CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

Operating High Variable, Renewable Generation Power Systems: Lessons Learned from Ireland and Northern Ireland

—Transcript of a webinar offered by the Clean Energy Solutions Center on 16 September 2015—
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Webinar Panelists

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Sean Esterly

Today's webinar is focused on operating high variable renewable generation power systems, lessons learned from Ireland and Northern Ireland. And one note of mention before we begin is that the Clean Energy Solutions Center does not endorse or recommend specific products or services. Information provided in this webinar is featured in the Solutions Center's resource library as one of many best practices resources reviewed and selected by technical experts.

And I just want to go over some of the webinar features. For audio, you do have two options. You may either listen through your computer or over the telephone. If you do choose to listen through your computer, please select the mic and speakers option in the audio pane. Doing that will just help eliminate any echo or feedback. And if you choose to dial in by phone, just select the telephone option and a box on the right side will display the telephone number and also the audio pin that you should use to dial in. And if anyone's having any technical difficulties with the webinar, you may contact the GoToWebinar's help desk at the number displayed at the bottom of the slide. That number is 888-259-3826.

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Now, today's webinar agenda is centered around presentations from our guest panelists, Robbie Aherne and Lisa McMullan, and these panelists have been kind enough to join us to give us lessons learned from Ireland and Northern Ireland on operating power systems with high levels of variable renewable energy. Before our speakers begin their presentations, I'll provide a short informative overview of the Clean Energy Solutions Center initiative, and then following the presentations, we will have a question and answer session, where the panelists will address questions submitted by the audience, followed by closing remarks and a brief survey.

And this slide provides a bit of background in terms of how the Solutions Center was formed. The Solutions Center is one if 13 initiatives of the Clean Energy Ministerial that was launched in April of 2011, and is primarily led by Australia, the United States and other CEM partners. Some outcomes of this unique initiative include support of developing countries and emerging economies through enhancement of resources on policies relating to energy access, no-cost expert policy assistance and peer-to-peer learning and training tools, such as the webinar you're attending right now.

And there's four primary goals for the Solutions Center. First goal is to serve as a clearinghouse of clean energy policy resources. Second is to share policy best practices, data and analysis tools specific to clean energy policies and programs. And third is to deliver dynamic services that enable expert assistance, learning and peer-to-peer sharing of experiences. And then lastly, the center fosters dialogue on emerging policy issues and innovation from around the globe. Now, our primary audience are energy policymakers and analysts from governments and technical organizations in all countries, but then we also strive to engage with the private sector, NGOs and also civil society.

And one of the marquee features that the Solutions Center provides is its no-cost expert policy assistance, known as Ask an Expert. And the Ask an Expert Program has established a broad team of over 30 experts from around the globe who are available to provide remote policy advice and analysis to all countries at no cost. So, for example, in the area of regulatory and utility policies, we're very pleased to have J. Riley Allen, director at the Regulatory Assistance Project, also known as RAP, serving as one of our experts. So if you have a need for policy assistance in regulatory and utility policies or any other clean energy sector, we do encourage you to use this valuable service. Again, the assistance is pry—provided free of charge. So if you have a question for our experts, please submit it through our simple online form at cleanenergysolutions.org/expert, or to find out how the Ask an Expert service can benefit your work, please feel free to contact me directly at Sean.Esterly@NREL.gov, or at 303-384-7436, and both of those are displayed on the slide right now. And we also invite you to spread the word about this service to those in your networks and organizations.

So now I'd like to provide brief introductions for today's panelists. First up today is Robbie Aherne. Robbie is the DS3 program manager at EirGrid, the transmission system operator in Ireland. He received his BE in electrical engineering from University College Cork, Ireland, and recently completed a master of science in electricity power systems from the University of Bath in the UK. He's been working in EirGrid for ten years in a variety of roles, including power systems planning, near time and real-time power system operations and long-term strategic operational planning. He's a member of the ENTSOE and ancillary services working group, the Cigre Ireland National Committee and the Engineers Ireland Electrical and Electronic Division Committee.

And then following Robbie, we will hear from Lisa McMullen. Lisa works on the DS3 program at EirGrid, the transmission systems operator. She received a BE in electrical and electronic engineering and master's of science in energy management from Dublin Institute of Technology. She's been working in EirGrid for six years in a number of different roles, including power system access planning and more recently in long-term strategic operational planning and real-time power system operation. And with that, I would now like to turn the webinar over to Robbie and Lisa.

Robbie Aherne Hi, good morning or good afternoon, depending where you're at. We're delighted to get an opportunity to present to the Clean Energy Solutions Center on the experiences in Ireland and Northern Ireland of operating a power system with high amounts of variable renewable energy in a safe, secure and reliable manner. I suppose we're going to split the presentation here today. I'm going to first of all set the policy context and talk about some of the initial studies that we've carried out, talk about the evolution of the DS3 program, which both Lisa and I work on and I'm going to give a sense of where we are today and the challenges that we had to overcome to get into our current position where we would operate with up to 65% of our energy consumed in real time coming from wind power.

My colleague Lisa is going to talk about the key enablers going forward and what we need to do to achieve our ambitious Ireland and Northern Ireland government mandated renewable targets. First of all, maybe just give you some context on EirGrid's role. We are the transmission system operator and market operator in both Ireland and Northern Ireland. So we were—we're—the Irish electricity system has been deregulated, so EirGrid sits alone as an independent body which is responsible for operating the transmission system and overseeing the electricity market in both Ireland and Northern Ireland. We are a fully independent body and have no relationship or no ownership of any generation or indeed network assets.

Just to give you a sense of the power system of Ireland and Northern Ireland, you can see there the island of Ireland is represented in orange, at the—on the western seaboard of Europe. At the moment, we have about nine gigawatts of conventional plants installed on the island, and typically these—the generators that comprise this nine gigawatts are actually quite large relative to the size of our system. A large number are greater than 400 megawatts in size, or greater than 0.4 gigawatts in size.

We have 2.8 gigawatts of wind farms installed on the island currently, and we have a peak demand of around 7 gigawatts for _____ and _____. We have a valley demand, during our summer when the weather is relatively warm, anyway, for Ireland, we have quite a low demand of around 2.3 gigawatts. Now, that's very important in the context of having 2.8 gigawatts of wind installed, because potentially we could meet our fully—our power system demand needs from wind. However, for many technical reasons which both Lisa and I will go into. That just isn't technically feasible right now.

We are a separate synchronous AC system, and by that I mean we are connected to the larger systems in Europe by two HVDC links. So in essence, you could say that we're an island-powered system, weakly interconnected to other systems. We have two HVDC links, one between Northern Ireland and Scotland, and another one between Ireland and Wales. They both come to 1,000 megawatts in size. Now, we've always been an isolated power system, and in essence, we've always had to be flexible and a lot of the challenges that we have faced and will continue to face, we will face on our own. And that's just by nature due to the isolated nature of the Irish and Northern Irish power system.

Looking at the renewable targets for 2020, this is broken out by member state in Europe. And Ireland has a—Ireland and Northern Ireland both have a renewable target of 40%. So 40% of all energy consumed by 2020 will come from renewables. Given that we have already exploited our hydro resource and given that we have a very—an excellent wind resource, really, the vast majority of that will come from wind. So by 2020, 37% of all energy consumed will come from wind energy. Now, that's a very ambitious target. There are other countries with higher renewable target, and indeed, Denmark has a higher wind target. However, what makes Ireland and Northern Ireland unique is that we're an island-powered system.

So whereas Denmark, for example, can rely on the larger continental Europe systems, the German system, for example, we really have to, I suppose, manage any of the challenges that we face largely on our own. Europe consist of about six large synchronous area, where you have the island of Ireland, you have the island of Great Britain, you've continental Europe, Scandinavia and then you have a number of islands in the Mediterranean.

So Ireland, who is also a different synchronous system, would have the most ambitious renewable target for 2020. And if you look at over the last say even 2010 to 2013, the fuel mix in Ireland has really radically changed. The pie chart on the right shows the fuel mix in 2010, and if I could point out the purple is the amount of electricity we got from gas, that was actually 61% in 2010. By 2013, that actually had dropped down to 45%. That really is a radical shift on the power system. And the majority of that change has come from increased amount of winds on the system and also increased interconnections across to Great Britain.

Now, last year, approximately 24% of all our electricity consumed came from renewable sources, again, with the vast majority of that coming from wind. So we're well on our way to meeting our 40% 2020 target.

We've had to—those targets were originally set in 2008 by our government and mirrored in Northern Ireland in I think late 2008, maybe 2009. We actually carry out a lot of technical analysis to assess how we're going to safely and securely and also economically operate the power system with such high levels of wind power. Really, it hadn't been attempted on another power system like Ireland anywhere else.

So in 2010, we kicked off the facilitation of renewable studies, and these studies took place over an 18-month period and we employed 3 external consultants, industry leaders like Siemens, like TNEI, et cetera, to carry out analysis on our behalf. And we really looked at all the different technical challenges that a power system could face, looked at the impact on frequency, small signal stability, transient stability, voltage stability, et cetera. We really looked at it from every angle.

That was peer reviewed by two external members of the power industry in Ireland, both well respected, both locally and also internationally. And at the time, that was the most comprehensive wind integration study of its kind in the world. Now, I'm just going to talk about some of the key findings from that particular study, and I suppose talk about how that has shaped the analysis that we're carrying out today.

So one of the key findings of this is the impact is where the system frequency in Ireland is normally 50 hertz, and indeed, 99.7% of the time, the frequency would be really quite close to 50 hertz. However, at times, generators do trip and that can cause the frequency to move away from 50 hertz down towards 49 hertz. But the graphic here shows the system frequency on the vertical axis going from 50 hertz. And then on the horizontal axis, it shows largely wind over you load. So say, for example, we had 2,000 megawatts of wind on the system and 4,000 megawatts of load, we'd roughly 50% of our demand would be met from wind.

And the green diamonds represent the system frequency following a large generator trip on the system. So you can see we're quite happy, really, if you look up to say 40% of wind over load, the frequency really doesn't dip that low, it stays above 49.5 hertz, and we're quite happy. Really we're quite happy if it stays above 49 hertz, however, when we started to go to higher wind over load percentages, we started to see the frequency going below 48½ hertz, and indeed going below 47½ hertz. And that's something we're not comfortable with and we wouldn't be willing to operate a system in that manner.

And the reason for that is if you can consider your local town, if, for example, that got isolated from the large power system, that may—and, for example, you had a wind farm feeding that local town, in theory, that's [Break in Audio]. But the system frequency would quickly move away from 50 hertz, given the variable nature of wind. And we have what are called—we have a special device called ROCOF relays, which are designed to detect that.

Now, if you have a very light system and you lose a large unit, those ROCOF relays can unintentionally operate, so you've lost your generator and now you've lost a whole load of wind, which causes your system frequency to go very low, as illustrated in this graph. So what we've done to resolve it is we are working with our colleagues across the industry to change the set points on these ROCOF relays, these are special protection devices, and essentially remove them from the equation really. And you can see there the blue boxes; the system frequency stays above 49 hertz, out to approximately 80% of wind overload.

So that's an absolutely vast improvement and making that change resulted in a significantly more stable power system. So that was the first issue that we had to resolve. The second issue is at very high levels of wind on the system, if you get a fault, you actually can lose a lot of megawatts on the system. So if you remember I said at the start of the presentation that our largest unit is typically around 400 megawatts on the island. However, the graphic—the three-dimensional graphic on the left-hand side shows at very high levels of wind, actually you can have a significant amount of faults, but they could be lightning strikes on the transmission network, which results in losing more than 400 megawatts, so in fact more than the largest unit on the system.

And obviously that's something we have to carefully watch and manage. The graphic on the right-hand side effectively shows the number of cases where actually you lost more than 500 megawatts, and that really was—it was too many cases and again would've put our system at risk. The third key finding we found was the risk to the dynamic stability of our power system. So by dynamic stability, I mean if you consider a tent which is anchored down via various pins to the ground, the more pins you take out, the more weakly that tent is anchored and the higher the risk that it effectively could get blown away.

Well, that's a good analogy for a power system where, if you continue to take off more and more conventional generation to make way for wind, you can actually end up in a very light system, to the extent that it could actually potentially—you could actually potentially lose it and have a blackout on the system. What this graphic shows, actually up to around 60, 70% wind over load, you actually have strong dynamic stability, so your system is well anchored. However, you do reach a tipping point, and if you start to go to 80 and 90% of all your demands are met from wind, you end up with a scenario where, again, you've taken too many pins out of your tent and essentially you have—you—there is a real risk that you could lose your power system.

But that's another issue that we have to manage. And the final one is the voltage reactive power control. So essentially to operating any power system is ensuring that your system voltages around the network stay within—stay really within limits. And we've found as you take off more convention—more and more conventional generation and replace it with wind, you actually can have a reactive power shortfall. And oftentimes people would make up for that shortfall by installing these devices on the network called capacitors. But you can only bring that so far, and indeed, you can again reach a tipping point for a system with an awful lot of wind on the system and an awful lot of capacitors installed to make up that reactive power shortfall, and indeed, you can—actually you have the potential of losing your power system. So that was the fourth issue that we needed to manage and was the fourth key finding from those facilitation of renewable studies.

Maybe just to kind of talk about it maybe bring it back to, again, one of the key drivers for any of the issues that we face on the system is when a generator trips. So if you look at there at the _____, say typically the frequency is at 50 hertz, and indeed, 99.7% of the time in Ireland and Northern Ireland, the frequency would be within .1 of a hertz or less than a small percentage of 50 hertz.

However, if you lose a generator, you actually can result in a significant frequency oscillation, and we would see in Ireland the frequency could often go to the—from 50 hertz down to around 49 hertz. Now, that's a big frequency swing and would be a big swing in the context of larger power systems, for example, in the US or Europe. In a scenario where you take off more and more conventional generation replaced with wind, the inertia on your system since that weight that's holding the system together is decreasing all the time, and the more of that you take off, the sharper this frequency drop is, and indeed, the lower the frequency would go.

To arrest that, you'd use your reserves. You actually basically pump megawatts into the system to make up for that frequency drop and that tends to bring the frequency up over the next five, six minutes, up towards 50 hertz again, and essentially contain the frequency drop and then bring on reserves or basically bring it back up to 50 hertz. You've got your normal operating period, your generator trips, and then your recovery period. When you have a system with a lot more wind, this actually gets—it becomes more challenging to handle.

And we carried out analysis, again, as a part of the facilitation of renewable studies back in 2010. And on the vertical axis, it shows that system inertia, and it's measured in what are called megawatt seconds, but typically in Ireland that we would have around 30,000 megawatt seconds on the power system. And back in 2010, you can look there, it's an inertia duration curve. So on the vertical axis, it shows the amount of synchronous inertia on the power system, and on the horizontal axis, it shows the hours—the 800—8,760 hours of the year. So basically what this graph is showing is approximately 100% of the time, the frequency is—or the inertia is above 25,000 megawatt seconds.

And this is all based on 2010. However, we carried out analysis to get a sense of what this curve would look like in 2020 when you replace a lot of conventional generation with wind. And you can see there the blue curve, it's a lot lower and indeed, a lot—for a significant period of time were below

25,000 megawatt seconds. An analysis that we have carried out has shown that this is potentially an insecure region in 2020. So effectively, you've taken off conventional generation, you've replaced it with wind, and that is posing challenges. And the only way really of resolving this is by bringing on and constraining on heavy conventional generation, and that costs money. And it was important for us to try to minimize any costs like that. Similarly reactive power, and again, this is the power that helps keep the voltage around our transmission and distribution network within limits, if you look at the 2010 versus 2020 case, again, there's a significant drop, a very real drop. And again, that's because you placed your—the amount of conventional generation on the system has significantly dropped.

Now, it has to be said that wind farms actually have some reactive capability, and if you do overlay that on the 2020 conventional generation reactive power curve, the gap is somewhat closed. But I guess it has to be said that typically we would install—or traditionally generation would've been installed very closed to the major road centers. So you would've had that voltage support right beside the biggest requirement for that voltage support. However, now, the majority of wind connects in remote regions, windy regions, so that voltage support is no longer quite so close to your load and maybe it isn't—we won't have quite as robust—again, if it's not managed, we won't have quite as robust control of our voltage, unless we take the necessary actions that Lisa will discuss further.

So that really kind of wraps up the facilitation of renewable studies. They took place over an 18-month period. They looked at it from every different angle, really. You can see all the different technical issues that were resolved, and really it kind of boiled down to, I suppose, four key issues that, again, that Lisa will go into in more detail in her section of the studies. But it was very important for us to carry out this very comprehensive wind integration study, because we had, at that time back in the early part of this decade, very ambitious target. We needed to develop a clear path and identify the key challenges that allowed us to meet those targets and that we needed to overcome.

So after the facilitation of renewables study was complete, it—essentially we created the DS3 program. Now, DS3 stands for delivering a secure, sustainable power system. And it was launched in 2011 and really built on the work of the facilitation of renewable studies and, indeed, other detailed technical studies we've been—we've carried out in—between 2008 and 2011.

And really it's about meeting the policy objectives in Ireland and Northern Ireland efficiently while maintaining system security. So whilst we have these ambitious renewable targets, it's very important that we continue to have high quality power supply. No one will thank us if, for example, we lost the power system whilst we were having, say, high levels of wind or renewables on the power system. It's very important to strike that balance. It's a very broad program. It's not just technical in nature, although maybe it was kind of evolved from technical studies; it also takes account of the commercial needs of the power system into the future.

And a very important aspect of the DS3 program right from the start was engagement with all industry stakeholders. We recognized that the DS3 program is really going to result in significant changes to how the power system is operated and it's very important to adopt an open, collaborative and transparent approach and work with other industry stakeholders to ensure that, I guess, we take the right approach and that we are meeting our challenges and in a very sound, considered manner.

So the DS3 program really consists of three pillars. The first pillar is system performance. So if you go from a system where traditionally it is dominated by conventional generation to one where renewable generation and particularly wind will now be the predominant force, how your system performs is just going to change. For example, we need to look at how our grid code needs to evolve. We need to carry out performance monitoring in a different way now that our system performing—is performing in a different way.

Even how your system performs changes. You need to develop new policies, particularly for use in the real-time control centers in Dublin and Belfast, to help you and ensure that you can continue to operate a very secure and reliable power system. And finally, operating a system with a lot of wind, it is more complex. Previously on the island we had nearly 80 generators on the system. Now we're going to move from one where if you take up, I suppose, all the individual wind turbine generators, now we will have a power system where you will have thousands of turbine generators operating on the island at any one time. And that's a lot more complex and we have had to develop new tools to ensure that grid controllers can securely and reliably operate the system, that more complex power system.

It has to be said that the DS3 program, it's about meeting the government targets, but most importantly it's about meeting them in a secure and reliable manner. Quality of supply, quality of electricity is—has always been very high in Ireland, and we would have a lot of, say, for example, semiconductor plants on the island who would've come to us because of our high quality of electricity supply, and it's very important that we maintain that, whilst also meeting our government targets.

Now, that's really, I suppose, the overarching objective of the DS3 program. I suppose the key metric for the DS3 program is if you—it's a metric called SNSP, or system non-synchronous penetration, and that's represented here in this graphic. On the vertical axis, essentially you've got your system load and on the horizontal axis, you've got your wind. Now the graphic there, the green section, we can operate the system with up to 50% SNSP levels, and that's where we currently operate the system. So at the moment, right today we would operate the system where up to 50% of our—all of our demand is met from a combination of wind, and I also should say from interconnector imports from Great Britain. The metric that we call that is SNSP, or system non-synchronous penetration.

The analysis that we have carried out has indicated that we can operate the system in a secure manner once we overcome the challenges I previously described, and again, which Lisa will go through in more detail. We can raise that SNSP up to 75%. That's represented by the orange area in the graphic above. We believe, based on the technology that's out there at the moment, we cannot go above 75% SNSP today. So we couldn't go to a scenario where 100% of our demand would be met from wind and interconnector imports. We would always need some conventional generation plants on our power system.

And look, we've a lot of challenges to get to that 75% SNSP, to get—go from 50% today up to 75%, there are a lot of challenges. I just mentioned there a changed power code. Previously our generation would've been located close to our large demand, where now it's actually going to be located on our western seaboard _____ on the graphic here you can see the island of Ireland, our major load center, about a quarter of the island—of the population of the island would live in the Dublin area. The largest wind resource is on the western seaboard. So that's a total change on our power flows. We also have a lot more variability. Wind can blow at different megawatt outputs over any point in the day. It doesn't follow any set pattern. And that represents a lot of challenges. We need to build a lot of new infrastructure, and indeed, we have data and plans in place to allow us to do that.

But really I'm going to focus on the operational challenges that we are handling through the DS3 program, which I mentioned there a number of minutes ago. So why is SNSP so important? I mean, why is there so much focus on it? Certainly from developers in Ireland in Northern Ireland. Well, this graphic actually shows we would need to install around 4,600 megawatts of wind on the island by 2020 to meet our targets. At the moment, we've about 2,800 megawatts of wind installed. So we've a gap of around 1,800 megawatts of wind to make up in the next two years.

Now, this graphic, you can see there back in 2000, that's really when the first wind farm was installed on the island. It's grown really quite quickly, and to meet the 2020 targets, we're going to have to install around 300, 350 megawatts of wind per annum to meet the target.

Now, if that SNSP—so as a reminder, that is your wind and interconnector exports over your system demand—if that stayed at 50%, the actual—you would have to reduce the output of wind by 25% of actually what it was capable of. We call that curtailment, just to ensure that you have a secure power system. So if, for example, a wind farm was capable of generating 1,000 megawatt hours. For system security, we even—we couldn't allow it go above 750 megawatt hours in any one year.

We believe by getting to 75% SNSP, curtailment levels will actually drop to around 5%, and that's very important. That five% figure is very important for wind developers, because essentially, if wind curtailment goes any much higher than that, their wind projects won't be bankable. So that's really one of the focuses of the DS3 program. It's about raising the SNSP from 50% to 75%, which, in turn, will ensure that wind farm curtailment will drop from 25% down to 5%.

And like, if you can't use five% of the output of wind farms, that's—obviously we'd like to use it all, but that is seen as a reasonable approach. To get to 50% in real time, that was a challenge in itself. We had to be able to control our wind farms all around the island from the control centers in Dublin and Belfast. So at the moment, around 70 or 80% of all our wind farms can be controlled from those two control centers. We have best in class wind forecasting. We have had a wind forecaster in our control center since 2002, actually. And we now—we—I suppose, originally we started of the wind forecasting ourselves, but now we have two external vendors and they are incentivized to provide, of course, highly accurate wind forecasts.

We carry out online real-time dynamic assessment of the power system, and really what that means is we carry out detailed technical analysis every five minutes approximately on the stability of our power system. And indeed, we were the first utility to do that back in 2011 and I suppose it is still the exemplar for this type of analysis. We also rigorously enforced standards on all of our generators. So we—our standards are defined in the grid code and we have—we, I suppose, performance monitor those vendors and ensure that plant was doing as it was mandated to do in the grid code.

So I mentioned the SNSP at the moment is limited to 50%. You can see there in the first 2 weeks of 2015, the SNSP regularly hit just—was just limiting—just hitting that 50% limit. That dashed red line should be—there's a kind of a typo there, but that would be at 50%. We can't exceed that limit. But we are—I suppose what this graphic really illustrates is that we are regularly hitting that 50% limit in real time.

This next graphic, it shows October 2014. As I said, the SNSP limit takes account of wind and interconnector imports over your load. Now we do—we, at times, will actually export on those interconnectors from Ireland and Northern Ireland to Great Britain, to—I suppose to take full advantage of the wind resource on the island. So actually, we actually have had up to 65% of our system demand being met from wind, if one assumes that all the conventional plant was exported on the interconnectors. But that is, I guess, very high real-time measurements.

Now I'm going to hand you over to my colleague. I guess I just set the scene there. I just wanted to kind of, I suppose, really bring you through how we got to where we did in the DS3 program, I suppose what we had to do thus far, all the technical analysis, and the various, I suppose, bodies of work we had to carry out with the industry to be able to operate up to 50% SNSP. My colleague Lisa now is going to talk about reaching 75% SNSP.

Lisa McMullen Thanks Robbie. Hello everybody. So as Robbie said, I'm going to now look at what is required in order to move forward into further _____ SNSP to _____ _____. So there are a couple of top items. Firstly, we need some additional system services. We need to change our ROCOF standard. There's revised operational policies that we need to implement and we also have a range of new control center tools. So I'm going to go through each of these in a little more detail now.

So firstly looking at systems services, so these services are those additional products that are required for security systems other than _____ and as Robbie said, non-synchronous generation is replacing the traditional synchronous generation on the power system, and with that comes the loss of traditional support services. So additional services are now required to manage the power system and safely and securely.

As I _____ _____ a number of the DS3 studies, including facilitation of renewables study, we've identified a number of areas where we have technical challenges on the system. So firstly a little context into those challenges. A reduction in the conventional plants means that we have a lower system inertia and a lack of synchronized _____, which means that the system is essentially live share, which is resulting in faster and more severe frequency fluctuations.

This is impacting our frequency in the DS3 _____ system with the lowest frequency rates that we're seeing, and it's also increasing the rate of change of frequency, or the ROCOF that's seen across they system, as well. With less controllable reactive power from the conventional units, we need to—the large portion of wind that's displacing the conventional generation and is absorbing _____ so we're having severe voltage issues, and the increased variability and uncertainty of the portfolio means increasing the ramping capability and across the system as well, so traditionally _____ _____ that were very conventional units might have a ramping up time of 8 or 12 hours, and which when you have really quick fluctuation in the wind generation, we need to improve our ramping capability.

The active power recovery rates of wind farms is also slower than conventional units, so if there's a fault on the system, the conventional units will generally recover almost instantly as will the demand, where wind farms have a slower active power and response. So we can see that sometimes there's a resulting frequency dip in our studies because of the slower active power recovery off the wind farms.

So this kind of gives a flavor of the technical challenges that are placed on our power system and why we need additional systems services to overcome these challenges. So I'm now going to give a quick overview of the mechanism for how we will procure these services, and a little detail on the 14 services that we will be requesting, as well.

So this slide shows the current market breakdown, so it's just the graphic here. So currently you would have a large block of the energy market is in the energy payments, then we have a block of capacity payments, and finally at the top there's the ancillary services or the systems services section. For the revised market now, there's a much bigger budget for the ancillary services or the systems services and a reduction in the energy payments and capacity payments. So the top dotted line shows where generators would need to be to be making a profit in the energy market. So you can see before that they wouldn't necessarily need to be providing ancillary services in order to make a profit in the energy market in Ireland and Northern Ireland.

But now with the revised market, you will need to be providing some services in order to make a profit. So the purpose of the new market is to incentivize the right mix of systems services to operate the system, with increased levels of non-synchronous penetration. So the _____ _____ incentivizing them to have the correct mix of services to match the system needs.

So just to look at the systems services products that we have, so originally we would have 7 products and we've increased that now to 14 products. So just looking at frequency control quickly, the graphic shows from the time period of zero seconds to a number of hours. So the box in the middle shows the traditional services we would've requested for reserves. So primary and secondary operating reserve and tertiary reserve so between 5 seconds and 20 minutes is the reserve times we would've requested previously.

Now we're looking for faster response times between zero and five seconds. So we're looking for a synchronous initial response to incentive synchronous generation to operate below them in the end, so that they won't be impacting the dispatch but they will be providing inertia. We're also looking for fast frequency response with the reserve _____ that can quickly provide an active power response to avoid those high ROCOFs and the low frequency nadirs, and also fast post-fault active power recovery for the wind farms. So as I was saying, I know that the wind farms have a slower active power response, so this service is to incentivize a faster recovery time for those wind farms.

In the longer term timeframe, we'd also be looking for additional ramping products for—from one hour to three hours to eight hours ramping capability time. So this is, for example, between the 6:00 am to 9:00 am load rise, if the wind _____ was to unexpectedly drop or a generator was to trip, we need to have the capability to ramp up conventional generation to compensate for this.

And then moving on to the voltage products that we've been procuring, in the area of voltage controls, we've introduced a new product dynamic reactive power, and this is a new product in the _____ timeframe to [inaudible due to background noise] and the stability of the power system. And we've also redefined our _____ for steady-state reactive power. The generators are currently paid for a megawatt range of their maximum output, but we're incentivizing generators to have a _____ facility across the four megawatt range for that generator.

Moving on then to ROCOF. So our current standard for the rate of change of frequency is 0.5 hertz per second in the control center. So we're proposing a change to that standard to 1 hertz per second over 500 milliseconds timeframe. So I think Robbie has briefly touched on this already in terms of why we need to change the ROCOF standard. There's three reasons that we would be looking to change ROCOF. So there's reduced inertia levels at the reduction in conventional generating, or through the loss of _____ increase, it could result in the cap getting—tripping our wind farms and generators at this current standard. Secondly, a severe fault that results in a frequency event could also result in cascading tripping of wind farms. And finally then the loss of main protection around _____ already, the distribution protection related to _____ _____ protection.

There are differing views in the industry at the moment. So the wind farms have no issues with this revised setting. They have—they are pro the new standards as they hope it will reduce curtailment on the [inaudible due to background noise] for investment. The DSOs, then, or the distribution system operator are concerned about revising the ROCOF standards as it might impact their loss of main protection, and the implications that might have for _____ _____ protection on distribution efforts. Conventional generators, then, are concerned about wear and tear on their units and the safety of their plants by changing the standard to one hertz per second.

So looking at then our ROCOF implementations project, given the concerns that have come from industry, we've had significant engagement and across the industry to see the issues that the different parties have with this ROCOF implementation project. It's now become a two-strand project, so a plan A and a plan B are being progressed in parallel with each other. So plan A assumes that we can move to a one hertz per second standard, and it has two aspects within it. There's a generator studies project, which request that all conventional generation connected to the power system will carry a certain analysis. So firstly electrical dynamic simulations to assess the impact on the transmission system, and of the initiative, it is the standard of the higher ROCOF. And secondly, then, a mechanical plant integrity study to assess the impact on the unit itself of withstanding higher ROCOFs.

The second phase of plan A, then, is a TSO/DSO implementation project, the joint project between EirGrid and the distribution system operators in Ireland and Northern Ireland. The DSOs are assessing if they can protect against _____ _____ on the distribution network through other means or different types of settings or _____ a ROCOF relay. It also involves bench testing of ROCOF relays and requesting the ROCOF _____ capabilities of the embedded generation on the distribution system.

The plan B then assumes that we remain at the .5 hertz per second ROCOF standard. It investigates and perhaps it proposes alternatives to a ROCOF—to changing the ROCOF standard. This project might be able to complement with the system services that we're requesting, as well.

Another project besides DS3 is realizing potential of distribution generation. So a large portion of the wind that is connecting to the entire system is connected to the distribution system. This project looks to realize the full potential of controllable distribution and connect to wind farms in terms of frequency control, voltage control and then ROCOF protection, as well. It's being carried out by the joint TSO and DSO engagement project. So if we look at just, for example, the DS3 voltage control approach, it's to ensure that all controllable wind farms realize their full potential for reactive power production and voltage support.

So now I'm going to go through one pilot project that's being carried out between the DSOs and TSOs for voltage control. So there's a specific area and on the network a specific node called Cauteen where there's a large cluster of wind farms that are connected to the distribution network. We're using this station as the pilot for a voltage control—node of voltage controlling. Analysis has been carried out to determine the voltage support that is required in the area, given the large level of wind that connects to the distribution system.

The table at the bottom right shows the mega VAR requirements for voltage support, and depending on what settings you have the power factors set to for the wind farms, so it ranges from 145 mega VAR tradition and support would be required if all of the wind farms at Cauteen are absorbing _____. Then we if [Break in Audio] we change the power factor setting to unity power factor, we'll need 55 mega VARs of additional support, but if we do use the full potential off the PSO, that the distribution in wind farms there would only require 15 mega VARs of additional reactive force. This would reduce the amount of network investment that is required in the area, if we can change these wind farms to fully use their potential. So we'll save around €14 million instead of having to invest in _____.

The next aspect, then, is the operational policies, so a big part of the DS3 program is to inform operational policies for use in the control center and across the operation department. This is tied right to engagement with real-time and near-time operation departments in EirGrid's control centers. If they're based on technical analysis that we've carried out across the DS3 program, they are required to be operating the system significantly differently to—in comparison to how it was operated traditionally.

So we do have an operational control process in order to implement the devised policies, but it _____ if we're suggesting revised policy for use in the control centers, we would have analysis carried out within the DS3 program to create the policies. The policies are peer reviewed and we have an operational policy review committee which is made up of managers from across the company that will review this policy before it is sent into the control centers. And if the policy is approved, it's trialed in the control centers before becoming permanent policy.

Moving on then to the control center tools, since the inception of DS3, we've had a range of different tools have been required. In 2011, there were certain tools in place to manage the system as it was, and this needed to be revised once we started connecting larger amounts of non-synchronous wind generation. So a number of tools have been implemented since that time. As Robbie described earlier, we have the wind security assessment tools, such as online dynamic stability assessment in the control center. We've also implemented an online real-time short circuit tool, which is being trialed in the control centers at the moment. It's run every 15 minutes and it alarms if there's any breaches to short circuit levels across the system, so it ensures a more proactive monitoring of the network in terms of short circuits.

We also have the wind dispatch tool, which was implemented in the control center. As the levels of wind increased on the system, a tool was required to manage the dispatch of these wind farms on an individual basis. So the tool introduced the capability to constrain or to curtail each wind farm across the system in a more centralized way. There's also a number of tools that are in the planning phases at the moment. So we have a voltage—a proposed voltage trajectory tool, as we try to increase the wind generation and reduce the number of conventional units on the system, a tool is required to ensure that the system is secure from a voltage and a transient stability point of view. As Robbie said earlier, we have a valley load at night time of about 2.3 gigawatts of demand. So we're trying to increase the level of wind that we would have on the system at night time, while still ensuring a secure and stable system.

Another tool we're proposing is a ramping tool, which I'm actually going to go through in a little more detail in just a moment. Finally, there are potentially other tools that we may require in the future as we increase the levels of wind on the system. These tools may come from further DS3 analysis or operational experience in the control centers, or internal or external workshops that EirGrid are involved in. But there may still be scope for further tools in our control centers.

So looking then at the ramping tool, basic concept of this ramping tool, as I said earlier, it's one of the system service requirements that we have in order to ensure that, given the variability of wind, that we are able to meet the system demand if the wind changes significantly unexpectedly. So this graph shows the demand on a particular day of the year, so for a 24-hour period. The megawatts is on the left-hand side there. If we look at, then, the forecasted wind for that day, as well as the forecasted demand and forecasted wind, you can see there's quite a difference between the wind and the demand. The green line then shows the next demand, so the demand minus the wind, so what could've been met by the wind generation on that day.

The partial wind trap here is at about 5:00 to 7:00 in the evening, so the evening load rise. We have an increase in the demand, but the wind also has that moment to produce, as well. But this here shows, again, the _____ just hones in on that period of the day between 2:00 and 8:00 pm. So ramping duty is the difference between the 3,500 megawatts and demand up to 5,000 megawatts in the space of 3 hours, which cannot be met by wind generation. But this demand needs to be met by conventional generation.

This change in megawatts is called the ramping duty, but at the same time, these are based on forecasted times, so we need to factor in an uncertainty level, as well, in case the demand is slightly higher than what we have anticipated or the wind is slightly less. So this is the ramping requirement over a number of hours for this particular day.

So the ramping tool will basically calculate the requirements for—the ramping requirements before for each hour period between one and three and eight hour periods. So the ramping duty is the forecasted load plus the forecasted wind, and we also include a forecast error. There's a load and a wind forecast error, and then a generator availability error which is based on whether the generator has not started or a generator trips off, and this becomes the ramping requirement on that particular day. The ramping capability, then, is calculated by the tool based on the generators that are synced to the system that have additional head room or additional megawatts that they can increase to if we require, and also the ramping capability of the unsynchronized generation, whether there is capability within that period for the generator to start up within the one or the three or the eight hour ramping period.

So the ramping tool is required to identify the times of potential ramping problems, if there isn't enough time for a ramping capability on the system to meet that ramping requirement that they identified by this tool. I'm just going to pass back over to Robbie there to give a summary of our presentation.

Robbie Aherne Well, thanks Lisa. I suppose one thing that caught me when Sean Esterly was kind of giving the introduction is that I mean, it is a quite a broad audience, so I know at times we've gone—it has been technical, this presentation, but if anyone post this would like to maybe talk about this in more detail and maybe your background is policy and would like to talk about it at maybe a more high level or at a policy level or indeed a commercial level, please like we're more than willing to engage after this and talk through what we've learnt with operating a system with high levels of wind.

I suppose one thing I—one point to make to close off is it is very important to reach this 75% SNSP target, so to get from 50% to 75%, it's not—there's no one thing that will get us there, not for something as complex as this. So we need—I think Lisa spoke about the system services, we spoke about the ROCOF issue, we need to put in place new policies and new tools in the control center. No one thing will get us there. It's—for something as complex as this, it's all very interwebbed at the—just the top left-hand I have a kind of a parentheses with industry highlighted.

It's very important, again, to know that the TSO, that's EirGrid, can't do this on its own. It's important that when we put out the incentives there that industry does respond, and no doubt Lisa said—Lisa highlighted that system service, the volume—I suppose the value of that particular pot of money has quadrupled as part of the DS3 program. So in other words, approximately €240 million per annum on the table with regards to system services. And that—and the industry is responding, it has to be said, and they are—I suppose money talks at the end of the day and there are—there is a lot of interest, both at home, but also, it has to be said, from a lot of international players who would see, I guess, Ireland as somewhat of a test bed for—maybe for demonstration and proof of concept at an actual industrial level with a view to maybe rolling it out in other larger systems.

So like we've, I mean, just I suppose link in there, a lot of the challenges we're facing in Ireland and Northern Ireland will be felt by other power systems into the future, as—if it continues per the current trajectory, renewables play an increasing role on the power system. Like for example, we would have regular engagement with the United States, obviously with Europe, we presented at Africa, China, just this morning Japan. I mean, really it's—we would—we're very, I suppose, open and transparent about the work that we're doing as part of the DS3 program, because we realize that a lot of the work we're doing is scalable to other, larger power systems and that that's reflected by the—I mean, there has been a reward in that with all, I suppose, of the key world players in terms of energy really looking at what we're doing in Ireland and looking at, again, how they can develop solutions that solve the Irish problems but are also going to be scalable and implementable in other, larger power systems.

But that's pretty much it. I think that, again, I'm conscious that it was a wide audience. I know at times we did get technical. I've we've lot anyone, please maybe in the questions here this afternoon or post this meeting, we're happy to engage further and have it bilateral if necessary. Maybe we—I hand over the microphone again to Sean, Tim and Emily.

Sean Esterly Yes, thank you Robbie and Lisa. Just getting my slides up here in a second. Great, very good. And just to remind the audience, if you do have any questions for the panelists, you can submit those through the questions pane. And so now we'll move right into those. We did receive a number of questions from the audience, so I'll just start at the beginning and work our way through those. The first few, Robbie, are directed towards your part of the presentation. And the first question we received asked the NB2020 _____ targets of RE are for energy and not electricity. Are the percentages shown on the slide for electricity allowing for other energy supplies such as transport and heat?

Robbie Aherne I—hopefully I didn't mislead anyone there. We actually have—I think it's quite complex, really, but by 2020, 16% of all energy in Ireland should come from renewable sources. Now, that's built into renewable heat and transport. So in—if you break it down into specific—did I say heat, transport and electricity. If you look at—specifically at electricity, we have a 40% target. So 40% of all electrical energy consumed by 2020 will—should come from renewable sources.

Sean Esterly Thank you, Robbie. This next question is also directed towards you and it asks what policies drive the wind power generation increment and what causes the generator to trip since you generate your power mostly from gas.

Robbie Aherne Well, I guess what policy is driving it, it's—well, from a European perspective, we have the renewables directive, which is a cross-European policy document or directive which essentially ensures that each member state in the European Union must define a target and then is—I suppose it's incumbent upon them to meet that target, but that's really the driver for it.

I suppose the second question is maybe different, what causes the generator to trip, we would lose probably one generator—one big generator per week. So like it's not that—it doesn't happen that common, considering your operating for 8,760 hours of the year. What could cause it, it could be anything. It could be lightning, it could be a spurious trip, a control system glitch, it could be—I mean, yeah, it could be just—there's a myriad of reasons why a generator could trip on the power system. Could be human error, as well. But really, look, it doesn't—it happens around once per week. We probably would have maybe about ten big generator trips per annum, so but there's no one drivers, it's—there's an absolute infinite number of reasons which could cause a generator to trip. But I suppose it has to be said that at the same time, it doesn't happen that often.

Sean Esterly Great, thanks again, Robbie. Moving on now to the next question, it asks can grid stability and system optimization be achieved with higher percentages of generation from non-dispatchable renewable energy plants?

Robbie Aherne Well, I suppose—yeah, we've always—we said any wind farm which is greater than five megawatts in size in Ireland and Northern Ireland, we've said as we have to be able to control the output of that particular wind farm. Now, that's small relative to other systems. I think in GB it's 100 megawatts and I think in continental US, I'm not sure of the exact figure, but I know 5 megawatts is quite small. And we implemented that at a very early stage and probably was quite a wise decision, particularly in retrospect, because we've had a lot of wind connects, a lot of small wind farms and we take them all together, they actually all add up to quite an amount of megawatts on a system-wide basis. So we've always made sure that that—the minimous level, five megawatts, is actually quite small. And I—we know that in other—so we have a really clear understanding of what's happening on our power system. We do know that it has been a problem in other systems where that the minimous level is a lot larger and it's—it can be quite difficult to understand what's happening on the wider power system. So that's been a very important thing for us from the very start, so yeah, but 80% of all wind farms can be controlled from the control centers. I'm not sure if I'm really answering the question, but from our perspective, we've always taken the approach that it—we're—it's important for us to have as much control as possible from the control center, again, given that we're an island power system.

Sean Esterly Great, thank you. And has there ever been any consideration for wind energy storage to assist in managing the system's stability?

Robbie Aherne Oh absolutely. We've—Lisa described our system services and that quadrupling of the budget or the money that's available. We are technology neutral as a transmission system operator. So we are going to define a need for a range of different products that we would require to continuously operate the systems securely. However, we're technology agnostic, so it is expected, however, that storage is well positioned to take advantage of any commercial opportunities and absolutely it is something that indeed we've had a number of meetings quite recently on potential storage developers. But from our perspective, we're technology neutral. We're going to define a need and if someone with a storage device can meet that need and I suppose if the project makes commercial sense from their perspective, we're happy to integrate that into the power system. But I suppose part of our license as a TSO we have to be technology neutral.

Sean Esterly Great, thank you, Robbie. This next question could elicit a lengthy response, but perhaps we can just touch on some of the elements. It asks for smaller grids with 5,000 megawatts or less, is there any limitations with increasing generation from renewable energy? So again, maybe just touch on a couple of those and what things need to be looked into.

Robbie Aherne It's kind of, I suppose, really everything we discussed. I mean, 5,000 megawatts or less, that's not that different from the power system we've just described there where the peak demand is around 7,000 megawatts. So I think everything really we've discussed is probably relevant. So the ROCOF issue, the need for incentivizing the performance of plant to increased revenue for systems versus, the need to develop new operational policies and tools, there's probably I guess actually probably every single thing we've discussed here is relevant for a power system of that size, because it's so analogous to the power system in Ireland and Northern Ireland.

Sean Esterly Great, and what is the implication of ROCOF change in frequency to 1 towards achieving the 75%?

Robbie Aherne It's a very important building bloc in meeting the 75% target. Absolutely, it's probably the two key enablers are changing the ROCOF standard from 0.5 hertz to 1 hertz per second, and the second one is the addition of those new system services. Now, it has to be said they do complement each other, and it's hard to explicitly draw out how much ROCOF contributes to changing the SNSP from 50% to 75%. But we would expect, assuming that system services are delivered and that ROCOF standard was changed, that over probably quite a quick time period, up to maybe when it—less than 12 months, the SNSP could change to or be increased by up to 10% in the control centers. So it is a key building block. It's hard to be exact at this juncture, but something along those lines. Hello? I think we've lost someone there?

Sean Esterly Sorry about that, Robbie, I was just [crosstalk] so we had one more question come in. It asks to what extent do you foresee that the work DS3 has done to evaluate and plan for 75% SNSP will lead to a revision of Ireland's RE target to levels higher than 40% after 2020.

Robbie Aherne I think that well, that is being looked at at the moment. There was, I suppose, a lot of work done at the early part of this year and late last year on renewable targets for 2030, or I guess, yeah, taken on a member state basis now. There isn't defined targets for individual member states, they didn't fall out of that decision and hasn't been defined thus far. But one would expect that or one could reasonably assume that there will be higher renewable targets beyond 2020. I suppose that is a question really for the policymakers, because at one point, wind was a little-understood technology that required a lot of support and priority, but it is fair to say that it is becoming a more established technology, and that it is starting to stand on its own two feet. So maybe looking to the future, targets will become less of a—will become less important and indeed, wind will be able to come into the market and really, I suppose, stand on its own two feet and play an ever-increasing role in the energy mix of the future.

Sean Esterly Great, and in Ireland, is there any energy efficiency regulation for power plants?

Robbie Aherne In Ireland, actually the—well, we again would—I suppose a lot of the—or a fair portion of the policy in the European Union is defined at a European level. So actually what came out at the end of last year was the Energy

Efficiency Directive. Now, that doesn't define specific targets. It's quite different to the Renewables Directive. But what it does talk about, it encourages, for example, demand response, it encourages storage, it encourages energy efficiency. So it's—we—again, we would fall under that and what we didn't probably discuss here today is all the work that's been done on the DS3 program on demand response and we have—we've put a lot of effort in that in particular. It's such a wide program, it's really hard to kind of cover everything in an hour-long presentation, but demand response has grown rapidly in Ireland in the last number of years. We've gone down the aggregator route, where, for example, small demand sites are aggregated together by third parties and then we treat them from the control center like as if they're a generator. So we've seen rapid growth in that space. It's growing by about 150% per annum since 2012, and indeed, up to 66% of our system peak is met from demand response on the island, and that would be quite high figures internationally. And it's—and has been a logical move, because demand response is inherently flexible and is a natural fit for the variability of renewables like wind.

Sean Esterly

Great, thank you again. And that is the last question I've received at this point, so we'll move ahead now, and if any more questions come in, we can certainly go back to those and respond. So at this point, I'd just like to ask our audience to take a quick minute to answer a short survey that we have. We just have three short questions for you that help us evaluate how we're doing and improve for future webinars. So Emily, if you could, go ahead and display the first question. Great, and the next one, please. And then the final question. All right, thank you very much for answering our survey. Before we close the webinar, we did have one more question come in, and since we have some time remaining, let's go ahead and address that. The question is what is the CO2 limit for the plants and what's the cost on carbon costs?

Robbie Aherne

What's the CO2 limit? Well, we have, through our Environmental Protection Agency, emissions limits on the various plants. We probably would be—that would be outside of our direct area of influence, but it is something that—it is a technical barrier that we have indirectly come up against as we've tried to progress with the DS3 program. And an example of that is if you consider the night valley when say the minimum demand is 2,500 megawatts, we could potentially have 2,800 megawatts of wind on the system. However, at the moment on the island, we require a minimum of 8 units roughly with a minimum of 200 megawatts each. So that's 1,600 megawatts. So if our night valley is 2,500 megawatts minus 1,600, it only gives us space for 900 megawatts of wind.

If we were able to drop the minimum generation output of those 8 generators from 200 to 100 megawatts, that would obviously allow us to install more—facilitate more wind on the system. However, for many reason, it is a difficult challenge and one of the issues that is being considered by generators because, look, it is obviously in their interest to ensure that there _____ is reducing that min from 200 to 100 megawatts, but one thing they have to consider and be—take account of is not increasing their emissions above their specific limits.

So I know I haven't directly answered the question. It's probably beyond the scope, really, of the DS3 program. I suppose in aggregate, the renewables directive is about decreasing CO_2 emissions, but on a generator by generator basis, we wouldn't have sight of it, but we know that the generators carefully keep an eye on that and ensure that they don't breach their limits, and that feeds into how they operate on a day-to-day basis.

Sean Esterly

Great, thank you once again, Robbie, and thank you also, Lisa for the great presentations and for addressing all those questions today. On behalf of the Solutions Center, I would just like to thank all of our attendees for participating in today's webinar, we very much appreciate everyone's time. And I do invite everyone to check the Solutions Center website and training page, where you can download PDF versions of today's slides, as well as a recording of today's presentations. Additionally, we have previously held webinars on topics such as grid integration and other clean energy topics posted on that site. Additionally, just a reminder, we're now posting webinar recordings to the Clean Energy Solutions Center YouTube channel, and please allow about one week for the recording of today's broadcast to get posted up there. We also invite you to inform your colleagues and those in your networks about Solutions Center resources and services, including the no-cost Ask an Expert policy support. And so with that, I hope everyone has a great rest of your day and we hope to see you again at future Clean Energy Solutions Center events. This concludes our webinar.