

### Webinar Panelists

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### This Transcript

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Sean Esterly

Everyone I'm Sean Esterly of the National Renewable Energy Laboratory and welcome to today's Webinar hosted by the Clean Energy Solution Center 21st Century Power Partnership and KTH Royal Institute of Technology. We are very fortunate to have Neil Strachan, Manuel Welsch, and Tom Alfstad joining us today. These great speakers will be focusing on the Open Source Energy System Modelling with OSeMOSYS.

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.

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Now, if you'd like to ask a question throughout the webinar which we encourage from all the attendees, we do have a Question and Answer session at the end where we'll present those questions to the panelist. You can submit a question through the "question pane" and then go to webinar panel. If you are having difficulty viewing the materials to the webinar portal, we will be posting PDF copies of the presentations at [cleanergysolutions.org/training](http://cleanergysolutions.org/training) and you may follow along as our speakers

present. Also, we will be posting an audio recording of the webinar following the webinar.

Now we have a great Agenda prepared for you today that focuses on OSeMOSYS the Open Source Energy Modelling System and before our speakers begin the presentation, so I will just provide a short informative overview of the Clean Energy Solutions Center initiative and the 21st Century Power Partnership and then following the presentation we'll have a Question and Answer session and then we wrap-up with any Closing Remarks and a very brief Survey for the audience.

Now this slide provide the intended background in terms of how the Solution Center came to be. The Solution Center is an initiative of the Clean Energy Ministerial and is supported through our partnership with UN Energy. It was launched in April of 2011 as primarily led by Australia, the United States and other CEM partners. A few outcomes from this unique partnership includes support of developing countries do enhancement of resources on policies relating to energy access, no cost expert policy assistance, and peer-to-peer learning and training tools such as the webinar you are attending today.

There are four primary goals for the Solution Center: serves a clearinghouse of clean energy policy resources. Also, serves to share policy best practices, data, and analysis tools specific to Clean Energy policies and programs. The Solution Center delivers dynamic services that enable expert assistance, learning, and peer-to-peer sharing of experiences. And then lastly, the center fosters dialogue on emerging policy issues and innovation around the globe. Our primary audience for the Solution Center is energy policy makers and analysts from governments and technical organizations in all countries but then we also strive to engage with the private sector, NGO's, and civil society.

One of the marking features that the Solution Center provides is its expert policy assistance does known as Ask an Expert and it's a great service offered through the Solution Center and we have managed to establish a team of over 30 experts from around the globe who are available to provide remote advice and analysis to all countries at no cost. So, for example in the area of Sustainable Energy Action Planning we are very pleased to have William Becker senior associate in Natural Capitalism Solution serving as our expert. So, if you have a need for policy assistance on Sustainable Energy Action Planning or any other Clean Energy Sector we encourage to use this useful service and again the assistance is provided free of charge. So, through request assistance you may submit your request by registering through our Ask an Expert feature at [cleanenergysolutions.org/expert](http://cleanenergysolutions.org/expert). We also invite you to spread the word about this service to those in your networks and organizations.

Now, I just want to provide a quick overview of the 21st Century Power Partnership. The next slide, Heather.

The 21CPP as it is also known is a multilateral effort of the Clean Energy Ministerial that serves as a platform for international efforts to advance integrated policy, regulatory, financial, and technical solutions for the deployment of renewable energy in combination with large-scale energy efficiency and smart grid solutions.

The Partnership aims to synthesize lessons learned from various CEM initiatives and advance integrated policy development through four areas of activity: faster learning, better tools, capacity building, and also meaningful partnerships.

This slide shows some of the initiative that the 21st Century Power Partnership helps to synthesize lessons from and those include the CEM initiatives and then some of 21CPP's resources include a global affiliate of technical and policy experts, a global private sector affiliate network, and a research policy and technical tool library.

So, for more information on 21st Century Power Partnership you may visit [21stcenturypower.org](http://21stcenturypower.org) and for questions about 21CPP participation you can contact [21stcenturypower@nrel.gov](mailto:21stcenturypower@nrel.gov).

Now, I'd like to provide some brief introductions for our panelist today. First up is Neil Strachan a professor of Energy Economics and Modelling at the University College London Energy Institute and then following Neil we will hear from Manuel Welsch, lead researcher and PhD candidate at the KTH Royal Institute of Technology, and then our final speaker today is Tom Alfstad of the International Atomic Energy Agency and with those introductions please join me in welcoming Professor Neil Strachan to the webinar. Neil welcome.

Neil Strachan

Thank you so much and it's a real pleasure to join you here from a great amp and some of wet London and I'm sure the weather wherever you are is probably best than the weather I believe we have here. I say this every time I talk to someone who upset London. It's a real pleasure to talk to you today. I will be introducing Energy Modelling and specifically why we do open sorts on energy modelling and my—I collaborate to Manuel will actually talking about the OSeMOSYS model and some detail and then Tom will be sharing his thoughts at the end as he discuss this.

So just to give you an overview of this webinar as I just said I'll be doing the introduction at the energy modelling and where OSeMOSYS fits into that. Manuel will really be going to the overview of the model, the interfaces, the modification, some of the technical details of the model, and some of the applications and as I said, Tom is serving as our discussor today.

So to introduce the topic which in overview maybe already familiar with but we do long term energy modelling because energy policy across the globe is really grappling with a set of unprecedented challenges. It's not

just the extremely difficult issues of security of supply and cost effective and provision of energy services but also at mitigating climate change and other requirement that use as key policy goals. These are complex issues that are interlinked whether its economic growth as the driver resource and reserves give you the option for supplies, technological development, how you use those overlaying at policies onto these. These complex issues require authoritative quantity of insights and the energy-law making community really tries to provide that for our decision makers in the public and private community. When we are talking about energy system models today and OSeMOSYS as part of that process and these models are long term planning tools and can really think about how the energy system will evolve quite far into the future. As I go through the introduction, I'll keep on talking about insights. You build models to try to generate insights rather than answers. I'm trying to look at the interface among all the different aspects of all the system. Our energy models have different methodologies. We're talking about on optimization model today but we will talk a little bit about some of these different methodologies. One important thing to know is that energy models are built, run, used, critique, argued over by people and their energy modeling is not just a pure science it also has a bit of art involved. Different people will go different models, slightly differently, will interpret models slightly differently. We will try to pick up some of these things.

So, what are energy models? It's quite easy to think as to what models are not. Models are not just there to generate research papers—I'm in academia that's what I do—or consultancy funding, which is important as well. They're not just the—a name that's based on some kind of acronym and to think models are random. You can have the GREEN model or the BLUE model, the PRISM model, or the CUBE model, the ALPHA model, the GAMMA model, the DELTA model—these are all actual models by the way. One of my personal favorites the ALBATROSS model which is the transport model and they're not actual—models are tools. They are not entities that have to ruin personalities. They are not conservative or liberal. They are not positive or negative. They are just tools that try to capture the information that put in. So, then we try to move away from what models are not and talk about what we are in terms of a structure approach to modelling and this is really starting to seek us to how we frame the OSeMOSYS energy system model. We know that it won't be universal model which will answer our questions because models are designed to answer different research questions and upgraded different skills, the time, the place, and the detail of technologies and behaviors. Although you try to think about models that will link across different ages if you aggregate you typically lose some detail and we'll be talking an energy system model if it tries to look at interactions across the energy system, it will lose details versus sector goal and issue specific models but it will try to look across the energy systems. Thinking about an extra-educated community of developers and users of the model is critical and this webinar is part of that process and OSeMOSYS is really built up from a

network of international based organizations, universities, and research institutes to try to have that network of global developments. We try to take on models and evolve them above the calibration with reality, testing with these hypothesis, and of course data is a key aspect of model such as OSeMOSYS and we try hard to populate them with the best data we can and challenge them through analysis.

In terms of how useful a model like OSeMOSYS like to be this about famous quote by alumni of UCL actually George Box who said, “All models are wrong but some are useful” which is the useful way to think about model such OSeMOSYS. My own personal and alternative version is “Some models are right, (or at least right enough), and even the wrong ones can still be useful.” So for example, if I’m trying to drop a tennis ball onto the ground I don’t need to think about general relativity and quantum mechanics I just need to use a utility in physics, action and reaction and we are often thinking about the way we can aggregate energy models and simplify them so they still capture the key aspects of what were trying to look at.

In terms of how complex you should make a model given, you’re trying to capture these key elements. I’m not going to try to break at my high school Latin because I will pronounce this correctly but this idea of [Indiscernible][0:14:18] mid evil philosopher is that entities must not be multiplied beyond necessities. So in modeling terms you are trying to build a model that is at simple, elegant possible is and only as complex as necessary. If you go to model that’s only as complex that complex as it needs to answer the question however the energy economic system that were trying to go does have any complex but OSeMOSYS is really trying to strip complexity down to the bare bones to have the simplest model that will use to answer some of these energy system that relates the question.

One of the key issues of OSeMOSYS is we thinking about transparency and other models that have been used have proposed the process, have been criticized for lack of transparency both in terms of the data they use and the equations in them and the way that the model are sold and is interpreted. To pick on one model actually little unfairly because I depict another models but the Primes model which is heavily used by European commission, the Primes model is instant model that looks very nice features however it has some criticism over the transparency of the model and whether it is in fact a black box that people can’t look into. OSeMOSYS is really designed to try to be as transparent as a complex model possibly can be.

Other people have different ideas over transparency. Richard Tol is very well known environmental economist and has built the FUND model, which is the integrated assessment model. Actually, it takes opposite view in that—you need such expertise to understand use and interpret the model that should actually be left to the experts. His quote here, “Not-understood models are irrelevant, half-understood models treacherous, and

misunderstood models dangerous.” It does have some credence but I would argue that it is so important to try to engage policy makers and private stakeholders with tools that they can interact with and that’s a major part of OSeMOSYS.

So, in terms of what transparency actually is then one can think about a model that is fully documented including all these data as you can repeat everything. Perhaps critically for OSeMOSYS the model source code is freely available and is designed to be on the suite. It’s not something you can pick up instantly but it’s something that you or your students or your colleagues can actually get grips with and download and actually look through the model code. The ideal of peer review paper whether that’s through dedicated peer review or the journal review process is important as an expert user groups whether this is the network refuses to use OSeMOSYS or the engagement we have with decision makers, in government organizations, industry and the private sector and this process is already extremely important to try to have a sense of understanding of the model and a sense of critiquing the model. Now of course there are issues that remain, intellectual property issues for some models, that’s not a problem for OSeMOSYS as its open source model. Can you replicate highly complex models? We said we hope you could do with OSeMOSYS that’s one of the ideas and there is a problem with energy models in general in that. If you really wanted to run it in a biased fashion, you probably could do it. If you wanted to really promote a given technology or a given resource or you wanted to show that this technology or resource was a very poor option, then you could put in data or model equation stops the device to model against that. We are fighting hard against that process by trying to make OSeMOSYS as open and transparent as we can.

I probably have more slides to finish this introduction before I hand over to Manuel to talk in detail about the actual OSeMOSYS model but just to point out that for a very long time we talked about modelling for insights not numbers. Hill Huntington the co-director of the energy modelling program at Stanford said this I guess more than 30 years ago and it still holds true today. Maybe a problem that decision makers actually don’t want insights they actually want numbers and they don’t want numbers with uncertainty box, they actually just want numbers. You get a whole bunch of examples for numbers whether that’s resource availability or energy cuts, or technology diffusion rates or whatever it might be. With a model like OSeMOSYS, we’re really trying to focus on insights.

Why is that important because these numbers really depend the policy process and is really important to think as to where those numbers come from and where the insights that’s how I derived five in those numbers come from. If you look at the Intergovernmental Panel of Climate Change, the last assessment report AR4 and AR5 is coming out in April of next year. I mean this is a multimodel [Indiscernible][0:19:33] assessment of literature that actually for a given climate stabilization target we’ll be talking about things that GDP impacts or CO2 prices and the like. This is

actually a very powerful way of thinking about different models and different calculations of these key numbers. Other ways you could think about is much more simpler modeling and maybe a scenario approach from the UK and example from the [Indiscernible][0:19:58] gas and electricity markets was talking about how much we had invest in the power sector by 2020 to think about smart grids and these sorts of issues. These sorts of headline figures get an awful lot of publishing the press and then policy service. But whether you have a full-blown modeling exercise or a simpler modeling exercise I personally would argue that's much better than thinking about numbers and targets just from a pure political process. The example I have given is as far as I can tell as an academic the idea that he use 20, 20, 20 targets in terms of reduction of greenhouse gas emissions, boosting renewable resources on the final energy basis, and improvement in energy efficiency. That 20, 20, 20 target sounds very nice but the actual process of getting to that was not a modeling derived process it was much more of a political negotiation process and I would argue that that makes policy making worse than otherwise would be.

I wanted to talk a little bit about where OSeMOSYS fits in before I hand over to Manuel. This is a typology that many modelers use from John Jean Hourcade to Mark Jaccard in their study, in energy journal some years ago and they thought of an energy model in terms of three axes how it deals with the macro economy, how it deals with behavior, and how it deals with technology. If I click through you can think of different types of models that are better or worse at some of these axis. An optimization models such as OSeMOSYS typically are not of technology information in them and that's one of their strengths. A Computer [Indiscernible][0:21:52] model would be much better macroeconomic feedbacks but correspondingly worse at technology behavior and when you think about an econometric or an agent-based model that would be focused on behavior and not too very well on the other two axis. All of these models are trying to improve in these other axis. For example, OSeMOSYS working hard as to how better capture behavioral change, social indicators. Ideally, you would like a perfect energy model that had all these three axis perfectly but that is perfection and none of us are at perfection yet but we are striving for that.

At that point, I like to finish the introduction and I'd like to hand over to Manuel to take us on and actually talk about the OSeMOSYS model.

Manuel Welsch

So, sorry just a few moments until I set out my presentation and got the remote to control over the online sides on my screen except for the introduction on modeling in general. I will now focus a bit more specifically about OSeMOSYS. As Neil already mentioned several models exist. Most of these models actually require significant investments. There might be commercial [Indiscernible][0:24:02]. There might be commercial [Indiscernible][0:24:05]. They're modeling tools themselves. They're softer baggages only require investments and the niche of OSeMOSYS is

basically to be a lightweight product which is fully transparent and fully relies on the Open Source philosophy, so basically everything is setup so that they can be operated freely with no upfront costs and the big effort is as well put into striving the code as well as it is possible so that everyone really understands what's going on in the depths of the model. Neil mentioned it already. OSeMOSYS is a shared institute with several UN and research institutions. For example, the atomic energy agency, UNIDO, UCL, University College London, Stockholm Environment or where I come from KTH Royal Institute of Technology in Stockholm.

Now, what type of tool is OSeMOSYS? We have heard that there are several different aspect of model and aspect of modelling which are considered in models. In OSeMOSYS is part of the family of bottom up models, so very technology-rich models which look decades ahead so they are used to develop long-term strategies. The linear optimization model, which basically means it calculates a single optimal need of capacity investments. So, it's basically as huge assistance configurations for the energy system of a country or a reaching or maybe as well as global aspect. The model is basically driven by demands for different energy services. So, it could be a demand for heating. It could be a demand for lighting but it could be simply a demand for electricity and to several what is called technologies are available within the model to meet these demands and what the model does is that it minimizes to overall discounted costs. Of course this cannot well be subject for example environmental constraints [Indiscernible][0:26:33] reduction targets should be fulfilled or there could be a sort of text on certain emissions, so this can all be considered on these models. Several other type of—just a moment please.

Manuel Welsch Adjust my mike is it better now?

Sean Esterly Much better, yeah.

Manuel Welsch Better are we?

Sean Esterly Yeah.

Manuel Welsch Can you hear me now properly?

Sean Esterly Yes.

Manuel Welsch Uh-huh because I have my....

Sean Esterly Yes we can hear you much better now thank you.

Manuel Welsch Okay, my volume is a bit on mute now. From the mess behind the model it is comparable to other tool such as message or times for those of you who know these models and it is as well integrated into LEAP.



I want to present some more detailed aspects of the OSeMOSYS model so that people can know how it works and how it can be used. For those of you where this might go a little bit too much in the text I hope that you can bear with me until the modification and applications chapter both of which are more applied and which might be more interesting for some of you who don't really want to use the modelling tool immediately but wants to know what it can be actually used for. OSeMOSYS is characterized by a very wide technology definition.

Basically, everything is setup as a technology. A technology can for example be a power plant. A technology can be a coalmine. A technology could be the transmission system or a technology could be the heating system or light bulbs. So, basically whatever element you want to have in this—you want represented in this model, which the model can basically invest in. So whatever converts energy from one form to another form. What the model does is basically it kind of understands how these different technologies are linked with each other and these different technologies are characterized by investment cost by the thermodynamic efficiencies, by their emission profiles, and there are several technical environmental operational characteristics which basically define these technologies and as an analyst you tell the model what the future demand for energy services might be and the model then simply tries to identify the most optimal investment pathway, so basically when you invest in what set or what combination of these different technologies.

That's basically what drives the calculation within the model. Within OSeMOSYS a big focus was as well to make the code itself be very understandable and very clear so that's always at first the conceptual description of what certain elements or certain blocks of functionality with what they basically they do. So even if you're not into math or into modeling its written in such a way that ideally someone from the outside just understands how is storage modeled within the OSeMOSYS. How are certain elements of smart grids potentially modeled in OSeMOSYS? It's at a very conceptual model then for those who would like to have a little bit more detail there's an algebraic formulation which basically the math behind it and this is formulated in a way which is independent of OSeMOSYS so it's just a mathematics so that anyone who wants to translate this into any modeling language can do so and that is basically easy from whatever background you come from to understand what the model does. Then of course, we provide as well the actual programming language, the actual code, and applications of how this code is used. Mathematical language is Gnu MathProg and the solver is called glpk. That's the open-source solver, which is freely available to find this optimal system configuration.

I don't want to talk about this much in detail, just to show the different blocks of functionality or some of them actually. There are many more but this is simply the structure of the code where we hope it makes it easy for

others to understand how this is set up but also to add to their own functionality and to improve the code as they go along.

I always like to show one screenshot of the mathematical formulation of the code not to scare anyone but rather for the opposite reason, simply to show how easy it is to read the math even though you might not have even read any background explanation. For example when looking at the first line, we can see that the model minimizes the total discounted cost. When going into the second line we can read that the total discounted cost is equal to the discounted operating cost plus the discounted capital investment cost plus the discounted technology emissions penalty minus something, which is called the salvage value.

So, it's quite easy to read the mathematical formulation and it's simply because deliberately very long parameter and variety names were chosen. This was done simply to make it all readable and as well, it translates quite seamlessly into the code. For example, in the first line, we have again the minimization of the objective costs and then in the second code line we have the summation within the language called Gnu MathProg.

Of course, probably 90% of the users never really want to deal with the code but still at some stages, it can be very useful to have the opportunity to go into the code if you like to. There are several interfaces out there for the use of OSeMOSYS. One is the interface of the modeling tool called LEAP. One is an interface which is being developed for OSeMOSYS which is currently under development. Then there's as well as the... probably the most key way to run the models simply to use an input file, to adjust the input file to adjust the code and then use several options to run the code.

I just want to show a few screenshots of LEAP. I mean LEAP is... Generally, it's a simulation modelling tool which uses OSeMOSYS in the background to optimize the power system. I guess some of you might have heard of LEAP. It's probably one of the most widely used tools with over 10,000 of downloads. LEAP is available for free for example for people from developing countries but as well for students and this is probably the... one of the cheapest and easiest to get into models out there. So it's... I would say it's a perfect entry point into this long-term modeling world.

Now in LEAP, we can see that in the optimization feature, it says it uses OSeMOSYS in the background to optimize the electricity generation sector. That's just a screenshot of how the LEAP interface looks like. There are several folders in the left hand side where people can define certain demands, the electricity generation, or the resources, which are there to meet the electricity generation, and if you would open the Electricity Generation folders then there would be the individual technologies, the individual power plants which produce electricity.

What LEAP does is when after the user enters the data in LEAP and when you then want to see the results, LEAP basically runs OSeMOSYS in the background. A little window is popping up. It writes a data file. It sends this data file to OSeMOSYS. It runs OSeMOSYS in the background and it reads the results back into LEAP. Then you can produce all types of graphs. For example how the future capacity mix is going to look like, which technology produces what types of greenhouse gases, and basically whatever you can wish for.

So as a user, you might not even know that you're using OSeMOSYS, as this is really something which happens in the background. Then a few, again, quite detailed slides. I will just go over them quickly before coming to the modifications and applications.

I mentioned this well, the kind of most detailed way of using the models for... especially for us at universities. It's kind of useful to improve the model and to adjust the model to our needs and then we can actually go into the code and add functionality in the code. There are just some screen shots of how these data files and how result files basically look like. This can then be run from the command prompt or there is this GUSEK which is kind of an integrated development environment which combines the solver, which combines and editor. It's just freely available. You can modify the codes, you can modify the data file, and you can run it all in one framework or other people may use programs like Matlab which is a commercial software and of course Matlab can as well be set up so that it costs the [Indiscernible][0:37:00] and runs the model file and then Matlab can be automatized to produce results for example here the dispatch and capacity investments in the future.

That's just some detail. I always find it kind of useful to always include screen shots just to get a feeling how the tool actually looks like.

As I mentioned at the university or when modelling when using these tools, very often it can be very useful to improve the tools and to improve the code when you see that results might not be accurate enough. Just some fact and figures... It's just basically just one example out of many examples of potential modifications of the OSeMOSYS codes.

The next few boxes basically they all say the same thing. Currently, there are very high investments in renewable energy capacities. 70% of the new additions in the European Union come from renewable energies and these would most likely... an important role as well in the future due to efforts to mitigate climate change and to shift to cleaner energy sources.

Now, as we know many of these renewable electricity technologies, they add fluctuations to the systems. I mean fluctuations in the power system are nothing new. Power plants might drop out. Demand might change or decrease but with a variety of renewable energy sources like wind or solar power, this adds significantly to these fluctuations in the system. The

power system needs to be able to deal with these fluctuations. The power system has to be flexible enough to compensate the variability.

For example as the weather change if there is another wind flowing in one moment and if the wind reduces, then... and the demand remains constant, it means that there is less generation than actual demand. What happens in such a case is that the system frequency is going downhill. We want to make sure that design frequency stays as closely or is maintained as good as possible. If it's 50 hertz or if it's 60 hertz, so in the power system, if there is a deviation from the design frequency, other technologies are quickly rent up or to change their outcome in order to compensate the fluctuations. Wind goes down and in the next moment, another power plant has to be quick enough. It has to be fast enough to compensate this reduction in wind power output. We're talking about timeframes of a couple of seconds until basically a couple of minutes so this really has to be... has to happen very fast.

Now, these long-term models, which we are talking about, they're usually characterized by coarse temporal resolution. They don't model every single second of... throughout the year. When you look at time horizons up until let's say 2050, you're not really interested how supply and demand looks like on the 12th of April 2037 at 09:36 in the morning. I mean that's just way too much detail. What you want to understand is how the capacity mix looks like. Like what would be the main technologies or how should we design our strategies in order that these technologies get invested in.

On the other hand, when we leave out this short-term effect completely and that's what actually happening in the many long-term with this right now, when we don't consider these short-term effects, it might be that the system is not flexible enough. It might be that there are not enough power plants available which can ramp up, which can increase or decrease their production quickly enough then there is a change in, for example, the wind capacity. Now, OSeMOSYS was very useful in this aspect as we try to make sure to capture these short-term aspects in a very simple way but good enough so that we can model the implications for long-term capacity investments. This was by including operating reserve requirements.

Operating reserve is exactly what I've been talking about. These technologies, these power plants, it can as well come from demand site but conventionally at least until now it's mostly power plants, which are held back so that they can increase their production or decrease their production quickly.

In OSeMOSYS, what we did is we modelled primary and secondary reserve so over the timeframe of tens of seconds and five, ten, or 15 minutes. We modelled the upward and downward reserve requirements. In this context, a model of like OSeMOSYS is very useful. Commercial models like for example TIMES have grown over decades to have a lot of

functionality and they have probably 20,000 lines of code so they can do a lot of stuff but also it gets very opaque sometimes to understand what a model with 20,000 lines of code actually does.

OSeMOSYS on the other hand is kind of much simpler in this regard. It's only built on a little more than 400 lines of code so it's really possible to understand every single bit of it if you want to and to simply add these operating reserve requirements which are at least conventionally not considered in other long-term models.

What we did was to enable OSeMOSYS to consider the contribution of different technologies to contribute to meeting these reserve requirements so I can define some ramping characteristics for a technology. I can define the minimal stable generation levels of a technology and I can constrain the cycling, how much the output is reduced from one time period to another one, to simply consider these operating reserve requirements.

The next step we wanted to see how much better two results get when we improve OSeMOSYS. We were lucky to collaborate with UCC, University College Cork who used TIMES. TIMES is a very well-known long-term model which is again as I mentioned similar to OSeMOSYS. They used TIMES and linked it with PLEXOS. PLEXOS is a power system model which focuses on power generation and provides much more technical and as well temporal detail.

The Irish TIMES model is set up using 12 characteristic time periods per year and was used to cut... to calculate the capacities over longer time periods. Then these capacities for one single year, for the year 2020, were used as input value for PLEXOS. Then PLEXOS rerun basically the year 2020 and modeled every single hour of that year to compare how these test results, how the use of technology is good change due to this increased technical detail.

For us this was very nice so we have TIMES which is a comparable model OSeMOSYS on the one hand and we have PLEXOS which only focuses on the power systems so for example a competition with or links to the heat sector, transportation sector can't be considered in PLEXOS. So it only focuses on the power system and models a shorter time period but in much more detail. It was very nice for us to see in which space in between these two models we operate with OSeMOSYS.

The next slide has some results for the Irish Test Case. I don't want to talk in too much depth about them but just on the very left, the light green bar is the simple OSeMOSYS model. The simple OSeMOSYS model calculates the exact same results as a stand-alone TIMES model. One could say it's the results of the conventional long-term model without considering operating reserve.

On the very right, we see the interlinked TIMES-PLEXOS model with... which includes much higher temporal resolution and much more technical detail. On the very left basically the course standard model and on the very right a more detailed model focusing on the shorter timeframe. This is for various types of technologies.

We can see that there is quite a difference in how these technologies are used in the system. When including operating requirements within OSeMOSYS, what is called in this graph "OSeMOSYS enhanced," we can see that results get much much closer to the enhanced PLEXOS models. So if over 20% of the yearly generation is dispatched basically by, one could say wrong technologies in the conventional long-term model without operating reserve, by including these changes and by using the flexibility of OSeMOSYS to modify its code, we could match a more detailed model by 5%.

The more detailed model again just focuses on what... focused on one year, 2020. With OSeMOSYS, we had the opportunity to model a much longer time period from 2010 up until 2050 and the whole calculation of one model run took a bit more than 10 minutes whereas the PLEXOS model for one single year took roughly 30 minutes. We can look at the longer timeframe and it's basically computationally less intensive to do so.

I just want to focus on one single value when we extend it to analyze this up until 2050. It is 23.5% of the capacity interventions of the simple OSeMOSYS model without considering operating reserve are different from the enhanced OSeMOSYS model, which considers operating reserve requirements. The moral basically of this one value is simply that conventional models can be quite far off in their core dusk. They're designed to... to get insights on the mix of capacities, on the mix of technologies, yet in systems with high shares of renewable energies, they can actually really misrepresent the need for flexible power system.

That was basically the first conclusion as well. Now to address this, I mean this is shortcoming of long-term models which is well known to analysts and conventionally or what is done many times is a very good approach, to use different tools, a long-term model and link this long-term model with a more detailed short-term model but then again the problem is that you need the expertise in two different modeling tools which might not be... It might not be one single person and actually, it might not even be one single institution who has expertise in such different modeling tools.

On the other hand, there's no over optimization across the two models so the long-term model optimizes capacity investments. The short-term model optimizes the dispatch but there is no overall optimization as a whole. The short-term model will only model for example one single year. If we have analyzed this from... with a long-term model from 2010 until 2050, then we can just investigate basically single years in more depth.

Now, with OSeMOSYS, we were able to get very close to the results of the more detailed PLEXOS model but considering... which is actually kind of surprising considering that OSeMOSYS only uses 12 characteristic time periods per year whereas PLEXOS models all 8784 hours, 2020 is a leap year, and basically has 700 times higher temporal resolution.

That's just one example of why this open-source nature, why this short, concise, well-documented, and transparent code can be very useful. There are some publications, but I think the presentation will be uploaded for those of you who are interested.

Next, I would like to select, to present several OSeMOSYS applications from other people and not from myself. One example is a Global CLEWs MODEL, which is developed by Manuel Weirich and Constantinos Taliotis and in that model, they used OSeMOSYS to consider interlinkages between resource systems. CLEWs basically stands for climate, land use, energy, and water.

The idea was basically that the energy system on its own or modeling the energy system on its own might not do justice to all these interlinkages between resources. For example, when irrigating fields for agriculture, there may be a demand for pumping and this pumping may require electricity. When assuming that there are changes in the global climate, this will reduce rainfall. Reduced rainfall means reduced hydrobar or when there is desalination needed in the future due to a reduced rainfall and this is of course also very energy-intensive electricity-intensive practice or can be very electricity-intensive.

There are several of these interlinkages between resource systems which in some cases should be considered in such modeling tools and they used OSeMOSYS for this work which served as the... as input for example the UN Sustainable Development Report.

Just partly I mentioned already how the different... how the system was set up. They modeled as well for example of food and water services on the right hand side. They modeled materials and services and tried to consider these interlinkages. For example, natural gas as a primary energy resource is used to produce fertilizer. Fertilizers used to produce food at the same time food requires water for irrigation. This irrigation may require energy as I mentioned.

OSeMOSYS was basically used for this purpose simply because it's easy to collaborate with it to access it and it's transparent. Yeah and of course, emissions can as well be considered in such a modeling tool.

Another example is work which we are KTH are currently doing for the World Bank together with Stockholm Environment Institute and the RAND Corporation. [Indiscernible][0:54:02] they model the South

African power pool which combines 12 countries and it's quite large. OSeMOSYS model has over 620 technologies in these 12 countries. It models over 120 different fuels and one year is modeled with 48 characteristic time periods. So, it's kind of a complex model up until the time period for 2050. As well in this model, the idea was to capture the linkages between the water and the energy sector for example to consider the reduced rainfall and hydropower availability, and yeah as well, to consider the implications of Grand Inga hydropower project which would be part of the Central African power pool.

Another example is the Sweden Energy Model which is developed by Nawfal Saadi, another colleague of mine, where he models the electricity and the heat system of Sweden and as well as several demands, residential demands, industrial demands, agriculture services, and transferred over the period up until 2050. Important aspect their office as well to communicate the findings as easily and as digestible as it can basically get. I mean not everyone really wants to get into the depth of modeling and for this purpose, we want to kind of use the UK's... the pathways calculated by the UK Department of Energy and Climate Change.

Just a screen shot of this calculated... what it basically does is that user... or it's basically online on a website and whoever wants can visit this website and play around a little bit with the main assumptions. So, one could for example say that he thinks [Indiscernible][0:56:14] more or less important and then instantly you can see the changes in the results for the UK and its system. A similar tool or a similar approach to communicate results is what Nawfal and my colleagues would like to implement for Sweden.

Another example is the modeling of electric vehicles and related smart control by Fabrizio Fattori from the University of Pavia who wants to model the benefits of smart charging so... so that the system can feel when to charge electric vehicles but as well as the benefits of vehicles to quit so that the electricity can draw... that the power system can draw electricity and probably operating reserve from electric vehicles.

He basically draws on one extension and a previous modification of the OSeMOSYS codes which is the function... the block of functionality to model storage in OSeMOSYS.

Another example from the British Columbia Institute of Technology from Taco Niet is the modeling of big hydro in OSeMOSYS. Originally cascading effects so the impact of the discharge of one-reservoir hydropower plants on the reservoir downstream was not considered in OSeMOSYS and so he used OSeMOSYS to model these effects.

For us at KTH as everything is open freely available, it's sometimes very hard to even know what initiatives are going on in OSeMOSYS. Sometimes we have to basically Google to understand who else is using



OSeMOSYS because we might not be contacted. I mean in the end that's the beauty of having an open-source effort that other people use what is there, expand on it, improve it, and trust it according to their needs.

Another example is the modeling of net metering in South Africa by Bryce McCall from the University of Cape Town. In his works, what he thought about OSeMOSYS, he wrote that he had to include several new parameters and for him it was very easy to learn and understand OSeMOSYS and add new parameters. In this case, I have to say as well that we were talking about modeling tools so every modeling tool requires some time and effort to understand it. Even for LEAP, which is a very simple tool, one might probably need a couple of these to play around the model to understand how it works.

Now, for OSeMOSYS as an optimization tool which is maybe more complex or which enhances the functionality of the tool like LEAP in certain aspects when it comes to the optimization, then of course this might mean that it requires even a couple more days so maybe some... If you want to change the codes then probably a couple of weeks but this is still quite easy and quite fast as compared to other tools which are out there which are simply in transparent and where it's basically impossible to modify and adjust the code, maybe apart from adding simple constraints.

One of his recommendations was as well that an interface would greatly improve the user-friendliness so for those of you who are only interested in the power sector I would say that the LEAP provides the perfect interface for you to use OSeMOSYS kind of silently in the background. On the other hand, a more advanced interface is something which we would like to develop at KTH but anyone who... maybe there's someone there in the audience who has expertise in this type of work or with an IT background and to get excited. You would be very happy to collaborate with anyone who would like to get on to OSeMOSYS.

Just a very few final words. Again, the need, of OSeMOSYS just to repeat, is that there are no associated upfront financial requirements. It can provide large aspects of the functionality of commercial models at the same time it is much easier to use and it uses an open-source solver, which as well on the negative side, means that on the negative side means that an open source will be of course not as powerful as a commercial source. There are reasons what you have to pay for this commercial source. So, sometimes, the calculation times may be longer with a tool like OSeMOSYS or for example, in other long-term models, you can maybe link them to climate models like the TM model for times. So, these interlinkages with the other types of modeling tools are not part of the standard repository of OSeMOSYS. On the other hand, a big advantage is it's easy to adjust the model to anyone's need and as mentioned again, an invitation to join in if this catches your interest.

With this slide, I would like to conclude and hand over to Tom.

Tom Alfstad

Hello. Can you hear me alright? Excellent. Okay. So, my role here, as I suppose to, is to summarize and echo a little bit of what have been said and also give the perspectives of sort of specialized UN agency that engages member states on this issue. So, as mentioned in the introduction, I'm an energy systems analyst with the National Atomic Energy Agency and more specifically, I work for something called the "Planning and Economic Studies" section and our mandate is to support member states in planning for sustainable energy developments not just pertaining to nuclear energy, but to any form of energy and support and planning in the analysis and assessments of energy—matters on energy policy and this is—I mean the target here is mainly developing countries and this is mainly implemented through our technical cooperation program, which is our main vehicle for technology transfer and for capacity building providing assistance to member states. So, the aim is the possibility to build the skills and develop the resources in member states to conduct their own energy assessment on energy analysis. So, for this, we typically organize national projects, which are essentially done with a counterpart institution from usually administrative energy and energy commission. There'll be a power company. It can also involve the universities and they essentially have ownership of the project. It's their responsibility. We provide essential input and assistance to that. So, for instance, we have tools—a set of tools available that we distribute for energy and then, more analysis for supply, assessments similar to what you could do with OSeMOSYS. We have tools for financing and for assessing environment impacts and we then deliver training courses worth fellowships and so forth to essentially conduct this or provide these inputs. Now, based on—we don't know sort of on a regular basis review our programs to sort of get feedback, how can we brew things, or how are we meeting our mandates and so forth and that feedback sort of left me—or left us.

Well, I think three points illustrate how something like OSeMOSYS can essentially add value to fill a little bit of a gap and I'm going to essentially bring up three points and the first thing is demand. There is, I think, a growing—well, a clear growing interest in analysis of energy sys—or say of the energy sector and the energy systems more broadly and one of these is investment planning whether it's assessment of the independent power projects whether it's carbon avoidance, electrification, water filter. There is the desire for countries to internally have the capacity to conduct these types of studies. I think in the current cycle, we have about forty-four projects. So, I think that there is a clear need for this type of work for—to have tools and skills available to conduct this type of analysis. The second is—one of the feedbacks we have gotten is that often the tools are seen as a little bit too complicated that essentially we deliver tools that have a lot of features often we have data requirements and to some extent with complex mathematical underpinnings. So, we've had a concern that even if you can develop the models, you can provide a training, but they may

not be able to sustain the effort and so forth. So, there's—one of the identifications has been the need for a sort of a learning tool, a more of an easy entry point that people can use as a stepping-stone to more advanced and complex tool or perhaps if it is flexible and available for expansion as offered for additive features like OSeMOSYS. Perhaps, it could essentially also be done through expansion of the OSeMOSYS tools or similar one. The final of the three points I want to bring up again is the need for transparency and the—coming to the—one of the key uses of models in this respect is to support policy and decision-making. To be useful in that regard, you have to be able to communicate what you're doing efficiently and clearly. In other words, if you're going to provide insights, that's not going to be very convincing if it's not clear to people how they will arrive that. So, having a tool that is open source, transparent in the methodology and so forth and then, the data input is, I think it serves a clear—has a clear need so [Indiscernible][1:08:23]. Obviously, there's a little bit more to transparency that just being open source especially as you could get more complicated, it's going to be challenging, but I think this is clearly a type of platform that could be used for that and that it is open source, it is relatively and easily understandable. As you say, it's available in sort of plain English format and it can such be very useful to use in either sides both, as I said, as a learning tool and as a sort of first-touch first-step support thrill for policy as it is. It can provide a convenient way of communicating the lessons or the insights that can be gained from a modelling analysis. So, those are sort of the three points that I want to bring up that I think is an indication that there's a need or room for these types of things. The clear demand for these types of tools, the need for a sort of easy in entry point both in terms of the skills acquired and also as was mentioned earlier, a lot the sort of existing tools that are out there actually have—you need money—a significant amount of money that might be prohibited for users especially at universities and so forth in developing countries, and finally, a tool that is transparent where you can also have a bit of a user community out there that you can engage with and get feedback, support, ideas, and so forth.

So, I think that sort of summarizes or concludes what I was—what I wanted to bring across. So, I thank you for the attention and I suppose we're open for questions.

Tom Alfstad

I think I still...

Sean Esterly

Yeah. Sorry about that, I was still on mute, but thank you Neil, Manuel, and Tom for the great presentations and we did get some questions from the audience and I just like to remind the audience that if they do have any questions, they can submit those to the "question" pane in the Go To Webinar window and with that, we'll go to the first question from the audience and Neil, Manuel, and Tom, I know you're there in the same room so you can kind of coordinate who wants to answer this. You can jump in and answer with however want. So, this first question is a multipart question and I'll just read it through and I can repeat it if you

need me to. So, is this demand-driven model supply a deficit demand and if so, according to which criteria did this apply the fine and what's the time horizon of the model?

Manuel Welsch If I may start answering that one, the time horizon is known as well as the time resolution of the model. So, how many time period are modeled within the year and how long the model or for what time future outlooks the model is used. It's completely up to the analyst. So, the model doesn't really mind. It all depends on the data, which is fed into the model. If it's up until 2020, 3050, or 2100. The other question was how the—this apply. I just do the demand-driven model and one constraint or—for the model is basically the demand has to be met. So, if there's a demand for, let's say, electricity, the model has to make sure that enough electricity is generated within the system and what is up to the model is simply the choice of how this electricity is generated. So, as a user, I tell the model 'Okay, I want to have a—I want to give the choice to modeling a certain, let's say, amount of—up until a certain amount of hydropower, coal fire degeneration, nuclear power, and basically whatever I want to have' and that is stating to the model and then, the model will make sure that the demand is met, but decides how to meet this demand and in which options to invest at what time. I don't know if Neil or if Tom if you want to add.

Neil Strachan No, I don't really have a...

Sean Esterly Great. Should I move on to the next question then and that question is 'Can OSeMOSYS be used to model intact of the energy sector on fresh water resources?'

Manuel Welsch Maybe, I'll take this question again. I would say yes. It depends on how you're going to model it. So, within OSeMOSYS for every technology which is active, I can kind of assign a certain emission profile so I can tell the model that's activating this technology generates, I don't know, CO2 emissions. I can as well say that it produces a certain amount of cubic meters of polluted water so to speak. Hmm, spatially like if you really want to know if you want to have the spatial model how the—I don't know—how river flows are affected and how this basically spreads downstream then probably via space-modelling tools like vip for example. It may be better if you are focusing completely on the water side, but if it's basically about the physical or mass balances than or some—then, this could be included into OSeMOSYS through the emission profile.

Neil Strachan If I can get to ask something to that, often, in modelling, it depends on what you can do again in terms of fresh water. If you really link interest in short-term variability because rain falls even here in London is actually available quantity, then there are other models that can do that better if you wanted to go, for example, into Monte Carlo simulation; however, if you wanted to look at long-term, hmm, changes in ground water for example and beyond depletion of that based on demands for energy and water combined, then OSeMOSYS might be a tool to look at that,

although even though I said that process and even if you wanted to look at short-term variability, that's not present and no concerned model like OSeMOSYS could think of a formulation or an addition to the model pole to look at that. So, the floor is actually open on that one, I think.

Sean Esterly

Great, thank you. Hmm, the next question is one I'm sure a lot of people are asking, which definitely get to and that is 'Where can you download the model and also, what kind of assistance is there to help you?'

Manuel Welsch

Yes. I almost forgot how to unmute. The model can be downloaded at [www.OSeMOSYS.org](http://www.OSeMOSYS.org). At the very last slide of my presentation, our online platform is basically mentioned. It's kind of a—how should I say—home-made home page, but you can see that we are no web designers, but I think it provides information required to download the tool and if you want the latest version, it sends you to the command webpage where you just have to briefly register so that we simply know how many downloads we have, but there's no other—I mean you won't get any e-mails from us or anything, but it's simply nice for us to kind of understand like who is the target audience of this tool and who uses this tool and then, on this command website where you can download the tool, there's as well a discussion forum on OSeMOSYS so if there are any questions, you can post this discussion—you can post these questions and either they're answered within the forum or one of our team is going to answer these questions.

Sean Esterly

Great, thank you, and we do have follow-up to the water question. Hmm, they were thinking about water supply and they were wondering if you know how much water is needed for each technology. Could OSeMOSYS help?

Manuel Welsch

Yes. I mean you have the identities data upfront into OSeMOSYS so that you have to tell the model how much this technological data—the user basically has to know. So, the user has to know the one producing one-kilowatt hour of electricity with this thermal power plant has a certain cooling demands and then, I can tell the model the ratio basically between electricity and cooling demand and the model will help me calculate the overall water requirements over the year over certain time period within the year. I don't know Neil if you want to add to this one.

Neil Strachan

I mean perhaps I have to add and drive something to that. You can actually have more fun with OSeMOSYS. I mean it's not just the imaginable to how it needs. It's, for example, the temperature of the water and one of the problems at the potential path for example where then you could oppose stations is that the height of the summer where you have lots of electricity with air-conditioning, you can't run some of their power plants, the nuclear plants based on rivers because the water gets too hot and you can't call the plants to function. Now, you could put that into OSeMOSYS. You could have a process that depending on how you divide at the time, you could actually say that in certain points in the summer,

you couldn't run this key energy installation and really explore some of the implications of that. So, I think again that it's a case of being innovative with how you set up the model. Clearly, you need to have good data on how much water and when you can operate it or not, but I think it is an innovative tool that you could play around with some of those assumptions.

Sean Esterly            Alright, thank you Manuel and Neil and then, next question is 'Can we use OSeMOSYS to model integrated community energy systems?' Oh, you're still on mute Manuel.

Manuel Welsch        Ha ha. My learning curve, not very steep. Hmm, yes, you can. On the other hand, I think OSeMOSYS is most useful when you're unsure about which technologies to choose from. So, if you have a small system, it might be that it's quite clear upfront what technologies we have available—I don't know—if you have a diesel generator or if you want to have some PV panelist and then, there may be some tools or stimulation tools, which then really optimize the technology mix because maybe, there are not so many technologies you may want to choose from. Maybe, the stimulation tools, which are designed for such smaller systems. I don't know. I'm thinking for example of [Indiscernible][1:20:48] for example. They might already serve the purpose and be easier to use. Well, on the other hand, you can of course model everything. I'd like to say it can model everything, but it's of course a little bit of a very broad statement, but if there's—if you're interested into which technologies to invest things or—and then, which technology will be used within a year and if this gets to some extent a bit complex or not intuitive any longer. So, you don't really know upfront for how much the ratio. I don't know wind power or diesel generation or how much back up battery whatever you need, then, OSeMOSYS can definitely help with that.

Sean Esterly            Alright and the next question is 'Is it possible to allow a certain amount of unserved energy or input a loss of load probability?'

Manuel Welsch        Hmm, if I may answer this question. Yes, you can allow unserved energy by, hmm—for example, you can include the technology, which his simply called "unserved energy" and give it a certain price and then, if your technology is above or is getting too expensive or if the other—if there is not enough capacity within the system, then the model will basically use this very expensive what we call "Dummy Technology" basically to produce this unserved energy. On the other hand, in one of the papers, I published, I modeled flexible demands, which is not part of the color code, but this is something, which can basically edit a block of functionality and it's well-described out there and when you google for it basically and then, you can define that a certain share of a certain type of demand can remain unmet if again, the electricity price is above a certain level and this can be different for different types of demands. For example, you can say that the demand by, I don't know, hospitals has to be met in any case independent of the electricity price; whereas, maybe for certain households, you want

to have a maximum ceiling or a threshold. In this regard, the loss of load probability, the long-term models as mentioned have course temporal resolutions so they look at the couple of time slides within a year, but they don't look at every single second within the year and if you, for an energy system configuration, really want to know how many seconds and how many minutes within a year the demand not be met, then I would think that the specialized power system model focusing on just one year focusing with the heightened part of resolution maybe combined Monte Carlo simulations so that it considers altitudes in power plants or a failure in transmission lines. So, it's very—I would say—technical or more power system-focused models are usually used to calculate these values. On the other hands, by these more tittle tools, you get an indication of how much more capacity you generally need and more capacity than demand you need in order to ensure reliable system operation and then, this information can be implemented in OSeMOSYS with what we call reserve margins. It's simple that you tell the models we need a certain share of capacity in addition to the actual peak demand to ensure a reliable operation or what I presented earlier by including operating reserve requirements. So, the loss of load probability is not an output of the model, but it's that the model can be used to ensure a certain reliability basically.

Sean Esterly

Alright. Thank you and we have time, probably one more minute, for the last question. Any remaining questions that I don't get to, I will be e-mailing along to the panelists. So, if your question does not get answered during this question-and-answer session, just wait, give the panelists a little bit of time, and they'll be e-mailing out responses. So, the last question for today is 'Are any governments picking up a transparent modelling tool such as OSeMOSYS to do their energy planning?'

Manuel Welsch

I think Tom and Neil would like to answer.

Tom Alfsted

Yeah, a short answer is yes, the South African government is actually using OSeMOSYS itself. That is the one I know of. I don't know if anyone else wants to add in, but to just add on to that, as you said, as part of the chair is that the tool is could call this quite as it seemed to access and deal with compared to some of these other existing tools. So, what the South African governments have done is they had added features that they were keen on and things like energy learning for instance and technology learning—sorry—is a feature they've added. So, they added a couple of the features and they felt were missing from the—in the sort of the basic or very core simple code and that's essentially something that they are now working with. They also developed their own little data management and handling tool for this to continuously work with larger data sets and so forth. That's more inconvenient if you're working with larger data sets. You need some system for handling data. So, it's—they developed that as well, which I think also that they're planning to share. So, the answer is yes, these are being adopted in member states. I'm not sure if Manuel only was familiar with other instances.

Neil Strachan Yes, Tom, thank you for answering. I mean in here in the UK too, we do this example, but it's a range of modelling tables from the very transparent. So, the data developed energy climate change as a calculator and a very simple accounting tool, but it's heavily used for interaction with the general population and the whole bunch of stakeholders all the way up to the extremely complicated tools that are very hard to explain, but no matter where the tool is. It is underlying desire by the UK and other governments for transparency and quality assurance and part of that is energy policy is A, large sums of money and they're quite controversial whether you are in favor of certain technologies or constraints on how people behave. I mean these big big issues and I don't think it's enough anymore for our governments just to see. Trust that we have a model and it tells us the answer. There is much more into that to process with stakeholders across the society and transparency and quality insurance of models is a key underpinning process of that.

Manuel Welsch If I may just as well add in line to this. PTH as well as UCL is leading EU think tank. We have basically one proposal recently and one part of this might be as well, but in our proposal, we really emphasized the use of open source models as a basis and to publish data and the assumptions used in the modeling effort. So, it may be based on the criticism with the prime's model that other universities couldn't kind of check what is going on within the model that may have been a reason that the last European Union seems to appreciate this open source nature and transparency.

Sean Esterly Great. Well, thank you again Neil and Manuel and Tom for the question-and-answer and the presentations. We'd like to just wrap up quickly now with a brief survey, three questions for the audience. Heather, you could go ahead and display that first question and the first question is 'The webinar content provided me with useful information and insight.'

Sean Esterly The next question is 'The webinar's presenters were effective.'

Sean Esterly The final question is 'Overall, the webinar met my expectations.'

Sean Esterly Alright. Thank you for answering our survey and on behalf of the Clean Energy Solutions Center, I just like to extend a thank you to our expert panelists today and to our attendees for participating in the webinar. We've had a great audience and good questions and any questions again that did not get addressed will be sent along to the panelists so that they can respond and additionally, you will find information on upcoming webinars and other training events at [cleanenergysolutions.org](http://cleanenergysolutions.org) and you'll find the posting of the audio recording of this webinar as well as PDF versions of the slides very shortly. We also invite you to inform your colleagues and those in your networks about the Solutions Center resources and services including the no-cost policy support and we hope everyone had a great rest of your day and hope to see you again as future Clean Energy Solutions Center reps and this concludes our webinar.