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IEA's Energy Storage Technology Roadmap

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Webinar Panelist

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Sean Esterly I'm Sean Esterly with the National Renewable Energy Laboratory and welcome to today's webinar, which is hosted by the Clean Energy Solutions Center and the International Energy Agency. And, today's webinar is focus on the finding from IEA's New Publication, Technology Roadmap, Energy Storage, which looks at the role of energy storage technology within our future energy system.

One important note of mention before we begin our presentation 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 before we begin, I quickly go over some of the webinar's features. For audio, you have two options. You may either listen to your computer or over your telephone. If you choose to listen to your computer, please select the "mic and speakers" option in the audio pane. Doing so will eliminate the possibility of feedback and echo. If you choose to dial in by phone, please select the telephone option in the box on the right side will display the telephone number and an audio PIN that you should use to dial in. Panelists you just have to please mute your audio device while you are not presenting. And if anyone is having technical difficulties with webinar,

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And today's webinar agenda features presentations from our guest panelist Didier Houssin and Cecilia Tam. These expert panelists have been contacted up to join up to discuss the IEA's Energy Storage Technology Roadmap which aims to increase understanding among stakeholders of the application that electricity in thermo energy storage technologies can be used for a different locations in the energy system, provide a comprehensive discussion of the nature, function, and costs of energy storage technologies. Again, identify the most important actions required in the short and long terms to successfully accelerate the development and deployment of energy storage technologies, and articulate actions to support progress toward short and long-term goal.

And before our speakers begin their presentations, I'll provide a short informative overview of the Clean Energy Center Initiative and then following the presentations, we will have a question and answer session, where the panelist will address question submitted by the audience followed by conclusion remark and then a very brief survey.

Now, this slide provides a bit of background in terms of how the Solutions Center came to be. The Solutions Center is an initiative of the Clean Energy Ministerial and it's supported to a partnership with UN Energy. It was launched in April of 2011, is primarily led by Australia, the United States and other CEM partners. Outcome to this unique partnership includes support of developing country to enhancement of resources on policy relating to energy access, no cost expert policy assistance and peer-to-peer learning and training tools such as the webinar you are attending today.

And there are four primary goals for the Solutions Center. It serves as a clearinghouse of clean energy policy resources. Also, serve the share policy best practices, data, and analysis tools specific to clean energy policies and programs. The Solutions Center delivers dynamic services that enable expert assistance, learning, and peer to peer sharing of experiences. And lastly the center foster dialogue on emerging policy issues and innovation from around the globe. Our primary audience is energy policy makers and analysts from governments and technical organizations in all countries. We also strive to engage with the private sector, NGOs and civil society.

In a marking service marking that the Solutions Center provide is the Ask an Expert Policy Assistance program known as Ask an Expert. Through the Ask and Expert program, the Solutions Center 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 Finance and Sustainable Energy Planning, we are very pleased to have Wilson Rickerson, the CEO of Meister Consultants Group serving as our expert. So if you have a need for policy assistance and Finance and Sustainable Energy Planning or any other Clean Energy sector, we encourage you to use this useful service.

Again, it is provided free of charge. So to request assistance, simply submit your request by registering through Ask an Expert feature at http://cleanenergysolutions.org/expert. We also invite you to spread the word about this service to those in your networks and organizations. So in summary, we encourage you to explore and take advantage of the Solutions Center resources and services including the expert policy assistance, the database of Clean Energy Policy Resources subscribed to our newsletter and participate in webinars like this.

And now I'd like to provide brief introductions for our distinguish panelist today. Our first speaker today is Didier Houssin, the Director of Sustainable Energy Policy and Technology at the International Energy Agency. And our next speaker following Didier, we will hear from Cecilia Tam, the head of the Energy Demand Technology Unit at the International Energy Agency where she also leads the IEA's Energy Technology Roadmaps Programme. And then we will also be joined today during the question and answer session of the webinar by Melissa C. Lott, from the International Energy Agency also has worked as an energy systems engineer and consultant for more than 10 years in both the US and Europe. And with those brief introductions, please join me in welcoming Didier to the webinar.

Didier Houssin Okay, thank you very much and good morning everyone. And first, I would like thank the Clean Energy Solutions Center and Nation Renewable Energy Laboratory for collaborating with us at the IEA today to launch this new technology roadmap on energy storage. I'd like to point out this one is the twentieth detailed roadmap. There's the program we started in 2008. This publication that we are releasing today outlined how energy storage technology can support the decarbonization of the energy sector and the transition to a local renewable economy. Energy storage technology including both larger centralized system but also small and distributed system can bridge the gaps between energy supply and demand. They uses a not limited to supporting the rival renewable generation and rather they can also help to optimize many parts of the global energy system. The roadmap work is based in this roadmap like for the others, on the IEA's local ETP scenarios, these scenarios that are presented in detail in our flagship road and technology—energy technology perspective outlined how we can limit global temperature

increases to 2 degree Celsius by having energy related emissions by 50 percent in 2050 compared to some 2009 level.

I'd like to take this opportunity to mention that this roadmap is based on our ETP 2014 numbers that will be presented next May 0in the side line of the Clean Energy Ministerial in Seoul and also I would like to highlight that ETP 2014 will update its scenarios but also take a special look at the important role of electricity in our energy system. And that's where we include special chapter of the role of storage in the energy system and how it compares against competing technologies such as grid infrastructure, dispatchable generation and the man side management.

And let me comeback roadmap process. We have developed this roadmap process in 2009, include cooperation with variety of stakeholders including key governments, industry and research process. These roadmaps are developed with the aim of developing a strategy to accelerate the development and deployment of a given technology by 2050. We try to answer three broad questions. First, where is the technology today? Second, where do we want to go in the long term? Third, what are the priority actions that I needed to accelerate the development and deployment of a given technology. So first, the roadmap identified the technology baseline based cooperation of variety of experts to understand where we are today. We then use our modeling tool to identify the growth pathway, the cheap this technology contribution to the overall litigation portfolio in 2050. We then identify the areas to fully realizing this potential and finally the roadmap sets—include a set of actions and milestones to guide implementation.

So what are the key points when we look at the role of storage in the energy system? In a nutshell, they can help to better integrate our electricity and heat systems and can play a crucial role with energy system decarbonization by doing a series of things improving energy system resource use efficiency, helping to integrate high levels of the variable renewable resources and end-use sector electrification. It can also support greater production of energy where it is consumed. It can also increasing energy access across the world; and improving electricity grid stability, flexibility, reliability as well as resilience. Let me now handle over to Cecilia for the key findings of the roadmap.

Cecilia Tam

Thank you very much, Didier. What I'd like to do now is really take everyone through the main features of our energy storage roadmap. One of the aims of this document which to provide a better understanding two a range of different stakeholders of the application that electricity and thermal storage technology could be used for in different locations of the energy system. As the figure in front of you shows what could be some hypothetical storage deployment across the difference electricity power system. And as you can see here, we see that a variety of those electricity and thermal storage technology can be deployed in the demand, transmission and distribution, and supply areas of the electricity and

energy system. Starting on the bottom if we look at demand or the energies level, there are another technology such as small-scale battery, underground thermal energy storage, and hot water heater with storage that are used to improved efficiency in the energy system. Then at the transmission and distribution level, there are flywheels and a variety of battery options that can be used. And then finally at the supply or generation level, we have pumped storage hydropower and molten salts with CFP, just a name a few examples just how these variety of storage technology can be used to better integrate our electricity and heat system.

As we discussed, the storage technologies that are being developed and that are available are used for address a wide range of different application. The figured here shows which application, the different electricity or thermal storage technologies can be used to address. So, if we look from time wise at very short-term application, there's a number of different technologies that can be very useful to address frequency regulation, demand shifting or integration of variable electricity supply which require response time at the level of minutes or less. They can also be used to help defer investment in transmission and distribution or for congestion really, and arbitrage, too much longer storage need for seasonal charge.

Today, we have already about 140 gigawatts of large-scale storage, which is currently installed, in our electricity grid worldwide. The majority of that, about 99 percent comes from pumped storage hydropower technology as you can see in the figure here. The remaining 1 percent is a mixed of battery technology composed of energy storage and flywheel.

The roadmap covers quite a large spectrum of the electricity and thermal storage technologies. And as you can see in this figure, storage technology got a wide range of maturity level. The figure before you tries to mapped out the maturity levels of this wide basket of both electricity and thermal technology, very mature technology that shows pumped storage hydro to cold water storage and underground thermal energy storage to less than and more demonstration deployment level technologies which includes quite a wide section of battery technology to less mature technologies such as the SMEs, hydrogen and thermochemical technology.

What we try to do in the roadmap is really to provide a comprehensive overview of the current status of the number of this technology. Some of the information that is available in the roadmap include table that tried to summarize really where these different technologies can play a role, what were there efficiency, investment cost that are required for the technology, and we also include some project examples and important part of the technology roadmap is what we call the technology annex which goes into quite a lot of details of the project examples that you see listed in this table here.

So we are looking at quite a large broad spectrum of technology to, you know, very mature technology such as hydro and underground thermal storage to less richer technology including quite a wider array of battery, including things such lithium based battery, sodium-sulphur and lead-acid battery and ice storage to much less mature technology that are only really [noise] such as super-capacitors and super conducting magnetic energy storage and thermochemical storage technology. So what we try to do is really provide additional examples that can be investigated by the readers to have a better understanding of the characteristics of this wide spectrum of energy storage technology. These examples include quite interesting in mature technology such the use of hot water heater in France that are very affected at reducing kitchenette. Two examples in China where they have at the Shanghai Pudong Airport a cold-water storage system that helps them reduce their electricity consumption. They're using cold-water storage for cooling purposes instead of consuming a lot of electricity. And then finally just another example of sodium-sulphurs that are used in Texas to increase reliability and help to defer investments in transmission and distribution. So I encourage everyone to go online, to download this technology outline, it will provide a lot more technology details and what is then in our very short and concise technology roadmap.

In terms vision or the scenarios used for these energy storage roadmap and Didier mentioned we based this work on our upcoming energy technology perspective 2014 and we used our two-degree scenario, our low-carbon scenario as the reference case for this roadmap. And in this scenario as you can see in the figure before you, we see that we need to decarbonized the electricity sector and in order to do that we need to see quite a big shift in electricity generation from renewable which we see rising project 20 percent today up to the 65 percent by 2050, with the share of variable renewable supplying about 29 percent of total electricity production by 2050. The figure here look only at four regions. To roadmap, we did some additional modeling focused on trying to quantify the potential of energy storage in four major regions, in China, India, the EU and the US, were we see the share of variable renewable ranging for the 27 percent to 44 percent in 2050. This increase of such a large share of variable electricity supply will need to be accompanied by greater flexibility in the electricity sector. And our technology roadmap on energy storage focuses on the role of energy storage technology in providing this flexibility. And as part of the roadmap work, we also developed a number of different scenario vision for energy storage so there's 2-degree scenario that I'd mentioned. We also developed a breakthrough scenario for storage, which is in very aggressive cost reductions in a variety of storage, as well as electric vehicle scenario where the man response for smart charging of electric vehicle fee provides additional flexibility in the system. And what you can see is that, under the 2DS, 2-degree scenario, by 2050, to improve flexibility in the electricity system, we would need to invest in an additional 310 gigawatts of storage capacity in these four regions of the world. And it's important to highlight that these four regions will make up

of their 85 percent of total electricity demand by 2050. And the breakthrough, okay, we see that this potential for reconnected storage who reached level without 500 and 20 gigawatts and then the EV case, this would slightly reduce to 200 gigawatts and the EV scenario is seen that about 25 percent of the daily electricity requirement from electric vehicles to control the load and available for demand response. The roadmap also include three country cases for the US, Germany and China which highlights national study that has then developed to analyze the potential need of energy storage in this countries and the modeling rebuilt of those studies are very much in line with what we had presented in our 2DS.

So just a little look more detail on our breakthrough scenario. The figure here shows that to get this breakthrough scenario, we've seen that the cost reduction for a wide spectrum of electricity storage technology will fall quite sharply, reaching levelised cost of energy for bulk daily storage of approximately 90 dollars for megawatt hour. This is an extremely and ambitious case. It is seen that in the future electricity storage technology will be as competitive as the least expensive option currently providing arbitrage services, which currently today is a combined hydro gas turbine. And the LCOE of energy and the electricity storage technology in the breakthrough scenario than it seemed that all the flexibility that required in our future's system will be served by electricity toward technology but it's important to highlight that these cost reductions are extremely ambitious particularly for pumped storage hydro and CAES technology, given that we have already seen quite significant reduction over the last few years. But it's possible that additional savings can be achieved through improvement in civil engineering and other technology improvement. For battery technologies, the cost reduction are extremely addresses and would require a reduction in their specific energy cost of the facture—by a facture of about 10 times. So although we see very promising development for a wide spectrum as electricity and thermal storage technology, the cost reduction that are needed to see storage being deployed at much higher level are ambitious. But we feel that a lot of dedicated R&D has been going into these technologies and that—in many cases there are room for optimism amongst the different storage technology.

And the roadmap also tries to provide set of recommendation covering quite a large number of technology areas. In the figure here, we are just showing the demonstration of the types of information that can be found in the roadmap. Here, we show the milestones and recommendation that are going to be needed that covered by a wide spectrum of technologies and application. Here we highlight the need for the collection of better data on existing project that will help us better assess and quantify future needs or potentials for energy storage and when we were developing the storage roadmap we did struggle as part of the process and being able to collect a comprehensive database to provide better estimation of the potential of energy storage and one of the key recommendation coming out of the roadmap is really to improve global dataset to allow us to better track

progress on energy storage project development and also to provide better global and regional potential then in target.

In addition to these cost cutting recommendation. The technology chapter of the roadmap also provide clear concrete recommendations and prepares timeline for technology development in electricity storage technology covering short term application, distributed battery as well as long-term electricity storage and for thermal storage technology, there are prior recommendations and milestone have been presented for low-medium and high temperature application to encourage everyone to take a closer look at these technology development milestone in the roadmap. As well as the recommendation that are more on technology development basis, the roadmap also include the chapter highlighting recommendations and actions that we need focus on policy, finance and international collaboration.

The recommendations that are shown on this slide here focused on policy and regulatory framework and one important part to highlight is that for storage should be more widely deploy. We need to address some of the current market and electricity values that are keeping energy or electricity storage technology realizing their true potential. There is a lack of price transparency on many of the current electricity grid. The high cost and significant price distortion in the energy market are quite an obstacle to wider deployment of electricity and energy storage technology. We need to have policies which will allow energy storage technology to be compensated for the spectrum and services that they can provide to the energy system and this include identification and elimination of the price distortion that create negative cost impact for storage technology. It is critical that storage can be compensated directly for the different services that they are already providing to many of the market. Furthermore, we recommend that we need to have policy that will enable benefits-stacking for energy storage operators. These are already have been proven in numerous studies to significantly improve this is case for energy storage project. Benefit stacking allows technology service system to receive revenue for providing multiple and compatible application. One I'm element policy to highlight that we saw in the US are FERC orders 755 and 784 which demonstrated how access to accelerate business market can have very positive influence on the economics of the electricity storage project. In the short term, we would like to highlight that priority should be given to encourage the deployment of storage technology in off-grid and remote community which storage is already competitive or near cost competitive for existing centralized storage facility. Efforts are needed here to improve the efficiency and flexibility, which could help integration, which could help integration of higher level of variable renewable.

And then just the end, I'd like to highlight some of the key findings of the roadmap. First, that energy storage technology can play an important role in supporting energy system decarbonization. But that storage is one of the

numerous key technologies that can help support energy sector decarbonization. It is not a silver bullet or the magic solution, but really one of a number of options for supporting wider decarbonization. Many storage technologies already competitive. Today while others particularly some electricity storage technology still struggle with very high cost but we see great potential in the near term in deploying storage technologies in small-scale system and for remote or upgrade application. And large scale thermal energy storage technologies already extremely competitive and widely used for heating and cooling in many parts of the world.

It has been encouraging to see quite a significant rise among public support for investments in energy storage R&D which has helped to significantly reduce a cost for a wide—for a number of these technologies, however cost still remains high in many of these technologies and additional effort are going to be needed on R&D to get this cost down. The optimal role for storage and the potentials that they can provide will really depend on a quite variety of factor that in many cases will be very regionally specific and it will also determine how they can impact or compete with other non-storage technologies for providing flexibility to the grid and enhancing system efficient. It's critical that we has the right market design and that power market are adjusted so that energy storage technology can be compensated for the suite of services they can provide to the energy system. And finally, just to highlight that thermal energy systems can play a much bigger role in enhancing and improving the efficiency of our energy are reducing the amount use of heat that is currently wasted. So for example, at large amount of industrial waste heat is currently not being captured and used in other system and we see that this could be quite a tremendous potential in the near end and the long term.

In terms of near term recommendations and actions, we're recommending that incentives that quite in place that will allow for the retrofitting existing storage facility to help improve their efficiency and flexibility. We also needs to develop markets places and regulatory environments that enable accelerated deployment of energy storage technology in part to limiting price distortion and enabling benefits-stacking for system. These will allow the technologies to be considered for the wide range of services that they can provide over their lifetime. We also need to have early action on targeted demonstration project that will help promising energy storage technology, document, performance and safety rating. We also need to share information and collect lessons learned and share through quite a wide sector storage stakeholder groups nationally and internationally. And we also need to support greater investments in R&D for early stage at energy storage technology, including technology breakthrough in a high temperature thermal storage systems, scalable battery technologies in hybrid system. We should establish a comprehensive set of international standard in a manner that allows for incremental revision as energy storage technology mature and we also recommend that there is an

international and national data co-operation and system which is establish to help foster electricity storage, research and that will allow us to monitor progress and assess R&D bottleneck. And then finally, we recommend that analysis is completed at the regional level to provide better assessment of the value of energy storage in specific region and energy market and that we can promote the development and adoption of these tools to help us better evaluate energy storage project proposals in the near term. And I just want to highlight that the roadmap and technology annex which for quite a lot of real project examples can be downloaded from the IEA website on the link that is showing in front of you. Thank you very much.

Sean Esterly Thank you, Didier and Cecilia for those presentations. And with that, we will now move on to the question and answer session of the webinar. And I just want to remind the attendees today that if you have any questions you may submit those questions to the question pane and I will red those and present them for the panelist for discussion. So I did receive quite a few questions during the presentation and we'll start with the first one that I received and move through. In the first question that came in was, you said storage for heat and electricity highlighting stability, the bridge of those two energy systems, but you didn't include how are the gas, but you did include hydrogen. Can you speak to where you would see how are the gas technologies or whether it was out of the scope of the report?

Cecilia Tam Yes, and we do mentioned it briefly in the roadmap, but what I'd like to highlight is and we're currently developing a roadmap on hydrogen technology so we decided that's the beginning of the energy storage roadmap process, to leave hydrogen evaluations for that particular roadmap. In the annex, there are also some more detail discussion of country and cases for hydrogen and power to gas option so I encourage people to have a look at the annex to get more information on these technologies.

Sean Esterly Thanks Cecilia. And the next question asks, what is the roadmap has a global focused of whether specific to the US?

Cecilia Tam The roadmap is global in scope as all of the IEA's roadmap by 10 divisions because that we had we focused on four key regions in terms of quantifying what was the potential for electricity storage under our 2DS and there we provided modeling analysis for India, China, the EU and the US and as I mentioned we have country case studies that highlight analysis. That was done in the US but also in Germany and in China. The recommendations for the roadmap are global in nature but we're possible, we also try to provide examples recommendations of god polices and so forth that we see in different countries including the United States, countries in Europe and also in China, Canada and many others.

Sean Esterly Okay, and the next question asked in regard to the electric vehicle scenario is the cumulative capacity of car batteries included are not in your estimate?

Cecilia Tam It's not included.

Sean Esterly Great.

Cecilia Tam Just to highlight that. The electric vehicle batteries—I'm sorry the electric vehicle scenario was done to show that if we could use the energy storage potential that represented in this electric vehicle suite, we could reduce the need for daily storage across a number of categories.

Sean Esterly Great. Thank you Cecilia. And the next question asked, if there is an IEA implementing agreement that houses, this comprehensive global dataset for their, is their coordination underway for that?

Melissa Lott And, so we have—this is Melissa Lott. So we have the IEA's implementing agreement that the energy conservation for energy storage implementing agreement and they—if you go to the website online you can see a number of reports that they have which case studies and information that has a lot of these data. A lot of them are used in reference in the roadmap that you'll see. But they also, you know, they were part of this development processes on the roadmap and they can identify also where the data gaps exist. So we would love to have comprehensive, operational and investment in data for all energy storage project across the globe but unfortunately, that's not, you know, reality, which is as we said presented some challenges when we were doing our modeling and our projection to 2050.

Sean Esterly Thank you Melissa. And the next question points out that Cecilia you mentioned what cost reductions would be needed in storage technology to meet the 2DS but how does that compare with expected or likely cost reduction?

Melissa Lott This is really interesting questions of the hard and a lot of discussion that we have in developing the roadmap. So in the vision, you'll see that the levelised cost of electricity that's presented in our breakthrough scenario is $90 per kilowatt-hour. And when you compare that, I mean that's essentially the same you're going to get other technologies so there's four categories backing as large-scale energy storage in the vision. And so you have pumped storage hydropower, pumped hydro, you have CAES, you have, slow batteries and you have other category batteries, more generalized battery. And we're saying that the levelised cost of electricity for those going to get down to $90—I'm sorry megawatt hour in the breakthrough scenario. If you look at that depending on the specific type of technology that you're using and how it is using energy system, if they're going to give you that answer as to how practical that is that we actually see that happening. And this is at the core of the concept but it's

not necessary about the technology that you're using energy system which will, you know, show you if that's going to be shorter term cost competitor technology or not. So Cecilia mentioned the benefit-stacking context and when you have a market where you can benefits stacking you can use the technology for many applications. You'll see that technology, you know, obviously bringing in, you know, more money potentially as a result of being able to stack those things. So I wish that there was a clear-cut answer but it's more complicated and we do discuss that primarily in the chapter right after the vision on this roadmap.

Didier Houssin I would like add to the report on this—what important and what we try to do in this roadmap and also I need to take to them co-ordinate, also to compare storage as with other tools for flexibility. So looking forward it would also I'm going to see on one side, what would be the demand for more flexibility of energy system and we expect with larger share of renewable that the demand for affectivity would increase very sharply which creates a good background for R&D progress for storage technology and there was a question before about power to gas it's pretty link for instance to the production of intelligence electricity like in Germany which it's almost at no cost and this provide a good case of course for developing power to gas technologies. But the other point is also to look on how other options or flexibility will—involving in the future and there will be completion between different flexibility tools. So one of the messages also of the roadmap is to emphasize the need for more R&D to encourage cost cutting in this different energy storage technologies. Thank you.

Sean Esterly All right, Thank you, Melissa and Didier. And the next question is more technology specific. It's asked, what is the recommendations, what is the best way to reuse wasted heat.

Cecilia Tam As I have said a number of ways we can better use of wasted heat, if we just look at industrial waste heat we have waste heat recovery systems that can be more widely deploy in industry. We could try better use wasted industrial heat for district heating in nearby remote countries. I think one of the areas where better utilization of waste heat struggled with is that it's not very well known today in our system how much waste heat is available and where it is available and where the consumption for this waste heat can be used. So, one of the recommendations of the roadmap and one of the IEA had had for quite some time now is also to have a better evaluation of our energy system to match where we have potentials for recovery this wasted heat and where we could better use the heat in local—for local demand. So in the work of our co-generation and just the heating and cooling collaborative, we have tried to highlight the heat for better studies that map better the availability of heat and supply and to better match it where heat is being demanded so that we can take advantage of this potential which could represent quite significant benefits in terms of improving the efficiency of the energy system.

Sean Esterly Thank you Cecilia. And the next question raise up the context a little bit for so bear with me as I read through it and I have several questions that then I'll be happy to repeat any of it if necessary. It's the attendee state as you're probably aware of electricity storage is questioning the fundamentals of the classic European electricity market architecture which set forth by the unbundling regime push forward by the EAU energy packages. Now, electricity storage seen encompassing the classic value chain separation and be suitable for cross chain application but it's not clear whether the European Commission will take a strong stand in favor of considering that a competitive rather than a regulated activity. So the attendee wonders did you go through such kind of discussion in your analysis? What's the IEA stances and how do you believe the creation of an ISO ownership unbundled from PNB could solve the issue of conflict of interest? Yeah, I'm happy to repeat any part of that for you.

Melissa Lott Could you repeat it one more please so we make sure we caught if off?

Sean Esterly Yeah, definitely. Just question or would you like me to start with the context as well?

Melissa Lott If you could go through the questions Sean, that would be great and make sure…

Sean Esterly Yeah, the first part of the questions is, did you go through such kind of discussion in your analysis? What is the IEA stand and how do you believe the creation of an ISO ownership unbundled from CND could solve the issue of the conflict of interest?

Melissa Lott In terms of the discussion, so discussion the roadmap contains within the text a discussion about how price distortion in the energy market impact the ability for storage and other technologies to compete in the energy system. This is a discussion that we had in the number of the workshops then you'll see at the beginning of the roadmap in the first section an outline of the three workshops that we brought in expert from industry, and academia, and government to really get up the core of not only the technology challenges, the energy storage are facing, not opportunity but also looking at the market environment, the other non-technical, you know, barriers and incentives of the storage deployment. So, actually if you—when you go on for the roadmap itself on age 47 of the roadmap, there is a table that talks about examples of government action that have positively supported energy storage technology deployment. No this isn't an exactly yes answer. I think to the question how I'm hearing it but it is giving an examples of how different government have set up environments in which energy storage is encourage to deploy or their deployment is accelerated. And so, this is, you know, a good start of just seeing some examples of what governments have been doing and then what you may have seen is the result to that. And I think there is one other part of the question that I might miss? This is something that is discussed in the roadmap, so talking about the concept of paper services model. So, one of

the key energy storage in terms of, you know, following as deployment and getting it out there in these numbers is the concept of them being able to be paid for the service of somebody. So in some markets it's not a clear cut. In many markets it's not a clear cut of saying, "This is the service we're providing. This is how much it's worth" and they get paid for it. Many times in the service is they're group together. The price is there, the cost of the services is not as transparent as it could be. And so there is discussion on that serving on the policy finance on the national collaboration chapter on page 46 in the roadmap and be happy to if anyone has specific follow up question to that after looking through that section, we'll be happy to follow up.

Sean Esterly Great. Thank you Melissa. And the next question points out that one of slides showed the possible percentages of variable renewable generation that could be integrated with the help of storage and the numbers that you reflected show 50 percent or less and they do know that those seemed to be very conservative compared to what some of the EU country like Germany you were talking about 80 percent. Could you talk about how you came about those percentages and determine that.

Cecilia Tam Yes, just to clarify that the figure that I showed was at the amount of variable renewable generation that our model picked up for those four regions of the world in their 2DS. This is based on our least cost optimization model. So it's not really limitations of how much renewable could we think could be pulled into the energy system but based on a least cost approach to the electricity system, how much variable generation within the electricity system. So although we see that target in some of the European countries and in particular go for much higher level and it is not really a limitation to how much renewable or variable renewable we could see in the system but what our modeling exercise showed based again this least cost optimization approach. So, there's a wide range of low carbon electricity technologies and they can provide different levels starting on the different condition of these four regions that we evaluate. Thank you.

Sean Esterly Thank you Cecilia. And the next question asked, is there any sensitivity analysis to less ambitious cost reduction target?

Melissa Lott So, there's—yeah that's a great question, absolutely. We were all nodding like that but thank you for asking that one. So presented in the roadmap are three variants. So first we have the 2DS which the storage specifically have assumed that cost of storage will be variable lowest cost technology providing the service today so that pumped storage hydropower we're talking about, again great connected daily energy storage kind of concept The second scenario is the breakthrough scenario. So this has the side of, "okay, what if we got down to that LCOE, the levelised cost of electricity of $90 per megawatt hour. And to be cleared, that $90 would include the initial investment, operation maintenance and the cost of electricity used to charge storage facility.

So, this would actually make some competitive with what we analyze is the least expensive option currently providing arbitrage services so that [inaudible] [00:52:23] operating at low factors within the range of 30 to 60 percent. So you got those two. And then on the other side in the electric vehicle scenario, you know, we looked at that electric vehicle suite as adding flexibility to system, which actually in fact, you know, decrease the demand. So it made up so that you would be what happened is there's wasn't as much, you know, demand for these electricity storage. So we get a range there. Beyond that in terms of changing individual cost parameters that are presented in the roadmap, but those three variants are which give you a kind of range to give you a better idea.

Sean Esterly Great, and a question regarding the impact of crises. What would be the impact on electricity crises?

Melissa Lott So this something that we didn't analyze in terms of you know looking at what we presented. So we looked at China and the other EU and the United State. And we also presented 300 countries focused case studies for the United States, Germany and China. We did not go into individual price changes but then you know market I mean just within the US, you got so many different markets going on from the different selected cities.

Didier Houssin I mean it's called the country I think that the country case show that when you have the public market signal you provide incentives to deploy and more rapidly energy storage technology and so as a discussion the roadmap about the importance of the putting in place that economy benefits or storage and the price signals that helps to deploy more rapidly energy storage technology so it's being the other way realm.

Sean Esterly Okay, thank you. The next question that I have points out or asked if you were aware that the IRINA, the International Renewable Energy Agency. They're also launching their roadmap for storage in the next few weeks. Had you had a chance to look at that or you know if the two publications are comparable?

Cecilia Tam We had in the IEA's technology road-mapping process. We had colleague an IRENA at the workshops and providing review of the analysis. I'd like to highlight that, no I think the two aim to do is lightly different aspect and from my understanding, they're more still in the process. I don't know they're actually reaching their roadmap in the near future. We have been in touch with our colleague at IRENA to make sure that they're not duplicating our effort particularly when we're developing this technology roadmap so they generally they to focus of different areas of the analysis.

Sean Esterly Okay, thank you Cecilia. The next question asked if you had any suggestions on how the value storage systems according to the services that they provide?

Melissa Lott That's a great question. So in terms of valuing energy storage, I mean so we didn't in the roadmap go to the point where we suggested that certain countries, you know, value or pay energy storage certain amount. It's more about, you know, valuing the service that they provide and if there's another technology they can provide that service where at a cheaper cost then, you know, that's how it goes, that technology supplies it. And their contact, their benefit stacking it, that Cecilia brought up earlier again, is a key one here saying that, often times you have one technology, one energy storage technology that can provide multiple services over its lifetime. So they're both technically and operational need compatible and so we don't say what a market should pay. We just say that the market should pay for the service.

Sean Esterly Thank you Melissa. And the next question refers to a specific kind of energy storage, it asks how superconducting magnetic energy storage can provide an electrical power of 1 megawatt from the $130 to $515 if that's the same as ice storage which is very simple technology is more than 10 times expensive. Could you just talk about those differences roadmap?

Melissa Lott Yes, from—we'll change sorry a really quickly on through roadmap. I think it's the right page number. Among the slides that Cecilia presented that talks about, the different maturity levels of energy storage technology. I'm sorry—bear with me for one second here.

Sean Esterly Yeah, no problem. We can also put, if you'd like we can put the slides back up.

Melissa Lott So, it's the slide that is about the maturity of energy storage technologies. And what you'll see here is pretty key. So when you got this curve shows the different technologies, you'll see that in the case, Sean, was that ice storage and SMES mentioned I think?

Sean Esterly Yes, yes.

Melissa Lott So if you look on Cecilia's slide which I think one of the questions asked that the slide should be available in the future and they will be put in online. But on the roadmap on page 16 figure 3, we talked about maturity energy storage technology and what you'll see on this curve is you'll see ice storage being in the section called demonstration and deployment. So on the Y-axis we have capital requirement times technology risk and then across the X factors we have what could be loosely termed, I think the audience are familiar with technology readiness level or TRL and so you'll see ice storage is much further long in that curve, yeah, exactly that slide. And so, you know, this is the word of a cautionary tale, you'll see it in the technology annex as well that if this is what you're seeing with that technology energy system yes, the SMES is still from out analysis sitting in that research and development phase. So versus if you look in the, you know, right hand side, you're looking at pit storage or pumped storage hydropower, you know, those are deployed technologies that have been

commercialized and so those are prices that people have been impacted in the commercial facility. So that, you know, very important for those two in contact and thank you for asking that question.

Sean Esterly Great. Thank you Melissa. And the next question specifies solar power asked. It points out that solar power had in some territories seen support from government taken away and some cases suddenly within, you know, severe consequences. So how could the energy storage space remain secure from the possibility of similar what are called changes apart?

Cecilia Tam I mean just a respond to that. I think, it's a bit different in many cases because the policies that we have to deploy solar technologies, I don't think, you know, if you don't have and so forth have really been the same than what we we're are seeing for storage technologies where a lot of the public focus or public—I'm sorry, public investment focus on early stage R&D to help improve and demonstrate these technologies. Not that many government has the mandating and the deployment of storage technologies where what we believe is that to help electricity storage where storage technologies developed it's market is what we really need to do is allow for the storage technologies to be paid for the services that are being provide. So I think in terms of the incentive that we've seen for energy storage, they've been focused more at developing the technology, in getting the cost of the technology stuff and necessarily, you know, high level of deployment of the storage technologies 'cause, you know, they're different in maturity level.

Melissa Lott One thing I will say that we also talked about is around I hate to have on benefit stacking and, you know, having storage to compensate to the service they provide. But when we set up that type of a system, if storage technology is able to provide that service in an economic fashion, you know, is in a more protected or secure space in that sense.

Sean Esterly Okay, thank you Cecilia and Melissa. Moving on to the next question, have you envisioned how different market arrangements would encourage or discourage storage technologies versus other solutions? For instance would capacity mechanisms, help or in their storage?

Melissa Lott So this is the question that I would want to follow up on 'cause I know that we're running short on time today and I would, if we get follow up on that question. I would hate to give a straight answer to just that and I know there are some people here at the IEA who have worked on that question detail and it had really good discussion with them. So if we could follow up on that one, that would be great.

Sean Esterly Definitely, I can—I will send that question to the three of you following the webinar so that you can respond directly to email.

Melissa Lott That would be great and then we will give you a full answer.

Sean Esterly Okay, yeah, no problem. And so, move down to the question which asked specifically about certain types of technology, they're wondering about hydrogen and its cost and they say that it was presented that hydrogen cost are now $200 to $300 performance megawatt hour. What's the cost of hydrogen converted that in electricity by using fuel so?

Melissa Lott I'm sorry Sean, you just quoted the performance megawatt hour number 200 and could you tell me—'cause I'm looking the trends that we had is the same as cost values is for megawatt number, but you're talking about the sharp decline and cost needed is that we were talking about hydrogen?

Sean Esterly I'm not certain.

Melissa Lott So, I'm going to go assuming, assuming yes and if not—whoever who ask the question please follow up so we can address it if that's not the case. So on one of Cecilia's slide and Cecilia and Didier slide, they talked about in the slide of sharp decline and cost needed and it shows hydrogen that was sitting between $200 and $300 for the levelised cost of electricity performance megawatt hour and for this one there are a bunch of, there are all the references for those cost numbers and are included in the roadmap but it's the chart that has direct cost and below included in that chapter so I would encourage, you know, look at, you know what those represents are in terms of exploring that number in greater detail. Again, we didn't focus on hydrogen on this roadmap because we are going to be focusing on it in such great detail on its own roadmap so I would certainly encourage you to look at that roadmap when it's release. But in the meantime, we would refer to the references that are in here, in the roadmap sorry.

Sean Esterly Great. Thank you Melissa. And this next question relates back to the question, previous question on policy support. And asks, what is the impact of the cost of solar electricity mainly MPV on the development of storage technology and what cost for MPV is assumed?

Melissa Lott You know, I don't have that information with me again. If we could follow up on that one that would be great. In terms of specific analysis to just the cost impart storage MPV that's in analysis that we presented on this roadmap.

Sean Esterly Okay, and that's another one I will forward onto you after, Melissa.

Melissa Lott I will say that if you do look at the percentage of variable renewable generation, so you know, you could put solar both DFC-MPV in there. When you're looking at higher levels of it across our analysis and three country case studies that we see, you see increasing amounts of storage being deployed. So there is that, that link between the technologies there. So that is for them in the roadmap when you see that but again, we didn't separate out specifically MPV or specifically DFC. And I don't know, I noticed one question that came in early that I wanted to just make sure we answered. That was about the best rules for storage, I mean it how it varies

across regions and a request that we elaborate a bit on that statement. And something I wanted to mention is in the roadmap on page 14 is a table that talks about the near term capability criteria for determining what the prime energy storage technologies for deployment. And here is generalized staff on where—what technology examples of what types of technology you might include in different systems. So for example talking about large scale electricity storage, so this could be pumped storage hydropower, this could be CAES, it might provide the most near term benefit scenarios that have more developed electricity grid that can more easily accommodate this centralized energy supply resources where if you were in a remote or an outside community, this table also discusses how you might first look at smaller scale electricity or smaller scale thermal technology. So that was a really question, thank you for and that has been discussed pretty in detail in the early question on the roadmap.

Sean Esterly And thank you, Melissa. And the next question asks, how you can deal with market arbitrage and assure that you are storing energy from renewable versus other sources?

Melissa Lott That's an interesting question. I don't know that you can ensure that the electron going into the system are from renewable or not, unless you have the case of the [CPC] facility with molten salt onsite and they are storing the electrons from that feasibility but if they're just connection to the grid separate from in generation resource I mean it's getting whatever electricity, you know, being out through the wires, so, you know, it's going to be a mixed, assuming that you don't have a hundred percent renewable system.

Didier Houssin Also storage would be very dated when you intermittence electricity coming from a new—the rival energy [inaudible] [01:07:46] that will be the rival. So in terms of incremental input to the grid, the onsite will be intermitted sources. And we also provide the ration for deploying this storage technology.

Sean Esterly Okay, thank you and Melissa. And the next question from the audience points out that some technology analysis including Lux and Navigant have said that while lithium-ion will dominate the battery space in the next five to 10 years, in the long term, costs are not likely to fall enough for lithium-ion to remain dominant beyond that. So what can be done to ensure spending remains in R&D to find and develop alternative instead of being spent to scale up production of lithium-ion batteries for short-term returns but a handful of companies are in the market. And then the second question for that is will it come back to adding value to the services storage can provide rather than accommodating—commoditizing the storage product itself.

Melissa Lott So this is, this is really is a great question. So in the roadmap when we present our technology recommendations, which includes the section that are recommendations or battery system, battery storage system. We don't

take out one, you know, specific company or one specific design and we do recommend a combination not only supporting, you know, for the more mature battery technologies are out there, helping them get up to scale in terms of production but also supporting the more less developed battery technologies that still, you know, maybe haven't, you know, they are not mature on that scale. And Sean can you tell me the second part of the question. I just left it.

Sean Esterly Yeah, it asks, will it come back to adding value to the services storage can provide rather than commoditizing the storage product itself?

Melissa Lott Sure, I mean the value of storage is a service that it can provide in the energy system. I mean that it does thing that we value and so a big key in accelerating the deployment that we present in here is about paying it for the services the application that used for, the services that provide the energy system. And that is, you know, at the heart of the discussion it's roadmap and so while we certainly recommend that technologies, you know, we need for the development many cases, we also recommend that people take a hard look at their—the energy market structure in their region if they want to effective incentivize energy storage in the long run.

Sean Esterly All right thank you again to each of the panelists for the great discussion based on the attendee's question. Those are all the questions I received. So at this point, before we take our quick survey, I just like to provide each of you an opportunity to—for any closing remarks or final statement that you might have for the audience.

Didier Houssin Thank you very much to all of you for your attention.

Cecilia Tam Just to encourage you to go on through the website to download those—the technology roadmap as well as the technical annexes provide quite a lot of information and I've got more of the current project that we see in quite a wide range of different energy storage technology. And to keep looking at new technology roadmaps that the IEA will be developing including one for next year on hydrogen which will look at more further at hydrogen storage option.

Melissa Lott If I would just encourage not only, if you have specific questions that are let's say, targeted towards building, that heating and cooling, there are technology roadmaps specifically address those types of areas at the energy sector and storage is included in some cases in this discussion . So I would certainly encourage you to go to the website and look at the different roadmaps and follow a question. And thank you very much.

Sean Esterly Yes, and thank you again, Melissa, Cecilia and Didier for those presentations and for the discussion. And at this point, we just like to ask our audience to take a minute to answer a quick survey on the webinar that you've viewed toady. So we just have three short questions for you to answer. Heather, display that first question, please. And that question is,

the webinar content provided me with useful information and insight. And the next question, the webinar's presenters were effective. And the final question is, overall the webinar met my expectations. All right and thank you to the audience for answering our survey and on behalf of the Clean Energy Solutions Center I's like to send a hearty thank you to all of our expert panelists and to our attendees for participating in today's webinar. And we very much thank our audience very appreciate your time. And I invite our attendees to check the Solutions Center website over the next week. If you would like to view the slide and listen to a recording of today's presentation as well as previously held webinars. So, the PDF copies will be put up there shortly. The audio recording will take about a week ago up there. So check for those. And we also invite you to inform your colleagues and those in your network about Solutions Center Resources and Services including the no cost policy support. So I hope everyone has a great rest day and we hope to see you again at future Clean Energy Solutions Center events and this concludes our webinar.