Webinar transcript

**A new Nuclear Energy Agency report and the true costs of decarbonisation**

The NICE Future initiative offered this webinar on 25 April 2019. It can be viewed at [www.youtube.com/watch?v=Zcx1ep9PyLU](http://www.youtube.com/watch?v=Zcx1ep9PyLU). For more information, see [nice-future.org/webinars](http://nice-future.org/webinars).

Webinar presenters

- **Sama Bilbao Y Leon (moderator)**
  OECD Nuclear Energy Agency

- **Jan-Horst Keppler**
  OECD Nuclear Energy Agency

- **Marco Cometto**
  International Atomic Energy Agency

- **Peter Fraser**
  International Energy Agency

- **King Lee**
  World Nuclear Association

- **Brent Dixon**
  Idaho National Laboratory

- **Katie Contos**
  National Renewable Energy Laboratory (webinar administrator)

About the transcript

Because this transcript was created using transcription software, its content might not precisely represent the webinar.

**Katie**

I’m Katie Contos, and welcome to today’s webinar which is hosted by the NICE Future. Today’s webinar is focused on the OECD NEA Report: *The True Costs of Decarbonisation*.

Before we begin, I’ll quickly go over some of the webinar features. For audio you have two options. You may either listen through your computer or over the telephone. If you choose to listen through your computer, please select the mic and speakers option in the audio pane. If you choose to dial in by phone,
Please select the telephone option and a box on the right side will display the telephone number and audio PIN you should use to dial in. If anyone's having any technical difficulties with the webinar you can contact the go-to-webinar's help desk with the number on the screen: 888-259-3826 for assistance. If you'd like to ask a question, we ask that you use the questions pane where you can type it in at any time during the broadcast today. We are also recording today's presentation and it will be added to the YouTube at the link provided on the slide and we'll also post it later.

Today's webinar is a part of the NICE Future initiative. The NICE Future initiative is a ministerial level initiative of the clean energy ministerial completing its first year. The initiative envisions a world in which nuclear innovation and uses advanced clean energy goals. The initiative recognizes that there's no one-size-fits-all solution to energy, and fosters collaboration among clean energy supporters in exploring solutions for clean and integrated systems of the future.

Today's discussion touches on themes that are very important to our initiative, including the potential for non-emitting nuclear and renewable energy to work together, the economics underpinning clean energy choices, and advice to policymakers and stakeholders regarding diverse innovation and options.

Our NICE Future team is currently gearing up for the next clean energy ministerial mission, which we're very excited about—our mission innovation meeting May 27th through the 29th, this year in Vancouver, Canada. So today's discussion and inputs from our excellent panel are very timely.

Now I'd like to introduce Dr. Sama Bilbao Y Leon, who will be moderating today. We're very fortunate to have her. Sama is the head of the Division of Nuclear Technologies, Development and Economics with the Nuclear Energy Agency. And with that super-brief welcome I'd like to welcome Sama to the webinar to introduce the rest of the panel, and to moderate our webinar. Sama, welcome.

Sama

Thank you, Katie. Thank you and welcome to everybody that is watching us remotely. So I would have [inaudible] a relatively large number of fantastic presenters today, so I'm going to very briefly introduce them so that we can actually start with the true discussions.

Our first presenter will be Dr. Jan Horst Keppler, who is a senior economic advisor at the Nuclear Energy Agency, and he's one of the authors of this study. He will be making the primary presentation of the study.

And then he will be followed by Dr. Marco Cometto, who is an energy economist at the International Atomic Energy Agency. And he is also one of the coauthors of this study, so we will also give him a little bit of time for him to provide his insights.

So afterwards we are going to hear some remarks and some feedback on the outcomes of this study from various presenters. We will start with Peter Fraser, who is the head of the Gas, Coal and Power Markets Division at the International Energy Agency, and he will be followed by King Lee, who is the director of the Harmony Program at the World Nuclear Association. And we will conclude with Dr. Brent Dixon, who is the lead analyst for nuclear systems analysis and integration at Idaho National Laboratories. So we've really seen that all these different speakers add different points of view that they are going to bring as are going to be very good to have a good discussion and hopefully very good questions.

So what I wanted to start with is—let me show you here—hopefully everybody has seen my slides. So before we start, I'm going to take a minute to tell you a little bit about the OECD Nuclear Energy Agency. I think that many of you know that the role of the NEA is we are an intergovernmental organization. We have 33 member countries that currently operate about 82 per cent of the world's installed nuclear capacity, and essentially what we try to do is to foster the international cooperation among these countries that tend to be the ones that have very mature infrastructure in nuclear energy so that we can increase the safety and the cost effectiveness of nuclear technology.
So the areas of work that we have at the NEA go all the way from safety, radioactive waste management, decommissioning, radiological protection, law, nuclear science, and of course technical development and economic studies, which is the division that I head. So I’m going to stop here and in the interest of time let me go to Jan’s presentation and I’m going to welcome Jan and he’s going to present the work that we are doing.

Jan

Yes, thank you very much, Sama; thank you very much, Katie. It’s a great pleasure here to discuss with you about the new OECD NEA study on the costs of decarbonisation, a study that was prepared together with Marco. It’s part of the ongoing work here at the OECD NEA. We had a study in 2012 on—first study on system costs, as we call it, then we had a study on nuclear renewables in 2015, the project cost series of which we are preparing, together with Peter, a new series for 2020, and we have the full cost of electricity [audio garbled] provision, and a paper on sustainable development last year.

This is a study about system costs. You’re of course all familiar with the plant-level production costs which are the LCOE costs, the levelized costs of electricity. And most of you will also be familiar with sort of the external costs, full costs, associate costs, things like pollution, climate change, security and supply.

System costs are of a different nature. System costs are real monetary costs that accrue at the level of the electricity system that’s connected by the grid, and the differences of plant-level costs is only that it’s being paid not by the plants that are causing it, but by the different members of the electricity system that are connected to the same grid.

Now our study is looking at system cost, the cost of producing electricity in a given electricity system, under a very strong carbon constraint. The carbon constraint that we are looking at is 50 grams of CO2 per kilowatt hour and is roughly consistent with what is needed under the Paris Agreement.

The Paris Agreement says that we should hold the increase in global average temperatures to well below two degrees Celsius. That would translate into a greenhouse gas concentration in the atmosphere about 450 PPMs of CO2 equivalent. With some calculations, that we’re not reproducing here, annual CO2 emissions would then have to be reduced by 43 per cent at the global level, or 61 per cent in OECD countries.

Given that electricity produces about 40 per cent of global CO2 emissions, and is expected to contribute over-proportionally to that reduction, annual emissions from electricity would need to decline by 73 per cent globally and by 85 per cent at the level of OECD countries. That’s a big discrete decrease from 100 per cent to 15 per cent. And it basically, or it does mean that from the current emission intensity of 570 grams of CO2 per kilowatt hour at the global level, or 430 grams of CO2 in OECD countries, we need to go down to 50 grams of CO2. Either divide by ten globally or divide by roughly four in OECD countries.

You are all familiar with the fact that in fact hydro resources are limited, and so the only way to grow is either renewables, of which the most important are wind and solar PV, which we call variable renewable energies, VRE, or nuclear energy. Those two groups of energy will need to substitute for fossil fuels such as coal, gas or oil.

We analyzed different electricity systems, all with the same carbon constraint of 50 grams of CO2 per kilowatt hour, but with different shares of nuclear and of renewables. And in particular we then look at how does the system react to the fact that with high shares of renewables you will have a lot of variability in their production in the system and what that does do to the remainder of the system.

Talking about these system costs why are systems with variable resources more expensive than systems without such resources? Well, let’s look in this slide first to number two and three, which are slightly more obvious. First of all, variable resources are uncertain, so you don’t know exactly what production will be in the half hour ahead, so we need some dispatchable plants that cycle, that are basically there
just to sort of—they basically turn at 50 per cent of their capacity so they can easily then sort of increase their capacity in case that there should be sort of a shortfall in renewable production.

We also have larger networks costs, both for the transmission system and the distribution system, with variable resources being more dispersed, after being distant from the load centers where the consumption is. These costs will also go up if their share rises. But by far the largest share of system costs are the profile costs. These profile costs are directly due to the variability, not the uncertainty but the variability of renewable production.

How do we need to think about that? Well, renewables, even if you made [audio garbled] sort of an average cost, they're similar comparables, slightly higher, slightly lower than dispatchable resources, they're variable. So we need dispatchable resources for the time when the variable renewables are not available. That's a residual system.

That residual system, however, will have to have a certain amount of capacity to be always there. That capacity, however, works a lower number of hours. Same capacity, lower number of hours, which means the average costs of the system of the residual system goes up, the more the variable portion, or the more the renewable portion is indeed variable. Those are the profile costs, and they are an increasingly important part of total system costs.

Let me quickly show what we did, eight scenarios that we presented, a base case [audio garbled] least cost option, when we have a case with ten per cent variable renewables, 30 per cent variable renewables, 50 per cent variable renewables and 75. Then we have two sensitivity studies, or sensitivity cases, one without interconnections, one without interconnections and without hydro. Why is that? Because both interconnections and hydro provide flexibility to the system. And the more flexibility resources you have in the system the easier you can absorb, in fact, the variability of the renewable. So that does make a difference. The more flexibility that you have, the lower will be the system costs and the total cost of the system.

And then we have a case, the green case, that becomes more and more important, sort of the way we think about it. That's a low renewable cost case. In the green case we do have some renewables coming in on their own merits because they do have lower plant-level costs than the nuclear, for instance. However, due to the system costs there will be some sort of arbitrage at the margin, and we will have in the least cost case both variable renewables and nuclear. That's sort of they balance each other—I'll come back to that at the very end of my remarks.

Now let us quickly develop a little bit of intuition what happens if you do have a lot of renewables in your system. You have here, over the 8,760 hours of the year the load curve, and you have in red the consumption of total electricity minus the hydroelectricity that's produced anyway that's always running. So the red curve is pretty much what is consumed. And then we reduce from the red curve the production by wind and solar PV, and we get the blue curve. And you see with ten per cent renewables the structure of the curve is very similar. It's basically sort of a downward translation and nothing much happens to the structure of the system.

You have 30 per cent renewables; well, you already start seeing that it's become a little bit different, the ramps are getting higher for the residual system, and you also have some hours where it's actually hitting zero, which basically means you don't need any dispatchable production, and these are the hours where you actually will also have zero prices. That's what's already happening in a number of countries around the world: 30 per cent contribution by wind and solar PV and quite a number of zero price hours. That increases quite dramatically with 50 and 75 per cent of variable renewables in the system, and managing the system is now becoming a lot more difficult. You have very steep ramps, you have a lot of stress on technology, and this is something we couldn't model—our model is an economic model, but nevertheless there will be, in practical terms, a lot of technical stress in addition to the economic costs that we actually did model. And you see that the traditional seasonal weekly and daily pattern of the electricity load is actually being completely destructured. You have a lot of excess production at certain hours, which needs
to be curtailed, to some extent exported in some systems, but in many systems, it will need to be
curtailed, and residual production is indeed getting less and less, however capacity is still needed for
those hours where variable production will fall short.

Now we're coming to the results. On the left you see the results in terms of capacity. Next, we have the
base case, with only nuclear production because in our assumptions _____ 2015 data there was only
nuclear in the least cost case. Then we have the case for 10, 30, 50 and 75 per cent renewables, and you
see that the capacity is going up dramatically. That, of course, has then impacts on land use in particular,
but also in terms of cost; we'll get to that in the next slide.

In terms of generation it's pretty much what you would expect: the more you add renewables to the
system the more will be renewable production; that's logical. Nuclear will decline in the pattern: the more
renewables you have the less nuclear you have. That's defined by the carbon constraint of 50 grams of
CO2 per kilowatt hour. And the share of gas is defined by the same constraint, by the same carbon
constraint, so that stays pretty much the same, production by combined cycle gas turbines and open
cycle gas turbines.

However, as we move towards the 75 case the share of open cycle gas turbines, because they're more
flexible, have lower capital costs, will actually increase at the expense of the combined cycle gas turbines.

Coming now to what is possibly probably the two most important slides of our research, of our study,
the total cost of the whole system to respond to a given demand. There's something I should have
mentioned right away: demand, in all eight cases, is always exactly the same. So the question is only
how do we actually satisfy that demand at the same carbon constraint with different shares of
renewables and nuclear. And you see here that the average cost of a megawatt hour in the base case
is about $67 per megawatt hour, and it rises to about $130 per megawatt hour in the 75 per cent
renewables case.

That increase is the result of different forces. To some extent, at least with the assumptions used, it's
due to an increase in LCOE costs, which you see in green. So just plant-level costs getting more. You also
have an increase in grid costs in blue, and balancing costs in light blue, connection costs in gray—all
that's pretty intuitive. What's interesting is the red part, which are these famous profile costs, that the
restructuring of the system will cause total system costs to go up. Basically think about it in terms of
backup capacity that's required for lower number of hours. And instead of course renewables coming in.

You can also look at the same information in a slightly different way. You can break it down in terms of
megawatt hours produced by variable renewables, megawatt hour VRE, as we call it. And there you see
that per megawatt hour produced by wind or solar you have added costs to the system, about $8 per
megawatt hour of renewable in the 10 per cent case, going up to $50 per megawatt hour of renewables
in the 75 per cent case. And that's the correct way to thinking about this. If you have 75 per cent
renewables in your system, and you look at the cost of those renewables and say they may be, I don't
know, $70 per megawatt hour in terms of to get at the cost of the system you need to add those $50
per megawatt hour VRE to arrive at $120, which you then would need to compare to the cost of a
dispatchable least cost that is not variable. Two different ways of thinking about that increase in
system cost.

I'll be very quick with the remainder of our slides. This is actually a slide that's not from our study but it's
nevertheless very interesting. It's from a study or related to a study that' done by MIT on the future of
nuclear energy in a carbon-constrained world that came out in September or October 2018, and we
worked very closely together with the same team that did the modeling for that study, Seffa Veda, who's
mentioned here as a source.

But that's not the point. It's a good occasion to mention the modeling team that we work with, but the
key point is here on the left side. Our study has a carbon constraint of 50 grams per megawatt hour. The
slide here shows what happens if you go down to 25 or even one gram per megawatt hour, sort of really
new total decarbonisation. Then you see how these costs really increase exponentially. And they do so
in particular to try to achieve that goal, in this sort of Z-axis you move from all-nuclear system to an all-renewable system. And then you get really, really, really very, very high costs, up to $300 per megawatt hour of electricity. If you want to have total decarbonization with a system that provides it only with renewables. So that's an interesting point in sort of framing what we're doing. We're somewhat in the middle of that approach there.

Let me go on. Low-duration curves, pretty much already what I described; you see in black what's happening in the system in the base case; the black line at the top and at the bottom the red case in the 75 per cent case that's low-duration curve as seen by a producer with dispatchable technology and you see that the hours are getting less and less and less.

We also see, on the right side, that price volatility increases enormously: with 75 per cent renewables we have up to 3,750 hours of zero price hours. Given that we have a profitability constraint in our system, which is normal otherwise, the technology would leave, this would be compensated by a high number of high-price hours. So the volatility of the total system will go up a lot, and possibly the cost of capital will go up because of that because the risk is so much higher. Again, that's something that's not modeled: our cost of capital is the same in all the different scenarios, but it would be something to sort of think about at least in a qualitative way.

In the interest of time I'll be very quick here. We have increasing demand on the flexibility of nuclear power plants; in the base case it's a blue line at the top; that's a little bit demanded in terms of load following from nuclear. As you move down you have less and less capacity, but more and more variability demanded, and in the 50 per cent case you see that nuclear needs to load follow very quickly. There's no nuclear in the 75 per cent case.

For gas you see that for open cycle gas turbines it's actually getting more as you move for higher capacity, which is 75 per cent case in yellow pretty much same variability for the 50 and the 75 per cent case, and for combined cycle at the right it's pretty much the same in all the different scenarios.

Let me rest a minute on the final slide of our results. On the left side that's actually something that will interest the economists quite a bit. It shows you the declining market value of variable renewables as you increase their share. How can that happen? Why does a megawatt hour, or a megawatt, rather, a megawatt of solar or wind, earn less than the average market price?

This is due to a phenomenon that we call auto correlation: all the wind turbines turn during a restricted number of hours, and during those hours they drive the price down. For solar it's even more obvious. You basically have good solar from ten o'clock in the morning until three o'clock in the afternoon, and during those hours all the solar panels are working and prices fall. And that's what they earn. And so in a completely competitive market these curves will look like that. That's another proxy for actually for system cost because it's related also to the variability.

Now look, I promised you to come back to the low-cost renewables case on the right. The base case the left column, the low-cost renewable case the right column. Due to the now much lower cost of renewables we do have endogenous entry of renewables: no longer any constraints, no longer any subsidies. They come in on their own merits. But with their system costs rising, and with the market value declining, at a certain point nuclear comes in again also on its own merits. So the least-cost version is now a case in which we have renewable as a low-cost option, a variable, and nuclear slightly higher cost, but dispatchable coming in there and both of them providing the low carbon technology together.

Our study—but this is more sort of in the interest of time sort of a plea for you to read it—we have a number of policy recommendations, carbon pricing, investment for low-carbon technologies by providing stability, for investors staying with short-term markets, adequate levels of capacity and flexibility, allocate system costs. You look at that at home; this is what I said, this is the synthesis; you can look at the slides later. Just recalling what we did, recapping what we did.
Study's working very well. We have quite a number of presentations all over the world today with you, and we're much happy about that. And there is one take-home message which we would all like to take home, that radically decarbonized electricity systems will rely on variable renewables and nuclear energy as their two main pillars, and that economic system cost analysis is the keystone that will allow to identify opportunities and challenges as well as to organize their complementarities into a coherent whole. Thank you very much.

**Sama**

Thank you very much, Jan. Now I would like to invite Michael to provide his comment to this study.

**Marco**

Thank you very much, Sama, for your introduction and thank you, Jan, for your very good and comprehensive presentation and introduction to the study. It is really my pleasure to be part of this panel, of this webinar. And I'll try to give you some complementary view to that that has been said by Jan.

Overall, I think there are many factors that have an impact on what is the optimal combination of generation technology and automatically the cost of decarbonisation. Jan mentioned some of that. Each country is different. The electricity demand profile, its correlation with variable renewable generation, the availability of hydroelectric storage is quite important, as well as the size of the system those vary among different countries, among different systems.

One other point that was mentioned by Jan: clearly the carbon constraint to be achieved is also an important factor on the optimum mix and on the cost of decarbonisation. We don't have to forget, also, there will be technology progress and cost reduction. I'm thinking about solar technology, demand side measures and flexibility of all conventional generation. All those will have a big impact on the future cost and on the future of the system. Finally, the cost evolution of no-carbon technology, either nuclear or renewables, are also a key element for the future of the system.

One other aspect that will shape the future system and the future cost is—I see an increase in the interdependency of the power sector, which has been modeled in our exercise with the global energy and transport sectors. Here I'm really thinking at the future heat market and the electrification of transport, which will also be decarbonized.

Clearly, we cannot predict what will be the evolution of those factors, and each of them will have an impact on the results. But however, I want to stress here that this study allows to draw some important conclusion which are genetic, which go well beyond the specific power system that has been modeled, and of the cost hypothesis that has been taken into the analysis.

And the two key points here to me are, first of all, that achieving a target of 50 grams per kilowatt hour is extremely ambitious, and really represents a formidable challenge from the whole power cycle. Achieving even the most stringent targets that are required to be beyond the 2050 will be more and more difficult.

The second point was also mentioned by Jan before, expanding further the share of valuable renewables in the system becomes not only technically more challenging, but also more costly from an economic viewpoint. And the key result of this study, in my view, is that the system cost of variable renewables increased significantly with their generation share, and Jan explained quite well the phenomenon behind this. These are facts which are basically equal to correlation of variable renewable production part.

I would say that those conclusions are also supported by current experience in many countries that sees that adding new variable renewable capacity becomes more and more challenging despite all the progress that has been made.
Now I want to shift a little bit in a different direction more on policy I would say that really if the society wants to achieve the climate targets embedded in the Paris Agreement that requires massive investment in both generation and transmission. The last real study from the International Energy Agency calculates that investments in the power sector are of the order of U.S. $1 trillion per year until 2040. That's huge.

And I would like to say here that the transition to our low carbon system has a profound implication on the cost structure of the power generation mix. This is natural because all low-carbon technology of the same economic [inaudible] that are characterized by high capital cost and low fuel and variable cost.

So whatever is the technological choice that is made our low-carbon generation mix will be inevitably more capital intensive than the carbon mix. And that has a big, big impact on investor in the power sectors because there is a significant increase in the market-based value investor. And those are the cost of generation _____.

The increased volatility that Jan showed in one of the slides, that increased volatility of electricity price is exactly one effect of this increased capital intensities across the system. And to me the key question here is how to finance this transition and what are the appropriate policies to encourage investment in low-carbon technologies. In my view there are three key elements. The first one is clearly carbon price. If CO2 is an externality it should be taxed. But probably it will not be sufficient. And do a certain extent policymakers have to balance two factors: they have to guarantee some form of revenue certainty to low-carbon generation on one end, but on the other hand, to ensure that there is a real competition between technologies and that technology that provides the maximal value for the system is effectively selected by investors. And this is quite challenging.

So to conclude my small speech I would like to underline two points. The first one, really the challenges associated with that carbonization are enormous, and in my view often they are underestimated by policymakers. It requires really a complete radical change from the current system to a new system in a very short time. And the second big point echoes what Jan says, really if you want to achieve the carbonization and maintain an efficient, reliable, diversified power generation mix of the one that we have now really all available low-carbon generation sources should be used. Variable renewables, wind and solar, hydroelectric, results where available, and dispatchable technology such as nuclear power and fossil fuel technologies if carbon capture materializes. So thank you.

Sama

Thank you very much, Marco, for your comments. So now I would like to invite Peter Fraser to please provide some comments to the discussion.

Peter

Well thank you, Sama, and good day everybody. I'm with the International Energy Agency, where I'm head of the gas, coal and power markets division. So as you can anticipate, I cover a pretty wide swath of energy questions. And certainly to create a low-carbon energy system will require a wide range of low-carbon technologies, as has been emphasized earlier.

And every year we look at a suite of 38 different low-carbon technologies, both on the supply and the demand side in our tracking clean energy progress. And out of those 38 we only find that four are on track, one of which is solar PV. And it's clear to us that the world is certainly not decarbonizing at the rate that we need to to get on a sustainable path. That was underscored quite recently with our recent assessment of the 2018 energy-related CO2 emissions which saw yet another increase in emissions, despite that being also a record addition of renewable generation of about 450 terawatt hours of extra renewable electricity.

It's clear that we're not on a good track, and certainly one of the reasons we're not on a good track is nuclear, which in the past was one of the technologies that helped decarbonize a small—reduce, say, the carbon content of a much smaller global energy system is far off track. And we are concerned that,
absent government action, nuclear, particularly in the advanced economies, could be far lower than even we anticipate in our scenarios, when we were actually counting on, especially in our low-carbon scenario, nuclear power increase.

For that reason we are preparing a report, which is going to be launched at the Clean Energy Ministerial, along with the nice work, a report called Nuclear Power in a Clean Energy System, which is we're going to focus on nuclear power in the advanced economies. The situation today, both in terms of existing plants and their competitiveness and their ability to stay afloat, and also the prospects for new build. And we'll be also touching on some of the new technologies which, of course, are counterparts on the NICE Future we'll be doing much more.

In that report we're going to actually look at a scenario, not unlike the high VRE scenarios that have been referred to here, where we actually look at a case in advanced economies where nuclear plants, instead of being life-extended, are actually closing instead. And as a consequence by 2040 nuclear in the advanced economies drops by about two-thirds from today's levels.

That has some interesting implications for integration of a higher level of renewables, particularly if you're trying to maintain the low carbon constraint. As Jan said, the report will be launched in just over a month's time; I hope you have a chance to look at it.

Certainly one of the issues we deal with in that report and elsewhere is the question of the flexibility of power systems. It's clear to all of us, I think, that the share of variable renewables is going to increase, and as Jan referred to earlier, in some countries, or in some jurisdictions, it's already getting to levels at which systems have already got to be re-engineered to manage the larger shares that they're seeing. It will be one of the key challenges to create a secure power system and secure energy system.

So we're doing a lot of work in this area as well, both on the sources of flexibility through our series called power system transformation, where we looked at, for example last year, the flexibility that could be tapped into from coal plants, and of course the flexibility from the VREs, the variable renewables themselves, which is subject to an upcoming report which we'll also be launching at the Clean Energy Ministerial.

Another area we're looking at which we think could be a key source is hydrogen. That's certainly something that's becoming a popular topic again, and certainly an area where nuclear has a role as well, and we're going to be launching a major report on hydrogen at the G20 meeting coming up in Japan in June. We're also of course looking at the question and the context of the long-term scenarios, and we're doing various analysis on that, both in China and also having a look at France right now. They're providing some advice on the technical capabilities there.

Finally, I'd just like to mention something that I think Marco touched on a bit, and I think Brent might touch on it later on, which is the recognition of the declining value of, say, wind or solar as you increase the share due to autocorrelation, suggests that you have to start thinking about what the value of the wind and the solar, or of other variable renewables are providing to the system. And at last year's World Energy Outlook we presented a new way of thinking about thinking about this, really new tools, not something that solves all problems, what we call the value-adjusted levelized cost of energy. It's something that helps you answer one simple question, which is what's the—instead of just asking what the cost, say, of a solar farm is, what's the cost or the value of the solar farm if you add batteries to it, or some other form of storage. From a levelized cost of energy point of view, of course, that's a nonsense question because batteries just add cost; they don't produce energy. But it makes all the difference when you start thinking about the value.

And so you can use a tool like this to really start to understand and probe how you could change the incentives when it comes to buying renewables in terms of if you have a power purchase agreement, or sending the price signals in the marketplace to actually getting a more efficient addition of renewables as the shares start to increase, and perhaps easing the integration and increasing the cost effectiveness of doing so.
So I think that is turning out to be a useful tool, and I believe both Marco and myself are involved in beyond LCOE work that's being done for DOE; we're serving on the advisor board, and I think that's certainly also a direction that I'm glad to see that several bodies were taking an interest in.

So thank you, and I'll leave my comments there.

Sama

Thank you very much, Peter. So now I would like to invite King to provide his comments to our report.

King

Okay thank you for inviting the World Nuclear Association in this seminar and to comment on the NEA very important study.

So start with I would like to highlight the challenge in the recent IPPC 1.5-degree report, which shows that nuclear is essential to achieve decarbonisation. It also illustrates a mix of energy that would be needed in the future and the challenge for decarbonisation.

In the middle-of-the-road scenario, B3, it shows that nuclear would need to increase six times to obviously current level by 2050 and non-biomass renewable like hydro, solar and wind will need to increase by nearly 900 per cent from 2010's level. As has already been commented by a number of people, that illustrates the challenge ahead, and regarding the electricity mix as shown in the pie chart here, nuclear would generate 25 per cent of electricity in 2050.

I would like to perhaps highlight some of the non-financial aspect associated with the study, and some of the issues for further consideration such as technology availability. There's no doubt in order to fully decarbonize the system new technology would be required, and new technology will be required to integrate renewable into the system. So we need to consider the potential risk would those technologies be available in time, and at the right couple.

The other consideration is from a sustainability point of view. What are the impacts on material use and land use, as a number of people have highlighted? And we need to look at, really, the life cycle assessment of an energy system so that we can understand the potential impact.

We are no doubt, for future development of nuclear power, we rely on political and public support. But in order to deploy a large amount of renewable that public acceptability may also be a factor, in particular with also the associated grid development as well. So these are some of the factors that will also need to be looked at.

So to meet the growing demand for clean and reliable low-carbon mix the nuclear industry have developed the Harmony Program, with the goal of nuclear energy generating 25 per cent of electricity by 2050. So to meet the Harmony goal we will need to build about 1,000 gigawatt of new nuclear capacity.

The Harmony Program is coordinated by the World Nuclear Association and for further information can be found on their website. Thank you.

Sama

Thank you, King, for your comments. Now I want to close with Brent Dixon, that is going to provide the last comments before we open it for a couple of questions.

Katie

Brent, it appears that you're still on mute.
Brent

That's better. Okay, what I wanted to talk about briefly was a new project within the U.S. Department of Energy that parallels a lot of these other efforts called "Beyond the Levelized Cost of Electricity." And this project is looking at the general problem of—it's very easy to measure the levelized cost of electricity independent of the system that is being applied to. All you need to do is be able to estimate the capacity factor, how much you will be utilizing your system to produce energy. And beyond that all of the parameters are independent of the system. So it's a quite easy calculation.

On the other hand, identifying the value of the electricity is a very difficult proposition. It depends on where you are in the system, when you are in the system, what else is being generated at the time, what the demand is at the time, and there are other values beyond just the electricity itself, for example, contribution to capacity reserves, a number of ancillary services, spinning reserves, frequency response, etc. Some of these right now are taken for granted—for example rotational inertia we have in most systems an excess of what's needed for being able to manage frequency and voltage. However, in some systems they are evolving with more variable renewable energy. There are times of the day when most of the electricity is being produced by the VREs, and some of these ancillary services may come up short. The markets today tend to only include a few of these factors and not all of them, so the markets are imperfect.

The approach that we are taking in the Beyond LCOE effort is to first look at an ideal model of everything that you could theoretically include, and then start to talk about, well, but what's the practical application of that ideal model. There are difficulties in identifying and modeling the ancillary services, in modeling the variability of the system, especially for rare events. Uncertainty is typically not included in these models; typically what we do is we run a few different scenarios, as has been shown in the first presentation today. So you don't really get an idea of how much uncertainty there are, especially in these forward projections. And that's one of the things that we want to look at.

We are keeping the scope of the effort focused on the power sector only, and some people, when they hear "Beyond LCOE" they start to think beyond the power system itself to include environmental impacts such as carbon emissions, economic impacts such as jobs produced, things like that. Those are outside of our scope, just to make our scope tractable. Also outside of the scope are subsidies and policies and that's important.

The main objective of the effort is to inform on research for how to improve the value of technologies, but the capabilities that are developed should also be able to inform on how to reduce the cost of the total electrical system, including there may be information there to help inform the markets on different ways to capture some of these additional values that are currently not captured but will become more important in the future. Also it could help with policy development because some policies are helpful to a point and then beyond that point, they may actually become hurtful.

There's a problem as you develop too much of one technology; it may start to cannibalize other clean technologies and we're seeing that in the U.S. where larger CRs of variable renewables are challenging baseload power and nuclear is primarily baseload in the U.S. There's also some hydro that's treated as baseload in the U.S. to maintain river flows, and that baseload is being challenged by negative prices during certain times of the day within certain markets caused by an excess of production from the variable renewables. And understanding some of these factors and how they interplay and being able to make them more visible to everybody should help in basically improving the overall treatment of the markets, the overall treatment of the electrical system, and how we can work to reduce the overall cost while maintaining the reliability and the resiliency of the electrical system.

This effort is being paid for by the three main applied energy offices within the Department of Energy: the Renewable Energy Office, the Fossil Energy Office, and the Nuclear Energy Office. It's part of a larger effort called the GRID Modernization Lab Consortium, and you can see on your screen that there are a number of participants in this larger effort.
Okay, thank you very much, Brent. So unfortunately because all our presenters have fantastic comments and very insightful remarks, I am afraid that we are not going to have a lot of time for questions. But I would like to make sure that we will provide our colleagues in NICE Future the information of all the presenters, and we are very much happy to answer any questions by email that any of that and of this panel may have.

Of course this study is available in the NEA website, so you can download it, read it more slowly, and perhaps some of your questions may be answered that way.

So with that I think I am just going to have a couple of final comments that I think that hopefully summarize a little bit the spirit of this study.

So the first thing that I wanted to emphasize, which has been emphasized by several of the presenters is that the ultimate goal of the work that we are trying to do is to achieve decarbonisation. And in order to achieve that we see more and more that all generation technologies are going to be necessary. So that is one of the key messages.

But another key message is we also need to be conscious of the capabilities and the features of the different technologies and optimize the design of the current energy systems so that they continue to be reliable and resilient and they are going to be cost effective while still maintaining or increasing the amount of carbon emissions that we already use. It's actually having less and less carbon emissions.

So this means, of course, that policymakers and decision makers are going to need to consider how to optimize our current system so that it is including technology and including more investment and also including appropriate policies.

With this I think I'm going to give it back to Katie so you can close.

Wonderful. Thank you so much. And as Sama said, for any questions that we didn't get to today we will connect with those attendees offline after the webinar. I'd like to extend a thank you to all of our wonderful experts and panelists today. It was such a wonderful group, and especially to Sama for moderating. We very much appreciate your time and hope in return there was some valuable insights that you can take back to your ministries, departments or organizations. Again, we'll be posting a recording of this life broadcast on the YouTube channel, where you can find other NICE Future initiative’s recordings of past webinars we've done.

Please enjoy the rest of your day and we hope to see you again at future NICE initiatives. And this concludes our webinar. Thank you everybody.