WIND POWER'S IMPACT ON GRID RELIABILITY, BACKUP SUPPLY, AND FOSSIL FUEL USE IN NEW ENGLAND

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Speakers

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Coordinator: Good afternoon and thank you for standing by. I would like to inform all parties that your lines will be on listen-only throughout today's conference. This call is being recorded. If you should have any objection you may disconnect at this time.

It is now my pleasure to introduce Mr. Bob Grace, President of Sustainable Energy Advantage who will serve as our moderator for today's webinar. Thank you, Mr. Grace. You may begin.

Bob Grace: Thank you very much, Emily. Welcome to the New England Wind Energy Education Project webinar 4 in our series. Today's webinar will be on the topic of wind power's impact on grid reliability, backup supply and fossil fuel use in New England. My name is Bob Grace. I'm President of Sustainable Energy Advantage and the principle investigator in the New England Wind Energy Education Project, which I will describe shortly.

Our speakers today are going to be Ed DeMeo who serves as technical advisor to the Utility Wind Integration Group, Michael Milligan of the Transmission Grid Integration Group at National Renewal of Energy Laboratory, and Bill

Henson, a senior engineer and renewable resource integration at the Independent System Operator of New England.

Today's topic is an important one. It does not pertain directly to the issues associated with wind power sighting and public acceptance per say as our prior webinars have but it's important in particular because a lot of the discussion around the issues associated with public acceptance get at the broader issues of wind's benefits and the cost associated with bringing wind in the system. And in that sense there's been a lot of information made available where wind projects are looking to be sited on this topic. Some of that information raises important concerns that we'll address today but some of that information also contains conclusions or assertions that may not be applicable overall or may be not as applicable in the New England region as they might in some other region.

So today we're going to have some excellent analysis and discussion of what is known on these issues to help set the framework. Before we go into our discussions I wanted to take a few minutes to just go over the New England Wind Energy Education Project and specifically talk about what we're trying to accomplish with NEWEEP. NEWEEP was created to provide sitting decision makers and those that are potentially impacted in the public with objective information on which they can make informed decisions about proposed wind energy projects throughout New England.

We do this by collecting and disseminating accurate, objective, up-to-date information on critical wind energy issues impacting the market acceptance of all the projects being developed within the region. Our objective here is to enhance the region's public acceptance of appropriately sited wind energy generation.

The overview of the project, this is a two-year project through the end of next year that consists of eight webinars and a full day conference, which will be next spring as well as outreach and awareness. We will create and have created a web-based home for the webinar related materials which live on the New England Wind Forum website.

NEWEEP was funded by the Department of Energy in December 2008 under a program for 20% wind by 2030, overcoming the challenges. All of the funding comes from the Department of Energy.

I'm having a little bit of trouble forwarding the slides. Here we go.

So just a little bit of overview on NEWEEP. The proposal was a joint proposal by Sustainable Energy Advantage and the National Renewable Energy Lab. So NEWEEP is coordinated by my firm, Sustainable Energy Advantage and directed by a steering committee which consists of a number of New England state agencies, regional and national research organizations, and New England's Regional Grid Operator who have all committed to participate in the project.

And the webinars are moderated usually by us or other guests with particular expertise on the subject matter.

The steering committee listed here consists, again, of National Renewable Energy Lab, Lawrence Berkeley Labs, a number of regional-state agencies and you can see all of them here. Again, NEWEEP is importantly neither industry funded nor industry driven.

The philosophy and approach of the program is one of objectivity, importantly starting from the perspective that wind energy has benefit but not every place is the right place for wind generation. Our framing principles are ultimately that the consequences of wind power are rarely as dire as made out to be by organized opponents. And they're often not as free of consequences as proponents would hope and sometimes represent.

Our stake is in the NEWEEP process and not the outcome. There are often hard discussions to be made with respect to sitting wind projects and decision makers in the public need to be armed with good information as opposed to information from parties who goals are either to build or to obstruct a specific wind project. So our objective is to have a good outcome and that's why we want and the steering committee is after a fair representation of the issues.

We'll certainly never be able to convince everybody that NEWEEP doesn't have a bias but we'll try to do so and hope we can be judged on our - the information that we put forth and the way that we gather speakers, the way we provide annotated bibliographies including gathering data and positions that are counter to the speaker's conclusions and posting all of that on the NEWEEP website, and the way we conduct Q&A sessions. I'll describe that further later but we won't be screening any of the questions and expect to have some challenging questions posed.

So we're doing our best job to make this a search for the answer and not one that starts with the answer.

Our approach has been to generally seek out knowledgeable speakers who can convey credibility, objectivity, and address the research that's known out there with various points of view. Our content is focusing on what is known and what isn't know about the issues associated with each webinar, and with a focus on scientific peer-review research and studies, literature reviewed. Again, we provide annotated bibliography for references and we are willing to add additional materials that are forwarded to us by other listeners. And we will discuss mitigation, identify research needs and so forth.

I will talk shortly about the Q&A that we will conduct at the end of today's call. And finally, we do have a repository for the webinar materials on the New England Wind Forum website.

So today's webinar will focus on New England Wind Energy impact on grid reliability, backup supply, and fossil fuel use in New England. We will start with Ed DeMeo. I will give a little further introduction of Ed in a moment. Ed will give us a little bit of an overview on wind power and the electric power system as an introduction. We'll then turn to Michael Milligan who will discuss wind energy integration, go over a number of frequently asked questions and key results of the full range of wind integration studies that have occurred in the industry. And then we will wrap up with Bill Henson of ISO New England, the Regional Grid Power Operator.

ISO New England is just about done with their New England Wind Integration Study. So they've been studying these issues here specifically in New England to understand the repercussions of adding wind to the system and will provide us with a very system-specific overview of ISO New England and the near final results of the New England Wind Integration Study.

Before turning the floor over to our speakers, I did want to run over the mechanics of our call and particularly the Q&A sessions today. So today we understand that there are many people who are very passionate about this subject matter but want to encourage a respectful dialogue and frankly not allow individuals to monopolize our scarce time. We're going to be speaking for about an hour and a half and have at least half an hour for Q&A. In order to get all of the questions in what we're going to do is ask participants to pose succinct questions in writing using the webinar's Q&A chat box, which should appear on the right-hand side of your screen.

In typing out a question we ask that you please identify yourself at the beginning of your written question with your name, your organization if you have one or you can just say member of the public, and your state if you would. And then if you wish to remain anonymous write at least your first name so you'll know that I'm referring to your question and your state, no need to offer your name. We'll ask that you pose one question each please; we've got nearly 350 participants registered.

And basically I will read each of the questions out loud in the order asked until we run out of questions or time, whichever comes first. I will not be screening or prioritizing the questions. I may skip a question that we feel has already been addressed however. The questions that were posed will ultimately be listed on the website as well. And at the end I do just want to point out that our next webinar will be in January, the date to be scheduled, and we'll address the impacts of wind turbine shadow flicker. And I'll come back to this slide at the end where we'll provide the links for additional materials.

So now I will be turning the floor over to Ed DeMeo who is President of Renewable Energy Consulting Services. Ed has been an independent consultant in renewable energy since early 1999, providing technical and management support to several federal and state programs aimed at advancing renewable power. Ed's focused primarily on wind for the past several years and serves as strategic advisor to the Department of Energy and National Renewable Energy Lab, Wind Energy Program, the Utility Wind Integration Group, and the National Wind Coordinating Collaborative.

From 1976 to 1999 he managed utility oriented renewable energy programs at the Electric Power Research Institute where he was responsible for major development in test programs in photovoltaics, solar thermal and wind power. While at EPRI he was recipient of Discover magazine's 1993 Annual Technical Award in the environmental category.

And most recently, Ed has served as project coordinator for the DOE NREL/(unintelligible) Initiative to examine the feasibility of 20% US electricity from wind power and served as co-chair of the advisory committee for that effort.

Ed is an electrical engineer by training, a graduate of RPI and holds a masters and PhD degrees in electrical engineering science from Brown University where he serves as an associate profession on the engineering faculty.

Ed, turning it over to you. Thank you.

Ed DeMeo: All right, thank you Bob. Can I be heard here?

Bob Grace: Yes.

Ed DeMeo: Yes, working fine. Okay. All right, well, I'm going to give you just a little bit of background and introduction on this general topic of integration of wind into the electric power system.

First we're going to step back in time to the early part of this decade, 2001-2002, the situation at the time is that utility systems and utility operators in several parts of the country were actually beginning to notice wind power.

They were seeing enough of it on their systems, you know, several hundred megawatts about the size of a pretty good power plant.

So they were beginning to realize that this was a technology that was different from the things they were used to in the past. Wind wasn't really under their control. It was under the control of Mother Nature. So the operators began to be concerned about the variability and the uncertainty of wind and what would be the impacts of that on the rest of the utility system because the system has to be kept in balance between demand and generation at all times. And this balancing job becomes harder with a power generation technology like wind, it's moving up and down with the wind.

So it would be an impact on the cost of operating the rest of the power system and the utility operators were getting concerned about that. And in fact, there was a fear that maybe that impact on operating costs would actually wipe out the value of the wind energy itself. So that was a serious concern.

So this slide shows a few of the wind plants of that era, late 90s, early 2000s, and the one on the lower right actually was - it was and it still is in a service territory of Northern States Power, Minnesota and South Dakota, a utility which is now called Xcel Energy. And that utility took the lead at asking this question, you know, what would the integration costs be.

So Xcel, Northern States Power, partnered in that era with the Utility Wind Integration Group and along with a number of other interested folks, carried out a highly credible study of the wind integration costs using the models and techniques that were well-respected within the power business. At the time, NSP, Northern States Power, had about 3% of their energy coming from wind so they studied that and found that the integration cost was not zero but it was also not a huge number. It turned out to be about a little under $2 a megawatt hour or two-tenths of a cent per kilowatt hour of wind energy, which was well under 10% of the wholesale value of that wind.

So UWIG published a report about that and also EPRI, the Electric Power Research Institute who was a co-sponsor, also published that report under their cover. So that result was received with a fair degree of credibility.

So what happened next? Well, for the next seven or eight years a number of studies, probably over a dozen of this type, were carried out across the country, a number of different utilities involved in them. And folks looked at larger and larger regions. The studies got more and more sophisticated, went I'm done here Michael Milligan will give you more of a run-down on the types of things that have been done.

Larger regions were looked at because the utilities realized that they don't operate in isolation, they're interconnected with their neighbors, what happens in one utility affects another and vice-versa. What happened through all of these studies is that even up to very high penetrations of wind, up to about 30% of energy in some cases that basic result held up. That is to say that the wind integration costs turned out to be under 10% of the wholesale value of the wind.

Now there are two primary reasons for one - two primary reasons for that result. The first one is that as you go to larger and larger systems and utilities then share their responsibilities for maintaining the reliability of the system, it turns out they have more generation to choose from, more loads to average out, and in that situation it's easier for the system to deal with variability of any type whether it be from wind or from load or whatever. So that helps just going to larger regions.

The second is that, again, as you go to larger regions you're aggregating wind over larger and larger areas. And, you know, wind plants - a wind plant that's 100 miles away of 200 miles away isn't doing the same thing as the one near you and at that the variations tend to average out to some degree as well.

So that was a very important realization that's come out of these studies. Just to give you an example of that, I'm showing you results where from the Northern States Power and then the whole state of Minnesota situation results from three studies here. On the top line you see the results from the very first study that I mentioned a few minutes ago with the integration costs of a little under $2 a megawatt hour with penetration a little under 3%. A year later the Xcel people looked at a higher penetration, they looked at 10% penetration and found higher integration costs, you know, a little under $5 in megawatt hour. That was not a surprise that was to be expected.

And then two years later a study was conducted for the whole state of Minnesota. And so instead of just Northern States Power there were now four major utilities, four so-called balancing areas considered; and penetrations of 15% and 25% were looked at. And the remarkable result was that even at 25% the total integration cost turned out to be less, you know, that $4.41 number, less than the 10% number for Xcel by itself, which was $4.60.

So what you're seeing, again, is these two points that I mentioned on the previous slide and that is that as you go to larger and larger balancing areas it becomes easier to integrate the wind and deal with its variability.

So what's happening with Xcel Energy today? They've got two major operating areas, a lot of wind in them; one's in Minnesota, one's in Colorado. And in both of those regions they are now approaching and actually exceeding 10% of retail energy coming from wind. So what's happening is that they're now revising their generation expansion plans largely in recognition of environmental concerns, need to go a lower carbon generation, etc. And although they previously had planned to add coal plants, they're now changing those plans with the approval of their public utility commission and replacing those plans with a combination of wind and gas.

Now wind, as I've said, is not an ideal resource in that it is not totally controlled by the utility but on the other hand, these folks who operate the systems are learning through experience how to deal with the natural characteristics of wind.

Now on the other hand, there are a group of folks around the country, a group of skeptics that are tending to fight this trend toward wind growth. They've made a number of assertions. They will say that wind doesn't work. It just doesn't really displace fossil fuels and it doesn't really reduce greenhouse gas emissions, you know, it just costs too much anyway. But the fact is what's going on in the field with the Xcel folks that I mentioned and many other utilities that Michael will tell you about around the country, they're relying now more and more on wind for significant portions of their energy. And, you know, these are not fly-by-night organizations. These are companies that are required to keep our lights on. They have tremendous responsibilities and they're seeing that they can rely on wind for a part of what they need.

So experience has show through these utilities that wind can and actually does provide substantial contributions to the energy needs of their systems and at the same time reducing the emissions from their total suite of generating plants.

So the position of the skeptics is grounded really in myth rather than in the reality of what is actually going on in the power sector today.

So you'll hear a lot more about this in more detail from Michael and Bill but Bob, at this point, I think I'll turn it back to you.

Bob Grace: Great, thank you very much. Before we turn over to Michael I think I wanted to clarify one thing. Many of our listeners may be not in the power industry, people in communities where wind projects are proposed, not used to hearing units expressed in dollars per megawatt hours. Most people are used to looking at their electric bills and thinking of electricity costs in cents per kilowatt hour so I just wanted to connect the dots here when Ed or Michael talk about numbers like $2 to $4 per megawatt hour that corresponds to 0.2 to 0.4 cents per kilowatt hour or less - the order of magnitude of a quarter of a center per kilowatt hour when electricity rates in the New England area are going to be in the teens of cents per kilowatt hour just to give you an ability to connect the dots here.

So as Ed pointed out, there are a number of valid concerns and questions that the people who operate the systems, the electricity systems throughout the country, have been asking. What will wind do to the system? How does wind impact the reliability? What are impacts and the costs and what additional needs does the system need in backup capacity, operating reserves? And ultimately does wind power cause the offsetting fossil fuels and emissions as wind proponents have claimed? And what can be done to integrate larger amounts of wind?

So Michael Milligan is part of the Transmission and Grid Integration Team at the National Renewal Energy Laboratory. Michael has authored more than 120 papers and book chapters and served on numerous technical review committees for integration studies. Michael is the co-lead for the Probabilistic Methods Team of the NARC, North American Reliability Council, Variable

Generation Task Force, a member of the Western Energy Council's Variable Generation Subcommittee, the International Energy Agency's Task 25 on Large-scale Wind Integration, and served on the Western Governor's Association Clean and Diverse Energy Wind Task Force. Basically, Michael has been a major technical asset to many, if not most, of the studies and has reviewed and evaluated the studies that he's not involved in.

Michael has a masters and PhD degrees from the University of Colorado and a Bachelors (unintelligible) from Albion College. And Michael will take us through on an industry-wide perspective what we've learned about wind energy integration. Michael, it's all yours.

Michael Milligan: Great, thank you Bob. And thank you for the opportunity to talk on this webinar. What I'd like to do is cover a few topics here, give you kind of a rough outline. We'll spend just a few minutes on power system basics in terms of kind the relevant characteristics of the power system when we talk about wind integration. Wind integration is essentially the study, the analysis, figuring out how to incorporate wind as a power supply into the rest of the power supply and as Ed mentioned a little while ago, what does that mean for the rest of the power system when you have significant quantities of wind energy.

So we'll talk about that, just a real brief look at wind in the United States today. And I'd like to spend a few minutes on the integration studies in terms of, you know, what they are and what is it they're trying to do and where does the data come from and so forth. We'll take a real brief overview of some results and some of the large studies.

And then I'd actually like to spend most of the time on frequently asked questions about wind energy. And I'll point out as we get there, I'll do it again now, that the questions are fairly common questions. We've seen that across the country, around the world. The answers come from a combination of actual operating experience and from these detailed integration studies.

That's kind of an overview of where we're going. I want to thank the organizers, NREL and NEWEEP for setting this up.

I just want to take a minute to talk about some very large-scale wind integration studies. NREL has managed these studies on behalf of the Department of Energy. The first one is the Eastern Wind Integration and Transmission Study; it came out in January of this year. There's a website here if you want a little bit of reading material, there's more than you probably want here at NREL.gov/eduits. It's a very, very large study looking at up to 30% wind energy penetration in the eastern part of the country.

This is sort of the companion or the sister study, the Western Wind and Solar Integration Study was released in March. You can find lots of information about that also at NREL.gove/wwsis. Both of those websites have executive summaries which are actually fairly lengthy, 30, 40, 50 pages as well as many hundreds of pages of reports, detailed analysis.

And what these studies show is that you can get up to 30% wind energy in terms of annual electricity sales in the relevant electrical footprint. It does require some changes in operational practice, in particular in the west. But we have a pretty good understanding of the kinds of things that are needed to integrate those large quantities of wind. And in some cases what's needed can be a little bit of a challenge but we think it can be done.

So let me just take a minute to talk about how we operate the power system. The graph that you see on the right-hand side of this slide show -- the upper part of the graph -- shows a sort of a typical daily load cycle and what this is is showing the demand for electricity throughout the day. This is sort of a stylistic but a representative view of how the power system works.

So in the early hours of the morning, 4 o'clock, 5 o'clock, as you see in the upper part of the graph, there isn't very much electrical load or demand for electricity as people wake up, go to work. Factories, office buildings, lights, computers, and so forth come on, you see a fairly substantial increase in the load. And that happens, you know, throughout the morning depending upon where you are in the country and the season of the year and so forth.

In the middle of the day there's typically a peak period. The maximum demand and, of course, at the time the generation has to be able to supply that demand. And then in the evening there's a little bit of a spike here, this is typical of winter time as heating loads go up, you know, dinner time, that sort of thing. And then we have a decline in demand at the end of the day.

And the process is repeated, of course, with variations day to day. There are several interesting timeframes, timescales, within the 24-hour cycle and those are highlighted by the little white bubbles that you see. The regulation timescales, very short, a couple of minutes. And the way that the regulation or what the regulation is is a combination of people turning on and off the lights on a very short timescale and there's specific generation that's tasked with meeting those small increases and decreases in demand.

Over a little longer time period, from ten minutes to maybe a few hours, there's a noticeable trend in the load and we call that the load following timescale. And that, for example, would correspond to the morning load pickup where you have the morning pickup in the load, increase in the load, and the generation on the system has to be able to keep up with the demand.

And so for that morning load pickup, typically the system operator will have some number of generators that are ready to go, they're synchronized in the system, and they're available to increase their output to match the load.

There is also a longer timescale that's involved with most utility systems and you see that down at the bottom. It's called unit commitment. And this shows a picture of about a week. And what this shows is you have a lot of cycling each day. So each morning the load picks up, each evening it falls off. And the generation on the system has to be able to match the increases and decreases in load.

So we know that there's a lot of variability in the load. The generation fleet that we've developed consists of a combination of different types of generation units from base load units that run at fairly constant output most of the time; intermediate units, which are the units that are responsibility for primarily picking up the load cycling, the increase in the morning, the decrease at night; and then the regulating units - I'm sorry, the peaking units, we also have regulating units, but peaking units, which may only be called into service a relatively small number of days or hours of the year for those extremely hot days with very high air conditioning loads or conversely those very, very cold days in areas that might have extensive electric heating loads. And, of course, the regulating units are running more or less all the time.

So we have a portfolio of different types of generation that manages the load or helps us manage the load. We also have extra generation that is available to be called on if and when it's needed. And the primary reserve is called contingency reserve. And every area calculates that a little bit differently but essentially the idea behind this is that at any moment a large generator or a large transmission line can fail. And so we're talking about a failure that's very, very big and it's also very, very fast. It can happen in much less than one second. And if a generator should happen to trip offline as a result of a malfunction, there is other spinning generation that's available that can be called on a very short notice so that there isn't any noticeable, you know, reduction in the supply of electricity. So basically the lights stay on.

There are also generators that can change their output pretty quickly. And we use those to manage the variability in the load. As Ed mentioned, if you have a system that has a lot of wind you're going to see the overall variability of the system increase. We'll talk about that in a few minutes.

Now the other thing that happens today, and even without wind, is the system operator has imperfect knowledge of what the electrical demand is going to look like, one day in advance when you're worrying about the schedules. How do I set up my generation schedules for the next day? And to some extent there's some uncertainty even on the order of hours ahead. You don't know exactly when a storm system is going to move through. You probably have a pretty good weather forecasting, as we all know it's not perfect.

So there is some variability already in the system without wind. There's also some uncertainty, but wind is going increase both of those. And that's really what drives a lot of concerns over wind integration.

This graph is actually based on data from one of the wind integration studies that Ed mentioned, the Minnesota study from a couple of years ago. And I think it's a really good illustration of kind of what happens when you introduce a lot of wind into the power system.

This is a simulation essentially that shows a 25% wind energy penetration. Now that 25% is calculated as an average across the entire year. And in any given hour you might have more than 25% wind or you might have less than

25% wind. So what the graph shows in the red is the electrical load. So that's without any wind. And so the red shows you how it would have to operate the power system without any wind. And you can see the daily load cycles are sort of a double-peak each day. And we know how to do that.

Now the green down at the bottom shows the wind, and I'll talk about how the wind power calculations for this integration study carried out in a few minutes. But essentially if you have a lot of wind on the system you want to try to make maximum use of that wind unless there's a particular reliability problem.

So I don't want to curtail or shut down the wind plants unless necessary because the wind doesn't require any fuel. So I don't normally want to make the choice of saying, well, I want to go ahead and burn some; you know, gas or coal and curtail my wind plant. Normally it's the opposite. I can save fuel if I can figure out how to keep the wind plant running. And again, if there's a reliability concern it is possible to curtail the wind and some utilities do that as needed.

But the basic idea is that for all the energy that is being supplied by the wind, I do not need to supply that part of the energy from my gas or my coal or my nuclear units. It's going to come out of something else. And so the blue trace that you see here represents what we call the net load. This is the electrical load after we subtract off the wind and that's what the power system operator essentially has to manage.

And you can see from the comparison of the red and the blue, there's more variability in the blue. You can see that in some days the wind contributes quite a lot to the overall demand. And other days, if you look above hour 1240 and this is 1248 hours of the year, that particular day's wind didn't contribute quite as much to the daily peak. And you see various other patterns in this graph.

Today we have wind, many, many areas around the United States. I sort of outlined – there are some areas that have more than 10% electricity coming from wind. You see Xcel Energy roughly in the middle, a little bit below middle at about 11%. This is from Lawrence Berkley Laboratories, 2009, Wind Technologies Market Report. And that's a very good survey and I recommend it if you're looking for some interesting reading about wind and its impact in the markets.

This is an example of an actual utility. This is not modeled. This is not simulated. This is an actual week. This utility has an instantaneous penetration of wind of 35% of the peak. And if you look carefully at the graph you'll see that the maximum wind output is occurring at a time when the load is low. And this is not uncommon. It's not what you hope for but in this case it's the middle of the night. The electric demand is fairly low but the wind is pretty high.

And this graph shows that, you know, this is a challenge. This utility is able to manage this. They have some flexible generation that allows them to manage that wind. And of course, this slide doesn't really address the issue of certainty or uncertainty. You certainly would like to know when this high wind is coming so that you can position the rest of your generation to manage it.

So let me talk just for a minute about the integration studies, kind of what they are and what they look at. These are very detailed power system studies. They involve some combination of simulating the operation of the power system, and Bill will talk a little bit more about that for the New England study.

What you want to do is represent the power system as accurately as you can. And so you've got actual data for the performance of the power plants that you already have in terms of their, you know, what type of fuel do they use, what are their operating characteristics, how long does it take to start them up. I mentioned the unit commitment process. For large thermal plants that might be operating, say, with coal as a fuel it takes many hours and in some cases up to a day or two get those units up to operating temperature so you can run them.

And so this whole idea of unit commitment is important. And we need to make sure that we fold that into the wind integration studies. So if a plant takes one day or six hours or whatever to start up we want to make sure that the simulation knows about that.

So we have lots of detailed data from the existing power system including transmission loading limits, you know, whatever we have available, whatever's appropriate for the study.

What you'd really like to do is utilize actual wind data. But we're trying to study the impact of future wind, wind plants that don't yet exist and so, of course, there's no actual data. So in lieu of the actual data we typically utilize data from large-scale numerical weather prediction models that are used to recreate the weather. And those models are essentially the foundation of weather forecasts in the US and around the world. And it allows you to extract things like wind speed at any time in space that you want.

I've got another slide I'll so you a little bit later on kind of how that's done but essentially we get some detailed wind data that represents the future wind build-out. And the data requirements are pretty stringent. And so virtually every study that I've been involved with, there's a great deal of effort going into collecting the relevant data, making sure that the quality of the data is high. We want to make sure that we're accurately representing the variability from wind in, you know, as much accuracy as we possibility can.

This is actually a slide that's based on our large-scale data set that was developed for the Western Wind and Solar Integration Study. You could actually see this on NREL's website. And what this is really supposed to show is that we model the weather around the region of interest, in this case the western part of the United States, and because this is based on a numerical weather prediction model as I mentioned earlier, we can recreate the wind speed at any time in space.

You know, what this map shows is different capacity factors of wind in different areas. And so the red blotches that you see here represent some very energetic wind resources. And the color scale you'll see move sort towards the cooler colors. These tend to be lower capacity factor wind plants. So their energy yields per unit of capacity is less as the capacity factor goes down.

And for the Western Study and also for the Eastern Study, what we have is a large variation in the performance of the wind plants that we're simulating. So we've got a consistent weather model that's driving all the wind and so the wind that we are feeding into the power production model is a pretty good simulation. And it does take into account the different wind speeds at different times and different locations across the footprint.

The integration study results - I alluded to this, they show that we can integrate wind into power systems. We can do it reliably. We can do it economically. In some cases there may need to be some operational changes and in cases where there would need to be operational changes to incorporate large amounts of wind, those changes would actually be beneficial even if there were no wind at all. Ed mentioned larger balancing areas; we've seen consolidation of balancing areas and reserve sharing groups across the US for decades. And that was driven not by wind. It was driven by the fact that there are many economies of scale and many reliability benefits that you get from larger operating footprints.

Most of the integration studies have a rigorous technical review process. The technical review committees typically come from various aspects of the power system industry and folks with various subject matter knowledge.

The Utility Wind Integration Group is essentially an industry group of folks that are trying to better understand the issues behind wind integration. This is primarily power system. I believe that all of the independent system operators and regional transmission organizations in the United States are members of UWIG along with many utilities. And if you are interested in following other integration study results I recommend UWIG.org as a website. Go to the wind integration library and there's plenty of information on these studies.

One of the things that we found in both the Eastern and the Western studies at NREL is that you can operate with up to 30% wind. As I mentioned, there are some challenges. We won't have time to talk too much about those challenges but I will hit some of them here a little bit later.

Wind does reduce emissions including carbon. The graph on the left is from the Western study and what that shows is the reduction in emissions depending upon the relative fuel prices of gas and coal it depends - let me rephrase that. If you have high natural gas prices then you basically turn on the natural gas plants last because you don't want to burn much gas because it's expensive and you turn them off as soon as you can. So that puts natural gas on the margin. When wind comes in you want to turn off the most expensive plant you have and when that's a natural gas plant it's natural gas that gets turned off.

And conversely, if - now this isn't really the case but if coal were more expensive than natural gas the coal plant would be the last one you'd want to turn on and the first one you'd want to turn off. There's, of course, a lot of middle ground in all that but essentially what the study showed is that the emission savings that you get depends to some extent on the fuel prices, gas versus coal.

The right-hand graph is from the Eastern study. It's unfortunately a little hard to compare this when the Eastern study looked at carbon reductions from 2008 and so it appears as though there's not a big reduction but then if you say, well, the study year was 2024 and without wind carbon would be increasing between 2008 and 2024. And we estimate somewhere around a 33%, maybe 45%, something like that, reduction in carbon from the 2024 base case and the wind would reduced carbon accordingly.

Of the North American Electric Reliability Cooperation, which is the reliability organization for the United States, has a number of working groups looking at wind integration. And it's not so much a question if we can integrate. It's a question of how we do it and that work is ongoing. There are a number of reports that are in process. A couple of reports have been approved by NAERC that show some of the things that we need to think about as we move towards a higher-wind future.

The frequently asked questions I'd like to talk about came from an article - I did not choose this title, Wind Myth Debunked. This was in a recent Power and Energy magazine, which is a publication of the IEEE Power Engineering

Society. We had a number of co-authors, Ed DeMeo, you recognize his name here. We had folks from literally around the world. And many of the folks from - Hannele Holttinen for example from Finland share the International Energy Task 25 on Large-scale Wind Integration. We have various consultants. We have folks from GE Energy, University of College Dublin and Sweden. And what we did in this article was to take a look at these questions and the questions that we addressed are questions that we've seen people ask, we've heard people ask from around the world and so we focused on these questions and attempted to answer them in as simple a way as we could.

And these are the questions and I'll go through them one by one here but the first question is can you - if you're a grid operator can you deal with the continually changing output of wind? Second question, does wind have capacity credit? Third question, does the wind stop blowing everywhere at the same time? Number four, to what extent can you predict wind power? Number five, isn't it expensive to integrate wind? Number six, doesn't wind require new transmission and doesn't that make wind expensive? Number seven, does wind need backup generation and don't you burn more fossil fuel with wind than without? Number eight, a question we hear a lot, do you need storage to integrate wind? Number nine, is all the existing flexibility that we have in the fleet - isn't it already used up? Number ten, is wind really as good as coal or nuclear because the capacity factor of wind is so much less than coal or nuclear? And then the last question that I hear a lot: is there a limit to how much wind that we can accommodate on the power system?

So I'll try to go through each of these questions and answer them in the time that we have. The answers do come from a number of studies around the world. You see a picture of the cover page for the International Energy Agency, A Phase-one Report, and this is really a comparison of wind integration experiences and studies from around the world. That work is ongoing, there's a second phase in process.

I mentioned UWIG, UWIG is a tremendous source of wind integration studies and I certainly recommend that if you're interested in reading more about that. And we've done a lot of work here at NREL as well.

So the first question, can you deal with continually changing output of wind generation? There are two graphs on this slide. The first graph on the left is from West Denmark. And this is a particularly interesting case because what you see in the pink is the electrical load. And you should probably recognize that daily pattern. And in the blue below that you see the wind. And it's interesting that there are a couple of times when the wind actually does exceed the load. And you say, well, how is it possible? How could you possibly have the system where you've got more wind power coming into the system than you have electrical load?

Well, it turns out West Denmark has a lot of good interconnections with the rest of Europe. And what this slide highlights for me is the power of large, no pun intended, power of large energy markets to help integrate wind. Denmark was able to export a lot of this energy to the neighbors. The neighbors were able to buy low-cost energy and so they were able to avoid burning more expensive fossil fuels. And so this really points to the advantage of large energy markets and wind integration.

The slide on the right is from Ireland. This is from - I believe it was last May where Ireland achieved a 40% instantaneous wind energy penetration. Now Ireland is very, very different than Denmark. Ireland is an island system. It has a very small interconnection with Europe; I think it's about 100 megawatt capacity on about a 5,000 megawatt system. And so what this shows is that if you have a system that has flexible generation you can manage a pretty significant level of wind energy.

As an island grid, the Irish grid operator has planned and built this system to say, you know, we really can't rely very much on the neighbors because we don't really have any neighbors. And so we've got to make sure that we have flexible generation to deal with our own needs and that's turned out to be really valuable in integrating wind.

This next slide shows the power of aggregation. This is from data that we collect here at NREL from a number of different wind plants around the country. This is based on one-second wind power data. The timescale is about eight hours and down at the bottom of this graph in the dark blue, what you see is a collection of 15 wind turbines. And if you look at that you can see there's a lot of variability. Now I will say that we've normalized the Y-axis because we want to take a look at the variability per unit of installed capacity.

So there's a lot of variability here in the 15 wind turbines that we have. And then if you take, you know, the same wind plant, you got to another collection of turbines, 200 turbines, well, these turbines because so many of them are spread out, and so you see that the per unit variability is less than it was for the 15 turbines.

And then the next question is, well, okay, so now you have 15 turbines that are pretty variable, you add those to the 200 turbines, what happens? Well, the red up at the top shows what you get. And essentially the statistic that you see there showed the sort an index of variability. And without going into the gory detail, the variability per unit declined. And as Ed mentioned earlier, this aggregation is a tremendously power feature not only for wind but also of load, so over larger footprints larger wind penetrations. The overall growth variability goes up but per unit you have less variability to deal with.

The second question is whether wind has capacity value. Now this is a topic that we probably don't really have time to explore in detail but the bottom line is that we use the same basic techniques for analyzing wind's contribution to overall capacity needs for the system as we do for other power plant technologies, coal or gas or hydro, you name it.

The bottom-line is that we want to make sure that we hold the overall reliability of the system constant. And this example graph, we're building a system with what we call a loss-of-load expectation of one day in ten years. And so we can't build a perfectly reliable system because we can't afford it but what we can do is build a very reliable system. And in this case, as you add - I don't remember what the number was here, this is an illustration. Let's say, 1,000 megawatts of wind capacity to the system, you get about 400 megawatts of capacity value.

We've seen wind capacity values ranging anywhere from about 5% of rated capacity to wind plant up to about 40% and it depends on the wind, it depends on the location of the wind, it depends on how much wind you're putting on the system, and it depends on how the wind is correlated with the rest of your load.

So wind does have capacity value but it's not nearly as much as you would get off of a thermal unit. For example, a natural gas plant might give you 90% of its capacity value; wind, maybe it's 20%.

I'm going to skip through this slide. This basically just shows that there are a number of entities around the United States that use non-reliability-based metrics. These are essentially approximation methods and if you're interested I can give you more situations on what this means.

The next slide, how often does the wind stop blowing everywhere at the same time? This is actually an event that occurred in Texas a couple of years ago, February of 2007. And so what happened was there was a very, very large dust storm that moved through Texas and in the bottom picture this is actually a satellite image that we got from Wind Logics. And you see the little yellow highlight that shows the dust. And so what this is telling us is this is a pretty big storm, is visible from the satellite. You could see the dust swirling around. And what happens is that wind turbines are built and designed so that they protect themselves when the wind is too high. And so the wind turbine will shut off, you know, somewhere around 50 miles an hour but it depends on the wind turbine.

This particular storm moved through Texas and as you see in the right-hand upper graph there was a decline in wind output. If you go over to the upper left-hand part of the graph you'll see - it's a little hard to make out in the graph here but we have traces for many of the wind plants and in some cases they dropped off pretty quickly. And you can see the red trace where there's about a 170 megawatt decline in wind over a 15 minute period.

So, you know, that's obviously cause for concern but in aggregate when you take a look at all the wind plants around Texas, there was about a 1500 megawatt drop over a two-hour period. Now you would certainly want to know that's coming but what these graphs show is that you have to be very careful about extrapolating what happens in a small wind plant to what happens over a large balancing footprint.

So if you were to look at the left-hand graph and say, 170 megawatts in 15 minutes, what if I had 100 times more wind and, well, that's a pretty frightening statistic but it wouldn't happen in reality because the wind turbines are spread out. They don't see the same wind speed at the same time.

And there was another event in Texas that had kind of a similar result.

I'm going to pick up the pace a little bit. I've got a lot of slides to cover and I know we want to hear from Bill Henson and have some Q&A time. But kind of the upshot for this slide is that, yes, we can predict wind power. It's harder to predict a day ahead than hour ahead but we'll never be able to produce it or forecast it perfectly but the relative forecast errors decline for large footprints in the same way that wind variability declines per unit over large footprints.

Ed talked about some of the integration studies. This is another summary of a few additional integration studies. You know, I caution you, if you're comparing these really closely, many of these studies utilized different methods to calculate wind integration costs. They all have different penetration rates or many of them have different penetration rates. But if you take a look at the range of integration costs it's relatively low.

If you say, well, why does it cost more to integrate wind? The primary cost really comes from additional operating reserve. Now that doesn't mean that you have to go out and build new generation when you put in wind. What it means is that the generation that you have needs to be operated differently. It's going to be moving around, ramping. You're going to be turning it down. You've got some efficiency losses. And so there is a cost impact of all that.

When people talk about additional reserves for wind, we're not talking about a constant level of backup of some kind that's available 87,060 hours of the year. There’s recognition that sometimes you’re not getting any wind energy. If you’re not getting any wind energy from your wind turbine then clearly you don’t need to worry about backing up the wind. It’s already at zero and you’re running the rest of your generation fleet to meet the load accordingly.

The variability of wind does combine with the variability of load. There’s very little correlation, that’s good and bad. It’s bad because you’d like to have perfect correlation, wind going up every time the load goes up; unfortunately that doesn’t happen. Wind does sometimes go up when the load goes up and it sometimes goes down when the load goes up. And so the good news of that is the variabilities combine and so you don’t need to backup wind one-for-one. We don’t actually backup any generation in the system one-for-one because it’s too expensive.

We also find the small balancing areas will find it more difficult and more costly to integrate wind because, as Ed mentioned, they don’t have the diversity in wind. They also don’t have the diversity in load.

We also find that sub-hourly energy markets help tremendously in managing the variability. Now the sub-hourly energy market does not magically reduce the variability that you have on the system but what it does it that it allows you greater access to the flexibility that you do have on the power system. And so we see that as a very big factor in integrating wind.

Don’t you need new transmission for wind and doesn’t that make wind expensive? Well, you generally need transmission for most new generation sources. You may need more for wind if you’re bringing in remote wind to a load center. Certainly transmission does have a cost. Some work by the Mid-west Independent System Operator and a number of other regional transmission organizations in the East have found a benefit cost ratio of 1.7 to 1 for transmission that would support a 20% wind energy penetration.

And transmission tends to be a pretty low percentage of overall power costs. And I think that the real take away is this last bullet point, if you build transmission that allows you access to other generation, which may be less expensive than what you have locally. And one of the things that we found in the Eastern Wind Integration and Transmission Study is that building transmission means that you can either defer or avoid building generation. Generation is where the real big cost is not only in terms of the capital cost but also the fuel that you need to buy over the lifetime of the gas or the coal plant.

And so, yes, there's a cost of transmission. I don't want to totally gloss over it but I think it's like anything else, you need to do a detailed cost-benefit analysis to figure out, you know, is this particular transmission - does it have value that exceeds its cost? If so we should build it. If its cost exceeds its value we should not build it.

What about backup generation? Don't we burn more fuel with wind than without because of the backup? And the simple answer is no. We never backup individual generation. We don't do that with wind. We could but it's very, very expensive to do so.

When you have wind coming into the power system, what it means is that you can back down some other generation. And typically the unit that you want to back down is the one that's most expensive, that's typically a unit that's burning fuel. Now if you've got a large nuclear unit on your system you typically cannot back that one down so you go to the unit that's the most expensive that does have the physical capability of altering its output over the timeframe in question.

Now there can be an efficiency loss if you've got a gas plant or coal plant and you turn it down and say, well, per megawatt hour that it's generating I'm finding I've got to burn more fuel. But I'd like to sort of think of this analogy, like all analogies it's not perfect, but suppose you have three people who commute to work. They all live right next to an interstate highway. They hop in their cars. They drive to work. They get very good mileage in their cars, I don't know, 30 miles to the gallon, whatever number you want. And then they realize they're neighbors and they live and work nearby so they decide to carpool. But as a result of carpooling whoever's driving has to make a couple of stops to pick up the riders and that may also involve stoplights and stop signs.

You say, well, whoever's driving the car has now had a decline in their fuel efficiency, you're getting I don't know, 20, 25 miles to the gallon instead of 30. Are you burning more fuel? Yes, that one driver may be but the other two drivers are actually leaving their cars at home and that's what we find with wind. It turns out that in the Western study, and I think this was on an earlier slide, in the Western study what we found is for every 3 megawatt hours of wind you could avoid committing about 2 megawatts of conventional generations.

And when we say avoid committing; we're saying you shut it off. So it isn't spinning, it isn't burning fuel. It's sleeping because you don't need it. And, of course, you can do that if you have reasonably good wind energy forecasts.

Another common question we get, well, you know, if you're going to put in all this wind don't you need some sort of storage? It could be pump shortage. It could be a big battery. We don't find that. What we do find is the storage always has value. We've been building storage in the US - haven't built so much in recent years but back in the 60s and 70s we had a lot of big coal units coming online. We had a lot of big nuclear units coming online. And it was decided at the time that, you know, you can't really move those nucs and those big coal plants around. Wouldn't it be nice to pump water up the hill during the night when you don't really need all that energy? And then the next day you let the water come down and turn a turbine and certainly there's a lot of value to that.

But when you take a look at the detailed operational analysis for existing wind plants as well as integration studies, we don't find a need for storage. We find that if you have storage and you're going to use it then that's a great thing, we love storage, but it's going to be pretty difficult to justify storage on a cost-benefit basis at today's storage prices.

We can also think about storage in terms of fuels. If I've got natural gas, if I don't burn the gas I can store that gas in the ground; that's another form of storage which we do take advantage of.

In the interest of time I'm going to skip through these two slides, they're actually very nice slides. You can read them in the Power and Energy magazine. They basically show the value of storage tends to decline if you have more flexible generation.

What about all the flexibility? As we've seen and as we see in this graph, load requires a lot of flexibility already. We've designed this system to be able to manage the load. We did some work here at NREL a number of years ago taking a look at this question. Is there existing flexibility in the generation fleet that is not being used and the answer is yes, there's quite a lot.

I won't drag you through all the gory details of the slide but we found a tremendous amount of flexibility that exists and in some cases there are no energy markets that allow you access to that flexibility and that turns out to be a pretty important issue.

So we think that, you know, you can get additional flexibility from your hardware, from new combustion turbines, reciprocating engines, hydro for example, but we also need to insure that we have institutional flexibility. If you have all this really nice generation that can respond quickly to commands to increase or decrease output, and yet you don't have any institutional framework that allows the system operator to say, I need more out of this plant, then we've got a problem. And so we've identified a number of institutional benefits so that we can take advantage of the flexibility that physically exists in the system.

Demand response has promise; it's hard to know exactly how much demand response there might be. How often can you call upon it? What's its price? People have talked about (unintelligible) hybrid vehicles in the future. We think that has a lot of potential, don't know exactly how much potential.

One of the other things that we've look at in some detail is scheduling rules between balancing areas. And without dragging you through the details of this slide, if you look down towards the bottom this is data from Bonneville that they have on their website and we did some analysis and sort of the turquoise that you see represents the swings in capacity that Bonneville has to provide today as they deliver wind from their balancing area to outside their balancing area.

If Bonneville were to change scheduling practice so that they don't just change once an hour but they change every five minutes, the little red line that you can barely discern here represents the swings in the hydro that Bonneville would need to give much, much, much less than what's currently required with the hourly scheduling.

Is wind as good as coal or nuclear? This report by Lawrence Berkeley in that there is an updated version of this. I was not able to get the slide for it in time for this webinar but this shows that the power purchase price for wind is competitive with other power plants depending upon the region you're looking at, depending upon the year the plant was built. And then if we go on and take a look at the capacity factors of wind compared to other generation sources, as a reminder on the right we see that the load varies quite a lot from, you know, day time to night time.

And so we've built up our generation fleet so that we have, you know, nuclear units, coal units for example that are pretty high capacity factors. You look at other steam turbines and you say, well, they're starting to decline about 55%. You get to wind, and this is from the mid-west a couple years ago, capacity factor of wind is 30%, which is acutely a little bit higher than even the hydro capacity factor.

We also have plants that we've basically built to provide peak energy. And so you can see some of the combined cycle, the gas-steamed turbines and so forth. You can pick your favorite here; out here to the right that have capacity factors in the 10% or even less range. Does that mean that they're less important or that we don't need them? Not really. We need all these plants because they work in concert together to provide the variability that we need to be able to provide for in the electric load.

What about limits? Is there some maximum amount of wind that we can accommodate? In the work that's been done so far we can manage up to 30%

energy penetration, that's easier in the East than it is in the West because the Eastern part of the US generally has more flexibility in terms of markets, generally has larger operating footprints, and both of those things make it much easier to integrate wind.

In the West, there are more challenges. I know that the focus of this webinar is not on the West but if you have a lot of small balancing areas as we have in the West it's going to be a much more difficult task.

There may be some changes needed in operational procedures and planning methods, larger electrical footprints help, sub-hourly dispatching within balancing areas helps a lot, scheduling between balancing areas sub-hourly helps a lot. And notice a lot of these are really institutional issues as opposed to technical issues. And there's some other ways that we could flexibility, either institutional or in other ways.

I'm going to kind of wrap up here real quickly. We saw this graph earlier, with wind you've got steeper ramps you've got to manage. You've got lower turn downs. You've got to be able to manage those with more flexible units. We've seen some high penetration rates. We can manage them.

And so let me see if I can just kind of summarize, wind does bring in additional variability and uncertainty. We do know a lot about how we can manage this and there's a lot of work going on to try to figure this out a little bit better.

So with that I'll turn things back over to Bob.

Bob Grace: Michael, thank you very much, a lot of good information there. We're going to now go from the general to the specific. Bill Henson will talk about the perspective for New England in particular.

Just a note on perspective here, even winds staunches advocates - I'm sorry. It's not uncommon to hear the question, you know, why bear the impact associated with wind for a benefit that's not meaningful? And people might site statistics like wind is only 1% of the mix and will always be a trivial contributor. But even wind's staunchest advocates are not claiming that wind will provide 100% but rather that wind can someday be a material - could contribute in material proportion to the portfolio, 10% to 25%, somewhere around the order of other major wind energy sources.

In advance of this webinar, I took a look at the mix of resources over the last 12 months of data available for New England, and in New England we had 37% of the mix supplied by natural gas, 30% from nuclear, 12.5% from coal, 8% from hydro, about 5% from oil, and wind today ranks about the tenth contributor. But the analyses indicate that wind - within the range of scenarios that New England and ISO was studying, that Bill will be telling us about, could very easily move to seventh on that list by the end of this year, fifth by about the middle of the decade, and fourth by about 2020 contributing roughly 10% of the system mix, and could easily move to third behind only natural gas and hydro and ahead of coal, oil, and large hydro, you know, within a reasonable period of time.

So the point I wanted to make there is wind is only a trivial component of the mix if the well-sited wind already under development doesn't proceed or if we can't figure out how to site wind well. As Mike Milligan has describe system operators studies are showing that wind can get to much higher shares of the mix without ruining reliability that is technically feasible and the cost is modest in terms of increases and regulations, spending and reserves, and other inefficiencies that should, of course, be taken into the equation.

But as Michael's pointed out, power systems differ. In Australia where the power system is largely based on coal plants or on islands like Ireland, the cost and challenges associated with any wind can be much higher than in other areas. Here in New England, we're lucky to have one of the more flexible power systems in the world. We have a much higher share in the typical of hydroelectric of storage, of flexible natural gas power plants, and some of the most advanced and flexible energy markets.

So Bill Henson of ISO New England will be telling us what the New England system operator has learned about the actual and expected impacts of increasing the contribution of wind in the system. Grid operators are the definitive source of understanding this information because of their mandate - their mandate is technical neutrality. Their responsibilities include keeping the lights on, defining how much of the various types of reserves are necessary, and making sure all the costs are paid for. And they ultimately have to answer to all the owners and operators of all types of generation, including those that might end up running differently if wind's role increases.

Bill has worked in wind power for approximately nine years. He is currently working on his doctoral dissertation at the University of Massachusetts in Amherst in wind power integration reviewing electrical power and controls as related - and related articles for the Journal of Wind Engineering and participating in a number of related task forces.

He joined ISO New England to help write the request for proposals for the New England Wind Integration Study and to carry out the study and to implement its recommendations as well as to evaluate renewable energy power generation and enable technologies and facilitate the cost-effective integration of renewable energy into the New England power system.

Bill, we're thrilled to have you on board here and look forward to hear what you've learned about wind integration in New England.

Bill Henson: Great, thanks Bob. I suppose you can hear me okay?

Bob Grace: Yes.

Bill Henson: Great, so actually that's a great setup for - what Bob was just talking about as to why we were really interested in doing this study. And I'll explain it to you a little bit more as we go through but about a year and a half ago ISO New England began this study to highlight the operational effects of large-scale wind integration in the New England. We were helped in this effort by a team lead by General Electric, GE, Energy Applications and Systems Engineering are the same folks that have been doing wind integration studies of the type that Ed and Michael have talked about for quite some time.

We were really thrilled to have them on it - on this effort. So as Bob sort of alluded to, we expect the power system to go through changes, large changes potentially, in the coming years for a number of reasons. And one of the things that we really like to do is we like to try and plan for those because that helps us deal with the sort of uncertainties that surround things.

As Bob sort of also mentioned, wind could really be positioned for large-scale growth in New England and that's because of the fairly high capacity factors of the wind resource here in New England and also that the wind is not physically located on the other side of the world from where our load centers are, with transmission it's actually quote close.

We have, also as Bob mentioned, we have a transparent set of markets, which means that people understand what the rules are and the rules are published. And we offer a full suite of those, the power market products, and that really as Michael I think was mentioning the institutional flexibility that we have is a good thing - really it's a good thing for all.

In the six-state region in New England there are some aggressive renewable energy and emissions policies. And also too, we do have a fleet that has a potential of having a very high flexibility that may aid in managing the variability.

So I'm going to give you a little bit of an overview of ISO New England and who we are and the system that we have, what our responsibilities are and that sort of thing just so you understand where it is that we're coming from.

We're a not-for-profit profit corporation, started in 1997 but it has actually strong roots in the New England Power Exchange. It's been around for quite some time. We're regulated by the FERC, the Federal Energy Regulatory Commission, and we're independent. That's what the 'I' is in the ISO is Independent System Operator so we don't own any of the generation of any of the transmission. We don't have any of financial interest in that.

Our major (unintelligible) responsibility number one is the reliable system operation but then we have some additional responsibilities in order to sort of facilitate that. We administer competitive wholesale electricity markets and we plan for the future.

So as I mentioned, New England is a six-state region. We've got six-and-a-half million customers or so, 300 plus generators, 8,000 miles of high-voltage transmission, interconnections to our neighbors. Our summer peak load of all time or all time peak was 28,000 megawatts. And we’ve got about 32,000 megawatts of installed capacity, that’s generation that’s available.

I have to remember to hit the right down button.

So there are three primary market mechanisms in New England. There are the energy markets, the reserve markets, and forward capacity market. The energy market has a day-ahead and a real-time component. And these markets reflect locational differences in the pricing. One of the important things about that is that it helps to highlight where loads will best be served. And all of our resources participate within the market framework.

The way we work the market is there’s a unit commitment process that happens and then when we’re in the real-time, the now, we do an economic dispatch where what we do is we select the minimum cost unit to run or resources I guess I should say because our resources cover generation and demand and imports. And then we do that with a uniform clearing price auction that I’ll show you in the next slide here. And the reason for that is to stimulate innovation. So whatever the marginal unit is that clears, so that the unit that clears with the price, its offer price, sets the uniform clearing price for the other resources.

As I say, the reason for that is if you can come up with a resource that you‘re able to offer in with a lower price you’re able to make money and that stimulates innovation to try and bring the offer costs down to try and reduce your operating costs.

I just wanted to show this slide. As Bob mentioned, we have quite a lot of natural gas generation in New England and so that the wholesale price of electricity here in New England tracks the price of natural gas quite well. And it has for quite some time.

This is also what Bob was sort of speaking about. There's quite a bit of wind resources that are in our interconnection queue. Right now we don't really have that much I would say in the way of wind generation that's currently operating in ISO New England. Maybe say 250 or megawatts or so but that number could grow substantially over the next few years. And so what we wanted to do is - this is one of the drivers for why we did the New England Wind Integration Study to try and make sure that there wouldn't be any insurmountable operational difficulties associated with integrating large-scale wind in New England.

In 2009, the New England Governors asked ISO New England for some technical assistance in developing their long-term renewable energy vision. And as a part of that, several scenarios were studied and some transmission sort of (unintelligible) was crayoned in, basically based on maps of where the wind potential is in New England. We used - we had transmission planners who have a great deal of experience in developing transmission systems just to see based on these wind maps where the likely regions of interest might be and then using their experience they developed what they thought would be a robust system in order to deliver that wind energy to our load centers.

Actually, we reused those transmission scenarios I guess you could call them in the newest study in order to go and get the wind where it was.

So this is a - the map on the right is a map out of what I'll call the Governor's Study. It's the study that I just showed you on the previous slide. The green areas are the regions where there's sort of a high-wind potential. And the red and yellow areas are the areas where our load is. So you can see that there's a need for transmission, a significant amount of transmission, in order to sort of go and get the wind to where it is to ship it to the load centers in New England.

So we needed a New England focused analysis and the reason for that is that the impacts of wind on the system vary with the resources that are on the system and they vary with the characteristics of what the winds are in the region. And so we started this New England Wind Integration Study and it's a comprehensive study.

As I said, it's meant to highlight the operational effects. We wanted to make sure, as I said that there were no insurmountable operational difficulties that we'd see. We're not quite done with it yet so today I'm going to share some details of the study that we put together and also some near final results.

I think Michael mentioned the wind data that we used in this study was developed through the large-scale numerical weather prediction type model, very similar actually to the data that was developed for the Eastern Wind Integration and Transmission Study, very similar. We did some additional validation, maybe some additional sitting criteria. And we also developed a wind data set for the entire New England wind resource area, which would sort of encompass from New England up even in to New Brunswick and the Maritimes, and certainly down the coast.

So along the way we wanted to - one of the tasks was to develop some recommendations for technical interconnection requirements because wind is new to us and we wanted to make sure that wind would be able to participate as a sort of a full member of the team to the extent that it was able to in things like supporting the grid and that sort of thing. So we actually released this report in November of 2009. You can see the link there on the screen.

And one other thing that I'd like to mention about the NEWIS is that it's meant to be, as I said, a New England-focused study. So we're really concerned with making the results scientifically accurate but also meaningful to New England stakeholders. And that's why we had several levels of review, we included the New England stakeholders in the process and we've also had the technical review committee, an independent technical review committee to help us insure that the scientific and accuracy and also the relevancy of this work.

So we studied various scenarios and the reason we did that was we wanted to see if we could develop some trending information to see sort of what the effects were in between particular scenarios. And also we wanted to explore, say as a first step, what the near term would look like for us. And then also to explore what larger penetrations of wind might look like for us as well.

So from our interconnection queue we had two scenarios that we looked at, a partial - I guess you could call it a build-out, a partial build-out of the wind generation that's in the interconnection queue of - you can see they're 1.1 gigawatts of the nameplate capacity. And these are wind resources that have been through a lot of our interconnection process. We have a pretty high degree of confidence that they'll be showing up in the fairly near future.

And then there's the full queue, which is all of the resources that at the time of the study were in the interconnection queue and this number is still pretty close, so 4.1 gigawatts of nameplate.

And both of these include onshore, primary onshore wind resources. You'll see in a few slides what the different scenarios look like. I have some maps that I'll be showing to you.

And then in addition to the full build out of the queue we wanted to look at higher penetrations of potential wind energy and so we look at a medium and a high penetration scenario but we look at different alternatives for this medium and high penetration. For instance, perhaps the majority of the additional wind added on top of the full queue could be offshore, perhaps it could be onshore, and perhaps it could be in different arrangements onshore. And as I say, you'll see hat tin a slide or two.

And one thing too, is that this is a system level study. We're not looking into local issues. We were very interested in how the - what the system-wide impacts would be for ISO New England.

The next few slides I'll have a table that you'll be able to see capacity factor. Capacity factor, I think Michael mentioned this, sort of mentions the productivity of the facility over time, sort of the actual production versus what the nameplate of the facility is. With NEWIS we compared not the actual product because we don't have much actual production but what the forecasted production would be using the computational fluid dynamics models.

So here's the first of the wind scenarios that we took a look at, the partial build-out of wind in the queue. These, as I mentioned, are the resources that are in our queue that we're fairly confident will be showing up in the near future. And in the table you can see by state what the number of sites are in the state, what the nameplate is of the total per state. And further over towards the right-hand side of the table you can see capacity factors of both by state or even there's a total aggregate number, you can see 37 is the total aggregate capacity factor. So you can see there's a site that's - it's an offshore site that's off the coast of - that's right. I need to hold it down. You can see that there's an offshore site that's off the coast of Massachusetts. There are some sites that are up in northern New Hampshire and Maine, also in the eastern portions of Maine.

The legend over here on the right side, if I can get my mouse to cooperate, you'll see these colors repeated in the next few slides. We wanted to just show that these additional sites are added sort of on top of the sites that are already in the queue.

So the transmission system that we used for this particular wind scenario was the existing - what would be the existing system in 2019 or thereabouts.

You can see that we've added some transmission in this next slide and, as I say, this is a transmission configuration that we adapted from the Governors Study that I mentioned earlier. You can see that there are some new blue lines and there's a new pink line there. Those are the - the blue lines I believe are 115 kilovolt transmission, might be 345.

But it's - on the surface of it it doesn't look like there's a lot of transmission there but actually this is a substantial build-out of transmissions. The main purpose of it is really to go and get this wind that's subsided up here in northern Maine.

Again, the table with the capacity factors and there's a fleet overall capacity factor there of 34%. The blue sites, as I mentioned earlier, are those in the partial queue. The green sites here and here up in northern Maine ad the ones that are in the additional - in the full queue.

So these will be some of the higher penetration scenarios that we looked at. This one we called the best onshore. So in addition to the partial queue, blue, and the full queue, the green, there are red sites that are the additional sites that we looked at. And this is one of the alternatives that we looked at where we looked at what if all the additional capacity was onshore. And it was onshore ranked by capacity factor.

So the red circles that you see are ranked by capacity factor in that - once we reached enough sites to make 20% of New England's annual energy we stopped looking for wind sites.

You can see the fleet capacity factor; again, the average capacity factor for the year studied was 34%. And again, we have a pretty significant amount of transmission. This is from the Governors Study; this is the 4 gigawatt transmission overlay that we used.

So the next of the additional scenarios that we looked at was the what if all of it - instead of being scattered out through the best onshore locations, what if it was all located where the best offshore wind resources were, again, by capacity factor? And that turns out to be all south, what is it? Southeast of Nantucket I suppose and near Massachusetts there. The capacity factors you can see here are quite high. The overall fleet it's 40%. This is the highest capacity factor scenario that we looked at.

So here's another one of the scenarios that we looked at, the sitting scenarios I guess I should say that we looked at. What if the offshore was spread out between the three states of Maine, Massachusetts, and Rhode Island? The additional sites to bring us to 20% energy. And then adding also to the best capacity factor sites from onshore.

That's the last of the sitting scenarios that I'll show you in the main presentation but we look at a few other ones as well that you can look in the bonus slides that I have included.

So capacity value, Michael I think talked some about capacity value, and the next chart is going to show you the capacity values using the loss of load probability analysis technique that we used. And as I think Michael mentioned, it's an industry standard way of quantifying the reliability contribution of a generation resource to meeting the needs of the system.

Also, too, and this is something that's been found in other studies besides the newest, the offshore wind has a tendency to correlate better with the load pattern. So that the capacity value of the scenarios that have a good deal of offshore wind, you'll see is a little bit higher and so that the chart indicates what the amount of offshore is. Say for instance in the best onshore case here you can see that only 8% of the nameplate capacity of the fleet was offshore. And as expected, as the offshore amount raises the capacity contribution, the capacity value also rises as well.

The light blue bars here, the aqua bars I guess are the average over the three years that we looked at. So you can see that the capacity in value using the ELCC or the loss of load probability technique ranges somewhere between 20% and, well, we have a good year here of say 42% or something like that. So that's a significant bonus to have an energy resource provide capacity as well.

The next four slides that I'm going to show you are a little bit of iChart tonight. I apologize for that. These are our charts that I went through as I was trying to make sure that the simulations that we were doing were as accurate as possible but I thought that they might be illustrative.

So the output of each generation resource is staked on top of each other. And the interesting thing about these plots is it's best to have the least variable resources on the bottom because the width of the slice on the graph shows the amount of energy that's being produced.

You'll see that the nuclear unit's outputs are quite flat and the combined cycle units changed their output quite a bit.

So this is a peak load, this is the peak load over the timeframe that we looked at. And this is the results with no wind. So here again, the nuclear units are down here at the bottom. The less variable units are riding on top of them to meet the system load. The system load here is the pink line at the very top. If you add wind, significant amounts of wind, you reduce the amount that the peaking capacity is being run here. So the steam oil and steam gas units are operated less during this peak time.

The same thing happens with a significant amount of offshore wind. Although it matches the load peak a little bit better here so, again, it reduces the peaking conventional capacity to some degree.

And here's even a worse iChart. This is an interesting link and I wanted to include this because not only did we see sort of what I would call great affects from wind but we also saw affects that would cause us some more difficulties in that in this instance the wind happens to increase the amount of ramp that we would have to deal with that our system would have to be capable of dealing with, the amount of load following ramp.

So in the morning, sorry, in the middle of the night when the load is very low, the wind is quite high, that's this yellow here, the load is quite low. As the load grows to a high amount, the wind drops off in this particular instance. And then as the load falls off, again, the wind comes back up again.

So this would be - this would have been a very interesting week.

This is an overall result of one of the years that we studied. You can see that the annual energy by fuel type wind displaces mostly combined cycle, natural gas, but also too it’s very difficult to see but the steam oil and steam gas also are reduced to some degree. And this chart shows by penetration scenario as well.

So as Michael, I think, talked about the emissions do go down. We used a pretty high fidelity model when we were modeling here where we modeled heat rates would change the with the generators output level. And so as we add wind the emissions do decrease for the entire system.

For CO2, you can see in the chart here and also in the chart over here on the right, it’s not quite one for one. As you get more wind you have a little bit more of a benefit for CO2 reduction and that’s because as you get higher penetrations of wind you have a tendency to displace not just natural gas but also coal, which produces more CO2.

So just a few more slides to go, one of the things I think both Michael and Ed talked about was regulation. Regulation is sort the fine-tuned control that we used to make sure that the power system balance is maintained. And one of the things that we observed was that changes will be required to our regulation capacity requirements. And that the increase is mostly due to short-term wind power forecast error, not necessarily that the fluctuation themselves. It’s more due to the uncertainty.

And these again, as I've said before, are preliminary results but as you can see there's what looks to be sort of a linear relation between the amount of wind - so the wind penetration that's down here on the bottom and the regulation requirement here on the left. We took two different estimates of it because we wanted to sort of have a high and a low.

The reserves are sort of, as Michael also mentioned, are sort of our insurance policy. And it's meant to protect against credible contingencies, things like generators that might go offline or transmission lines that might have a fault. And we use several types of reserves here in New England. And because of winds our imperceptibility to forecast wind, we will also need increased reserves.

This slide here shows in a similar fashion the preliminary results that we had with increases in reserve requirements. So if you trace over here, let's say, for no wind on the system. Our ten-minute spinning reserve requirement - our average ten-minute spinning reserve requirement is about 725, 700 or so megawatts in any given hour. And as you increase wind the penetration of wind, even in the 20% scenarios, let's say the increase goes up to somewhere around say, 1,100 or so megawatts of required reserves.

So these are the - this is my final slide with sort of the overall observations that we have so far. As I said, we're not quite done yet. We'll be presenting more expansion results to our New England stakeholders at our - the forum is the planning advisory committee.

The capacity factors, as I've shown, are quite good but they do diminish with increasing penetration, sorry, the capacity values do diminish with the increasing penetration and also if the transmission is not available.

Wind could displace combined cycle, oil and gas fired steam units under the high penetration scenarios in the energy market but one of the things that we've learned in this study is although our system has potential for high flexibility, we need to maintain that flexibility and doing so under decreased energy market revenues is a potential challenge for us.

Some coal was displaced at higher levels to if no carbon tax is assumed. We have found that centralized wind power forecasting, the quality of the wind power forecasting have a significant impact on our ability to integrate wind. And as the wind penetration levels increase in New England we will require more regulation and (unintelligible) capability in order to maintain our reliability.

As I showed you in those map slides, essentially above levels of what is in the queue - sorry, what will we have a high degree of confidence in showing up in the queue? If we get beyond those levels significant transmission and upgrades will be required in order to effectively integrate those scenarios.

I think that's about all I have in my main presentation. So I think with that I'll probably turn it back over to Bob. I know I probably hustled through some of those but I'm trying to help keep us on track on the time so we can have plenty of time for our Q&A.

Bob Grace: Great, thank you very much Bill, very helpful. So let's see, if we can go to the slide here for the mechanics of the call. Again, I'll keep this up on the screen as a reminder for how to do this. I see we've got about 15 questions already posed. I will go through them in order so please use the Q&A feature to raise your question and I will go through them one at a time here.

Just a note, it is ten minutes of 3, more like five minutes of 3. Michael Milligan will have to leave not too long from now. Ed DeMeo and Bill Henson can stick around longer so we'll be able to keep working through some questions for a little while.

I will start with the first question here. I am having a little bit of trouble with the Q&A board.

Okay, so we have a question here from (Gregory Fennel) who has asked, what do you see as the future of energy storage? Do you believe it will be required and to what extent? Recent preliminary National Renewal Energy Report on Eastern Wind Integration Study does not believe it is technically required but another report from Sandia in 2010 gives many non-internalized benefits to storage that may not be captured by (unintelligible). Thank you.

Michael Milligan: This is Michael. I can take a shot of that. We have not done an exhaustive study to look at storage. What we have done is looked at both the Eastern study, which, you know, the system works without storage, and the Western study. We looked at storage only from an arbitrage point of view and we recognize there are other ways that storage could be utilized, you know, flywheels for regulation for example.

And it is, you know, a good question. I mean there's a market value and sort of a value storage that can be monetized and probably some values that cannot be. So I think there's more work that could be done to look at that in detail. I, you know, at this point we don't think it's required but storage does have value and some of that value is going to be relatively easy to measure and others may not be easy to measure.

But I think the other sort of - the point I'd like to make is we think depending upon what it is you're looking for if it's some sort of flexibility on the load following timeframe there are probably multiple ways of getting that, that flexibility and storage ought to be considered alongside everything else. We think that it makes sense to go after the ones that are most cost effective and certainly storage prices, you know, may well come down and make it more effective.

You know, these studies are looking out ten and 20 years from now so it's pretty hard to predict what storage prices are going to look like at that point.

Bill Henson: This is Bill. When we look at storage we also looked at it from an arbitrage standpoint mostly. And we saw that there were some increases in use with wind penetration but there was no need for new large-scale storage.

I would agree with Michael about the flexibility of system, flexibility point, in that anything that reduces our system flexibility will make it more challenging for us to integrate wind. And so having the flexible resources that we have on the New England system certainly makes the system run better in all cases.

Bob Grace: Okay, I'm going to go on to the next question then. This one was posed by (Kevin McCarthy) who asked so then spinning reserve is the same as contingency reserve? I think that's a clarification question.

Michael Milligan: This is Michael. I probably introduced that and I'll let Bill jump in and correct me. The rules differ a little bit in terms of, you know, different reliability organizations such as the Western versus Eastern but they're not the same. In the West the contingency reserve requirement is that you need to have - it's about 6% of your peak load. There's an older rule, 5% of the load supplied by hydro and 7% by thermal but the basic requirement is that half of that contingency reserve needs to be spinning and the other half needs to be available within ten minutes.

And so that ten-minute reserve you could get off of non-spinning units. You can quickly start them and synchronize them but you might have actually more than that 3% that's spinning just because you may not have non-spin available or it may be that you're setting up your generation to do something different, you've got plenty of spin available.

Bob Grace: All right, thank you Michael.

The next question is posed by (David Hyman) from the Green Group in Boston, Massachusetts. The question is is knowing the mean and standard deviation of the wind speed sufficient to address the uncertainty or does one need more sophisticated analysis? If more sophisticated methods are need what are they?

Michael Milligan: Well, this is Michael. I'll take a shot at that because I feel guilty because I've got to take off for the airport here in a minute but the essential - the standard deviation and the mean give you a sense of the variability of the wind. It doesn't necessarily tell you about the uncertainty but the integration studies typically have another piece I didn't really have a chance to talk about, which is not only do you have, you know, simulated actual wind but we also try to get a simulation of what a wind forecast would look like.

And that's sort of based on the, you know, what do we know about forecasting errors today for wind. And so you set up the simulated system by saying, let's only give it the knowledge of the wind forecast. And so you go through the usual unit commitment process and then you get into the actual day or hour and we're actually simulating the fact that you've got a forecast error.

The forecast error rates depend upon how far in advance the forecast occurs. You know, hour ahead is somewhere in the 5% to 7% mean absolute error, day ahead somewhere around 15%. It depends on penetration and regime and so forth.

So the uncertainty and the variability aren't quite the same, although some folks would argue that the standard deviation is a rough approximation of the uncertainty but we don't typically do that in the integration studies.

Bill Henson: This is Bill. You have to be a little careful when you're talking about standard deviation and mean in that if load and wind were perfectly uncorrelated then you'd have a little better of a shot at it with mean and standard deviation. But that's the whole reason for the net load issue is that they're neither perfectly uncorrelated nor perfectly correlated nor perfectly anti-correlated. So it's really - you need both pieces of information and that's where the simulation of the system really advances your knowledge of the impacts.

Bob Grace: This is Bob. I'll just look to clarify one thing. I think the questioner is perhaps interpreting the description of the studies that were done as using mean and standard deviation of wind speed - it is my understanding that the analyses used actual very detailed sub-hourly wind profiles and that the mean and standard deviation is a way of summarizing that information but that's not the actual wind data that's used. Is that correct?

Michael Milligan: Yes, for me, Bob.

Bill Henson: Likewise for me too.

Bob Grace: Great, thank you for that clarification.

The next questioner is Matt Rarity a senior wind integration analyst for Puget Sound Energy in Washington. This question is for Mr. Milligan if you are still there Mike.

Michael Milligan: I'm here.

Bob Grace: When assessing the capacity value of wind how do you make the connection between affective load carrying capacity using loss of load probability analysis for long-term planning purposes and the reality of meeting peak demand or the potential loss of load hour in real time? It's one thing to calculate a 5%, 10%, or 15% capacity value of wind and use that number for resource planning but it's another to use that value when trying to meet peak demand in real time or even a day ahead or month ahead. Thank you.

Michael Milligan: Yes, it's a good question and I agree that, you know, we use ELCC and various loss of load probability based metrics to figure out how much generation do we have to build. And that's a different question than, you know, how am I going to operate the system. And let me sort of make the analogy with a conventional plant. So forgetting about wind, you can go off and do an ELCC study and LOLP study and figure out, excuse me, how much generation do I want to build and you come up with some answer and you build some gas and coal and hydro and whatever.

And what that tells you is now I've got a system of generation or portfolio of generation that is sufficient to meet my needs to get me to a, you know, one day in ten years or whatever your reliability target is.

Now for any individual day or hour or week or month you're conventional unit may - you know, maybe it's down for maintenance for three months or maybe it had a forced outage that takes it out of service for six or eight weeks. And so the way that you schedule the system is doing to depend on the load, it depends on what units are not on maintenance, whether they're forced or planned maintenance.

And the other issue with LOLP is we're really looking at these critical times, you know, generally peak times. And so most utilities have weeks and even months where you're not putting any stress on capacity at all. Your loads are low, you've got a lot more installed capacity than you need and that isn't - you don't build capacity for the month of April for example in most areas because you've got more capacity than you need in April, and that's particularly true in the northwest when you get lots of hydro flows.

So we don't really care if wind contributes in those times where it's not needed, when you don't need capacity. What we do care about is that it contributes alongside the other units during times where the need is greater. And any given unit can have an outage and so the loss of load probability technique takes that into account when you're trying to figure out how much generation to build.

But you're right, scheduling is a different issue but I don't necessarily need to schedule all of my capacity all the time anyway and so this recognizes that fact. And Bill may want to add something to that.

Bill Henson: Yes, I think one thing to keep in mind is that the way that LOLP calculation is used in the wind integration studies, at least that I'm familiar with and certainly in the NEWIS, is that we use the wind profiles. We don't come up with some probability distribution for what the wind might be doing and then apply that to the loss of load probability calculation.

We use the actual synthesized wind data along with the actual historical load data. So it's not as if we've separated out the variability of the wind all on its own in a sort of random statistical process sense. We've included the variability along with the load variability that the dispatchable resources are going to need to be able to meet.

As I mentioned before, wind and load are neither perfectly correlated nor perfectly uncorrelated nor perfectly anti-correlated at least in this part of the world. And so you need to use the (unintelligible) load concept when you use the LOLP as opposed to using some sort of Weibull distribution or whatever for the wind power production forecast.

Ed DeMeo: Just to add one thing, this is Ed and you can correct me if I don't have this right, but in doing the hour-to-hour simulation of the operation of this system, you just don't use the capacity credit number at all. It's a totally different kind of analysis.

Michael Milligan: That's correct.

Bill Henson: Yes, Ed.

Bob Grace: Okay, thank you. Just a note here, I see a number of folks that have raised hands on the Q&A board but I don't see questions there, (Dwyane Briger), (Alex Reck), (Paul McGlin), (Chris Capsemblis), you'll need to finish typing your question and submit it for me to see it.

So I know we're going to be losing Michael Milligan shortly. Let me go on to the next question here. This one is posed by (Tom) in Ohio. Does any of the analysis consider economic dispatch factors, locational marginal pricing, or is it built on assumptions about the future growth build-out? Does the analysis reflect the thermal impact of today's wind energy penetration in the ISO region or does it make adjustment for higher penetration levels play in the future?

I'm going to break there. (Tom) has asked a whole series of questions here and let me, you know, let them be answered first.

Michael Milligan: This is Michael. I'll take one shot and then I do need to duck out but I'll let Bill pick up the pieces here.

The locational marginal price is a byproduct of the modeling and so you can put in a wind scenario, for example, we did this with the Eastern study and you can see what impact wind has on LMPs. It's not - the LMPs are not an input to the study per say but we can run the model, you know, with wind, without wind, with different scenarios of wind to get an idea of how it works.

The simulations do have characteristics of all the plants so the simulation is, you know, it's kind of a ground up sort of thing where you can change assumptions about the types of plants that you have and how much wind do you have and so forth but the models - we don't do this is in the West because the West doesn't run on LMPs but in the East you can certainly look at that.

I'll let Bill follow up if he's got anything to add.

Bill Henson: Yes, certainly in the NEWIS we used LMPs as part of the simulation, the production simulation of the system.

Bob Grace: Okay. I'm going to ask another one or two of (Tom)'s questions and then maybe come back to the rest of them later on just to give other people a chance to ask.

The next of his questions was how much hydro carbon based fuel is required to transform a given wind energy resource in New England ISO into a capacity resource and does this change with growing penetration of wind?

Think that would be for you Bill?

Bill Henson: Yes, it sounds like it's for me. Actually I think that this question is sort of not well posed in that the way to do it is to aggregate the system. The aggregating affect that the transmission system has allows us to deal with the uncertainty and variability - not just of wind but also of load too. And in sort of the idea of matching up one for one, a conventional generator with each wind plant is not really the right way to formulate the question.

Really the right way to formulate the question is is how does everything in the system interact with each other? It's just - I think Michael might have even mentioned you could. You could build a - I suppose a gas turbine at every wind plant in order to turn it into a "firm resource" but that would be a rather expensive proposition and there's no need certainty system-wide that we see for that.

Bob Grace: Thank you Bill. Let me go onto the next question. This is - his name is (Charles) and he asks many New England towns and cities are struggling with consideration of installing one or two turbines at 1.5 to 3 megawatts. How can these small units be integrated into the system with huge connection and transmission costs as well as the variability of imperfect management as opposed to the professional management of a major wind farm?

And (Carla) (over here is) - what about the recent study showing lower wind production over the past decade?

Bill Henson: I'm trying to think - this is Bill. I'm trying to think - so this is sort of a local integration question is what it sounds like to me. And the answer, at least from the NEWIS, is, as I said in the presentation, we didn't look at local issues at all. The transmission overlays I guess or build-out scenarios that we assumed in our study, it was assumed that the wind plants would be connecting to those transmission configurations in order to supply the system. We didn't look at local congestion issues or things like that at all.

The focus of the study for us was to see what the operational affects of large-scale wind integration in New England would be. We were less concerned about what the local affects might be. The reason being is that we need to maintain the system reliability and local issues are not something that we really had in the scope of this study.

Bob Grace: Okay. This is Bob Grace. Let me take a stab here. I believe the question, and trying to do justice to the questioner, breaks down to three pieces; one, talking about the relatively larger scale connection and transmission costs associated with small projects, I think those are issues that go into the financial viability of those projects and aren't really operations issue at all.

The second question I believe is one of having to do with scale. So if you have a small wind farm you might not have people that are operating and submitting forecasts that have high accuracy. To the degree that they - 100 megawatt wind farm would clearly justify a major wind developer, having people involved in the operations at a much deeper level.

So I think, Bill, the question there was do we lose some of that accuracy in being able to manage and predict when you're dealing with the smaller wind farms?

Bill Henson: Yes, sorry about that. I - one of the things that we have had found out through the study, and is actually in the Task 2 report as I mentioned in my presentation, was we looked at sort of distributed wind from a - what the forecasting requirements might be in order to come up with a good forecast for it.

And it would definitely be important for us to be able to come up with an accurate forecast but it's very likely that we will be able to have an accurate forecast if we know information like the exact location and model specs of the distributed wind. Essentially then, what happens is that let's say it modifies our load forecast. But we'll still be going forward I think with a centralized wind power forecast. The thing is that those - the distributed wind projects that aren't necessarily transmission system connected will be taken care of by the centralized wind power forecast by knowing things like the location and the size of the units.

Bob Grace: Right, and I think the last part of the question might be one that I'll Ed DeMeo to respond to and that was, what about the recent studies showing lower wind production over the past decade.

Ed DeMeo: Well, I have to be ignorance on that because I don't know about that recent study.

Bill Henson: Same goes Bob - I don't know about - I'm not sure what the question is actually asking.

Bob Grace: Okay. Move onto the next one here, this is posed by (Dorothy) in Massachusetts and the question is: are emissions from reserves accounted for in the calculation of carbon emission reductions achieved by wind penetration presented on the slide?

So I assume that is for Bill.

Bill Henson: Sure, so the short answer is yes. The emissions are counted because essentially what happens is you have to take them into account when you're doing your unit commitment and your dispatch in the simulation. And so those units are indeed running and they're being committed and run in the simulation.

So yes, the spinning reserves are being accounted for in the emissions.

Bob Grace: I think this is much like Michael Milligan's example of the carpooling where there are some units that are operating less efficiently.

Bill Henson: Yes, I think that's probably a good description, Bob.

Bob Grace: Putting out greater emissions on a per unit basis but you're operating less or you're burning less fuel overall. Is that correct, Bill?

Bill?

Bill Henson: I'm sorry, Bob. I was agreeing with you that - sorry, I had it on mute. I was agreeing with you that it's probably very similar to the carpooling description.

Bob Grace: Okay.

Ed DeMeo: But Bob, if I could add one thing, this is Ed. What hasn't yet been studied in any great detail is what happens within the hour? You know, the simulations that Michael and Bob and Bill have been talking about have used hourly data. What we do know is the operation of the plants within the hour, the ramping up and down on a minute-to-minute basis does have some additional inefficiencies associated with that. So there is likely to be some increase in emissions over what we've already calculated from that factor.

What we don't know is how big that is. We don't think it's large but we have to say that it hasn't been studied in detail.

Bob Grace: Okay, so that's an area for further study that suggests that - that further study might suggest moderately higher emissions than the initial study results presented here?

Ed DeMeo: That's correct, yes.

Bill Henson: Yes, thanks Ed.

Ed DeMeo: Yes.

Bob Grace: Great. I'm going to take an opportunity here to pose a question of my own. I think the last couple questions here have teed up an interesting issue that's worth talking about. In operating a power system there's a difference between dispatch, you know, turning a power plant up or down, and commitment, turning it on or off. I've heard argued that if we can't forecast or control wind variability that you can't change commitment and can't turn plant off and therefore aren't displacing fossil fuels. So can you explain that set of issues and the apparent contradiction with the results of the studies that you've presented?

Bill Henson: Bob, this is Bill. I would say that what we observed in the NEWIS anyway is that it had a significant impact on our unit commitment.

Bob Grace: So does that mean that the forecasting is assumed or expected to be accurate enough to be able to impact unit commitment with reasonable accuracy?

Bill Henson: Yes, forecasting is critical - good forecasting is critical.

Ed DeMeo: Yes, just to add to this, this is Ed. What's been found from many of the studies is that the value of a forecast, even though it's imperfect, is quite substantial in deciding what the day ahead commitment schedule should be. And in fact, if one had a perfect forecast there would be additional value but it turns out it isn't all that much. So you might get, say, 80% of the value of forecasting with the accuracy that's available today.

Bob Grace: Great, thank you.

The next question is posed by (Rachel) who is in both Massachusetts and Rhode Island. Does the New England-based report deal with the geographic distribution of wind sites, in other words the last alternative versus the clustered offshore, relate to uncertainty?

Bill Henson: Actually, that's something that we noticed in the study is that the more distributed the wind was the less variability and therefore really the less uncertainty about that variability there was. We didn't actually notice huge changes though in the amounts of uncertainty and variability between the different siting scenarios. But, yes, we were - that's actually one of the main reasons why we posed the different siting scenarios was to take a look and see how that diversity would impact us.

I don't have final results but as I say, the - we did notice some affect but it wasn't as large actually as we thought it was going to be.

Bob Grace: Thank you. The next question is posed by (Emmi) at the National Resources Council of Maine. And her question is, is there a way to increase the displacement of coal in New England without driving up the cost of electricity?

Bill Henson: I don't know the answer to that one Bob.

Bob Grace: Okay, I mentioned earlier that I had taken a look at some recent statistics on the relative share of generation in the region and noted that the coal contribution to the mix is already fairly small. It was not very long ago that coal was a material contributor of probably 20% of more of the mix or at least somewhere in the high-teens. And at least over the last year coal has only been 12.5% of the New England mix.

So a lot of the coal I believe is getting displaced by natural gas over the last several years as the operating fleet is turned over and been modernized. So I think part of the reason, and Bill please correct me if I'm wrong here, that we're not seeing as much displacement of coal as you might see in some of the mid-west or western studies is that there isn't as much coal to displace.

Bill Henson: Yes, that's true, that's true. Without - you know, I'm not the perfect forecaster here but without some sort of additional cost for carbon or for coal I don't really see us displacing too much coal just because it's a pretty cheap resource and we don't have that much of it on the system now, not nearly as much as many of the mid-western ISOs do.

Bob Grace: All right, thank you. The next question is posed by (Ed Linton) in Barrier, Vermont and he asks, what would the loss of (unintelligible) and increased imports from Hydra-Quebec do to the value of increasing wind capacity in New England?

Bill Henson: We didn't study that Bob. I don't have a good answer for you.

Bob Grace: Okay, apologies to (Ed) there. We will move on to the next question, which is posed by Gurpreet Neeraj. I apologize if I haven't pronounced that accurately who is an associate with the Resource Systems Group in Vermont. And his question is: what model was used to calculate avoided emissions in ISO New England with increasing wind penetration? The question is particularly directed to Bill Henson.

Bill Henson: So I'm not exactly sure what the question means but what we did was we used a production simulation type platform. We stepped through the system that on an hourly basis for each of the three years that we studied. And because of that we know from that model which units ran when and that sort of thing. So we know what their heat rates are. We know what their emission rates are and so that sort of information falls out of the analysis.

I'm not quite - we didn't really use a model to calculate avoided emissions. We used the simulation in order to have those results fall out essentially.

Bob Grace: Ed, is that something that you could discuss on a more typical basis for some of the other studies?

Ed DeMeo: Well, it's - I think it's exactly what Bill says. You know, you do the production simulations and one of the outputs is the energy from the plants, another output is, you know, how much SO2, how much CO2, etc. So those numbers do naturally fall out from the analysis.

Bob Grace: So that these production models typically include functional relationships between the level of operation and the emission of a particular pollutant?

Ed DeMeo: Yes, if you want to get that information you can get it out of the model, out of the calculations.

Bob Grace: Thank you. The next question is posed by (Ming Mo) at PNNL in Richland, Washington. Very informative presentation, have you studied the value of demand response programs for wind integration?

Bill Henson: Well, I can give you the particular in the NEWIS but maybe Ed can talk about maybe the more general sense. We did include demand response in our portfolio when we did the study. And from an - again, it's a little bit like the large-scale storage. Because of the flexibility of the system, we didn't really observe it being activated very much. Then again, as I said, anything that reduces the flexibility that we have on the system is going to make it more difficult for us to integrate variable resources like wind power.

Ed DeMeo: Yes, this is Ed. To add to that, demand response has been studied and included in some detail in some of the other major studies like the EWITs and in particular the Western Wind and Solar Integration Study that Michael mentioned. And, yes, demand response is found to be really quite valuable. For example, in the Western study done by the General Electric people, demand response actually made up a fairly significant portion, I forget the number, about 10% or 20% of the reserves that were used. And that was found to be far more cost effective than assigning or building additional plants to provide that additional level of reserves.

So yes, it's been studied to some detail in a number of the projects.

Bob Grace: All right, another question from Douglas Smith, Green Mountain Power. This is for Bill. Did the scope of the NEWIS include estimation of wind integration cost in a dollar per megawatt hour of wind comparable to the figures from the other studies that Michael showed in his presentation? If so, what do your preliminary results suggest?

Bill Henson: No, we did not study integration costs. We were more concerned with the numbers, the values of things like capacity, as opposed to what those numbers might cost.

Bob Grace: Bill, is that envisioned as something that might be addressed in a subsequent phase of the study?

Bill Henson: It could be. I don't know.

Bob Grace: I can imagine that'd be of a lot of interest to people.

Ed DeMeo: Bill, I'm sorry. Was GE the primary contractor?

Bill Henson: That's right.

Ed DeMeo: Yes, I think it's interesting. There are sort of two approaches to these integration studies. There's one that the GE people have used and there's another that some of the other engineering consultants have used. And the GE people have never really warmed to the idea of calculating an integration cost. Instead, they have tried to look at the entire picture, what are the impacts of the wind on the system and they've come up in many cases with a value for the kilowatt hour of wind, which includes everything including the impact of the integration cost.

So it's unlikely that that number is going to come out of the GE approach but some of the other people that have done these analyses have actually focused on that particular number. It's an interesting question. It's a sort of debate that runs through the community that does these studies.

Bill Henson: Well, and then too Ed there's market dynamics issues that I wouldn't know how to address.

Ed DeMeo: Yes.

Bob Grace: It certainly seems to be the type of question that is - that people want to know the answer to to the extent that the valid question is raised, if there are these costs of integrating wind do they offset the value of wind? And then at least some of those mid-west studies have suggested that the cost might degrade the value a little bit but it's often less than 10% but these things are system specific.

Ed DeMeo: That's right.

Bob Grace: And I will pose the question to Bill, if there's a further phase of the analysis that might be a good question to try to pose an answer in that phase.

Another question from (Jim Rodgers) who asked, many towns through Massachusetts are looking to erect one or two wind turbines with hefty subsidies accruing to the town. What, if anything, is one turbine actually doing to reduce CO_2 emissions or cause a power plant to run any less?

Ed DeMeo: This is Ed. I'll take a crack at that. I mean one or two turbines, yes, doesn't have much of an impact on the grand scheme of things. You'd have to look at this in aggregate, if there many communities that are doing this then, yes, in aggregate they could have an effect.

You know, it's kind of like voting. You know, like next Tuesday, what difference does my one vote make? Well, I can't look at it that way. I've got to look at, you know, what difference does voting make in general. It's really very important in aggregate.

Bill Henson: Yes, this is Bill. In a total sense I would agree with Ed, but in a sort of how many, let's say, megawatts of conventional resources, does a very small wind installation replace? You know, in a one-by-one sort of thing and very small amounts, I showed in the slide that the capacity value of wind actually - can be quite high. So it can be as high as a sort of a one-to-one type thing in a very, you know, in the very small.

Bob Grace: Okay, I think that's an important question to answer. These are the questions being asked, where individual wind turbines are getting sited and the people in those towns need to know that there is a benefit or whether there's a benefit in exchange for impact to view sheds and so forth.

Bill Henson: Bob, this is Bill. I'm going to beg for a - I'm off here. I've got to go take care of some stuff so.

Bob Grace: Okay, well, I was going to ask the last question here.

Bill Henson: Okay.

Bob Grace: If you can hold on for one more I think we will have worked through everything. The last question was posed by Bill Vino of the Martha's Vineyard Commission in Massachusetts. The first presentation stated that large balancing areas are preferable over small balancing areas. Is there a figure for megawatts or percentage of the system or distribution of wind facilities to differentiate between large and small? The scenarios indicated different scales of wind turbine installations by the size of dots. What was the megawatt of the smallest of these?

Bill Henson: You know, Bob, I'll be honest. I don't know off hand what the smallest of those was. If it was in our interconnection queue as of the beginning of the project it's in there, and there are some pretty small ones that are on the order of say, I don't know, 5 to 10 megawatts let's say.

It's being - we've modeled them. So that's the size of the smallest units.

Bob Grace: Right, Ed is there something you can add to that in terms of the scale of the balance areas in that impact?

Ed DeMeo: I don't think so. It's just in general, at least as far as people have gone, although bigger seems to be better. The more units you have to choose from the more interconnections you have with neighbors, the more you can average out variations in load, the more you can average out variations in wind, and the better it's going to be.

Bob Grace: So like many things, bigger and small don't have any absolute meeting but they're relative any time you can expand the system or add more diversity to it that increases the ability for the system to adequately integrate wind?

Ed DeMeo: Yes, I think that's right. And of course, you might get into practical limitations with just, you know, how big can you go with it? Do you want to go for the entire United States? Well, you know, that's a whole other ball of wax.

Bob Grace: And does this work the other way on the other extreme? So that if you had local transmission or distribution constraints that might effectively make an area seem much smaller and increase the potential issues associated with integration?

Ed DeMeo: Absolutely, we have some examples of that particularly out here in the West. The utilities that service most of Montana for example have very weak connections with the rest of the West. And they're working hard on that but right now that's the situation. And it's difficult for them to integrate wind because they just don't have many options to pick from to help out.

Bob Grace: So Bill, let me pose the last question to you. I think today, much of Maine is seen as somewhat constrained. Is the NEWIS study in effect modeling - adding enough transmission to do away with those types of constraints so that Maine for example or parts of Maine wouldn't have those types of local issues?

Bill Henson: Well, first, as Ed was talking it made me - it got me thinking a little bit in sort of relative terms since - that ISO New England is actually a pretty large balancing area. And as I mentioned before, we have a lot of institutional flexibility and things like that - the fast markets that we have.

And as you sort of mentioned, if you get really very small I think, yes, the issues may be larger so transmission is really - usually it's more the problem than balancing for an area like ISO New England. And yes, in the study we -

the scenarios, the transmission configurations that we adapted from the Governors Study essentially showed very little congestion. They showed some but very little congestion.

So I - as I mentioned, we were more interested in the system-wide issues and so I would say that the local issues, I like I said, they weren't really in the scope of the study so we don't know exactly what those affects might be but there could be significant problems with local issues.

Bob Grace: Right, thank you. I'd like to thank our speakers very much for this very helpful and informative and detailed presentation as well as your participation in the dialogue. I believe we've gotten through all the questions now.

Just as a wrap-up here, the next NEWEEP webinar will focus on the impacts of wind turbine shadow flicker. It will be scheduled for some time in January with information to be forthcoming.

If you would like to opt in for the distribution list for the NEWEEP webinars, the link is shown on the screen here to do so. And that signup will allow you to receive both NEWEEP webinar invitations as well the New England Wind Forum Newsletter, another DOE and NREL funded initiative.

The materials from the webinar, number four, will be posted on the New England Wind Forum website at the link showed by approximately November 9. And those posted materials will include a number of things, the recorded webinar and transcript, the annotated bibliography and references on the topic. So I believe that might already be posted or be very shortly so we've provided a lot of information, peer-reviewed studies and others on wind integration issues and the other issues addressed today, including some studies that come to conclusions different from those presented by the speakers.

If others out there are aware of other sources that are not included in our bibliography we would ask that you forward that information to us at the same email that you used to register for the webinar and we'll be happy add those to the bibliography. And we'll also be posting all the questions asked by the participants.

So again, thank you to the speakers. Thank you to the participants very much. And we look forward to your participation in the next webinar. And enjoy your week.

Ed DeMeo: Thanks everyone.

Coordinator: That does conclude today's conference call. You may now disconnect and have a great rest of your day.

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