AWEA WINDPOWER Presentations Overview
June 18, 2014

Coordinator: Good afternoon and thank you for holding. Your lines have been placed on a listen-only mode for the duration of today's conference.

And I would like to remind all parties the call is now being recorded. If you have any objection please disconnect at this time.

And I would now like to turn the call over to Ian Baring-Gould. Thank you. You may begin.

Ian Baring-Gould: Hello everybody and welcome to another WINDExchange webinar. And on this webinar we took the opportunity of some great presentations that were presented at the wind power conference.

And as we all know not everybody can make it to wind power. So there were a number of NREL based presentations that kind of focused on studying deployment and the current understanding of energy systems or wind energy systems I should say.

And so took the opportunity of bringing in a few of our colleagues here to give their presentations to this audience who might not have been able to see them at WINDPOWER. So we'll dive into those in just a second in this order as you see here.

But just to remind everybody as always do—we do the Q&A through typing them in. And so go up to the top of your screen under the Q&A tab, hit Q&A and then that allows you to type in your questions.

We will do that, do questions at the end of all of the presentations as we normally do. So without further ado I'd like to invite Aaron Bloom to give his presentation and that's a covering of the Eastern Renewable Generation Integration study.

Aaron is an expert in electricity markets where in his work here at NREL really focuses on the market design for high contribution renewals including solar and wind integration studies and then also looking at offshore. Prior to joining us here at NREL Aaron worked in market design auxiliary services renewable integration and reliability standards for FERC.

And so comes to us with a bunch of expertise. Most specifically it was the principal order or the FERC order, order 764 and then has done a lot of other work in over 100 proceedings regarding the integration of energy markets.

He also enjoys, he tells me, sailboat racing, which I'm not sure where he does here in Colorado. If he does sailboat racing it's not very far. They're short sailboat races.

But then, also, mountain biking which is much more a Colorado type sport. So Aaron could you please give us an introduction or an overview of the Eastern Integration study?

Aaron Bloom: Great. Thanks a lot Ian. Let me just get this thing started here.

Ian Baring-Gould: Yes just so people know because Aaron's presentation had some animations in it we're going to have to do it in a slightly different fashion. So it'll look a little different on your screens.

But that allows us to—or allows Aaron to go through those animations.

Aaron Bloom: Great. Well thanks. So the Eastern Renewable Generation Integration study is a multiyear DOE funded research project by the National Renewable Energy Laboratory.

It's designed to model the eastern interconnection at an unprecedented fidelity to understand what could happen to system operations when you take a system that was designed to manage a fleet of resources based on—oops there, I see that's working. Based on coal, gas, nuclear and water and add a significant amount of wind and solar generation to the mix.

To understand these impacts we look at things like dispatch stacks and transmission flows and a slew of other statistics. And for whatever reason despite all of our testing the animations didn't show up on this particular item.

But the reason we undertake these analyses—and I'm sure you would have loved the graphics—is to understand critical questions like what could happen to the operation of the power system under high penetrations of renewables? And how might operations under regionally driven versus nationally driven policies?

Lastly we tried to look at how might high penetrations of renewables impact current regional practices. This being said every study of this nature has its limitations.

It's just a model. It's not reality.

For example we lacked some critical information about bilateral transactions, make assumptions about unit commitment and dispatch and lack actual unit

specific data. Furthermore long-term planning studies like this always face uncertainty.

We don't know what will happen to fuel prices. Transmission expansion is difficult to predict.

Now that we have the descriptions and the caveats out of the way let's talk a little bit about the eastern interconnection. The eastern interconnection is huge and its size has historically made it difficult to model at high resolution and fidelity.

There are a lot of generators attached to the system. Approximately 7500 units when you include Canada which by the way is modeled at the same resolution as the U.S. system.

Over 70% of all the load in the United States is in the eastern connection. And as you can tell from our transmission map there are transmission lines and nodes and transformers nearly everywhere.

Okay so how do we make this happen? How do we actually study these questions?

Well, at NREL we focus on bringing together the best tools, the smartest analysts and industry experts to create industry leading research. The TRC is a group of industry experts that help make our study more relevant and credible by providing guidance on a variety of fronts including scenario development, modeling methods, assumptions and results analysis.

One of the first things the TRC helped us do was to find our study scenarios. We've got four.

The base case assumes the existing levels of renewables that we have. It's all the wind and solar generation that's on the system right now in 2012.

We then retire the necessary coal and oil units based on EPA projections and build out additional combined cycle and CT plants to meet load requirements. In the state RPS standard we've built out all of the generation necessary to meet existing past renewable portfolio standards.

So if there's an RPS in place as of today where that projects that renewable penetration to be in the year 2026 is what we use. And here we see a relatively high presence of land based wind resources.

The next two scenarios are 30% scenarios. The regional scenario constrained the renewable resources that can be used to meet the load requirements.

That means a small region—we use NERC regionals—must procure all of the renewables for that 30% target from regional resources. This is kind of one approach that goes a little bit further than the existing RPS standards but provides a boundary for, you know, a state by state or more incremental approach.

The US EI 30% scenario is kind of a best resources scenario. And as you can see this has the highest wind penetration.

That's because of the high quality wind resources in the middle of the country. We then used a suite of tools to optimize the capacity expansion and system operations according to numerous modeling constraints.

For capacity expansion we used NREL's industry recognized regional energy deployment system. This model considers the variability of wind and solar resources, reflects some reserve requirements and has a simplified transmission representation.

To accurately reflect current regulatory and legal rulings on plant retirements we seeded the model with announced retirement data verified by our technical review committee. The Plexus cost production tool by Energy Exemplar is an industry leader in software for integration studies.

It includes a full day ahead unit commitment and real time five minute dispatch. There's a nodal DC power flow and it uses mixed integer programming to optimize the generation.

AS far as we know no one has tried to exercise this tool with these settings on a database of this resolution and fidelity. But up to now it all seems so easy.

You just identify the scenarios, identify the tools and hit run, right? I wish it was.

High fidelity models simulated at high resolution require a lot of data. Much of the data required to conduct this type of study didn't previously exist.

At least not in a public form. And that's where my colleagues Dr. (Erin Townsend), (David Pelcheck) and (Jack King) stepped in to validate, analyze and implement data sets like the NREL Eastern Wind data set, the NREL Solar Integration data set—both of which are available to the public—and a couple data sets regarding our load and hydro resources.

But as any seasoned planner will tell you if you want to increase modeling resolution to more accurately reflect operations you have to be prepared for some substantially longer solve times. This is due to the nature of the unit commitment and economic dispatch problem.

The graph before you shows a simulation generation stack for nine days. Most of the time these calculations are performed consecutively one day after the next.

And that's because there are many plants like nuclear, coal and combined cycle that had multi day run times and significant constraints on startup and shutdown. In other words the decisions you can make tomorrow are predicated on the decision you make about today's operations.

This means most unit commitment and economic dispatch models cannot take advantage of the multicore processors on modern computing architectures. But my colleagues Dr. (Marisa Haman) and Dr. (Clayton Burroughs) had an idea.

They wondered that if a decision at time is not dependent on the state of the system at the previous time intervals given a delay of time period. Said more simply Drs. (Haman and Burroughs) figured out if you broke the simulation up into weekly partitions and simulated two to three overlap days for each partition you could dramatically decrease the solve time while capturing all the necessary unit starts, stops and other metrics necessary to create a coherent annual solution.

And this led to a significant decrease in solve time from over two months to less than half a week on one of the most energy efficient computing facilities

in the world. In fact the benchmarking simulation we did over the winter actually helped heart our office spaces at the ESIF.

Okay. So we have the tools, we have the data and we have some big computers. It was time to start hitting go on our simulation runs to see what our database looks like.

To prove the sufficiency of the database and make sure we understood what was going on we undertook a series of benchmarking exercises for the year 2010. We compared our simulations to historical generation and transmission data provided by the EIA.

When we started benchmarking we didn't know if we were going to be able to parallelize the unit commitment and economic dispatch. We didn't know if we'd have the HPC available.

So we started with a simplified nine node system. And as you can see we identified a couple problems.

We didn't have the hydro generation working out quite right in New York. And Florida the load wasn't quite right.

We also did some of the transmission flows between the regions and compared those to the EIA data and we found further room for implement. So we increased the resolution to 33 nodes.

This gave us a more accurate depiction of some of the constraints that happened within the country and also helped us hone in on what was happening with the generation. But we still have more to go.

And then we finally had our HPC breakthrough. We made some significant upgrades to the transmission system that were identified through the benchmarking exercises and began running full nodal runs for the Eastern Interconnection on (unintelligible), all 60,000 transmission nodes.

We worked with our TRC to analyze this data and felt confident in our 2010 database was an accurate depiction of system operations. We noted several possible causes for differences between the simulated solutions and historical data including imperfect knowledge of actual costs and availability from 2010, non-economic dispatch and actual operation and imprecise reference data.

While we could model and monitor all 60,000 transmission nodes enforcing all the transmission constraints was impractical. Most of the lines aren't constrained most of the time.

And that means there wouldn't be -0 there would be considerable computing time spent enforcing requirements that rarely need enforcing. To identify the lines that should be enforced we ran interactive simulations to determine which lines function as flow gates.

We then teamed up with the researchers in NREL's visualization insight center to create tools to explore the transmission data. And let's see if this video works.

Rats. I guess I should have updated my Codex beforehand. Well here we had a couple things going on.

And I wish you guys could see it. What we tried to show is how our transmission flows changing between macro regionals and then what is happening to the individual transmission lines that we're actually enforcing.

So if you could see this now you'd see a variety of lines that would be linking green or yellow or red to identify their transmission loading level. And then you'll also see some lines that helps give an idea of what energy was flowing say from West Virginia to Maryland. Or from Georgia down into Florida.

This is a tool that's still under development and we hope to release a newer version in the coming months.

So I guess what you guys are probably wondering is where those results are. I mean my speaking time is actually almost up.

Well the simulations are running right now. And finally the gratuitous photo is the one that has the video working.

We plan to review the base case results with our TRC in August and will being our sensitivity analysis by the fall. These runs will be aimed at maximizing wind and solar system value by minimizing curtailment and reducing the impact of variability and uncertainty.

If you'd like to get involved, get access to some of our data or just learn more about the study here are some links. Thank you.

Ian Baring-Gould: Great thank you Aaron. It's too bad those graphics didn't end up working—well the last one I guess.

So moving on to the next speaker, Jason Cotrell. Jason is a senior engineer and manager of the wind technology—wind turbine technology and innovation section here at the NWTC where he's managed that group that includes a bunch of different activities in the turbine technology development including gear box and generator research and testing, advanced controls, distributed wind and then manufacturing.

Over the 17 years that Jason has been working at NREL he's done a lot of different work across the wind turbine spectrum including stuff on drive trains, advanced rotors, wind to hydrogen, turbine blade and drivetrain testing equipment and facilities including support the testing infrastructure that we have here. And then recently on marine and hydrokinetic testing facilities.

Jason has also done a number of visiting stints at other locations including a year in Germany working with GE as well as a year at the U.S. Department of Energy in Washington being a—providing technical support. His most recent work and what he's going to be talking about here really focuses on wind turbine manufacturing and supply chain opportunities within the United States.

So Jason. You guys on mute?

Jason Cotrell: Ah-ha.

Ian Baring-Gould: There we go.

Jason Cotrell: Hi. Before I get started I wanted to make sure to acknowledge the team members upon whose shoulders I'm standing on. Listed here.

I'll go ahead and go to the next slide in the interest of time. If I can—I'm not in presentation mode but how do I do that?

Do I have to use the keyboard here? So just use the arrow keys?

I'd like to start with this slide. It'd a picture of a—I think it's something like an 83 meter blade that's used on something like a 7 or 8 megawatt turbine.

Very large machine. I like it because it shows the technology is being used to transport such a large blade.

It shows how big these blades are. I like it because it's serene.

But there's something wrong with this picture. Why are we working on this problem in the U.S. if we're able to transport such large blades?

And that's kind of a trick question. The answer is this is in Denmark, I believe where what we've learned is that the interstates are basically designed and built to accommodate large wind turbine components which is not necessarily the case in the U.S.

So taking a quick look at the project motivations and objectives. This chart up above shows over time on the X-axis how wind turbines have grown over time as well as shows the levelized average cost of energy—how that has decreased over time.

And then where things might be headed over on the right hand side. You can tell that there's—you can see here that there's a correlations between levelized cost of energy and wind turbine size or perhaps an inverse correlation.

And as you might expect wind turbine size is correlated to as I described levelized cost of energy. But where it gets interesting—what those things start to affect and that's what I'll go into in more detail in this presentation is that those transportation logistics issues associated with transporting those larger machines could very well affect stakeholder support, market stability, the manufacturing competitiveness of the U.S. wind industry and domestic content.

As well as the development of new U.S. land as shown in this slide. So the objectives of this presentation were to—or at least of this project were to identify the U.S. logistical and transportation limits, barriers and impacts.

And then as a DOE sponsored study we were—some of the deliverables and outcomes were to provide recommendations for the strategies and specific actions that the U.S. could take. I have so much trouble here going to the next slide.

Use these right here? Okay. All right.

So how did we do this? Well what we focused on doing is identifying the mass, cost and size break points for blades, towers and (unintelligible).

And by break points I mean in general the mass cost and sizes at which something like the cost becomes much more expensive than a smaller size. We did literature reviews.

There isn't that much literature out on this topic. So we relied extensively on interviews we performed with executives, with subject matter experts, with the wind industry as described in the second bullet here.

And I think most interest we performed analyses using this information to identify which transportation logistics challenges affect wind plant installation today. We also determined increase in turbine size that could be achieved if these transportation and logistics barriers are solved.

All right. So this is a nice summary slide. Giving you some of the results right up front about what the transportation and logistics barriers we identified are.

The colors indicated here as indicated in the legend—red indicates those barriers that are impacting wind turbine installations today. Orange indicates those that potentially impact turbine installation today depending on a variety of parameters.

And green are those that might become problematic in the future. just very quickly some of the ones in red are not quite transportation and logistics barrier but the uncertainty regarding the FAA blade tip height which is right now at 500 feet which corresponds to I believe it's 152 meters.

Another very impactful one today is the trucking of large diameter towers. Those are limited on the order of 4.3 meters.

They can go larger in some instances in the country. But 4.3 meters is the size that's often used.

Hoisting large NSLs onto taller towers was a little bit of a surprise. It's not necessarily problematic in all installations today.

But it could become more problematic. I think most of us know that trucking large blades with wider cords is a challenge, trucking larger blades is a challenge.

For rail as well some of these apply. And then going into the future trucking larger blades with big root diameters could become much more problematic and trucking heavier NSLs.

So that's a brief summary. And what I'll do is go into—time permitting one or two of these barriers in more detail.

So looking at the FAA height barrier. What's happening here is that there's uncertainty in some of the developers we talked with at least at the time of the study, this is a dynamic situation where the situation is changing.

However when we talked to folks last year some developers indicated that they would not pursue wind turbine developments that had blade tip heights—so that's the tip of the rotor blade—exceeding 152 meters in height as listed here. Now what we tried to do was we wanted to quantify well what sort of impact could we have if we reduced that uncertainty thereby eliminating this perceived barrier/

So here's where things get pretty interesting. And what we did was we took I believe it was a 1.6 megawatt turbine, thereabouts.

We looked at it at a 96 meter—on a 96 meter hub height tower. And then we looked at it—I actually can't make this out here.

But it's 110 meters is what it says there. We looked at it at 110 meters.

We used real wind data, real wind shears across the country. And we calculated and we show here in green colors those areas where the capacity factor—the gross capacity factor increased above the 30% threshold level.

We used that level as an indication of wind turbine deployments begin to become feasible for lack of a better term, or economically viable. And I think what's shocking here is the number of—well one, the amount of land, 320,000 square kilometers.

But how much deployment does that relate to? Well that's 1000 gigawatts if you use a rule of thumb of 3 megawatts per square kilometer.

A tremendous number—much greater than the less than 100 gigawatts that we have installed here in the U.S. today. So there's potentially there's a lot of gross potential here is the takeaway from this.

WE have some recommended action here. Basically DOE is addressing this issue, they're working this issue.

And the recommendation is pretty straightforward. We encourage them to keep working the issue and to further reduce uncertainty and risk for that barrier.

Another one that's a little bit interesting—and I'm going to have to step it up here. So actually I'm not going to go through this crane one.

I think it's less severe of an issue perhaps than some of these others. We basically did the same sort of analysis as indicated on this slide.

And what you see here is I believe it's 2000 gigawatts if you were able to increase the tower height by addressing this barrier and other barriers from 96 to 140 meters. It's the high level summary.

I want to get to this one because it helps illustrate an important point. Blade and tower transportation barriers.

You know, I think as we all understand transporting these very—these big blades, big towers, there's certainly limits on that. They're impacting industry in many cases today in the U.S.

But what I want to draw your attention is to this plot in the lower right hand corner. As you would expect the tower trucking costs for larger and larger towers, for larger machines as indicated here on the X-axis, they increase from a rough (unintelligible) calculation they increase essentially linearly.

But so the costs go up. But what's often missed—I believe the most important thing about this barrier is what happens to the capital cost of the tower.

And that's indicated by this purple line here. My background is in design engineering.

I can tell you that design engineers take those trucking constraints and that they constrain the tower to a certain diameter. And that results at least with some simplified assumptions in a super linear increase in cost.

So the important takeaway there is that these transportation logistics barriers are not just driving transportation and logistics cost. They're driving the entire turbine design cost.

So another motivation to address these issues. Moving to this next slide.

Now this one's got a lot going on. I encourage you to take a closer look at it on your own time.

I'll just tell you the high level takeaway from this slide. What's—what we've got going on here is we tried to compare all of these barriers on an apples-to-apples basis.

So we related them to using a variety of assumptions to rotor diameter so we could look at which ones are the most important today. But perhaps most importantly what might be possible in terms of wind turbine size if these barriers are addressed.

So if you take this first one the blade tip height break point—that corresponds to a rotor diameter of roughly 104 meters. That's associated with the FAA uncertainty.

If you were to address that barrier—well and basically what the arrow implies here is that the sky's the limit. So you can see that if you wanted to install a machine with a rotor diameter with some corresponding tower height of 160 meters you would have to address all these barriers—if you follow my arrow there—all the way to about here, including NSL hoisting break point.

So that's one way that the chart can be used. I need to wrap up here pretty quick.

So this is my final slide. I didn't spend a lot of time on it but I wanted to revisit this hypothesis so to speak that these transportation and logistics barriers—I think what we know is that they would—by addressing these they would enable larger and taller turbines.

One thing we believe will happen that will provide LCOE reduction pathways as well as unlocking new U.S. lands for deployment. But then the interesting

thing—something that's harder to quantify but we believe is occurring is that by deploying more turbines you can improve stakeholder support and market stability.

And using another study that was performed in this area we believe that we can improve the manufacturing competitiveness and domestic content. Those two things equal U.S. jobs by addressing these issues.

The underlying implication or assumption there is that these larger wind turbine components tend to be manufactured in the U.S. because it is more difficult to import these and more expensive to import these from offshore. So that's a key finding there.

We have some future work identified there down below. But I think that's the end of my time.

So in the interest of time I'm going to wrap it up and move on.

Ian Baring-Gould: Great. Thank you Jason. Our last presentation is by Katherine Dykes. But before we jump to that just a reminder that to ask a question go up to the Q&A tab at the top of your box there and then hit that and that will allow you to type in a question and we'll get to those at the end of all three of the presentations.

So the last presentation is from as I said Katherine Dykes. And she's going to be talking about integrated system modeling for wind turbines and wind plants.

So a fairly fun activity that is moving beyond just trying to understand what the wind turbines are doing, but the engineering and economics around putting

those wind turbines into a wind plant which is what we know we all do. so as a—as kind of an introduction Katherine joined NREL in 2011 and was brought in really based on her experience in these—this work on systems engineering and to apply work she had done previously to wind turbines specifically.

And as I said it really is working in integrating engineering and cost base analysis tools to really understand the tradeoffs from an engineering and engineering performance and then system cost perspective. Before coming here Katherine got her Ph.D. from MIT in the area of systems engineering with kind of a focus on wind technology but really understanding the system engineering area.

Her work in wind began doing wind program analysis for green energy in Ohio. And then also doing data analysis for the Renaissance Group.

She's done a fair amount of consulting in related fields around integrated engineering and demand response for a number of different companies. So Katherine?

Katherine Dykes: Thank Ian. Yes so we're going to be shifting now a little bit from where Jason was talking about looking at, you know, kind of deployment and how big we make the pie.

And looking at, you know, studying exactly how those LCOE reduction pathways might play out if we model things at a plant and turbine level. So I will skim through and jump through a bunch of slides.

I think the slides will be made available afterwards. So for the things I don't core today as I'm talking the slides will be made available.

So I'll talk a little bit about our effort in the software and some work we're doing in this area. So we all know that wind energy systems are complex and integrated.

In terms of their design often things are compartmentalized. But there's an increasing need to look at things at a system level in order to understand the subtleties and how changes in one part of the system will affect the entire system performance and cost.

And this is particularly relevant when we're talking about looking at design innovations, whether it's taller towers and really large diameter rotors or even some more nonphysical and system level design characteristics. In particular looking at controls.

So typically what we want to do then is the main metric for evaluating wind plant performance is often the cost of energy for the plant. And so the cost of energy ties in the capital cost for the plants and the turbines along with the operational expenditures for the plant over time and the energy production of the plant over time.

And so there's a lot of complexity. And then a relationship here that are—can be condensed into this simple formulation for overall plant costs.

Historically how we have looked at this at NREL and there's something wrong here with this slide. There we go.

I guess I have to click on the slide there. Okay so historically the way we've looked at assessing plant cost of energy has been to use this cost and scaling

model that was developed at NREL in conjunction with industry back in the early to mid-2000s under the effort of Wind Pact.

And it abstracts what were a site of very detailed design studies on wind turbine and plant technologies down to a set of simple parametric relationships. It's a particularly useful model for looking at a few different things.

In particular looking at input factor price changes over time, both on the labor and materials side. As well as scaling of conventional technologies within a limited range.

It's also one of the few publicly available cost models out there for looking at overall wind turbine and plant cost. And so because of this it gets used in a lot of work, research studies, et cetera looking at wind turbine and plant cost.

However it has some significant limitations in terms of looking at improvements to the system and innovation. So here at NREL we now have a dedicated effort in wind energy systems engineering that is really looking at assessment of innovation and technology changes on system performance and cost and better capturing important system interactions in that process.

So I will skim through the software section just to provide you a few highlights of how we're developing the software to do this. It involves integrating wind plant and turbine engineering performance and cost models to enable this full system analysis.

It is coupling then that system tool with plants and turbine models to advance analysis method and high performance computing techniques in order to really do state of the art research and capturing these subtle system interactions. And

it's also focused on developing a common platform—software platform and tool set so that others can partake and bring their own models and analysis to bear on a system modeling level.

So this very briefly is an overarching view of the system tools. It's many components and the thing I just want to focus on here is a representation of the full system.

So we have the structural design of the turbine, aerodynamic performance and design. We have the cost side of the plan in terms of the turbine cost, the plant costs and energy production feeding into a financial analysis.

And then here in the center as we know the dynamic modeling of plants is a very important piece of everything. And so one thing that I like to highlight because obviously this is a huge broad scope is that any given analysis will probably only be dealing with a subset of the models to assess the system for the particular question of interest.

And maybe using models of very simple fidelity in certain parts of the system and more complex models in other parts in order to address that particular question of interest. So I will briefly here touch on the mechanics of this.

It's all open source software that will be released, the NREL portion of it this fall. It's based on an open source software called Open MDAO out of NASA that is specifically designed to support this type of integrated system modeling.

On top of this NREL is collaborating with BTU wind energy in order to create a standardized way of implementing wind turbine and plant models in open MDAO to support interchange of models across different collaborators so that

DTU models or NREL models can be interchanged or those of third parties. On topo of this we are building our own implementation of the model set in (unintelligible) using our NREL tolls that we will release as a full system tool this fall.

So our goal then is integrating full set of models to represent the system for analysis. Starting with relatively low fidelity in each of the areas and then increasing the levels of fidelity in each of the models over time.

So as a first step we have the NREL cost and scaling model implemented in the tool set. And that's available as a default model for use.

We're improving fidelity modeling in each of the buckets, both on the turbine and the plant side. And this set of models represents our first version that will be available this fall.

And as I mentioned before one of the key things is you can mix and match the models together to address the certain types of questions you're interested in based on the particular research questions. So if you're more focused on the plant you may use a very simple representation of the turbine for your particular analysis.

And vice versa if you're really focused on a turbine specific analysis. So that's the software.

And if anyone is interested in more of the details of the software then please feel free to contact me at any time. And now I'm just going to highlight a little bit of the initial analysis work we've been doing with the tool set.

So a big thing to move to address in terms of moving to the system modeling space is that at any given analysis you're going to have to have both a turbine and a plant representation. So there's always some site specificity and that can be a very generic wind turbine site or something that's very specific based on actual conditions.

And so in our studies we typically are using the NREL 5 megawatt reference turbine models. And in this case an offshore site that's typical of a mid-Atlantic U.S. offshore site.

So we've done a few different initial analyses. And I'm going to talk about some of the work in each of these areas today.

One of the things that we've looked at is comparing the model fidelity across model in terms of their impact on the assessment of system performance and cost to the coolant. We've looked at the increased tip speed constraint and moving from lower to higher tip speed and how that can affect potential LCOE for the plan.

And we've also begun to list a little bit at integrating design of the turbine and the plan in an effort to reduce LCOE. So in our model comparison work we're using our reference turbine and we're looking at three different configurations of our model set and looking at global sensitivity analysis using the open MDAO software around the parameters—key turbine parameters of root diameter, hub height, rated power and maximum allowable tip speed.

In all cases we're leaving the design of the turbine and plant fixed and only varying these parameters in order to not to be optimizing at each step which is beyond the scope. So the full report for this was presented as part of the AAIAA side tech conference last year.

And is available on our website. Basically we looked at the model comparison in terms of a based line COE analysis comparison across the site.

And we see that the new models are bringing us closer to our actual estimate of cost of energy for offshore plants as we've seen in Europe. Primarily increasing key areas of cost in the turbine and balance station side which we knew were not reflected properly in the earlier cost and calling model.

So the background work with the details of this study can be found in the reference paper from the conference. But basically what these (unintelligible) indices do which are trying to explain the influence of variation from the input parameters on the output parameters in a sensitivity analysis is that moving from the old cost and scaling model to our new set of system models we're much better capturing systems interactions across the full system.

And so there's a lot of detail in there I won't go into. But basically highlighting that in our new models that we're really able to capture system interaction impacts on LCOA—LCOE in new ways that we weren't able to do so before.

So next I'll talk a little bit about the work we've done on tip speed. And tip speed study we've performed two studies.

One was using higher fidelity models and doing a sequential optimization of the turbine rotor then drive train and tower followed by a cost of energy analysis. And in the second we're looking at an integrated system level optimization of the plants modifying the turbine for reducing cost of energy.

So our first effort involved a collaborative work with Sandia National Laboratories. Overall we found that about a 1% to 2% reduction in cost of

energy could be obtained by moving from tip speeds of 80 to 100 meters per second.

And a lot of that showed subtle tradeoffs in blade dimensioning and way it compared to energy production and the drivetrain sizing for the rest of the drivetrain that reduced what would have been a large impact on cost of energy from the torque reduction and the downsizing tin the gear box. The second study uses lower fidelity models but is able because of that to look at a range of turbine classes and sites and also varying of rotor diameter and other design variables in order to explore a much larger design space.

And this study found that on average you could find around 5% reduction in cost of energy. But that involved of course moving to very high tip speed of 120 meter per second an (unintelligible) impacted of that of course would be significant.

The final study looks at integrating joint turbine and plant design. This is preliminary work and involves bringing a full energy production model into the mix as we are optimizing the turbine and the layout together.

And so in this case we involve a sub optimization at the plant layout using open wind within our turbine optimization process. And in the interest of time I'm going to skim really quickly through this set of slides.

But generally what we found is in the baseline—and again this is for an offshore plant and we were using a very small set of turbines—a pilot project of just 20 turbines. So we're starting with a really high cost of energy to start with using our baseline analysis.

Just using our turbine as is and then optimizing the layout. Going to a point where we then re-optimize the turbine after layout has been fixed.

So this represents sort of an iterative optimization approach of turbine and layouts and turbines. We can find that we can have huge cost savings basically because of the economies of scale of going to a very large turbine when the balance of station costs for offshore plants are so large.

But we find if we actually further integrate these into an integrated optimization process we found a further 8% reduction in cost of energy from the second case due to the fact that we are bringing totet6her the qualities of the layout sizing, the array losses and the dimensioning of the root diameter in particular. So the main point of this work is showing that there are significant improvements to be had the more we can integrate the design of turbines and plants.

So that's the full set of work in this area so far. I will just briefly touch on the summary.

So we have this new capability for integrating wind plant modeling in particular with engineering and cost. And we're looking at this to assess a lot of different innovation impact on system design and cost.

We are continuing to work with DTU on the development in this tool. And we're planning to release the software in the fall of this year.

And it will all be open source. We're also going to be hosting a third workshop in the area of wind plant systems engineering in January 2014.

And so love to have anyone interested in come participate in that. Or sorry 2015 there's a typo there.

So with that I'll end my talk. And thanks everyone for calling in.

Ian Baring-Gould: Great. Thank you very much. So we'll jump into questions but we only have one.

So that makes it relatively simple. Though everybody else if you do have questions please go up again to the Q&A section and type one in.

We'll dive into this first one that is for Aaron. And it's from (Mark Richardson).

Given Southwest's power pulls heavy wind penetration and current integrating practices to what degree is their model applicable to other ISOs? Is your model I would say.

Aaron Bloom: Yes so I can answer that question two ways. So the first question is kind of about power—Southwest power pool's practices, you know, applicable to other ISOs when.

When SPP redesigned their market which they just recently launched they kind of took the best practices from all the other RTOs to create their new rules for their ISO. So I think that's where they got a lot of their great capabilities.

If you wanted to talk a little bit about how our model compares to what the RTOs actually do we can talk about that too. One of the big things about our

study is we actually operate the entire eastern interconnection including Canada as if it is one giant RTO.

So it's a little bit more optimal than reality would be because it doesn't' have any of the market friction that would happen between them. But the underlying mathematics and the way that we try to do reserves is very close to how they actually do these operations in the RTOs.

Does that maybe answer some of that question? So we do things like we have a five minute dispatch, we have regulation reserves like all the other markets, we're going to turn sensitivity analyses where we include the emerging market design ideas like flexibility reserves.

And we're also going to check out a couple new practices that aren't being used in the RTOIs yet like look ahead dispatch and a couple other items.

Ian Baring-Gould: Great thank you. That's it for questions. So we'll move on.

But please we have—we do have a few more minutes so if you have an additional question just type it in and we'll pop back to it. Just want to let folks know what's kind of up and coming in regards to webinars.

Next session in July on July 16 we're going to be talking about offshore. And this should be a pretty interesting set of presentations.

We're going to get an update of the not quite but recently or hasn't' been quite released but a few presentations have been done on it, the offshore market overview that has just been completed by Navigant. We'll also get from the Department of Energy an overview of the three demonstration projects that were recently announced.

And then lastly a presentation on kind of current challenges from—for deploying offshore wind technologies. Where are we in that kind of deployment chain?

So it should be a good kind of overview as stated here. But getting a little bit more in depth on what's currently happening in offshore wind deployments.

In August this is tentative but the plan is to provide a more detailed presentation on the market reports both out of LB&L and PN&L for land based and distributed wind respectively. Those reports were given at the summit but because of the technical problems they weren't really broadcast.

So we'll—once those reports are released we'll do overviews of those two. And then we haven't determined what the September webinar is going to be.

So if you have ideas please don't hesitate. As always they happen on the third Wednesday of the month.

So last but not least again a special thanks to the U.S. Department of Energy. Thanks to our three speakers, Aaron, Jason and Katherine for taking the time to kind of bring us up to speed in those three areas.

If you have any questions or comments you have our emails there both for (Bree) at the Department of Energy and then myself and (Suzanne) here at NREL. So thanks again.

We'll give everybody a couple more minutes to their beautiful Wednesday. And look forward to talking to you between now and then or seeing you on next month's webinar.

Thanks a bunch and we'll talk to you soon. Bye-bye.