as are all the presentations for these webinars are available on the Wind Powering America website. And it typically takes about a week or so before they can land there. And I think those are the only two things that I neglected. So I apologize for that and back to you Trieu.

Trieu Mai: No problem. So you can see on this slide kind of the motivation behind why we're doing this study. As many of you know, renewable technologies are low carbon, low pollutant, low fuel use, low water use, domestic and sustainable electricity source. As many of you also know. Although the industry, particularly the wind industry in the US, has grown substantially over the last decade. From 2000 to 2010 with today's term we are up to about 50 gigawatts of installed capacity.

However, if we look at the overall generation mix in the US. Renewable energies, including hydropower, make up less than 10% or approximately 10% of that energy on an annual basis. Wind is a small portion of that 2% or 3% or so. Although wind and solar are growing, these percentages are

relatively small compared to the conventional fossil and nuclear sources that are powering our electric grid today.

So the study, and the real motivation behind this work, is to look at to what extent can renewables grow from this relatively small base. To largely power the US electricity system for the next several decades. To provide a little bit more context. I think it's fair to say that there are many people in the industry and many stakeholders out there who believe that renewable electricity, including wind and including solar, can only be a niche player in the overall power generation mix. What we want to look at it is, from a technical perspective, to what degree is that true? Or is it not true at all, and renewables can largely power the US system.

And here's a summary of our key results and I'll get back at the end to show these in detail. But, what we find from this very detailed analysis, modeling analysis, is that renewable generation technologies from commercially available technologies, with a more flexible power system can supply 80% or more to the US generation mix. While meeting demand at the hourly level in every region in the country. And that system flexibility is a very important component of that. And there are various sources that could increase the flexibility of today's system.

We also find that the abundance and diversity of the US renewable energy resources can support a variety of combinations or mix or technologies, to all result in deep reductions in (GSG) emissions and power sector water use. So this report does look across the renewable technologies portfolio. It's not solely focused on wind, although as you'll see wind does play a significant role there.

And finally, we also look at the direct incremental costs associated with these scenarios. These high renewable scenarios, and find that they are very similar to other estimates of clean energy futures. In which you're largely transforming the US power sector. And that technology improvements are the biggest driver in reducing these incremental costs.

So like I said, I'll get back to those summaries of results and provide some supporting evidence to some of them later on. So what is this study?

The study focused on the US power sector only. And primarily looks at the year 2050, although we do look at some of the transitional changes that will be needed. Primarily it's a technical document that looks at the balance of supply and demand with this high level of renewables, particularly with high levels of variable renewables, wind and solar generation.

We use models with unprecedented geographic and time resolution for studies of the entire US and at the penetration levels that we're looking at. And finally we're focused on this energies constraints and operational issues with such a transformation.

The study is broken down into four volumes. Much what I will be discussing today is volume one. Where the modeling scenario analysis is conducted. Volume two is a summary of the different renewable generation and storage technologies that make up a lot of the scenarios that you'll see in volume one. Volume three is a top down approach to electricity demand and use through time and adoption of energy efficiency measures. And volume four is a qualitative summary of bulk electric power systems operations and transmission. Primarily related to how renewables influence the issues that we're seeing there.

So the study was a US (dually) sponsored collaboration with more than 110 contributors from over 35 organizations, including national lab industries, universities, and NGOs. (Unintelligible) was also thoroughly reviewed by many experts in the field.

So before we get started with the results, it's good to define the bounds in which the study tried to address these questions. First of all, our futures identified commercially available technologies that can make up these high penetration scenarios. It doesn't look at the policies, operating procedures, market rules that could help lead to such a deployment. In other words, we're looking at a technical analysis of high penetration renewables and this is not a policy analysis.

It does identify, however, electric sector characteristics associated with these high penetration futures. But we did not try to do a full reliability assessment. We looked at a large number of scenarios, as you'll see, none of which are a forecast or prediction of the future.

We do estimate some of the carbon emissions benefits or reductions from these scenarios. But our goal was not to find an optimal carbon or low carbon pathway. Finally, we did look at other, including the GHG emissions, we looked at other economic and environmental and social impacts with our scenarios. But we did not attempt to do a comprehensive cost benefit analysis.

Finally, what this report does, is that it looks at a renewable specific pathway to a clean energy future that might inform a more integrated approach to looking at that clean energy end goal, if that is what we want to achieve. But it's definitely not the definitive assessment of high renewable generation. But we do identify areas for further research.

The modeling framework that was used was primarily lead by this NREL modeling analysis. With support from ABB's grid view model. Essentially if we follow this chart to the left, those contributors that I mentioned before from those different organizations, provided the data input to use in our model. These include technology costs and performance, includes resource assessment and those types of assumptions that are used in the NREL reads or regional energy deployment system model.

For those of you with the wind 20% report, this model is essentially a later version of the wind model used in that study. In addition, we used NREL's solar deployment system model. To model rooftop PV penetration over that time period. As you may imagine, the DG market and deployment. Drivers in the DG market are different than they would be in the utility scale market.

And finally, one of the unique features of this study is that we used these NREL tools to do the capacity expansion build out over this 40 year time period. And then we took that generation and transmission mix and fed it to a commercially available production cost or unit commitment economic dispatch model. Essentially it's the tool that planners from utilities and ISOs use to do their planning. But it's a detailed hourly operational model to verify or confirm whether our results from our NREL model make sense. Or where are the deficiencies and I'll show some results from there.

In some we have this modeling framework that gives high resolution using 134 different regions and the hourly time step of a 2050 scenario with very high levels of renewables.

The scenario framework, this is a somewhat complicated figure, but I did want to inform you of the variety of scenarios that we did explore. Most of them are under this low demand assumption. Where load growth is largely flat from

here on to 2050, and I'll show a slide of what that really means. And that's through adoption of energy efficiency measures.

We do look at a baseline scenario essentially it's a no new policy scenario. And how the system might evolve given the assumptions that we used under that scenario.

And then we looked at a set of exploratory scenarios that span a renewable penetration level of 30% in 2050, all the way up to 90% in 2050. Amongst those exploratory scenarios we focused on the 80% value. From there we did a variety of sensitivities, including looking at how different technology improvement projections might lead to different futures. And how anticipated constraints to the power system might be a barrier impediment to renewable deployment and how that would affect getting to 80%. And those constraints include constraints (to) building new transmission, constraints to how the system might manage variability, and constraints to resources. In other words, competing uses of land, or citing and permitting limitations.

We did also look at high demand and different fossil fuel sensitivities. But I won't focus on those scenarios here. Some general assumptions, again most of our scenarios focus on this low demand projection as you can see there on the solid black line, that low demand projection does include some electrification of passenger light duty vehicles from the fuel sector into the electric sector. So plug-in vehicles are there in that orange wedge.

We did generally assume that the system was operated in such a way that it was flexible to handle the increase variability that might come from increased wind and solar deployment. We did, in most of our scenarios, look at a regime in which new transmission can be built. And we looked at a regime where citing and permitting was possible for new, primarily renewable, but all

different generation sources. And again, as I mentioned before, we did look at constraints to those latter three and how that would affect deployment.

The technologies that we looked at, I just want to remind everyone that we looked at technologies that are currently commercially available. In other words, we did not model enhanced geothermal systems, marine hydrokinetic, or a floating wind system. What we wanted to assess was given today's technologies with expected engineering improvements over time, what are the impacts of getting to high levels of renewables?

And as you know the modeling has to match the characteristics of the technologies we're trying to model. So we did look at location dependence of renewables. As you can see from the maps here, the whole portfolio of renewable technology, not just wind, spanned the whole country. They are widespread, they're deployable at various locations with various technologies. However, renewables do have a unique characteristic in that you can't easily move the resource from one region to another like you could for fossil based technologies.

Of course the resource technical potential, which are the numbers shown on this slide, do vary across these renewable technologies. There are more limited ones. For instance, biomass is somewhat limited. Hydropower or new hydropower and geothermal are also somewhat limited. The solar, wind, technical resource potential is much larger than those other technologies.

And of course the grid output characteristics were also considered. Wind and solar PV tend to be variable with little controllability compared to the more dispatchable technologies. Including solar thermal with storage or bio power and hydropower, etc.

So before I go on to the key results I can pause here if there are any clarifying questions?

Charles Newcomb: There's one question out there. In one of your slides you have kind of a floating banner that indicates that the high resolution modeling was used using a 130 photo nodes and hourly time steps. But in the report, there's a question, somebody said, "I thought there was 17 time slices?" and can you explain how those two map?

Trieu Mai: Sure. Sure. So in the capacity expansion the reads NREL tool, the purpose of that tool is to model deployments - future deployments, in other words capacity expansion and growth over time. And in that model there are only 17 time slices because of the computational limitations there. However, as I mentioned before the really unique characteristic of this study is we take the results from this relatively coarse (templorary) model and fed it into an hourly production cost commercially available tool that does look at that hourly chronological time step.

Charles Newcomb: Okay. And then another question on, I guess it's Slide 10, it shows wind at 10,000 gigawatts which some folks are thinking might be a little small and how come solar is so much bigger than wind?

Trieu Mai: Sure. So these are technical resources that we've gotten from a variety of sources. The 10,000 gigawatt number is through the latest (AWS) True Power assessment at 80 meters. The offshore resources are more uncertain than the onshore ones there. Solar is much greater simply because the solar technologies can operate at a more widespread areas.

However, these numbers don't capture the economic potential. These are simply the amount of capacity that you could install. In other words, the

technical potential, and we'll get into the actual deployment figures later. The important note really 10,000 or 80,000 is in some ways irrelevant in that the generation fleet today is at 1,000 gigawatts. So the capacity potentials here well exceed what we would actually need to power the country. But it indicates both of these are tremendously large.

Charles Newcomb: Okay. Thank you. I think those are the only questions. Oh, one last question. When you were looking at wind, were you thinking only utility scale or was distributed scale wind at all involved?

Trieu Mai: That is a good question. We only looked at utility scale wind and predominately for all the different technologies we focused on utility scale. With the sole exception of rooftop PV. In some ways that's just a limitation in the analysis tools that we had at hand and certainly some of the wind deployment that we're showing here can be community based or distributed wind.

Charles Newcomb: Okay. Thank you so much and I think we're good to keep going.

Trieu Mai: Great. So I do want to summarize some of the major key results that we have. This one Slide here is the dominant key result that I would say is the take away from this. We have a map showing today's existing system. Including the generation which, not surprisingly from what we know, is predominately fossil and nuclear and the transmission system underlayed beneath that. Of course there is hydropower, of course there is the existing wind, and other renewable technologies deployed today. But this map clearly shows that they are a relatively small share compared to the rest of the fleet.

If you look at 2050 here, from one of our 80% renewable scenarios, you can see the colors do change. The country becomes much more colorful and what

we tried to address in this study is, what does that mean for the power system? Can you have a power system with this many colors in them with this much wind and solar and other renewable resources deployed? You can see there that transmission is part of that story for many of our scenarios. But what are the other grid operational aspects that might change?

And what we've found from doing this detailed modeling is that with such a system as the one you see on the right. The system does operate. It will require more flexibility but we can get to 80% of total US generation in 2050 while still meeting hourly demands, that is always an important component. Reliability still must be maintained in the power system.

So the results that I'll present are broken down into multiple sections. The first has to do with the resources and technologies that are deployed. These (setup) plots here show at the top, the installed capacity in 2050 and the percent of generation for, again, in 2050 for our baseline scenario. Which gets to about 20% renewable penetration in 2050, all the way up to our 90% scenarios.

And what you see from these is the mixture of technologies that gets deployed, ranges as you increase deployment. At the lower levels deployment is primarily wind and of course the existing hydropower. But as you get to higher penetration levels, wind does increase as you can see here, but so do the other technologies. Especially dispatchable ones, bio power, CSP with thermal storage, etc. In fact the share of variable generation, which has the largest impact on the grid operations, only reaches about 40% to 50% even at our highest penetration levels, the 80% to 90% renewables scenarios.

On the lower chart you can kind of see the evolution of that system over time. And I won't focus on that so much here. Since we'll be looking at the colors,

the same color scheme throughout, I will make those definitions a little bit clearer in case you can't see the legend.

Starting from the bottom is nuclear in that dark red. The fossil technologies, coal and natural gas, are in the darker and lighter blues respectively. Biomass is green. Geothermal is purple. Hydropower in grey. The solar technologies, CSP in the orange, PV in the brown. And finally the wind technologies in the peach color at the very top.

So one of the big results that we find from doing this analysis is there's not just one pathway to achieving high penetration renewables. The renewable base in the US is very diverse and very abundant as you saw from those technical resource maps earlier. And we could get to a multitude of combinations that still get to 80%.

What drives the particular mix of technology is whether that be more weighted towards onshore wind versus offshore wind. And solar versus wind, or the more dispatchable technologies are driven by a variety of very large and uncertain levers. And we tried to explore the bounds in which these levers would drive deployments of different technologies.

Of course technology costs. Future technologies costs will have a big impact on that and certain technologies that have greater reduction potential may have greater deployment if those potentials are realized.

Constraints to transmission may limit certain technologies from deploying. For example, it may be more difficult to deploy large amounts of onshore wind but offshore wind, which is closer to load centers in the East coast primarily, might be deployed to a greater degree. Or local PV resources might be deployed to a greater degree.

Constraints to system flexibility might lead to greater dispatchable technologies being deployed. Primarily by utility scale storage or CSP with thermal storage technologies.

And constraints to resource accessibility might lead to greater deployments wind and solar because, as we saw earlier, the wind and solar technologies have great technical potential than some of these others.

So what you see in the figure are those ranges there. And you can see if we focus on wind, the deployment ranges from about 300 to 450 gigawatts by 2050 for onshore wind. And an additional 50 or so to almost 200 gigawatts for offshore wind. You can see the various ranges for other technologies as well. For wind, that leads to a penetration of roughly 20% to 35% for onshore. And about 5% to 15% for offshore.

Another result that we looked at from a deployment perspective, is where are those technologies being deployed? And what we find is that all regions of the country could contribute substantial renewable supply. And just a reminder, this study looks across all renewable technologies. Not just wind. So we do see how, for example, biomass or solar could be deployed in the South East. Which is generally not a wind rich resource.

The map here shows the generation and capacities for one of our 80% scenarios by each of these 11 regions. Again, we modeled the country with 134 different nodes but broke it down into these regions so we could digest the information.

When we look at California, we can see that much of its local demand - indicated by that dash line there - is met by renewable resources. Primarily geothermal, solar, hydro, and a little bit of wind.

If we move up to the North West, we can see not surprisingly, that there's a lot of hydropower technologies being deployed, and wind technologies being deployed there. And to such a degree that on an annual average basis as a net exporter of power or energy.

If we move to the Great Plains region, that's even truer to a greater degree. Where they are exporting an even greater amount of wind. And of course all of this will require transmission. We'll get into that story a little bit later. There's a tremendous amount of bio power that's deployed in the plains, in the Great Lakes region. And in the Great Lakes region there is, of course a great amount of wind, as you can see there.

Offshore wind is deployed to a great degree in the Eastern Seaboard. As is bio power and solar PV.

In the South West and Texas we do see a great degree of solar, both CSP solar thermal and PV technologies.

As I mentioned before, in the Eastern parts of the Country, even though they are - or sorry South Eastern parts - they are importers of power. Even in these regions, however, there is deployment of bio power and PV.

So the next set of results has to do with the operational challenges and results that we see from our modeling analysis. And as I mentioned before, the primary result and our most powerful result I think from this study. Is that we

find that with 80% of renewables, supply and demand can be balanced every hour of the year, in every region.

So the figures shown here are the peak demand hours for the baseline scenario on the left and the high renewable, one of our 80% scenarios, on the right. And on the bottom are the off peak times. So in other words, we're looking at the summer afternoons. In the top, the hot summer afternoons where the A/C loads are very high. And the off peak were the cool spring evenings.

During these peak time periods are the times of most concern for utilities and planners today. And these times are aware you're operating expensive units combustion turbine plants that are inefficient and relatively expensive. There's a large disparity between the load at night versus the days. So there are ramping challenges, etc.

What we find in our analysis with 80% renewables, the peak period is still a challenge. There will be ramping concerns because of those load profiles. However, with renewables it does decrease and depress the amount of expensive, inefficient units that you might need without renewables there.

During the off peak periods, during this baseline scenario which largely resembles today's system, there's not really a tremendous amount of concern to operate this moderately loaded system. However, we find with 80% scenario, in the Spring evenings there are additional challenges. And I'll get to those in a couple slides.

But the primary results is during this peak period, this off peak period, or any period that we look at, any hour that we examined with 80% renewables we still found a balance between supply and demand. And that's a pretty powerful result. It doesn't imply that there will not be shortages and outages.

What it implies is, with the model that we're using where we try to represent the same reliability and resource adequacy constraints in the system, we have the same levels of reliability can be maintained even with 80% renewables.

So how do we do that? How is that possible? Well, one thing is, the system is built with flexibility in it today to manage primarily the changes in load seasonally and (dihourly). And what we find is a more flexible power system is needed with these higher penetration levels of renewables.

And the source of the flexibility come from both the supply and demand side. It includes including having sufficient capacity on your system. Having sufficient operating capacity to manage increased operating requirements, such as through forecast errors for wind and solar. Mitigating curtailment with storage or controlled charging of electric vehicles. Operating a system of the existing power plants with greater ramping and cycling, and this includes conventional fossil power plants but also dispatchable renewables, bio power geothermal, CSP with storage, and hydropower.

And of course the last three is leveraging the geospatial and technological diversity of the various renewable technologies to smooth that output ramping. And this would also require or would benefit from greater coordination across greater areas. And all of this would require greater transmission expansion to make it happen.

I'll show some examples of some of those in that bulleted list. This first one is that same peak summer afternoon period in July for our model year. And what you notice is that we do have sufficient capacity available for the operators to call upon to operate during these peak periods. And so there's a capacity expansion perspective or a planning perspective to deploy sufficient capacity and then you have to operate them during these times. As you can see here the

installed capacity versus what they actually operated during these periods and all of those dispatchable technologies or firm capacity technologies are deployed at full (nameplate) or largely at full (nameplate) during these summer afternoon periods.

Those challenges I mentioned earlier during the off peak periods are also prevalent. They include curtailing electricity, we find that 8% to 10% of wind, solar, and hydropower is curtailed in 2050 in one of these models scenarios. However, we can reduce that curtailment through storage and other demand side options.

We looked at storage deployment levels of up to 100 to 150 gigawatts in our 80% scenario. That's compared to the 20 gigawatts or so that are deployed today. On the demand side we looked at deployment levels of up to 30 to 50 gigawatts compared to about 50 gigawatts of demand response today.

Transmission as I mentioned earlier is a significant portion of the story for many of our scenarios. We find that transmission needs to get to 80% would require 110 to 190 million megawatt miles of new transmission. And just for reference, in today's system there's about 150 to 200 million megawatt miles depending how you count. So this incremental transmission build in most of our scenarios are pretty significant.

In addition to that we find that the three (asynchronous) interconnections would benefit by having greater DC ties to link them in many of our scenarios. However, realized that transmission infrastructure build outs are a challenge today, we did examine that constrained transmission scenario where there are severe limits to building new transmission. Primarily cost limits.

And the results of the scenario are very surprising. First, we find that 80% renewable penetration is still achievable despite very severe limits to transmission builds. There's a threefold increase in cost there. And one of the reasons, one of the ways, in which it's still achievable, is through reliance on more local resources. Such as offshore wind and PV. In this scenario we get 30 million megawatt miles of new transmission. So a much smaller number than what we saw before.

In addition we also identified that the economic costs of transmission are relatively small compared to the economic costs of new generations. In our scenarios we find that $6 to $8 billion dollars per year of transmission investments are needed to get to those 110 to 190 million megawatt figures I showed you earlier. And these numbers are actually in line and within the range of recent industrial and utilities investment in transmission.

So the cost is not really the factor. It's the other obstacles that may impede new transmission build outs. But again, I do want to emphasize that we did look at that scenario in which transmission builds are severely limited and yet 80% is still achievable.

So we've looked at the resources, the amount that are deployed by technology. We looked at where they're deployed. We looked at how the system can still operate with 80% renewables. And our last set of results has to do with some of the implications. Some of the non-power systems planning and operational implications, and these include deep reductions in greenhouse gas emissions and water use.

Of course with 80% renewables we have to have a reduction in generation from other sources, primarily from coal and natural gas. And from that reduction in fossil fuel use we find there's about an 80% annual reduction

from the power sector in 2050 in greenhouse gas emissions, and about a 40% reduction, cumulative, over the 40 year study horizon. And we did these emission studies based on a combustion only or (unintelligible) basis and also on a full life cycle basis.

We also looked at water, electric sector, water use and found a 50% reduction in power sector water use across the country. Some regions have much greater reductions than that, some have fewer, but on average its 50% reduction in both withdraws and consumption.

Finally renewable resources, including wind, are (diffuse) energy resources and do have some land use impacts, and we did explore that. On the table on the right there, you can see for our range of 80% scenarios. Some of the gross land use impacts from the various renewables. Primarily in these scenarios about half the land use impact is from bio energy crop production for bio power plants. And that range is to 44,000 to 88,000 kilometers squared.

For the rest, the other half of the land use impacts - the gross land impacts - are primarily due to wind farm footprints. And what we, so you could see the numbers there, that range is from about 50,000 to 80,000 kilometers squared.

However, if you only look at the disrupted lands, the land that is actually taken over by the roads and the turbines, that number reduces significantly to only 4,000 to 10,000 kilometers squared.

And we also looked at the land use impacts from the new transmission and storage and found them to be about 3,000 to 19,000 kilometers squared. These numbers are hard to picture. So to provide some context, if we compare that with the land area of the continuous US, which is 7,700,000 kilometers

squared. The land use from all of the renewables in our 80% scenarios make up less than 3% of that total land area.

Some other numbers for comparison. 2009 corn production was about 350,000 kilometers squared. Major roads and major golf courses were about 50,000 and 10,000 kilometers squared. So those number are comparable to the numbers for renewable footprints that we saw earlier.

And the report does discuss other impacts. Including visual, landscape, noise, habitat, ecosystem, that may be specific to each renewable technologies and volume two describes those in some detail.

Finally we did explore another implication of these scenarios. Including the direct incremental cost, and what I mean by that is we did not monetize any (externalities) or any other social or environmental costs. These are a direct electric sector cost. And we compared them to other transformative scenarios of the power systems conducted by other independent researchers.

The figure here shows the incremental electricity price in dollars/megawatt hour relative to our baseline scenario. And that's in the shaded grey region there, over time for our 80% scenarios. And then the blue squares indicate analyses conducted by the EPA on clean energy or low carbon scenarios, and the line indicate EIAs analyses of similar clean energy or low carbon scenarios.

All of these scenarios plotted on here have very similar levels of carbon emissions reaching approximately 80% by the 2050 timeframe. And all of these comparisons are based on their studies specific baseline or reference cases.

So if we look out in 2050 we see that with 80% renewables under our analysis, we have a comparable if not lower incremental cost relative to the EPA (unintelligible). Which looks at other technology options beyond just renewables. Then if we look into 2030 and 2035 timeframe, our analysis sees very similar costs to what EIA projects.

What are the drivers of these costs? The primary one is replacement of existing generations with new generators. And the additional balancing requirements, new storage, new transmission needed. And I would remind everyone that our baseline scenario, it's not a projection of the future, it's simply for comparison purposes and it reflects a continued evolution of today's system. Including essentially no retirement of coal plants which is obviously counter to what we're seeing in the marketplace today.

Finally, I won't focus too much on this slide, but what we find is that our costs and what drives that incremental cost is largely due to the technology costs projections. Those balancing requirements as I mentioned before - transmission, storage, additional reserves - have a relatively small effect on the incremental cost of getting to 80%.

It is really technology R and D that could lower these incremental costs dramatically. In fact from the figure I showed earlier. The ranges there are largely driven by those assumed technology costs and we did not look at the lower floor in which costs can be achieved in the future. In other words, transmission costs, the ability to manage flexibility, they have relatively small on the order of $5.00 per megawatt/hour impact on the incremental cost. Whereas looking at lower possible cost projections in the future really drives this and could drive the incremental cost to very low levels, relative to other analyses.

Finally, we looked at other constraints to the long term build out of renewable technologies. And the primary finding there is that there's no insurmountable long term constraints in the industrial scale up, or manufacturing capacity material supplies, or labor availability across the renewable portfolio or the renewable technologies that we explored.

There will be challenges however. We find that in our scenarios during this decade, 20 gigawatts per year of renewable technologies will need to be deployed. That number reaches up to 40 gigawatts per year in 2040s and 2050s timeframe, to get to 80% renewables. These are evidently much higher than what we've seen in the last few years. Where approximately 10 gigawatts a year, primarily wind capacity, is deployed.

However, if we look at the global growth and scalability of the renewable industries we don't see any long term constraints to having the industry grow to meet these demands. In fact, that figure on the right there shows a global PV installations and global wind installations in 2010. And they are on par with the US demands that we project in our scenarios.

We also did look at higher demand growth scenarios and the main message here is really that higher demand growth would impose greater challenges. Both on that industrial scale up chart I showed earlier, on some of the implications with greenhouse gases and with water use as I showed there as well. And in terms of the operations of the system. With higher demand growth there will be greater reliance on wind and solar technologies and therefore increasing the greater operational challenges of the system. So energy efficiency can play a role in these high renewable scenarios.

Future work that we've identified include a comprehensive cost benefit analysis. You've got a summary of some of the implications that we looked at but they are not all comparable on an apples to apples basis.

Secondly, although we did look down to the hourly level and did look at the major operational issues and modeling for these types of power system scenarios, we didn't fully look at system reliability down to the sub hourly level or down to a contingency analysis level.

Again, we didn't look at some of the market mechanisms. We did characterize what a system might look like, to inform those market developments. But we didn't fully look at the market mechanisms to get to 80% renewables.

And finally, we didn't look at how accelerated technology advancements might change some of our results. We did look at it to some degree but not fully.

I just want to summarize with our key results. Again, we find that 80% or more for renewables in the power system in 2050 is possible. If you have a more flexible power system, and our modeling finds that it is possible down to even the hourly level in every region.

That system flexibility comes from a variety of sources. Both on the demand and supply side. We find that the abundance of renewables and diversity of renewables can be put together in a variety of ways. And although we can't predict how or which path we will go down, we know that there are quite a number of paths that are possible. And they all get you deep reductions in greenhouse gas emissions and water savings.

And finally we find that the cost of our scenarios are very similar to other published costs from other clean energy scenarios and that renewable technology improvement is the biggest driver in reducing this incremental cost.

The Web Site is shown here and I do want to close with some remarks that I think are very important. I think there are many, as I alluded to earlier, in the industry that still believe that renewables can never reach on a technical basis even a few percentage points. I think there are examples that we are seeing today across the country, across the globe, that are starting to debunk that myth. And I think our analysis shows is that we can sustain that high level of renewables over a total annual period and the system still seems to be operable.

Corrie, if you could change to that visualization.

Charles Newcomb: And Trieu while she is doing that - oh she is so fast, I was trying to get in a couple questions while she did that.

Trieu Mai: Sure we can get in a couple questions.

Charles Newcomb: Okay. I guess one was more of a comment that was right online with what you just said, which was about renewables being able to make a substantial contribution without any real clear technical barriers. One of the listeners was pointing out that Germany has been hitting some pretty substantial numbers and they're not even seeing the need for storage until they get to the 50% mark. That was one comment.

One of the questions was, how did you select 80%? Was it just coincidence with the State of the Union address back in 2011? Or is there another reason you landed on 80% as the mark.

Trieu Mai: Sure that's a good question. Of course it is somewhat motivated in looking at the levels of carbon reductions that will be needed. That have been estimated both by the administration's perspective and also from climate change experts who have indicated that the US reductions will have to reach a comparable level to what we've shown here.

More importantly however, is we examined scenarios from 30% all the way up to 90% and part of the motivation behind that was to see if the system would break at any point. Or if there would need to be a huge increase or investment in storage or costs, other costs that might incur a kink in that curve as you march up the penetration levels. And we simply didn't find that.

So what we did is we wanted to examine a scenario that was at very high penetration levels. But to achieve those similar targets that I mentioned before that we could really delve down at a great degree and still have a lot of buy in from stakeholders that might believe a higher level may not be possible or may be beyond the realms of our modeling capabilities.

Charles Newcomb: Very good. So you showed, the wind specifically showed about 10,000 gigawatts and one of the questions from one of the participants was, so there's an assumption that you have some exclusions in there. You're not going to put wind turbines in downtown Chicago. To what degree were environmental exclusions accounted for in terms of birds and bats?

Trieu Mai: Sure. So the 10,000 gigawatts is the raw resource estimate. We did do exclusions based on population, based on (smoke), based on national parks,

etc. We did not fully look at the wildlife exclusions, or public acceptance, or radar exclusions here. Of course we did exclude FAA zones by airports, etc.

But that number, in some of our preliminary analyses at NREL independent of this study, does reduce that 10,000 gigawatt figure but not all the way below the actual deployment figures that you've seen from these analyses. In other words, we look at deployment levels in the 300 to 450 gigawatt range. So a tremendously smaller number than that 10,000 gigawatts number, so I don't think the conclusions that we've drawn here would be dramatically impacted by a fuller exploration into wildlife exclusions.

Charles Newcomb: Indeed. When you start to talk about thousands of gigawatts the unit conversion for many of us can be a challenge. Because I look at that 10 like, and I'm like, "I thought we were looking for 300?" and I was off by a factor of a thousand. So it's a big number, there's no question about that.

In terms of transmission siting, did you get into the siting of transmission at all? And if you did, did you look at - assuming you go right down the existing rights of way? Or would you have to make the assumption on hitting some greenfield sites?

Trieu Mai: Sure. So the analysis conducted here, although it has very high resolution at the national level, we did not go to a site by site or corridor to corridor basis. But as I mentioned before, in our constrained transmission scenario, that scenario essentially assumes that only existing corridors can be used. But it was unconstrained for many of our other scenarios.

Charles Newcomb: Very good. It wasn't obvious that tidal or wave energy was considered. Were those considered?

Trieu Mai: No. We have a chapter in the report that describes other ocean technologies. All or many ocean technologies, including tidal and wave, but in the modeling analysis we did not include them for a couple of reasons.

One is the resource assessment and output characteristics for those technologies are in a relatively earlier maturity level than some of these other technologies. Secondly, we wanted to focus on technologies that are commercially available today.

And part of our story and our results are, I think, impactful and powerful because it doesn't require large breakthroughs or large reductions in costs for the renewable technologies. We're looking at a technical aspect with today's technologies.

Charles Newcomb: Very good. Finally, do the greenhouse gas reduction estimates account for the imbedded greenhouse gas in the capital investments? So the equipment itself and moving the dirt around? Or were those not part of the calculations?

Trieu Mai: Yes. The greenhouse gas emissions were a full lifecycle estimate. So including both upstream, downstream, imbedded emissions for all technologies. Including fuel extraction for the fossil technologies. The only caveat with that is we didn't look at greenhouse gas emissions from land use changes.

((Crosstalk))

Charles Newcomb: Finally, back to the exclusions real quickly. You mentioned a few of them and it's good to hear that there's some nice logic behind that as we would expect. Are those exclusions called out in the report so people can track them down?

Trieu Mai: Sure. In the wind technologies chapter they do list the various exclusion layers that were applied.

Charles Newcomb: Enough of the interruptions. We'll let you continue on. Thank you.

Trieu Mai: Sure. So just Corrie if you could push play? This figure which can be found on our Web Site, the report Web Site. These visualizations, excuse me, there's a whole set of them. This one is particularly interesting to me because what we're doing is we're marching every hour of the year through the year 2050. And we're seeing what technologies are being dispatched during those hours. And I apologize if the resolution is unclear. It will be better if you go directly to that Web Site.

But what you'll see is the Sun rising in the East moving across the country and setting in the West. And as it moves across that country, I powers and lights up all those solar PV panels. The wind is generally, the output is generally greater in the evenings and night time, so you can see that as well. And then you can see the rest of the system dispatching to meet that variability in wind and solar, and load.

Corrie if you could pop the dispatch stack, you can see what technologies are deployed during which hours of the year and which season. And you can actually toggle on or off the different technologies. The real point here, this is real model data that we're using here, and this really demonstrates this hourly operations system and how it's possible for the system to blend supply and demand. Even if supply may be variable uncertain.

And there are other visualizations with transmission flows. Importing and exporting power, how the system might transform that I encourage those who are interested to explore. And that's it for me Charles.

Charles Newcomb: So there is one last question that I'm trying to read here. So was there any consideration for the great expansion in the Tres Amigas? Tres Amigas I guess, is it, in the New Mexico - sorry I'm trying to read this and it's kind of across a couple window - which should be done by 2015 in New Mexico. Are you familiar with the Tres Amigas?

Trieu Mai: Yes. Yes I am, so we did not explore any particular future projects specifically. Including Tres Amigas, which for those who might not be familiar, it's a set of AC/DC/AC interties that will link the three interconnections and allow transfer of power across the three asynchronous interconnections.

However, we did look at that possibility and in many of our scenarios we expanded the system. Especially that Tres Amigas like projects are expanded to a great degree in many of our 80% scenarios. Including 50,000 megawatts approximately in many of these scenarios. That's in comparison to about 3,000 megawatts that we have installed today of such technologies. So it's quite a large expansion. However, as I mentioned before in the constrained transmission scenario, we assume that the interconnects are largely separate, as they are today.

Charles Newcomb: Excellent. Thank you so much Trieu Mai for that fantastic presentation. I know it's difficult to delve into politics at all but, just so you know, there's a cry out there from the crowd saying, "Fantastic presentation but could you please include externalities for fossil generation next time." That's a hot

button issue, but I think we're all well aware that when you throw those things into the calculations things move pretty quickly. So thank you.

(Corey) I'm trying to bring up the intro slide where we can talk about what's coming up next. And again Trieu, we really appreciate your expertise today and folks if you want to contact Trieu directly you can look him up on the NREL.gov Web Site. We actually have a staff phone book, I hope that's okay. And the study, as was mentioned, is available on the Web Site. Which I can't see here but Trieu can you mention it one more time just verbally?

Trieu Mai: Sure it's nrel.gov/re_futures.

Charles Newcomb: Very good, thank you. And the animation is quite extraordinary when you actually look at it directly online without seeing a coarse recording of it. It's quite beautiful in my opinion.

Okay. So that concludes today's installment of our monthly webinar. Coming up, as many of you know, we have these on a monthly basis. It's usually on the third Wednesday of every month, usually, every time it's on the third Wednesday. Next month, because we keep moving things around and the latest move of pushing social acceptance back by another month is kind of an exciting one. Eric Lantz is to be expecting another child coming up soon so we wanted to give him a little bit of time to be at home as opposed to doing a webinar. So that's kind of fun for us on this team.

So what's on the short list is a market report. And there's two that we're trying to choose between based on the availability of speakers. One is the new market 2011 report, wind market report that came out just yesterday. So that's very exciting and you can find that on the ERU Web Site, if you also just Google 2011 wind market report you'll find that.

The other one is the DWT market report which (unintelligible) put together on behalf of the Department of Energy. That came out earlier this summer and we've been waiting for an opportunity to discuss that as well. So we will let you know in the next couple weeks or so via the Web Site, which one lands based on the availability of speakers.

But look forward to one of those on September 19. And we will, I promise, we will do social acceptance and it will be on October 17 no matter what. That's our goal. So again I'd like to thank the Department of Energy for its continued support of this important effort, wind deployment. There's a few contacts for you. Jonathan Bartlett, who is our intrepid (unintelligible) lead who brings great energy to the team. We are very thankful for Jonathan's participation. Ian, who would be doing this today, but he's up in Anchorage. And me on the bottom there.

So until next month I hope you all have a safe return to school and the traffic associated with all of Congress coming back to Washington, DC, etc. Wherever you are, and right now we're hoping our visibility in Colorado improves because we are at about 10% of what we normally have which is of course why I had to mention that with renewable energy futures, we're looking for a cleaner environment. So we'll look forward to that with you all. Thank you take care.

Man: Thanks all.

Man: Thanks everyone.

Man: Thanks Trieu.

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