Wind Turbine Recycling and Repowering
January 21, 2015

Coordinator: Welcome and thank you for standing by. At this time all participants are in a listen-only mode for the duration of today's meeting. Today's meeting is also being recorded. If you have any objections, you may disconnect at this time. I now would like to turn the meeting over to Mr. Ian Baring-Gould. You may begin.

Ian Baring-Gould: Great, thank you everybody and welcome folks to another wind exchange Webinar, this one focusing on wind turbine recycling and repowering so kind of these end-of-life issues in regards to turbines and turbine systems and we have three great presentations to look forward to.

First Eric Lantz talking about a paper that he primarily authored on repowering so what has been the experience both here in the U.S. but most importantly kind of bringing-in Europe, the experience in Europe and then how this might play out as we go into the future.

As all of us know the wind energy in the United States is not very old and there aren't very many plants that have been around for long enough that we would consider repowering them but we're starting to get to the point where more of those plants will be and then certainly as we look going into the future, more and more plants will start becoming kind of to the age of repowering.

Then we have a great speaker Rick Miller from EDF to give kind of a more on-the-ground case study of repowering and then finally a presentation from another NRELian, Jason Cotrell to talk about a study that he authored Looking at Recycling.

So again what is the experience both here and then pulling-in from Europe about what do you do when you actually want to take down the turbine and get rid of it? How much of it is recyclable and what are kind of some of the issues that we're going to be looking at as we get to the point where we're getting to turbine end of life?

So quickly before we jump into the actual speakers, as always the Q&A is done by entering your questions into the Live Meeting Q&A so if you go up to the top of your screen you'll see a Q&A. Click there and then you can type-in your question and click the ask to send the question to me and then we'll have a moderated Q&A at the end of all three presentations.

Just as a final reminder, the Webinar as you heard is recorded and the recordings of the Webinar will be available on the WINDExchange Web site in approximately a week so I'll remind people about that at the end but the materials will be available for you to review or pass on to other colleagues.

So without further ado, let's jump to our first speaker Eric Lantz. Eric is an analyst here at the National Renewal Energy Laboratory where he's focused primarily in markets and policy. His primary research includes markets, economics and policy associated with wind but he's also done a fair amount of work in the other technologies as well.

Eric also is a representative of the IEA, the International Energy Agency's working group on public perception and the response of public to wind power. Eric holds a master's degree in energy policy from the University of Colorado and has been a great asset to the team here, the wind exchange team here for quite some time so Eric, it's a pleasure to have you talking.

Eric Lantz: Great. Thanks Ian. As Ian noted, I'm going to sort of kick things off here. We'll give a little bit of an introduction to the concept of repowering, talk about where things are with respect to repowering both in the U.S. and globally.

I'll delve into some economic analysis we did to sort of see when some of those older plants that do exist in the U.S. might start to consider repowering as well as when some of the more recent plants are looking at potentially repowering in terms of projected lifetimes today.

Convert that, those estimates into demand for repowering out in the future and then we'll wrap up with a brief summary and some conclusions so the first portion or the first slide here really focuses on clarifying some things around repowering. You may have heard repowering discussed generally.

Actually it can take on various different forms. I've defined two of them here, one of those being full repowering where you completely dismantle your project essentially and you replace all the turbine equipment. This probably includes building new roads and new foundations.

Perhaps you can use a little bit of the electrical infrastructure associated with the prior project and obviously your preconstruction development costs are going to be lower because you know the site well already. Maybe you don't have to re-permit things, probably depends on the specific case but that's essentially the full repowering version.

Essentially you're building a new wind power facility on an existing site. The other one here is partial repowering and this involves replacing specific components, perhaps a rotor, a drivetrain, some other feature of the turbine

that will extend the life of the facility at some cost that's less than full repowering.

The idea here is that perhaps you can do some things that extend the life, continue to be able to operate the plant in the black for a number of years into the future and you can potentially do this under essentially the existing contracts and regulatory regime that you're in, in some cases a full repowering might trigger more regulatory review or require new contracts.

In terms of why people consider repowering, there's sort of a list here on the slide. I would highlight the first three of those as probably being the most critical, really looking at greater project productivity, improved grid support, grid integration services and then the ability to better utilize your high-value resources.

By and large, at least in principle there's the theory that we tend to build our best sites first because those are the most economic and so those are also then the sites that might benefit the most from improvements in technology that result in greater productivity for a given wind resource regime.

In terms of repowering this is a concept that's been around for a number of years. It actually started getting some attention in California and Denmark in the early 1990s and then was followed by the Dutch and German markets later on in the latter 1990s and into the 2000s.

In terms of the status of repowering today, it's really not a particularly large market. In Denmark and Germany both you're looking at probably tens to hundreds of megawatts per year.

Both of those countries have provided incentives in addition to their traditional feed-in tariffs to try and provide a stronger encouragement for project owners to repower but you still see relatively limited amounts of repowering actually occurring in both those countries.

There are a variety of reasons that repowering hasn't been especially large in those markets. Probably the largest one is simply the economics and we'll get more into that later on in the presentation.

Other factors include the fact that you're moving to larger turbines. In Denmark particularly there's been a shift in sort of ownership models from the community-based ownership model to more of a corporate or utility-based ownership model.

And in Germany there's things like the setbacks and turbine height restrictions that have come into play and prevented the installation of new equipment at some sites. For the U.S. obviously California's really the primary market for repowering today.

Historically though repowering activity has been limited there by what's been called by some to be the California fix and what the California fix is it goes back to some of the standard offer contracts that were the 1980s vintage projects sold their power at.

Those tended to be relatively favorable contracts in California and there's some question when you repower as to whether those contracts can be extended and if those contracts are extended, whether then you can qualify for the PTC or not. I imagine Rick our next speaker can provide some greater insight there.

We'll just say here right now to date, repowering has really tended to be the full repowering version. There's a lot of discussion around different versions of partial repowering and what that might entail and the opportunities there.

But I do think by and large it's tended to be full repowering and primarily the reason for that is because the technology has advanced so significantly from turbines that are on the order of tens of kilowatts to obviously what we have today, the multi megawatt machines.

In terms of our economic analysis, we really conducted two different economic analyses. One is based on sort of average national data and that's shown in terms of the inputs that we assumed on this particular slide.

What we did for this portion of the analysis was create some hypothetical projects that were intended to be sort of national average representations for projects built in 1999, 2003, 2008 and 2012 and then we wanted to look at what are sort of the decision points that developers might be facing into the future, looking at full repowering as opposed to developing a new Greenfield or adjacent Greenfield site.

And then also looking at the partial repowering at least one representation of that specifically for the 2003 plant. You can see the parameters that we've used here. Let me see if I can get the pointer working. This here is the sort of the turbine assumptions.

Again these are national averages and then our costs are actually national average historical capital costs, capacity factors and prices for the power that's been sold. Into the future we're obviously projecting costs. You can see those projections here in the lower left-hand side of your screen.

For repowering we assume that happens to be about 5% lower capital investment based on the ability to use some of the electrical infrastructure that's in place as well as the more limited preconstruction development costs that would go into a repower project.

For the partial repower project, I'll get to this in more detail a little bit later but basically we're assuming a relatively large overhaul of the turbine, essentially replacing the rotor and the drivetrain but leaving the tower and foundation intact and so that's an additional roughly speaking 10% reduction below full repowering in terms of costs.

But the tradeoff here when you look at the capacity factors is that you only get about half the capacity factor improvement in this particular hypothetical example relative to what you would get if you did a full repowering job.

You will note we do assume step change sort of in the capacity factors for projects between 2012 and 2015. This is related to the proliferation of the IEC Class 3 turbines, the large rotor machines that we're seeing today.

In terms of the results from this first portion of the analysis, we do want to try and move through these relatively quickly. There's a lot we could talk here but we'll try and highlight just the key points.

Essentially what you want to look at here in these plots is the difference between the two bars for each of the different time periods. We essentially looked at decision time point or decisions that might occur at five-year intervals out to 2030 and looked at the value that would be added to the project either by building an adjacent Greenfield site or by repowering.

Now the numbers here really shouldn't - they need to be - there are numbers but I wouldn't read too much into the numbers there. We can talk about that in the Q&A if you have some questions there. Really again focus on the difference between the repowering and the existing plus Greenfield options that you see here within the different time periods.

So for the 1999 plant those power plants are about 15 years old today obviously and based on the assumptions that we're using, they remain relatively profitable at that age so what that means is that in order to sort of maximize the value of your capital, it's probably better off to do that by investing in a new Greenfield site that's potentially close by.

Or alternatively somewhere further away but essentially you're going to get a lot more value out of building a new Greenfield site and continuing to operate your existing facility even if it's not necessarily as profitable as it might be if you were to repower the facility altogether and that's shown by the difference here between these two bars.

As you move further into the future as that plant ages and your operations costs grow and perhaps your availability and your performance of your project begins to decline, you start to move closer to the red, the red zone if you will and the value that you get from repowering relative to building a new Greenfield, that difference starts to diminish.

Obviously then out into the 2025 period you see a little bit of a flip there and that's when it looks like you can gain greater value from actually repowering that facility than from continuing to operate it and building a new Greenfield.

Essentially at that point you're probably starting to lose money or very close to beginning to lose money on the existing project and so you really do get the most value out of that repowering effort.

That difference then grows with time as you move out to 2030. For the 2003 plants by and large the industry was quite competitive in the 2003 time period. You had very low PPA prices at the time and what that meant is that margins were a little slimmer so you actually start to see this shift.

Again it happens between 2020 and 2025 but you're looking at a plant that's, you know, three to five years younger for that 2003 plant and so the economics there again start to shift in the 2020 to 2025 period or somewhere in that sort of 15 to 20 years of operations.

Looking ahead at the 2008 and 2012 periods, 2008 was pretty close to our peak PPA prices so that means you have at least in theory some additional cushion in terms of the operations cost increases you can bear with time and what that suggests is that really repowering doesn't appear to be all that attractive throughout the time period of the analysis covered here.

So really it's not until 20 years that these even start to approach one another - or greater than 20 years I should say - where you're looking at sort of a comparable impact from building an existing Greenfield or repowering.

Also obviously the technology improved between the early 2000s and the 2008 time period so the productivity of those machines is somewhat higher and that factors-in here as well.

Similar story for 2012. Obviously you're not going to repower in 2015 three years after the project goes into place and that's shown here by the results.

You just haven't extracted enough cash from that project, you haven't recovered your capital and gotten close enough to achieving your sort of threshold returns there.

What's interesting here is that these projects are probably looking at something more on the order of a 25-year life, at least based on the assumptions that we are using.

This will depend heavily on how quickly O&M costs escalate but by and large it looks like a 25-year life based on this analysis is probably something that's feasible for more recent projects and we've heard that sentiment echoed by others in the industry.

Trying to move here quickly, again when you look at partial repowering, you can see sort of the assumptions that we made here. I talked about those briefly earlier. Basically with this construction of partial repowering it's not viable relative to full repowering or building a new Greenfield. It comes in below both of those.

Keep in mind though that this is for one particular concept of partial repowering and if there are things that you could do to extend life, keep those operations costs low for an additional three, five-plus years then that could be far more viable than what's shown on this particular slide.

The second portion of our analysis was the same, essentially the same type of analysis but we tried to take one step to bring it a little bit closer to reality. We looked at projects or a project in the northeast, one on the West Coast and one in the Midwest that were of an age that sort of put them in this let's start thinking about repowering mindset.

We tried to collect as much project-specific information about or as we could and then run that through our financial models and what we found is essentially that for both the northeastern plant which is in the range of 15 to 20 years old and your Midwestern plant more in the 10 to 15-year-old range.

Repowering, you know, for the northeast plant it looks like maybe you're starting to think about it but it's not a really compelling financial gain and then for the Midwest plant you're probably still looking more at building that existing Greenfield and continuing to operate your plant.

The West Coast here is the exception and that's actually where we have seen a few recent repowered projects so this is a good, this is consistent with what we're seeing sort of in the real world.

Essentially these plants are a bit older and the difference in technology really gives you a boost in productivity, allows the repowering to come out well ahead in terms of continuing to operate versus repowering.

So these conclusions I think they generally did fit with what we learned from the developers we talked to about these projects. For the case study here, really the West Coast project is the one that has been repowered. The other two projects are not currently looking at repowering.

In terms of then how this translates into future demand for turbine equipment, what we've done is used the results from the economic analysis to try and project future lifetime. What that's done is we've come up with sort of this distribution of lifetimes.

It's relatively crude but it is a bit of a distribution. We say, you know, 25% of our existing facilities repower after 20 years. Fifty percent repower after 25

years and the remaining 25% of the fleet either repowers sometime after 25 years or they're decommissioned.

And when you put that distribution through our existing fleet, you end-up with a curve that looks like this shown here on the right-hand side and you can see that really you start to see some repowering activity pickup in the 2019-2020 time period, growth pretty steadily through the mid-2020s and out to 2030 and gets to a cumulative level of repowered capacity of about 14 gigawatts by the 2030 timeframe.

And now this curve would continue to escalate based on the fact that 50% of our fleet's repowering after 25 years of operation, you know, and that puts everything that was built post or puts a large portion of the fleet built post-2005 to be repowering sort of in that 2030 timeframe.

And as many of you know, the vast majority of the operating wind fleet today was built post-2005 so the 2030s could be a good period for repowering and obviously to the extent that growth remains at a relatively healthy level, then into the future repowering could constitute a quite large portion of the wind industry rather than just be new capacity expansions like we see today.

You could be in a situation where maybe half of the new investments on an annual basis are in repowering and half are in new capacity expansion. Just to summarize here and pull things together before turning it over, basically if your project's in the black then you're really not going to be looking at repowering and based on the assumptions that we're using, that's going to continue after the 20-year period perhaps even to 25 years.

Obviously though there is some time in that 25 years plus or minus a few years' timeframe when the economics start to tip and you are going to be probably looking at repowering for all those projects.

Obviously the big wild card here for the most part is operations costs. There are other factors which are shown sort of at the bottom of the slide that may also play a role such as technology advancement and the increase in productivity relative to cost that you might get for future technologies.

But, you know, if operations cost escalate at the rates we're assuming which is about 5% on a nominal basis per year, then you probably really are looking at plant life on the order of 25 years.

Partial repowering, the jury's really still out it. It depends on what sorts of options are developed and what might be the opportunity there in terms of the technical opportunity. That's really what's going to drive the decision-making and the investment around partial repowering.

If it's going to cost similar or just slightly below what it costs to do a full repowering, then you're probably not looking at large amounts of partial repowering and finally outside of California we probably won't see a lot of repowering activity at least for the next decade but then we do expect to see a steady ramp-up from that point moving forward.

With that, if you're interested in the full report, it's shown here and if you have questions that don't get answered during the Q&A portion, my contact information is listed on this slide as well. Thank you very much. Look forward to the Q&A.

Ian Baring-Gould: Great, thank you so much Eric. Our next speaker, really great pleasure to have Rick Miller join us from EDF. Rick joined EDF in 2009 but was promoted to the Director for wind business development in 2012 so very senior person at EDF and so it's a pleasure to have him with us.

Under his current position has as Director oversees all of the planning, leadership, management and oversight for all elements of project development preconstruction for the Western region of the United States including California and what we all consider the West but most apparently California for this discussion here in looking at repowering which is something that EDF has done.

Rick also serves on the California Wind Energy Association so CalWEA's board of directors and was a point person for the first U.S. Fish & Wildlife golden eagle tag permit which is also another achievement so it's really with great pleasure we have Rick talking to us about EDF's experience in this repowering market. Rick?

Rick Miller: Well, great, thank you so much for that kind introduction so this flows perfectly from the last presentation that Eric gave because this is a full repower in California and I thought it would be helpful to run through. This is a bit of case study sandwiched between these two great presentations so assuming everybody can hear me okay, I'll just get started.

Ian Baring-Gould: Yes, we can hear you just fine, thank you.

Rick Miller: Great, so my presentation has a lot of pictures in it because one, I have them and two, I think it paints an interesting picture of the scene out there. This project site is located east but close to San Francisco and the Bay Area in California, Northern California and PG&E service territory.

And in this picture I just skipped over shows you some of the existing older type turbines with some new modern turbines mixed in as a juxtaposition visually and a little bit later in the presentation in a few slides you'll see an overview of the map.

There are several large wind developers in this wind resource area called the Montezuma Hills area. Currently there's about a gigawatt of wind power there and there's approximately three to four large wind operators including ourselves running turbines there.

So this project called Shiloh Four was originally installed using kinetic technology in 1989. It was approximately 60 megawatts with 100 KW turbines. EDF renewable energy acquired this project site in 2001 and between in the first part of 2012 EDF endeavored to remove 235 turbines to make way for the repowering that would be called Shiloh Four.

Shiloh Four increased the electrical generating capacity by 10% or four times the installed capacity that was there which I think nears what Eric was talking about in terms of some of the efficiencies that can be gained by replacing the old technology with new multi-megawatt platform turbines. This project was repowered with the MM92 which is basically a 2.0-megawatt machine.

So here you'll see the map which just, you know, it's just in order to show you that the project is sandwiched between a whole host of other projects here - let me get this going here - so this, this green area here, if you can follow this red (ballot) that's working is the location of the Shiloh Four project and (smug) runs some turbines out here and so does NextEra.

Okay, so decommissioning the old turbines so these are some of the questions we had asked ourselves when we endeavored to get the old turbines out of there in the beginning of 2012 and I should have mentioned at the outset that this project - I know there's probably a question brought up about the old SO4 contracts and PTC - let me just mention now so I don't forget.

This project did obtain a new modern if you will PPA properties agreement with Pacific Gas & Electric and I think it did capture the 2012 PTC cycle at the time when they went commercial operational in December of 2012.

And I think it's worth noting here in case I forget that really when we look at repowering and what we'll see in the future, it really comes down to the old real estate adage of location, location, location. This project site is fairly close to load and it has very robust winds so it made a whole lot of sense for us to do a repowering here, very competitive.

So these are some of the questions we asked ourselves, you know, what are the local jurisdictions decommissioning requirements and, you know, in California of course there's strict permitting and sighting requirements and obligations. There was endangered species issues that had to be contended with so definitely want to be on top of that.

And then are there existing conditions the existing facility is subject to. Again if there's some specific obligation attached to this project, you want to know what it is and work it into your timeframe of your project planning. What was the lease agreements with the underlying property owners?

Some lease agreements will be standard and the number of property owners and leases that make up your project, there's sometimes fine details in each individual lease agreement that may vary in which case, you know, you need

to be aware of what needs to be performed on the individual portions of the project.

And then germane to this discussion, you know, what existing components can be salvaged, what can be reused, what can be sold in secondary markets and then what would be the disposal methodology.

I've mentioned the due diligence regarding species issues and your consultation with resource agencies or local jurisdiction and then the best management practices to implement including erosion control, substances that are in the turbines, you know, removing oil, etcetera.

I'll get into that a little bit later and then is the site setup for repowering so decommissioning Shiloh Four, a little bit of the details. You'll see here I don't necessarily need to read through all this so I want to have plenty of time to get through the rest of it.

But this slide shows some of the equipment that was utilized and I have a picture showing it but in general we went out there with this (cap) and this really neat shear attachment like a giant pair of scissors, kind of Edward Scissorhands on steroids and basically swept the steel turbine towers at the base, folded and lowered the turbines to the ground.

And, you know, this was done, they fold and bend and, you know, fairly in a controlled manner just to make sure that we didn't have stuff going everywhere which we didn't. It was a pretty controlled situation, you'll see a picture of it in a minute and then once on the ground, these things are basically chopped-up using that giant scissors and put in little piles and separated to be picked-up and hauled off.

And you can see here, I mean, it's a pretty rapid process with an average of five towers per shift with a single crew and then in this project we've done multiple different things on repowering or on decommissioning.

But in this particular case we were able to sort of dig areas around the (pure type) foundations and push the concrete over and then bury them at least six feet from the natural grade and this talks about how the electrical poles - aboveground poles - were taken down again and then wire bundled and shipped to the recycler.

Wood poles were treated and then sent to landfill for burial and then the transformer decommissioning you'll see, you know, the oil had to be drained and containerized, verified no PCPs or other hazardous materials and then we separated the aluminum wire from the rest of the units and sent those metals to the recycler.

All right, let's keep moving along here so this is what I just described as kind of captured in this picture. This shows the cap and that giant scissors sort of snipping these old towers down and like it says up there, it basically takes about 10 minutes.

Here's another picture once the turbine's on the ground. This gives you a little bit better view of the equipment and the attachment used to chop these things up and then getting into the repowering so that's sort of the decommissioning portion of the case study.

Here it gets into the repowering and I'm going to pick-up the pace here a little bit but of course, you know, renegotiating the underlying land leases was a critical phase as we were entering into a new 20-year power purchase

agreement so those leases had to be extended and new rates in some situations had to be renegotiated.

And then of course you want to ask this question ahead of time but has your decommissioning plan left your site ready for repowering? Of course, you know, any foundations that we have in place, you don't want to be in the way of your new project layout in the repowering scenario.

Do you have the right kind of data on-site and I'm referring here in terms of wind data? As you know some of the old (met) data will be at a lower altitude than you want, you know, maybe 40 meters or even lower whereas now we want, you know, typically 80 meter or higher (met) data and we've run into some issues here.

You know, do you have the right wind information for sighting the new modern turbines and then of course what is the permit strategy and requirements for redevelopment? How will the existing interconnection agreement be treated and what equipment can be reused?

Looking at the main power transformer as an example, some of the thing that Eric that talking about, you know, what kind of equipment can be reutilized in the new project?

This is a schematic I often like to show, I think gives you a little bit of a sense of the scale size between the kinetics that were replaced with the repower I guess now called senvion turbine. This gives you a sense of scale there and of course of the rotor's swept area.

Again this is so now we're into the repower project. This shows you this is a dry land farmed area up here in Northern California so this shows you sort of

the, you know, when you're bringing-in this new, large equipment, you know, the roads that are existing often times are just abandoned or recontoured.

We utilize them as much as possible to minimize disturbance but the breadth of the road is quite dramatically different, obviously the size of the blades and the turbine pieces coming into the site for construction because it was on a scale much greater than the previous project in many cases.

This is just an example showing you the wind turbine deliveries. Thought it would be fun to take a couple of peeks at this since we have them. This is the foundation ready for pour midway through. These are spread-type footings and this is the foundation once it's completed, ready to accept that tower.

Here's just a quick picture of the calibration tower that was installed. This was replaced eventually with an actual turbine and then here's just some more shots of them getting the tower in place and then getting ready to fly that rotor.

And again here's a final picture showing you a much less cluttered scene out there. I think Eric mentioned visual, you know, I think the lessening of visual clutter is really beneficial out here. It's certainly a very graceful scene out there in Solano County with all the wind turbines, very pastoral views and it's a much less cluttered situation.

Obviously I think the removing the lattice towers has also been very beneficial. We do think that it's supported that the environmental benefit to wildlife will continue to be documented.

We're reduced mortality based partly on getting the blades higher from the ground for some of those species like burrowing owls but also just in more modern day sighting practices.

And then following some of the guidelines that have been put out and best management practices that the industry's been using voluntarily for many, many years now and the thing that we've learned about flyways and micro-flyways on sites have really reduced impacts to avian species.

And of course the ground disturbance is minimal once these projects are installed and operating compared to the old turbines so then I wanted to wrap-up a little bit with some of the non-monetary benefits. Obviously in this case like I was saying in terms of locations, I mean, this was just a very rich, high-resource area which are not easy to come by now in California.

It's an area with very constrained land. The local jurisdiction's trying to keep the spread of wind turbine farms, trying to reduce the spread of them so doing this somewhat infield project was a major benefit.

This county has since taken a less optimistic view of wind energy and actually has in place a moratorium that may or may not last much longer than another year, you know, on new projects so the timing for this was just right back in 2012.

And as I was saying here, you know, there is limited additional land in this wind resource area and we think in general in California, you know, most of the hotspots for our robust MCFs have basically been developed and so they may be great opportunities for repowering in the future.

This project was slightly easier to permit than a new area. I think the landowners were certainly excited about the opportunity. You'll see here that there was increased financial benefits for these landowners with the same space but more generation meant more money for them.

And then of course the improved power quality, greater tax base for Solano County, can't underestimate the amount of green jobs provided during construction and the spin-off that the community felt during construction and then as I was saying the improved aesthetics.

And then finally I think Eric talked a little bit about the operations costs but kinetics are pretty notorious for being difficult and laborious to operate whereas these new modern turbines I think are much more efficient and more cost-effective to operate in the long term so with that I'm going to go ahead and turn it back over. Thank you very much.

Ian Baring-Gould: Great, thank you so much Rick. Always wonderful to see pictures of installations and get a sense of the scale of the turbine technology that we have these days. Our last speaker is Jason Cotrell as I mentioned at the top. Jason is another engineer at National Renewable Energy Laboratory here at the National Wind Technology Center where he leads the wind turbine technology and innovation group.

Jason has been at NREL for over 20 years and has done a lot of different work in many technical areas which include manufacturing and supply chain, work with wind turbine drivetrains, advanced rotors, wind turbine blade and drivetrain testing including support in the development of the test facilities that we have here and then more recently in marine and enterokinetic testing facilities.

From a leadership perspective he supports the distributed wind group manufacturing and also advanced controls. His most recent work is looking at strategic energy analysis around wind and water manufacturing as well as doing some recent work in market assessment in Brazil and other international destinations.

But here he is focusing on a recent study that he led with a couple of other people looking at the recycling kind of current status and future projections for recycling of wind turbine technology so Jason?

Jason Cotrell: Thank you Ian so I'll be discussing the results of the wind turbine recycling study. It's titled preliminary mainly because this work hasn't been published yet. The publication for this paper is under review and I expect will be out in a few months.

If you want to send my your information, I'm putting a list together of folks that have expressed interest in the final deliverable and we'll try and make you aware of once it finally is published so I also want to do a couple of quick disclaimers.

This is a relatively small project compared to some of DOE's other projects. It's more of a survey project of what are the main issues associated with wind turbine recycling. It's a great follow-on to the previous two presentations in that those presentations beg the question well, what's going to happen to those repowered turbines and what happened to those kinetic turbines?

How much of that was recycled? How sustainable of a process is this? I also want to disclaim that I'm certainly not an expert in recycling. In fact Ryan King the first author here did the majority of the heavy lifting and assembly of the content for this presentation.

And I think it's important to point out that if you ask me to name a recycling expert in the U.S. for wind turbines, I probably couldn't do so. I can tell you some people that have been involved in the area and that's kind of a red flag and gets to the motivation perhaps, some of the motivations behind this presentation.

And so I hit the down button but I'm not able to advance the slide. Could someone do that for me and we'll just proceed in that fashion. That'll work just fine so the overall objectives of this survey project were essentially to identify the critical issues and also the business opportunities that might be associated with recycling of these large wind turbine systems.

Some specific things we were asked to do by the Department of Energy who funded this study are to scope the size of the recycling. It's labeled a problem. I would say a challenge or a potential problem might be fairer characterization.

Also to get a status of what technologies are available to perform the recycling of these wind turbines and how much industry activity is going on in the area? What are the gaps in the recycling infrastructure if any and what sort of recommendations would we have regarding recycling that would ultimately advance the wind industry? Next slide, please.

So I'm going to give you some of the results of the study right up-front. I'll revisit these at the end along with the recommendations. On this plot there's a lot of color going on. There's a lot of things going on but what you have in the left-hand column are the components that we examined in this study.

The blade REE stands for rare earth elements so those are the rare earth elements contained primarily in the generators found in permanent magnet wind turbine drivetrains and then a generator, that implies copper generator essentially, the standard configuration, gearboxes in the wind turbine and then the tower and hub.

Moving across the top row, it shows the metrics we decided upon to try and assess what sort of challenges we have and what the status is for recycling technologies for each one of these components and the general idea here these are listed in terms of priority from the biggest priority challenge and/or opportunity down to the lowest priority challenge.

The general idea is the redder the color along the row, the more attention that component deserves in terms of recycling so the metrics along the top merit some explanation.

The potential economic burden basically that's an indication of what sort of problems or what sort of challenge this component might be relative to the other components on the chart so that's important to remember.

Just because blades show-up as red doesn't necessarily mean it's a challenge for the industry right now but it certainly could and it has a potential to be much more of a challenge than say your component at the bottom tower and hub which has a green.

There's a legend at the bottom that says the green means it with regard to economic burden that there's an opportunity in tower and hubs and for blades it can potentially be a problem and again that's all relative.

Recycling technology maturity so that metric is basically looking at do the technologies even exist to recycle these things? Are we actually going to have to reinvent the technology or is it more of a market problem, an infrastructure problem as indicated in the next metric, recycling infrastructure?

And then finally recycling R&D activity, is this area getting much attention basically? Is it being ignored or if it's green is it getting lots of attention so let's use blades for just a moment to kind of give some examples of these metrics so right now blades although in the U.S. it's not such a burden relative to the other technologies.

It certainly could be an economic burden if restrictions were placed on the disposal of the organic materials in the most common blade. One of the reasons why it's red or the logic is right now most blades are reinforced composite polymers. There are no substitutes in the market.

If government policies such as what has occurred in the EU becomes more restrictive, then our wind industry could have a very significant problem on their hands. In contrast you can look at rare earth elements, well, let me just keep going on blades.

So if you look at recycling technology maturity with regards to blades, there are some technologies out there that people have explored but there still remains relatively little compared to some of the other technologies there or other components there.

And then with regards to recycling infrastructure there is to our knowledge at the time we wrote this study there was no commercial blade recycling facilities in existence at the time and that was actually on the planet.

There might have been some pilot projects, some demonstration projects but very little infrastructure. In addition the problem had been largely ignored. There was some attention in Europe a decade ago and most recently there's been we've had some inquiries from our European colleagues about what's going on in recycling.

But in general there's been almost very little attention and that's part of the motivation for this study so I'm going to have to proceed pretty quickly here. Let's go to the next slide. I've already talked a lot about blades.

I'll just focus on a couple of things, mainly the drivers for the recycling technology in the blade space are coming - the technologies - are coming out of the aerospace industry and also from the automotive industry being driven in large part by the European Union end of life for vehicles regulations. Let's go to the next slide.

So this is an interesting slide especially if you're more on the business side of the house. What's shown here in the graph in blue is basically how much material and this is done on a per-megawatt basis is contained in each of these components we looked at?

And it's from increasing to decreasing and then on the right-hand side I was base constrained. There's the rare earth elements and then very interestingly on the right-hand plot it shows well how much are those materials worth, the materials actually using a market value of virgin material?

And so what you see is there's a lot of steel in wind turbines and as you expect there's a lot of value there and then on the right-hand side you've got the rare earth elements and although there's very few rare earth elements, the value of those elements is actually some of the highest.

There's also CFRP, that's carbon fiber reinforced polymers. There is some of that in blades. Most blades are made from fiberglass. To put things in perspective I presented a reference up there that says in Q1 we had about 61,000 megawatts installed in the U.S. and so you can do the math there and figure out what some of the gross value is of virgin materials.

I also have I try and put in perspective in the table below well what do these volumes represent compared to the entire composites industry and the key point here from this slide is it's relatively small.

In fact although it lists domestic installation assumptions of about eight gigawatts per year, the repowering estimate that we can expect or probably a quarter of that within the next 10 to 20 years so the key takeaway from this slide is that the wind industry is not consuming enough of these raw materials or recycling enough of these materials to drive the technologies in these areas.

We have to partner-up, we have to team-up and collaborate with others working in this space across industries such as automotive and aerospace if we're going to address these problems so next slide.

Here's a couple pictures, I'll go through this one really quickly. It's an example of one of the technologies or demonstrations used for recycling a blade. This is actually two different situations here. Up top going across is a pyrolysis. There's a definition of what pyrolysis up top.

Basically it shows one way you can start to decompose a blade. Much of that material still is structurally strong and then the next row basically shows some recycled carbon fibers that have been formed into a wheel well for a Corvette.

So that gives you an example of both how the fibers can be decomposed and then down below what some of the potential applications might be for these materials. Next slide.

So what did we find so GFRP, that stands for glass fiber reinforced polymers. That's what most blades are. That's fiberglass effectively. We came back to I wanted to contribute it to Schoolhouse Rock but I think most people would recognize Jack Johnson's recent song Reduce, Reuse, Recycle, the three Rs.

Basically if we want to have an impact on these blades, one of the biggest things we can do is simply reduce the amount of new materials consumed by wind turbine blades primarily by extending the blade life of the blades on the turbines.

Now ultimately whether it's 20 years, 25 or 30 years, those blades are going to wear out so perhaps we can reuse the materials and avoid the disposal. This is a little bit of a tongue-in-cheek joke but the picture below shows some dormitories created out of some old concrete. Perhaps we can do something along those lines from blade materials.

We also have some other creative uses around here. Unfortunately I don't have time to go into them and then of course recycling, there are certainly some things we can do in developing recycling technologies for blade materials.

Now that's glass fiber. I think one of the key points here is that recycled glass itself doesn't have much value and so we really want to return to this reduce, reuse then recycle strategy and if you go to the next slide, we talk to talk about the carbon fiber so the C in CFRB is carbon.

The key with carbon fiber is as you can tell from one of the previous plots is that it's a lot more valuable. However, recycling that carbon is pretty challenging because at least in wind turbine blades and many other composites, it's mixed-in with the lower-value fiberglass and other things you don't want.

So clearly technology there is figuring out ways that you can split-up this carbon fiber from the fiberglass is one of the technology challenges that we would need to take on.

With regards to increasing the demand for CFRP materials - that's recycled CFRP materials - I think again creative ideas with how you could use these recyclates that come from the recycled materials and also some sort of certification program that would address what the requirements are of that recyclate that you get from those blades. Let's go to the next slide.

So I'm really going to go fast here. Rare earth elements, I don't want to spend much time here but the key points are that there's been a lot of attention on rare earth elements because it affects many, many industries, clean tech industries.

In wind turbines especially direct-drive turbines, there can be quite a bit of this material. There's quite a bit of volatility in the material prices. It's calmed down recently. In fact China even I believe is demolishing or getting rid of the quotas that caused price swings in the past that I'm sure you've heard of, you know, from things such $6 a kilogram to $450 a kilogram.

Bottom line is there's probably not a lot we can do here beyond what the broader industry and other industries are attempting. Next slide. Now generator recycling, this one's pretty interesting. When we visited some OEMs

and generator designers, they basically didn't know what happened to their generators once they left their supply chain.

What they did know is that many of their generators made it back into service, that is they rebuild and reuse these things so the primary source of value there is in the permanent magnet materials and the copper winding.

The challenges, there are some challenges but what I would say is most of the challenges not including the rare earth element is simply separating the materials and categorizing the materials in the generator. Bottom line here, not really many problems, major problems. No major problems in generator recycling. Next slide.

Steel recycling, now this was interesting. We were worried about well, does the paint on the tower and some of these exotic steels used in gearboxes, does that cause problems? The bottom line on this slide is no, it doesn't. In fact what's shown here in this graph is the amount of steel recycled in the United States relative to the tonnage of steel produced.

In fact in 2009 you'll see it exceeds 100% and that's because not much was produced and more was recycled in that year but this picture of a vacuum arc furnace up above, the U.S. economy and most economies are very efficient in recycling this steel. Great material. Next slide.

So I want to wrap-up here, it's 2:00. It's the same summary slide with which are the problems or which are the challenging components? There's some recommendations, specific recommendations on the right-hand slide. For blades, you know, the key thing - the easy low-hanging fruit - is extend the blade life.

There are some technological things we could be exploring in that space. For rare earth elements there's a lot of activity being undertaken. Some of the key things we can do in that space is to effectively fight some of the brain drain that has occurred in that area.

Get some of our smartest folks working on it and also make sure that we're leveraging the existing research that's occurring through collaboration. With the generator, there are some smaller value-add activities there in the gearbox, tower and hub, all of which are steel.

With the gearbox specifically, it may be a value to create a new scrap metal category. With the tower and hub I think that industry is very efficient and productive and there really aren't too many problems that we've compared to these other components in that space so that's my last slide. Thank you.

Ian Baring-Gould: Great, thank you very much Jason. Quickly hop into a couple of questions and then if you have a question again going up to the top of your screen, hitting that Q&A and typing the questions in, please do so.

A question from one listener (John), what about part obsolescence? His understanding is that many of the older turbines have part availability questions. I'm not sure if one of you is in a position to answer that but if you could, that would be great.

I'm thinking not. We'll track that down. I do know that there is a fairly big business in manufacturing of even if it is sole part manufacturing especially in the California area to keep those old wind farms operational even though as Eric mentioned the costs of that are relatively high.

From (Heather Rodes Weaver), are there still many of the 100-kilowatt turbines up and being refurbished and reinstalled elsewhere or are those sizes just being scrapped and Rick, your example might be a good one.

Rick Miller: Sure. Can you hear me?

Ian Baring-Gould: Yes.

Rick Miller: Okay. There is a market for some turbines but we haven't seen it for the kinetic but we have some other turbine types I believe bonus and I'm not sure about the (nordtank) but there is a market. Traditionally I know one project that we took down, the turbines got put in containers and shipped overseas, were reutilized in Europe.

So I think it depends on the turbine itself and I don't know about the United States using those smaller-type turbines, 60 or 100 KWs but there is a market for them depending on the type of turbine it is.

Ian Baring-Gould: Great, and that's it for questions at this point in time so unless people quickly type-in something, oh, let's see. Why not - another question - why not encourage reuse of turbines in distributed wind applications as Europe does? I think that gets to the question that we were just talking about.

There certainly is a market pretty active market for the smaller turbines coming out of California and I do know that there are a number of companies out there and Rick certainly jump in if you would like that do commercially refurbish the California turbines mainly focused on different turbines, the Vestas, the smaller Vestas turbines and the like are commonly redeployed in other places but...

Rick Miller: Well, thanks for the chance Ian because I would like to mention - I didn't mention the aftermarket - need was for some Micon turbines that we had out of site so I should have mentioned that. Some of the other types just haven't had the we haven't seen the desire for them and I guess in general I'll just say because it's worthwhile, I showed a lot of construction pictures are our goal when we do the decommissioning is just to get into a net zero on the books.

If the construction company we hire APC can get some value out of the scrap metal or the turbines themselves and get our costs under zero, that's what we're kind of shooting for when we bid-out these projects so there's definitely a market out there. I think people are going to start taking advantage of it.

Ian Baring-Gould: Great. Another question for your Rick. How do you factor-in the NEPA process into the repowering process on federal-controlled lands? Do you have to go through completely new NEPAs?

Rick Miller: Well, look, that's an interesting question. There aren't a lot of wind products on BLM-controlled land yet. I don't know if there will be and it's similar with CQUA. We've run the gamut. I mean, to be honest with you some of the decommissioning we've done on just the local jurisdiction approval and then gone in for the full-on consultation for the new projects.

Other times we've approached it totally differently and we've gone in for consultation and then done NEPA or CQUA with the full decommissioning restoration and then new construction.

So in general I think the answer to the question is if you know what is involved in decommissioning at the time you give your initial entitlement and you can include it to the level of detail required by NEPA, that's certainly fine.

I found most jurisdictions are uncomfortable with that. They're just worried about approving something that's going to happen 25 years from now so we've seen different agencies do different things. I don't really know a specific to the BLM where they're at right now but if you can figure out a way to get that into your plan of development up-front, I think it's worthwhile to try.

Ian Baring-Gould: Great, thank you and I think that's all of the questions at this point so again thanks to the speaker and quickly some final slides before we go. This is a list of the Webinars that we're planning over the next couple of months.

As you can see the next three of them are really focused on national development and deployment sighting conditions so an overview and looking at avian species in February and April looking at sighting considerations with a focus on radar and then tentative right now but we're almost positive that June will be on public wind and public engagement in regards wind deployment.

As you'll note by this, we're dropping the Webinar series at least for the foreseeable future down an every other month and that's mainly because the regional wind resource centers that are funded by the Department of Energy are starting to hold kind of regionally topical Webinars.

And so we're trying to build a little space in the agenda so that we're not Webinaring everybody to death and filling-in a little bit of time for the regional groups to be doing Webinars that are regionally-focused on activities that are pertinent to those specific areas.

But we'll certainly keep these Webinars as well as all of the regional Webinars in the wind exchange e-newsletter so that you'll be able to keep up-to-speed on what's happening.

Just lastly the contact information for (Bree), myself and (Suzanne), the kind of leadership of wind exchange and we're always looking forward to any kind of feedback that we have from anybody.

Again I thank you to all of you and then a thanks again to the Department of Energy that supports this activity, the wind and water power technologies office that also supported as was mentioned during the presentation Eric Lantz's and Jason Cotrell's research in repowering and recycling. Both were funded by the U.S. Department of Energy.

So again thanks to all three of our speakers, Eric, Rick and Jason and we'll look forward to hearing from you either at the next Webinar or before then so thanks everybody and have a very good new year. Bye-bye.

Coordinator: This now concludes today's meeting. All lines, please disconnect.