[Speaker: Kristen Ardani]

Cover Slide: Thank you everyone for joining us today for the DG Interconnection Collaborative's informational webinar. The focus of today’s presentation will be on enhanced modeling and monitoring tools for distributed PV interconnection. We have a guest speaker from Green Tech Media (GTM) today, Rick Thompson. So before diving into the enhanced modeling and monitoring tools information, he will provide us with a quick overview of Green Tech Media’s (GTM) new Grid Edge executive council.

Slide 2: With that, I would like to introduce all of today’s speakers. We have Rick, like I mentioned. Mark Rawson of Sacramento Municipal Utilities District and David Pinney of the National Rural Electric Cooperative Association.

Slide 3: So with that, I'd like to introduce today's speakers. First, we have Rick Thompson, the president and CEO of Greentech Media. Prior to cofounding Greentech Media in 2007, Rick spent 15 years at leading technology startups, incumbent networking and communications companies, and technology, media, and market research firms.

And then following Rick we're going to hear from Mark Rawson, energy research technology officer in energy research and development at Sacramento Municipal Utility District (SMUD). Mark Rawson has over 15 years of experience in energy research and policy development. He serves as SMUD's principal research technology officer, responsible for research, strategic planning, and portfolio management.

And then we'll hear from David Pinney. David is the engineering lead for the NRECA's Power Systems Modeling Project: The Open Modeling Framework. He designs and builds mathematical models of grid technology with an emphasis on cost effectiveness of smart grid investments. Prior to joining the NRECA, David led consulting engagements for software and data mining company MicroStrategy, and built biological models at the UCLA Institute for Pure and Applied Mathematics.

So with that, I'd like to turn it over to Rick Thompson, who will start us off with a quick overview of the Grid edge executive council. Rick…
Great. Thanks for having me here today. I'll be brief, just a few minutes, so we get to the meat of the presentation by Mark and David. But again, I'm Rick Thompson, president and cofounder of Greentech Media. And yeah, I was invited to talk a little bit about our Grid Edge initiative, and specifically, our executive council, so I'll just run through a few slides here, and kind of explain what that is and how it ties into the topic we're discussing on the webinar today.

So Grid Edge, and I'll kind of get to the – the bottom line about Grid Edge is the combined force of general grid modernization, but also with the growth of distributed generation largely. There's some other main drivers and things that are happening. But this diagram here really illustrates at a high level the major market forces.

And if you look at – kind of left to right, at the top you've got the various grid modernization activities that have been going on, smart grid, you know, whatever you want to call the term, but there's a – at a high level, there's things going on at the physical layer and things going on at the higher kind of software and intelligence layers in terms of grid modernization that we're all relatively aware of.

And then on the customer side, you've got things happening obviously with distributed generation, the growth of storage, and then things kind of from the optimization perspective, whether it be energy efficiency programs or energy management systems or things like that. And what these are both kind of pointing to or leading to on the right there is the next generation energy system, and it's kind of broken up into two broad areas, one being kind of a market evolution, looking at how the utilities will evolve from a market perspective, and then importantly, how they will evolve from kind of a technology perspective.

So again, a lot of this, at the very high level, Grid Edge is in a lot of ways defined by the growth of PV, the growth of decentralized energy generation resources, and how that's impacting the existing kind of centralized architecture of the grid infrastructure.
At Greentech Media and GTM Research, we do quite a bit of market research in both grid modernization, but also PV, and that includes everything from utility scale to residential to CNI. Just a couple of quick facts here. I mean, we really view PV as the ultimate driver of our Grid Edge initiative. On the left, we were actually quoted in the State of the Union Address earlier this year. It was actually going on while we were all DistribuTECH, and the quote was, "Every four minutes, another American home or business goes solar," and that came from market research that we had published just very shortly before that.

On the right, you can see some of the numbers that we've put out. The U.S. is predicted to install nearly 6 gigawatts of solar in 2015 for a total – or 2014, sorry, for a total cumulative of 18 gigawatts. That'll put the U.S., in terms of solar installations worldwide in 2014 in third I think behind only Japan and China.

So you can see there that PV growth is happening rapidly. We're moving from a very centralized architecture to a decentralized one, and that's really spawning this concept, what we call Grid Edge.

So this chart, I'm not going to through every little box and piece of text on here, but this was a – kind of a market taxonomy that we had developed here at GTM Research to help us kind of better understand the different segments of the market, the different technologies within those segments, different companies that were providing those solutions or technologies. If you kind of view this diagram – obviously, there's three sides to the cube. If you view the edge of the cube that would be facing you, that's essentially where the meter is, so that's essentially the demarcation point between the utilities distribution network and the consumer, whether it be residential or CNI.

So everything sort of on the left hand side of the front face is really utility-owned grid infrastructure. Everything on the right hand side of the front face is what we'll call consumer owned. There's obviously models where some of these devices may be sitting behind the meter, but potentially owned and operated by utilities. But these are physically sitting behind the meter.

And then you've got on the top there kind of the market evolution part of the cube, so how the utilities will evolve, how the regulatory environment will evolve with the growth of distributed PV. And I think the interesting thing – so when we talk about Grid
Edge, we're really talking about the last mile of the distribution grid, so the edge of the grid and how it combines with a lot of the shifting things that happening at the consumer, but in addition to that, it's not totally – it's not literal in terms of its physical location. You will have also back office utility systems that may be other upgraded, newly deployed, and potentially sitting in a very centralized utility-owned location, but the function of that system might be driven by something that's actually happening at the edge of the grid, like the growth of PV. So derm systems or various add-ons to OMS or DMS systems those types of things.

And it's – if you look at it from a layered perspective, kind of going from the bottom to the top, we view the bottom layer as kind of the physical asset layer, whether it's the physical assets on the distribution grid itself, anything from smart metering, AMI infrastructure, to the transformers and recloser switching, whatever of the plethora of technologies that are on the physical architecture.

And then on the consumer side, you've obviously got things like distributed PV, distributed storage becoming more popular, potentially other types of generation, whether it be fuel cells or something else, new load types, like electric vehicles. So this is all kind of the physical layer.

If you go to the layer above that, that's really more of kind of the network and control layer. So again, in terms of on the utility side, that would be really where the networking and control protocols for AMI networks might reside, or for various distribution automation applications, etcetera. And then on the consumer side of things, it would be things that are controlling the devices, the physical devices behind the meter, like smart converters or PV chargers or various software controls for storage, things like that.

And if you move up the stack to the next layer, you get to the application layer, and then the analytics layer. And I think there's a lot of talk about analytics in the market today, and it's interesting to us that it's – clearly, consumer analytics is very important, and probably getting to become more important now with the distribution, with the growth of distributed PV and these types of things, but there's a lot going on with the utility infrastructure in terms of analytics of their infrastructure and new sensor technologies and those types of things. So hopefully, this kind of gives you a little bit of a map of how we kind of see that market segmented, and the various technologies that have a role there.
Slide 8:

So just briefly, I want to end up with a couple of slides just talking about our executive council. We launched this Grid Edge executive council last fall, and it was really an extension to our smart grid research practice here at GTM Research, which is the research arm of Greentech Media.

So if you look at this diagram, on the right hand side there, it says market analysis, so the whole council is based in a lot of our market research. So we periodically and frequently publish in depth market reports and technology reports. We have exclusive report briefings to members and subscribers. We've created a Grid Edge deployment tracker database that has about 4,000 entries of global utility deployments of various Grid Edge technologies in their infrastructure and networks. And at various levels, you have access to the analysts that are creating this content, and then we do a quarterly market briefing on the market as a whole.

And then what we've added really to create this executive council is everything on the left. So we've added in person meetings, about three to four per year. We do several web-based council meetings. We share the membership directory amongst members. And then we host a number of industry conferences that all of our Grid Edge council members have access to coming to, and many of them end up being speakers there, and engaging there.

So this is – it's a relatively new initiative for us, but it's been growing very rapidly. We've got over 60 member companies, and approaching 80 or 90 actual individual members, and it's been kind of growing on a weekly basis here, and I'll show you the members here in a minute.

Slide 9:

But if you go on to the next slide, it's a quick snapshot of the – some of our new and upcoming market research, just so you can get a sense of the titles that we're producing. We recently released the first top two titles. We released a report on distributed energy storage, with a focus on CNI markets.

We very recently, about two weeks ago, released a new report on advanced grid power electronics for high penetration PV integration, so that's very much in the wheelhouse of the topic we'll be discussing today. That was a very in-depth report, and I think the first of its kind out there that gets into this level of detail. And some of the ones we've got coming up, we'll be releasing a micro-grid report next month. We'll be releasing a report on derr
systems. We're looking at kind of a next generation DR report. The author of the power electronics report is currently starting a volt/VAR control and CVR report, and then we'll be looking at grid edge analytics in the third quarter. So this is just kind of a flavor of the types of research that we do and the type of research that we publish.

**Slide 10:**

Just a couple more here before we get into the depth of the presentation. So just to kind of give you a flavor of who are the members of the council. I certainly won't go through all these, but you can see there that it's a very nice collection of both vendors large and small, and utilities, both kind of North American and international. And we've actually been getting quite a bit of utility interest lately. We just – I think Exelon just joined in the last week, and we've got a couple of other ones that we're in the process of joining as we speak. But you can see there, many of your peers are represented, and there's some very interesting technology companies, hardware/software, kind of full breadth portfolio type companies that are engaged in the council and the meetings that we have.

**Slide 11:**

So if you go on to the next slide, the other part of the Grid Edge initiative is we're having an annual conference that's going to be held on June 24th and 25th in San Diego. SDG&E is actually the host utility. It'll be at the Hyatt Regency Mission Bay Spa Marina. And it's called Grid Edge Live. We're going to have 19 sessions, roughly about 63, 64 speakers, and we're expecting about 350 attendees, again, that are majority kind of director level and above decision makers at both vendors and utilities.

And then this conference, since it's looking at a lot of the impact of distributed PV on grid infrastructure, we're expecting quite a few more attendees than normal kind of from the solar side of the world. So everything from the installers to inverter manufacturers and integrators, etcetera. And on the right there's just a couple of diagrams of the types of sessions that we'll have, and the types of companies that we're expecting.

**Slide 12:**

So if you just go to my last slide, it has some contact information for me. If you've got any questions at all regarding the council or any of the research that we do or the upcoming conference, you're
– feel free to email me directly, and I'd be happy to get back to you, or there's a couple of links there. The first one is a link to the executive council, and the second is a link to the conference, with a lot more information.

So I appreciate the opportunity to tell you about this initiative, and I thank the folks at NREL for inviting me here today, and I'll hand it back over so we can get moving with the presentations.

[Speaker: Kristen Ardani]

Slide 13:

Great. Thanks, Rick. I hope that's helpful for folks to know what other efforts are going on in this topical space. And with that, I'd like to invite Mark Rawson to present his presentation for us today.

[Speaker: Mark Rawson]

Slide 14:

Great. Thank you very much. I think Rick's presentation gave a nice overview of kind of the broader strategy and how these pieces fit together when we start to look at grid modernization. And my discussion is going to step a little bit lower down into some specifics about how SMUD's approaching the proliferation of photovoltaics, both customer and utility scale, within our service territory.

And I'm going to talk a little bit broader than just interconnection, and I'll talk about the breadth of activity that we're doing relative to solar integration, because it's broader than just do we have capacity on a distribution feeder to interconnect. Certainly it is an important part of the puzzle, but I'll talk about some of the other things that need to be considered as we kind of migrate to a greater dependency on photovoltaics to serve our energy needs.

Slide 15:

So if we move to the next slide, so SMUD, for those that don't know who we are, we're a public owned utility located in Northern California. We're the sixth largest public owned utility in the United States. We have an elected board of directors. So our motivation or driver for how we operate is different than investor-owned utilities in that we're owned by our customers, so from that perspective, the drivers and the policies and strategic directives that we pursue tend to be slightly different than they are for other utilities around the country. So just to give you a little context for who SMUD is.
Slide 16:

So these are the five points I was going to cover. I was going to give a little bit of context for why we are investing a significant amount of public dollars into solar R&D, the growth in solar at SMUD. I'll talk a little bit about our strategy relative to PV integration research and development, and then dive into some specific projects around solar resource characterization, quantifying the impacts of what PV is doing to our distribution system and our bulk system in the aggregate, and talk a little bit about some of the different things that we're pursuing as mitigation strategies, and then I'll finish talking about kind of what does the future look like? Where do we think photovoltaics are headed from a resource planning perspective?

Slide 17:

So this graphic gives kind of a history of SMUD's experiences with solar. We've been involved in solar for a long time, starting way back with the first utility scale one megawatt PV plant that we constructed at our decommissioned nuclear plant, Rancho Seco, back in 1984. In the nineties, we rolled out a program where SMUD would deploy and own rooftop solar on residential and commercial customers' facilities, all the way into early 2000s, where we rolled out innovative programs such as Solar Smart Communities, which is a program where we actually partner with new construction residential developers to incent solar at new construction, where it's most cost effective to implement. And that program has been wildly successful.

Other programs like Solar Shares, for those types of customers that maybe don't have the right residence or commercial business to facilitate solar, we do community scale solar and let them participate through a Solar Shares type of program.

In the last couple of years, 2010, '11, '12, we rolled out a feed-in tariff program that was eligible to all renewables that are eligible for the RPS here in California. That program was capped at 100 megawatts, and lo and behold, it was all solar that came in to propose to our feed-in tariff program. All of those systems are now online, and you can see a pretty substantial jump up in the interconnected capacity of solar in 2012 timeframe.

And we're now looking at continued expansion of rooftop solar, and an additional large scale, utility scale solar here in the next couple of years. And then of course, all the way on the right, upper right, is California Governor's goal of a gigawatt of solar coming online, and SMUD's portion of that could be pushing up
into the 500 megawatts of installed PV capacity, certainly within this decade.

So really, what this shows is that we've – we're seeing exponential growth in PV deployment in our system. We expect that to continue. And really, for utilities here on the West Coast, in Hawaii, Arizona, Nevada, they see similar trends in terms of solar deployment being interconnected at the distribution and sub-transmission level.

Slide 18:

So what is SMUD doing about that relative to this expected wave of PV interconnections? We've been fortunate up to this point that our system's been able to accommodate the solar that has been interconnected. Even in some high penetration pockets, we've done some very good with NREL as a partner to look at some all-solar communities. And basically, our findings thus far have been – and we don't have any problems yet. Our voltage regulation approaches and our interconnection processes are working. But as we go forward and start to see much larger penetrations of this variable generation source, there's some things that we need to find answers to to make sure that we can still ensure a reliable energy service for our customers at a reasonable cost.

So to accomplish that, we've embarked on a structured R&D activity around specific issues associated with PV integration, and we characterized those into these three key platforms. The first platform, grid impacts, is really trying to understand as we go up in penetrations of PV, how does that impact how we regulate voltage on the system? What happens when we start to have reverse power flow in the distribution system? How does it affect reliability and power quality?

And from that body of research, we look to investigate certain mitigation strategies. It could include things such as new distribution system architecture, voltage regulation approaches, smart inverters, energy storage, using load as dispatchable resource to deal with variability of PV. So that second platform is all around mitigation strategies.

And then, of course, the bottom platform is taking what we learn through these other two activities and trying to understand really how do customer programs need to change to reflect changes in the T&D system to accommodate PV. How does that impact our policies going forward relative to utility and customer sided PV?
And what new business models may present themselves that may change how our relationship with the customer is today relative to customer sided PV?

And really, what we're shooting towards is this vision where our smart grid, our T&D system, is really able to accommodate this growing penetration of PV in such a way that we can still maintain high reliability, have a system that's still operational, operationally flexible, and try to minimize grid integration costs associated with photovoltaics.

Slide 19:

So I'm not going to go through all of these elements on these next two slides about the different research questions that we're trying to address through our portfolio of research projects, but just to give you a flavor, we've, through grant funding and internal funding, we've been doing a lot of work here on the left hand side of this chart to really understand what PV means in terms of impacts to the grid, both from a temporal and spatial perspective, and whether it's very dispersed or pockets of high penetration. How does that affect voltage in the distribution system based on the resource in our area? How severe are the ramp rates that we experience? Looking at how the interplay between wind and solar impacts our system.

So we've been doing a lot of work on solar resource characterization and distribution system impacts, and then rolling that up to trying to understand in the aggregate how high penetrations of solar and wind impact our bulk system.

As we move kind of through the middle and out to the right, out to the future, once we've kind of characterized what we think the impact is, based on different penetration levels, we want to understand how we may need to change our strategy around distribution voltage regulation, how intermittent PV may affect certain strategies around conservation voltage reduction or volt/VAR optimization that we're pursuing through some of our other smart grid activities, understanding how photovoltaic deployment may affect how we protect the system, etcetera.

So this is all the body of activities around the grid impact characterization platform.

Slide 20:

On the next slide, this presents the different activities that we're pursuing from a mitigation standpoint. So we're looking at
activities from solar forecasting to better grid design and operation strategies, looking at advanced inverter technologies, demand responsive load control, energy storage, to help us identify ways that we can accommodate this intermittent resource and maintain reliability.

Our perspective on this is that there's not one simple solution, that we need to look at the suite of technologies that we can deploy in our system to address the intermittent nature of PV so that we can maximize the renewable production from this resource and not have to curtail it if at all possible going out into the future. So we're doing a lot of work in trying to understand the state of the industry relative to solar forecasting. Can we do a better job of forecasting where PV production is going to be in the next 15 minutes, the next hour, this afternoon, or day ahead?

This is important because in the absence of a better idea of what solar production is going to be, there is a tendency for grid operations to potentially over-plan ancillary services or other generation resources that in essence could just drive up the integration costs of solar. So if we can get a handle on our ability to predict what we can expect from PV production, we can better optimize our other generation resources to make sure that we can meet the load with that intermittent resource.

We're looking at storage as a way to better align the PV production to our system peak. It could be as much as a five to – four to five hour difference between peak solar production and when we actually are serving our system peak, which is in the early evening. We're also looking at storage to help deal with the more real time intermittency of PV production, and potentially use storage as a way to dampen the impacts of the variability on voltage regulation. We're starting to look at demand response as also a viable resource for dealing with variability.

We're doing a lot of work in trying to understand how we can leverage our full smart meter deployment, our advanced metering infrastructure and distribution automation networks that we've deployed to actually monitor what's happening with PV inverters, and ultimately look to see if we can use those systems to help us control those inverters, should we decide that curtailment is a viable, cost effective strategy for us.

And then as you move across this particular platform, you start to look to looking at more systems-related issues around how is PV variability going to impact other strategies around volt/VAR...
optimization and conservation voltage reduction. Are those things going to be at odds with one another when we have our resources dispersed on the distribution system that could be impacting the voltage profile on a circuit?

Slide 21:

If we go to the next slide, this is the last platform I'll cover here. And really, the takeaway here is that we're looking at are there limitations to the amount of PV that we're going to be able to accommodate in our system before we have to trigger costly system upgrades? Do we need to start looking at prioritizing where on our system we would want to encourage PV and promote that either through incentives or other mechanisms? And on the flip side of that coin, are there areas in our system where interconnection of PV is actually a detriment to the T&D system, and would we want to consider policies that would discourage those types of interconnection?

So this is really now starting to take a more granular look at our – at our integrated T&D system, and understand places to promote PV and places to discourage it from the standpoint of reliability and reducing grid integration costs.

Slide 22:

If we go to the next slide, I'm going to shift gears and talk about each of a couple of these areas in a little more detail. This is a project that was focused on really trying to get our hands around what's the solar resource look like in our service territory, in the 900 square miles of our service territory? Do we see differences in the solar resource? And based on that solar resources, what are the implications of just a dispersed fleet of PV across our service territory in terms of how it affects voltage and grid operations?

So to get a handle on that, we deployed a network of irradiance sensors across our service territory on a five kilometer grid. This was work that was funded under the California Solar Initiative's R&D program with co-funding from the California Energy Commission. And what we used this one minute data for was to start to evaluate different solar forecasts offered by the private sector to really try to get a handle around what's the state of the art in terms of solar forecasts. For any of the participants on this call, we have a very rich data set of over a year's worth of one minute data from this 71 sensor network that can be made available to researchers or other utilities that want to understand how solar resource varies across a service territory.
Slide 23:

So this slide presents some of the results from that work. In the upper right hand or left hand corner, you can see that five kilometer grid and the different sensors that were deployed. The green dots show some of the larger PV – utility scale PV systems that are on our system. And the data in this chart illustrates how variable a solar resource can be across our service territory. This happens to be a fall day. We see most of the variability in the fall and the spring months. But you can see pretty substantial ramp rates from different solar sensors across the service territory. And when you start to look at the average of those solar sensor – that solar sensor network, you do certainly get some damping.

So what are the ramifications from that when we consider a very distributed fleet of PV across our service territory? And then also on this chart are some of the hour-ahead solar forecasts that were generated from one particular company that really illustrate there's some – that work needs to be done on our ability to forecast what's going to happen with solar production.

Slide 24:

So based on solar resource characterization, we've been doing a lot of modeling work around looking at different parts of our system, where we have solar deployed currently, doing pretty in depth modeling of those feeders, those distribution substations, and/or those bulk substations, trying to baseline what the situation is on those systems based on the solar that's deployed, and then doing some different penetration scenarios to understand based on those models that are validated against the solar resource, looking at different deployment scenarios to really understand as we go forward and start to see high penetration, so what is that going to mean for us in terms of grid planning and operation?

We're also looking at developing some visualization tools to assist our operators and planners with what happens with the solar resource and how that translates into PV production, and likewise translates into impacts on a particular feeder or substation within the service territory. Another activity in this space was to understand and demonstrate how we could use our AMI communications network to communicate between our smart meters and the inverter, to first monitor the PV production, and then secondly, be able to curtail it. That work was done using the SEP protocol.
Slide 25:

This is another activity that we've been doing with a company called Gridiant, where we've integrated our complete transmission and distribution system into a single model, and we're evaluating different penetrations of photovoltaics and different deployment scenarios. So we're looking at 100 percent, 150 percent, 200 percent of daytime minimum load, looking at different deployment scenarios. All of the PV is very distributed across the system, versus PV that may be deployed in pockets at certain points in the feeder, and really trying to understand voltage deviation across the system, and characterize what kind of reverse power flow we have.

We do have parts in our system today where we experience routine reverse power flow, not only in the feeder back into the distribution sub, but onto adjacent feeders, and even out of the distribution sub back onto the sub-transmission system. So we're starting to see penetration get high enough to where we're starting to see impacts. And the graph down below is a GIS representation of a part of our system down where we have some large solar systems, and you can see this green, yellow, red signifying that we have places where we have high voltage occurring on our distribution system as a result of distribution interconnected PV on the system.

Slide 26:

So we've been doing a lot of work in the energy storage space. We completed a major project for us at an all solar homes planned community called Anatolia, where we demonstrated both behind the meter residential energy storage, or RES, versus edge of grid deployed community energy storage, or CES. These were lithium ion battery-based systems in this all solar community.

So every home had solar, and we evaluated the I guess efficacy of kind of the customer sided storage versus edge of grid side of the storage, utility controlled, and trying to understand both the grid integration implications of both types of configurations, how effective they are at dealing with variability of the PV production from each of the homes in the aggregate or individually, and we're just getting ready to make available to the public a report that we've produced from that study and that has been provided to the Department of Energy. That project was funded under an ARRA grant from the solar program in EERE at DOE.

A couple of other storage projects. Mitsubishi, we're doing a big project with them. This is a lithium ion battery system that's deployed right next to a large three megawatt PV plant in a very
rural part of our service territory, and we're using that battery system to firm the PV production. I apologize, the upper graphic on the right is not very good quality, but the upper red line shows what's happening with the battery system. There's a pink line through the middle that's showing the PV production, and effectively what we're demonstrating through this particular project is what we can do with the blue trace, where we have the ability to use the energy storage system to shape the PV production in such a way as to try to minimize the variability of the voltage on this feeder.

We've got another project with FEOM looking at a different battery chemistry. Sodium nickel chloride is a high temperature battery. That's the lower picture, showing the installation of that system. That's installed next to an 80 kilowatt PV array here at our corporate headquarters, where we also have level two and level three charging for electric vehicles. So in this particular case, we're looking at multiple use cases of the energy storage support, shaping the PV and smoothing the PV, as well as addressing peak load issues associated with electrical vehicle charging.

And then the last project here is a all solar home community where we're deploying residential battery storage. We'll also being demand responsive load control, and looking at this development as really a grid asset that we can dispatch to help us deal with grid issues associated with these all solar homes at this particular location.

**Slide 27:**

I'm going to skip over this one. I spoke to it a little bit ago, but this project really was to demonstrate that yes, we can communicate to inverters through our AMI system. We can monitor them and control them. We've got follow-on work planned to understand how we might move forward with SEP 2, and potentially open ADR standards for communicating with inverters.

**Slide 28:**

So what does the future look like for SMUD? We're doing a lot of work right now in the research planning space. We've got a couple of different projects that are looking at the bulk system implications of high deployments of both solar and wind going out into the future. We're looking at a 50 percent renewable portfolio standard by 2030, and what the implications of that would be from both a renewable resource acquisition as well as operational impacts to our T&D system.
And a couple of projects here of note. One project's looking at the operational impacts of 1,500 megawatts of solar and 600 megawatts of wind on our system. That's a project with Energy Exemplar and NREL and Clean Power Research. Then we've got another project that's looking at what would be the value of having better HEC in a solar dominant resource mix, and how would that impact how we would want to dispatch our other generation resources to deal with regulating frequency on the system.

So the takeaway from this slide really is that from SMUD's perspective, we expect to see continued exponential growth in intermittent renewables, such as solar and wind, and our portfolio of research is really trying to help us get answers to these grid integration questions beyond just interconnection, so that we can make we can operate our system reliably.

Slide 29:

And really, that body of research is around forecasting, modeling, planning and operation, resource planning, etcetera. One area I didn't talk about was rates. We are doing some working in looking at net metering and where do we go into the future relative to net metering and its implications for PV deployment and how we design and operate our system in a way that's equitable for PV and non-PV customers. And with that, I'll conclude my comments.

[Speaker: Kristen Ardani]

Slide 30:

Great. Thank you so much for that informative presentation. Before we transition over to David, let's go ahead and take a couple of questions that came in. So Mark, one of the questions that was submitted is in relation to the one minute data from SMUD's R&D program, and whether or not that data has been applied to the impact study process with tasks like load flow and voltage study. In particular, has the data been used to model a more realistic ramp rate for PV output for studying the voltage effects versus studying voltage effects in a binary fashion? If you need me to repeat the question, I'm happy to, but –

[Speaker: Mark Rawson]

No, so we have used that data to model PV performance of some of the larger systems that are interconnected to our system, some of the projects that came in through the feed-in tariff program. Most of those – the studies relative to distribution impacts of that variability, though, have not been predominantly time sequence-oriented. They've been more static. So we do have work to do in understanding the dynamic implications of that PV production and
the variability of that production. There's actually going to be a report here published in July on some of the work that we've done in that space under our California Solar Initiative study. But I don't have results that I can convey to you at this point.

[Speaker: Kristen Ardani]
Okay. Great. And so another question for you. Has SMUD been monitoring substation transformers under reverse power flow? Are there any results either hard or anecdotal available on how reverse power flow affects the performance, reliability, and lifetime of substation transformers?

[Speaker: Mark Rawson]
So we have been monitoring a couple of the instances where we've seen reverse power flow into – and I'll characterize it as two types of situations. One situation is reverse power flow off a high penetration PV feeder, and that generation serves load on an adjacent feeder. In that particular situation, anecdotally, we haven't seen really any issues relative to excessive LTC operations that would be cause of concern for our distribution planning group or our operations group, at least at the penetration level that we see on that distribution sub.

We've also seen some instances where the load was such on the adjacent feeder where we saw reverse power flow back up in to the sub-transmission system, but again, we didn't – we haven't seen anything anecdotally that has been a cause of concern in terms of implications for either voltage regulation equipment in the distribution substation and/or transformers in that substation.

[Speaker: Kristen Ardani]
Okay. Great. I think we have time for one more before we transition, and then we will have more Q&A at the end. So Mark, what protection provisions are in place on transformers to permit reverse power flow? For example, high side relaying? Are there any types of transformers or other conditions where reverse power flow is not permitted?

[Speaker: Mark Rawson]
Great question. I don't know the answer to that one. In fact, if the person that submitted that wanted to get that question to me, I can run that through our distribution planning folks and try to get a specific answer for you.
[Speaker: Kristen Ardani]

Slide 31:

Okay. Great. Yeah. We can definitely facilitate that. I can send it over after the webinar. So I would say let's go ahead and transition to David's presentation to allow for more time at the end for additional questions. So with that, I'm going to turn it over to David at the NRECA, and he's also going to provide a bit of a demo on this tool as well.

[Speaker: David Pinney]

Great. Thank you. So my name is David Pinney, and I’m with NRECA Cooperative Research Network.

[Speaker: David Pinney]

I suppose people can see the cover slide right now, I assume.

[Speaker: Kristen Ardani]

David, you're ready to go.

[Speaker: David Pinney]

Slide 32:

Okay. Great. So I work for NRECA, where I lead our power systems modeling efforts inside the Cooperative Research Network, and I'm the engineering lead on this Open Modeling Framework (OMF), and I also written a lot of code contributing to it.

So what is the OMF? The OMF is software for modeling the grid with a focus on emerging technologies and smart grid technologies. Our goal in writing the software was to enable cost/benefit analysis and some engineering analysis for our member co-ops, basically, to make their modeling lives easier.

The problem originally came to us from our Smart Grid Member Advisory Group. A couple dozen cooperative utilities came up with some key barriers they were facing in terms of deploying the smart grid technology, and being able to do a cost/benefit analysis for an AMI deployment, for energy storage deployment, for a volt/VAR optimization scheme. This is one of the things that they were struggling with.

We also – the co-op community, during 2008, as part of the American Reinvestment and Recovery Act, won about – won and did about $64 million worth of grant funded studies of new grid
technology, and as part of that, those projects, there were some modeling results that were needed to fulfill the requirements, and we figured, well, if we're going to build these tools, we want to build them in a way that they're usable in the future, and they're not just throw away after the particular study was done.

There are a couple of areas where we think that we've improved upon the state of the art. One of them is that the best models that were out there when we started took weeks or months to run, and that was unusable for the smaller utilities that we work with, and also, we felt that it was limiting the usage of these tools that were very powerful. We also found that no one tool had all the features we needed to model interactions between say customer demand, weather, and various components in the power flow simulation.

We also, in building the modeling framework kind of in an open way that all of the member utilities can access, we were trying to avoid the problem that a lot of the results we found in the literature were not reproducible. We found modeling results, people would have great say volt/VAR optimization predictions or measurement and verification results, but the code wasn't published, the data wasn't published, and cases where we contacted the original authors, the data and code were no longer available.

And so when I show you the OMF, it's all available via the web, and there's a database of past results and models. And the idea here is that we want to allow these results to live on. And it's also a way for these 900 utilities to collaborate.

**Slide 33:**

When we started this project, the world of distribution modeling, there were basically two types of tools. On the right is Milsoft WindMil, which is great, incredibly widely deployed, easy to use load flow and voltage drop tool. And on the other side we have kind of a illustrated screen shot of GridLAB-D, which is a very powerful time series power flow tool, but as you can see, has no usable human interface. You essentially, if you wanted to do power flow on a particular feeder, you would write tens of thousands of lines of customer configuration, run it through a command line tool, and then you'd consume the text files that came out the other side.

**Slide 34:**

So our goal was to bridge these two worlds in whatever we built. We worked with a couple of partners in this effort, and we continue to work with many of them. Pacific Northwest National
Laboratory, PNNL, are the ones that build GridLAB-D, which we rely on for our time series power flow results. And in continuing to work with these modeling results, we worked with them to send changes back to the GridLAB source and identify things that are of particular interest to our utilities. Oak Ridge also contributed to the code base. They focused on performance of GridLAB-D, and looked at some optimization techniques that hadn't been investigated yet, and also are working on visualization tools for very large utilities with hundreds of thousands of meters. We found that even the best commercial tools out there had trouble visualizing time series data at that scale.

Department of Energy, of course, has provided matching funding for a lot of this effort. NRECA at Milsoft, currently well-loved in the co-op space, their distribution modeling tool, WindMil, has about a 80 to 90 percent market share.

Slide 35:

So what does the tool actually do?

Slide 36:

I put these slides in here just so they would be in the deck, but I'll move actually now directly to a demonstration.

So when somebody wants to use the OMF, assuming they are writing code on top of the framework, they would come to OMF.coop, and they would log in, and when they come into the system, they see a set of models that have been run before that are either shared with them, or public, or ones that they've created themselves.

We're currently in a beta test of the system, and sometime this year we'll roll out to the 900 or so cooperative utilities.

The beginning of any grid distribution analysis starts with description of the distribution system, and so we built some import tools. We imbibe data directly from Milsoft, because it's so readily available in the co-op community. And also, soon, we'll be able to import also from SIME, which should allow us to cover a much wider set of utilities. We've had some interest and been talking to a couple of investor-owned utilities about potentially offering them the software.
So I'll come in here, and here's an example of the data we get in from Milsoft, a representation of of course the entire feeder in question, lines, transformers, meters, loads. We had to unfortunately build an editing interface for this data, because there are a lot of features such as PV that aren't handled in the existing tools. GridLAB can handle it, but Milsoft doesn't have a way to characterize it. So I can go in here and add, for example, an inverter and then a solar panel. I believe that – 20 percent efficient. That's a little high.

So when somebody wants to look at a particular solar problem, they would start here in characterizing the system, and then actually running the code is in another portion here. I'll jump directly to some results about what kinds of models we're looking at right now. For utility-owned [audio glitch] solar, we didn't do a lot of work on it, because we found that the existing tools out there, particularly the System Advisor model out of NREL, covered a lot of what people were asking for. But we threw it into the framework, because we're a framework, so we might as well support multiple models.

And in this case, it's a – we did this for a Midwestern co-op. It's a comparison between a fixed one access and two access solar system. And we look at essentially power generated over time, total energy. As expected, two access generates more.

And then look briefly at what we think the avoided cost would be for this utility in terms of serving their customers from the energy from this system, and we do a comparison between the three different cases based on their – that particular co-op's energy rate. Now –

[Speaker: Kristen Ardani]

David, I really hate to interrupt you, but we're getting a lot of feedback on the line, and we're having a really hard time hearing you. Do you happen to have a cell phone sitting near the interface, or are you on the same phone as when we were talking earlier? We're getting some inference on the line.

[Speaker: David Pinney]

It is a land line.

[Speaker: Kristen Ardani]

And you don't have your cell phone near the phone or the computer? Sorry to interrupt.
[Speaker: David Pinney]
Not very close.

[Speaker: Kristen Ardani]
It might help if you turn off your cell phone. I think it might be interfering with your presentation, and we all really want to hear what you have to say, but we're having a hard time.

[Speaker: David Pinney]
Oh, sorry about that. Let me change the volume here. Is that any better now?

[Speaker: David Pinney]
Is this any better?

[Speaker: Kristen Ardani]
That's a little better. Yes. I don't know what you did, but it's a little better, thank goodness.

[Speaker: David Pinney]
Yeah. Switched to headset. Gosh. Sorry about that.

[Speaker: Kristen Ardani]
Thank you. No. I'm sorry. Thank you so much.

[Speaker: David Pinney]
Well, forging on, so that was kind of the tour of the individual system performance model. And as I was saying, it's not an area where we think there's a lot of work to be done. But in terms of analyzing impacts on distribution feeders from distributed generation, there we have kind of more interesting results. And this is a model we ran for a co-op in Arizona, and it looks at a number of different penetration cases for a given feeder.

And so this was a simulation – this was done only over ten days to make it quicker and easier to investigate the data. The installation data here we're taking from the typical meteorological year data set. We have the ability to play back a particular set of days, historical days, but we find that typical meteorological year is a better characterization. So these are ten days from that data set, and we see here in Arizona, quite sunny, and one day overcast, and some partial cloud cover on another day.

Then we looked at a couple of different scenarios, and this is power flow across the substation into the feeder. And this is the no solar case loads being served from the sub-transmission system.
And then we looked at four other cases, a 5 percent, 20 percent, 50 percent, and 90 percent penetration of typically sized residential PV systems. And what we see from the power flow results is that rapidly, I believe even when we're at 20 percent penetration, we reach a situation where there's reverse power flow, which for this particular utility was most troubling because their power supply contract is a fixed terms contract, and so they wouldn't – they would be transporting that energy, but they would not be receiving anything for it.

And when we get up to 50 and 90 percent penetrations, which are pretty unrealistic at this point, but can certainly be modeled, we see that the power flow across the system at the peak solar hours far exceeds the amount that was transported to serve the loads before, and in fact, we – when we sum up the energy served in loads and also lost in technical losses, we see losses quite a bit higher in the higher penetration cases.

The other impact that was troubling for this particular utility were the voltage effects, naturally, of the distributed generation. These charts are a little tricky to read, but basically, we have all of the different scenarios. There's solar 5 percent, 20, 50, 90. And we have the min, mean, and max voltages at the meter for the entire ensemble of meters on the feeder, and we see in the low case, this – well, it's at a 240 volt scale, but in the 5 percent and 20 percent case, we see we rarely exceed the ANSI band, but once we get up into the 20 and 50, the maximum system voltage, there are a few meters that exceed the band every day, and of course, when you get to 90, you get to the point where the average system voltage is touching the top of the ANSI band.

So – now this particular situation only looked at the feeder as currently regulated. What we'd like to do in the future is kind of do an iterative design, so look at the results for a particular penetration, and then re-regulate, change the projected simulation coordination, and then re-run the simulation.

So that's kind of where we are these days in the – and this year, we'll be rolling this out to all the co-ops, and we'll also be looking at some additional PV models. So getting from just a view as to the effects of DG to a – to an actual prescription of what the possible mitigation options are. And that's basically what I have for the demo, and I'll hand it back over to our host.
Great. Thank you so much. And I think that for the recording of this webinar, we'll be able to omit the static during the first part of presentation, so any folks that want to retroactively go back and visit the webpage and hear David's presentation without the interference during the first portion should be able to.

But I think – let's take a few more questions from our audience. Let's see here. Several questions have rolled in. This question is for David. One of the participants has asked, can the model accept and analyze all types of existing distribution equipment, or is it limited to power flow? For example, can you model line regulator or LTC operations, CAP bank switching events, etcetera?

Yeah. We rely on GridLAB-D for the capabilities there, and they have a very broad suite of devices that they can model, definitely LTCs, CAPs, distributed generation, wind, solar, diesel gen sets, energy storage. And actually, right now they're working on a networking component, so you can model power flow, the time series power flow, at the same time you can measure the communications to look at questions of if you have a – say smart switching scheme, is that durable in the face of communications losses, or if you're doing some kind of fancy edge of network control, what will happen there if you lose comms?

Okay. And we have another question for Mark. Mark, can you provide a little bit more information on the 500 kW 125 kilowatt hour battery research? And is that an insignificant amount of storage for the kilowatt capacity level, or what were some of the findings as it relates to if the storage was sufficient or not?

So that project is more of a power application. The system just came online here in January, and we've partnered with Mitsubishi. It's their first North American deployment. The system was designed by Mitsubishi. We provided them the production characteristics of that three megawatt PV plant, given the solar resource in our area, and they sized the energy storage system based on the production characteristics of that particular PV plant, and sized both for capacity and energy. And they're demonstrating their proprietary PV smoothing algorithm based on the performance of that PV plant.
So to date, we don't have any – we don't have – we just started our MNB plants. We don't have any data to really assess the performance of that storage system relative to addressing certain ramp rates. Most of the information we have has been just observation of the performance in terms of how it dampens the ramp rate.

But that particular PV plant, based on the year and a half of performance, we have seen ramp rates as high as 3 megawatts down to less than half a megawatt in 30 seconds, so pretty substantial ramp rates on that PV plant. But since we've deployed that storage system, we haven't seen like types of solar events to really understand how well the PV firming algorithm is working.

[Speaker: Kristen Ardani]
Great. Thank you. So David, there were a couple of questions just asking for a little bit more clarification of the transfer of the tool to other utilities. I think it may have gotten lost in some of the static. But if you could, just maybe revisit the points you were making about other utilities gaining access to the tool, how that tool might be shared or implemented by others. We've had a few questions around that topic.

[Speaker: David Pinney]
Certainly. This year, it'll be able – it'll be accessible to all cooperatives, and in the future, we'd like to open source what we've done and open it to the utility community at large. The question there is unfortunately above my pay grade, so I have no real idea of when that would happen. But in putting open in the name, we've basically made a promise to make it available as widely as possible.

[Speaker: Kristen Ardani]
And also, David, as a follow-up question, will there be any type of research or metrics that kind of demonstrate the benefit of the tool with respect to any kind of time of cost savings for the overall process for interconnection?

[Speaker: David Pinney]
Hmm. We haven't looked at interconnection particularly. Right now, we're focusing on essentially re-regulation, protective device coordination, and rate adjustment. There are a couple of large commercial and industrial projects that the cooperative research
network is tracking among co-op utilities, and so some time in the future, we would like to look at how the power flow models might apply to an interconnection request for a specific system, as opposed to calculating impacts in a general way.

[Speaker: Kristen Ardani]

Great. Thank you. So there's a question for Mark, and Mark, the question reads, how much money has SMUD invested in developing the grid impact mitigation/business model platform, and identifying the research questions and answering those questions? In other words, so kind of on average, what proportion of the funding has been invested by SMUD proper as opposed to say grant funded or partner funded research?

[Speaker: Mark Rawson]

Good question. Collectively, the body of research that we have underway right now relative to PV integration across those platforms, the total project value is about $46 million. These are multi-year projects, both internally funded and externally funded through grants from state and federal agencies. On average, we leverage internal funds to external funds to the tune of about four to one. That's generally across all of the research activities within the department. And that probably holds true for a lot of this PV work. There's not a big – there's not a big divergence. So when I say across the whole research department, we do research in electric transportation, energy efficiency, climate change, demand response storage, distributed regeneration, renewables, renewables integration.

So – but the work specific to photovoltaics and integration of photovoltaics, the total project budget's around $46 million, and about 4 to 1 is how that's leveraged.

[Speaker: Kristen Ardani]

Great. Okay. I think we have time for about one more question. So David, this will be a question for you. Were line regulators modeled in the distribution study, and what delays were used?

[Speaker: David Pinney]

Ah, they were modeled. I can't remember what the delay was. I could probably figure that out for you. But in general, the insulation data that we have right now is at a hourly resolution, so we don't model say fast moving clouds. We don't model down to the minute or down to the second. And part of that is the power
flow software, the time series power flow software out there, is not really set up for it.

But also, after reading the reports that came out of D-STAR a couple of years ago about the harmonic impacts of solar, we thought that focusing on the hourly behavior would be more important than looking at high resolution effects.

**[Speaker: Kristen Ardani]**

Okay. Great. So with that, I just wanted to thank all of our speakers today for the very helpful and informative presentation. With each of these webinar meetings, we're going and compiling all of the questions that are asked and we'll be providing some type of summary document with frequently asked questions, and compiling information and data in a way that makes it usable by the group.

**Slide 37:**

And also wanted to just encourage folks to register in advance for the next webinar meeting with speakers from APS, and they will highlight APS interconnection process for systems greater than one megawatt, and feature case studies on high penetration, and explain APS's lessons learned with early PV plant integration. So that should make for an interesting presentation as well.

**Slide 38:**

So just thank you again, and if folks have any feedback or input on the scope or direction of the topics that we cover and the way that we're collecting information, you can email me directly, and I encourage you all to also visit the website for our archived recording and past presentations. And again, thank you so much to everyone for participating today. Appreciate it.

**[End of Audio]**