UNITED STATES DEPARTMENT OF ENERGY

ELECTRICITY ADVISORY COMMITTEE MEETING

Arlington, Virginia

Wednesday, June 7, 2017

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P R O C E E D I N G S

(1:06 p.m.)

CHAIR TIERNEY: Good afternoon. Hi, everybody. I'm Sue Tierney, and I have the honor of participating on this advisory Committee as the chair. And as part of our welcome, my welcome today, I think it might make sense for everyone to go around and introduce themselves.

We have a newcomer in our midst, Katie Jereza -- did I get it right? Yes.

MS. JEREZA: Uh-huh.

CHAIR TIERNEY: -- from the Department of Energy is one of the new political appointees to join the Department of Energy, and she is filling in I think with one-hour notice for Patricia Hoffman. So we are going to make her feel warm and cozy, and by doing that, let's just have everybody go around and introduce yourselves. And recall that we are being transcribed, so everyone should probably use the microphones just to make sure that you can be heard not only now when you say hello, but later on today. And then

I'll just go through the agenda quickly after that. Mr. Gellings.

MR. GELLINGS: Well, thank you, Sue. I'm Clark Gellings. I'm an independent.

MR. CASPARY: Hi. I'm Jay Caspary with Southwest Car Pool.

MS. MARILYN BROWN: Marilyn Brown, the Georgia Institute of Technology, and the Board of Directors at Tennessee Valley Authority.

MR. LAUBY:: Mark Lauby, NERC.

MS. CURRIE: Phyllis Currie. I retired from the Pasadena Water and Power, so I come out of the public sector.

MR. ROBERTI: Hi. Paul Roberti, Ernst & Young.

REPRESENTATIVE MORRIS: Representative Jeff Morris from Washington State.

MR. NORDSTROM: Ralph Nordstrom with the Great Plains Institute's non-partisan, non-profit based in Minneapolis, Minnesota.

MS. CARMODY: Paula Carmody, People's Counsel from the Maryland Office of People's

Counsel. We represent residential utility customers.

MR. ROSENBAUM: Hi. I'm Matt Rosenbaum from the Department of Energy.

MR. PARKS: I'm Bill Parks, the Department of Energy.

MS. JEREZA: I'm Katie Jereza, Department of Energy.

MR. ZICHELLA: Carl Zichella, NRDC.

MR. CENTOLELLA: Paul Centolella, Paul Centolella & Associates. I'm a senior consultant at Tabors, Caramanis & Rudkevich.

MR. BROWN: Merwin Brown, California Institute for Energy and Environment at UC Berkeley, and retired, then hired back.

MR. ADAMS: John Adams, Principal Engineer at Electric Reliability Council of Texas.

MS. LIN: Janice Lin, CEO of Strategen, Cofounder and Executive Director of the California Energy Storage Alliance, Cofounder and Chair of the Global Energy Storage Alliance, and Chair of Energy Storage North America.

MS. LANEY BROWN: Mine's shorter. Laney Brown, Modern Grid Partners.

MR. MORGAN: I'm Granger Morgan. I'm on the faculty at Carnegie Mellon University in both the Department of Engineering and Public Policy, and in the Department of Electrical and Computer Engineering.

MS. WAGNER: Good afternoon. Rebecca Wagner, Wagner Strategies, and fully recovered regulator from Nevada, former regulator from Nevada.

CHAIR TIERNEY: That's the first time you've said fully recovered.

MS. WAGNER: I know.

CHAIR TIERNEY: I'm amazed.

MR. MORGAN: The question, Sue, is are you fully recovered? (laughter)

MR. ALMGREN: I'm Ake Almgren with Orkas, which stands for new energy technologies. I serve on the PJM board where I chair the Reliability Committee.

MS. SILBERSTEIN: Pam Silberstein,

NRECA.

MR. FELLER: Gordon Feller, ambassador from Silicon Valley. I see Nancy is not here, right, so I'm the only one. Cisco Headquarters. Retired. Back again. Like Merwin's story, you know, the people in California can't make up their minds. And on the non-profit side, of the Meeting of the Minds, non-partisan, non- profit.

MR. SHELTON: I'm Chris Shelton, Chief Technology Officer at AES.

CHAIR TIERNEY: Heather, we've just gone around. Would you introduce yourself?

MS. SANDERS: Heather Sanders, Southern California Edison.

CHAIR TIERNEY: Anjan. You slipped in and I didn't even see you. Sorry.

MR. BOSE: Anjan Bose from Washington State University.

CHAIR TIERNEY: Thanks everybody. It's great to see you all. We have a really good meeting. I know our meetings are usually very good, but this one is a little different, and I think we've got a number of really interesting presentations.

As you know, today we're going to hear an update from Katie about the Department of Energy. After that, we will have some presentations, including starting with Anjan on the grid modernization working group.

After the break, we will have a panel discussion, and I have the pleasure of participating on that on gas and electric industry interdependency issues. Then there will be Committee reports.

And then tomorrow we have the experiment that we are very excited about, and I will thank Janice in advance for all of the work that she's put into tomorrow's workshop day. Of course, it's a meeting, a second day of our normal meetings, but we're going to have a different kind of approach which I think you'll really enjoy. Lot of great panelist on different aspects of the storage issue.

So with that, I would love to turn it

over to Katie to say hello. I've asked her to describe her own background. She's no newcomer in this industry, and so she'll tell us more, as well as give us an update about DOE.

MS. JEREZA: Thank you, Sue. So I am the Deputy Assistant Secretary for Transmission Permitting and Technical Assistance. I started about two weeks ago. So before that I was with the Edison Electric Institute and Infrastructure Resilience still working on different security issues, and also smarter energy infrastructure, also known as grid modernization.

And then before that, I spent many years as a management consultant, and some of my time was working with the Office of Electricity R&D programs, and also there's two of you in the room who I met through a Women in Clean Energy program that (inaudible) about five years ago, I guess.

And my background is I have a Bachelor's in Chemical Engineering from Virginia Tech, and an MBA from Loyola University in Maryland. So thank you, and I'm very happy to be here.

So getting on with the update. So we have the presidential executive orders. As many of you know, about four weeks ago the President signed an executive order on cybersecurity, which I'll go into further in a moment.

During his first 100 days, President Trump frequently employed his power to issue executive orders. Of the 32 orders issued, several affecting DOE we're mentioning here today.

Comprehensive plan for reorganizing the executive branch. OMB director to propose a plan to reorganize governmental functions, and eliminate unnecessary agencies, components of agencies, and agency programs. Each agency director to submit proposed plan to reorganize the agency, if appropriate, within 180 days. So about mid-September.

Enforcing the regulatory reform agenda. Designation by each agency a regulatory reform officer, and establishment of a regulatory reform task force to oversee implementation of regulatory reform initiatives and policies to insure that agencies effectively carry out regulatory reforms. Also, 90-day report on improving implementation of regulatory reform initiatives, and identifying regulations for repeal, replacement, and modification.

Reducing regulation and controlling regulatory costs. Two-for-one order, which is to eliminate two previous regulations for every new one proposed. Another one is promoting energy independence and economic growth.

The clean power plan order, I'm sorry, clean power plan review order. Plan was due 45 days hence, about May 12th, from head of each agency to review any burdens on domestic energy production with final report due 120 days out, about mid-July, and a finalized plan due 180 days out, about mid-September, and the review of the clean power plan, as well.

Executive order on strengthening the cybersecurity of Federal networks and critical infrastructure. Just the day before the

(inaudible) attack, President Trump

signed an executive order on strengthening the cybersecurity of federal networks and critical infrastructure.

While I could spend my entire allotted time here today discussing just this executive order, let me quickly highlight the main points of affecting DOE.

As risk management decisions made by agency heads can affect the risk to the executive branch as a whole, and to national security, it is the policy of the United States to manage cybersecurity risks as an executive branch enterprise.

Effective immediately, DOE and all other Departments are required to use the National Institute of Standards and Technology's framework for improving critical infrastructure Cybersecurity to manage Cybersecurity risks. All agency heads will additionally provide a corresponding risk management report within the next 90 days.

All Departments have also been directed to show preference in a procurement for shared IT services to the extent permitted by law, including email, Cloud, and Cybersecurity services.

In coordination with DHS and other Departments, DOE will identify authorities and capabilities. Agencies could employ to support Cybersecurity efforts of Section 9, critical infrastructure entities, and engage with these stakeholders to evaluate the entities and engage with these -- to evaluate the effectiveness, and any obstacles from employing these authorities and capabilities.

A report will then be issued with the findings and recommendations for better supporting the Cybersecurity risk management efforts for Section 9 entities.

DOE, in coordination with DHS, the DNI, and with SLTT governments, will produce a report within 90 days assessing the potential scope and duration of a prolonged power outage associated with a significant cyber incident against the electric subsector. The readiness of the U.S. to manage the consequence of such an occurrence, and any gaps or shortcomings, and assets or capabilities required to mitigate the consequences of such an incident.

The Trump administration wants to improve cooperation with the nation's critical infrastructure providers by improving the existing framework of public/private partnerships. The new Cybersecurity executive order, as an example, provides new emphasis to innovate beyond the limits of past partnerships and joint collaborations to provide increased protection against the full range of cyber thefts.

Well, that covers that. Now, onto the FY17 budget summary. The FY 2017 enacted appropriation provided DOE with a $24 million increase, which is a positive 9 percent over the FY 2016 enacted appropriation. Increases were primarily for two areas. The first is energy storage where $31 million was provided, a 10.5 million increase, an increase of 51.2 percent over

FY 2016.

The committees did not direct how this increase be used, but did encourage support in several areas. The first is developing an operational energy storage test facility capable of performance- driven data in the utility environment.

Next is partnering with leaders in the energy storage industry to establish a pilot project in order to demonstrate how energy storage technology can reserve electricity generated offshore for use in meeting peak demand.

Next is expanding R&D partnerships for energy storage development, and deployment with stakeholders in diverse geographic regions with unique market dynamics and policy changes that can help to inform nationwide efforts to improve grid resiliency, reliability, and security, and power consumers, and increase integration of a broad range of generation sources.

Last is further the development and demonstration of non battery advanced storage components, including compressed air energy storage development and demonstration to enable efficiency improvements for utility scale bulk energy storage solutions.

The second area is smart grid R&D where $50 million was provided, a $15 million increase, 42.9 percent over FY 2016. The $15 million increase was directed to be used for regional demonstrations of onsite generation and microgrids, $5 million flat with FY 2016 was directed to be used for development of advanced, secure, low cost sensors that measure, analyze, predict, and control the future grid during steady state and under extreme conditions.

The report also encouraged continued research on transactive controls given the increasing prevalence of distributed energy on the grid, and the shift away from a utility-centered model when the customer is a passive participant.

Promotion of regional demonstrations of the utility-led residential connected communities advancing smart grid systems, ensuring that efforts in application, integration, and investment in grid technologies across all sectors of the economy are coordinated and focused on the evolution to the grid of the future.

Identifying and addressing technical and regulatory barriers and keeping grid integration of distributed energy systems reduce energy costs and improve the resilience and reliability of the electric grid.

Smaller changes include transformer resilience in advanced components, six million provided, a one million increase, inclusive 20 percent, with direction to support R&D on low cost power flow controlled devices, including both solid state and hybrid concepts that use power electronics to control electromagnetic devices, and enable improved controllability, flexibility, and resiliency.

Cybersecurity for energy delivery systems, $62 million provided, flat with FY 2016 with $9 million, a $4 million increase, 80 percent for the industry scale electric grid test bed, $5 million, a million reduction less than 50 percent as requested to complete the virtual energy sector forensics analysis platform, and transition it to industry. Five million flat with FY 2016 to develop cyber and cyber physical solutions for advanced control concepts for distribution and municipal utility venues. Forty-three million, a one million dollar increase, plus 2.4 percent for other R&D and operations activities in the account.

The report urges the cybersecurity for energy delivery systems to prioritize the cybersecurity risk information sharing program, which will build on the existing public/private partnership to share threat information and enable utilities to identify and respond to suspicious activity on the electric grid.

The next area is clean energy transmission and reliability, $36 million provided, a $3 million reduction, less than 7.7 percent, $32 million, a $2 million reduction, less than 5.9 percent for R&D, $4 million, a $1 million reduction, less than 20 percent for energy systems risk and predictive capability.

The other area is infrastructure security, and energy restoration, ISER, $9 million provided, flat with FY 2016 with several (inaudible) activities. First is further development of energy sector situational awareness capabilities. (inaudible) Eagle-I, the federal government's situational awareness tool for national power outages.

The Committee encourages the Department to further illustrate how to benefit from increased access to more varied sources of data.

Continued development of implementation strategies and analysis with industry to address potential impacts of geomagnetic disturbances, and electromagnetic pulses to the electric grid.

Regional and state activities to improve capabilities to characterize energy sector supply disruptions, communication among local, state, regional, federal, and industry partners, and the identification of gaps for use in energy planning and emergency response training programs.

We also have national energy delivery, $7.5 million provided, flat with FY 2016 without further guidance. And then program direction, $28.5 million provided, a half a million dollar increase, 1.8 percent without further guidance.

So there was also a recision of.3 million of unobligated balances from FY 2012, and prior appropriation year funds resulting in a net FY 2017 appropriation for OE of $229.7 million, $23.7 million above - 20 percent above- the FY 2016 inactive bubble.

Currently unallocated recisions of $3.2 million and $40 million taken from FY 2013, and from FY 2014 through FY 2016 unobligated balances, respectively, from DOE energy programs may further reduce the area total once allocated. And that's all I have, Sue.

CHAIR TIERNEY: Thank you. Thank you, Katie. Does anybody have a question for Katie following up on that? Oh, Granger.

MR. MORGAN: Yeah. Talk to us a little bit about what, if anything are your views about how this budget is likely to fare once it gets up on the Hill.

MS. JEREZA: So I'm fortunate to have a lot of my -- of OE staff here, so I'm going to defer to them.

MR. PARKS: So for clarification, what she went through was the FY '17 budget, which was allocated. Those funds are being spent this year. The budget that went to the Hill most recently was FY '18 budget that Congress is looking at. We have started to have hearings with the House. I briefed the Senate, and we brief the House staff next week. So there's continued dialogue. I think there are changes, significant changes between FY '17 and FY '18 TBD. It's still to be determined what the reaction to all that will be. And, again, a lot of discussions are going on. We've been asked for specific briefings on OE. Kevin Lynn is here today on the EERE side.

They've been asked for briefings as well, and are having those kind of discussions on the Hill about their grid related activities.

CHAIR TIERNEY: Yes.

MS. MARILYN BROWN: Katie, you started off something about the executive orders, and you mentioned what's going on with the clean power plan, and I couldn't exactly follow it, and I am a little confused about the review process. Is a report being written? Is there a review underway, or is it just hanging there. What's going on?

MR. PARKS: Marilyn, I'm not sure exactly how that is coming forward. I don't see some update kind of things, but I don't have the (inaudible) information. I don't think we have been involved in that.

MS. MARILYN BROWN: Yeah. I guess it is EPA, so --

MS. JEREZA: So I believe our final report is due, I hear, 20 days out, and a finalized plan due 180 days out next September, so it does look like there will be a report out.

CHAIR TIERNEY: Katie, I thought I might follow up on the, your mentioning of the cyber report that is looking at the potential implications of the very long-lived outage on the grid. I can't remember which one this is called. Maybe it's -- yeah, Cybersecurity of Federal Networks. And I thought I would just mention that Granger Morgan, and Anjan Bose, and I are all on a National Academy of Sciences panel, which is close to finishing up its report. I think we're expecting that in, to come out in several months.

MR. PARKS: Yeah. Actually, I spent most of Monday at the NRC trying to push this thing out. It sounds like it'll go back to the Report Review Committee in a week or two, and then they have to decide if they're happy with it, and so I can't imagine it getting out before sort of mid-July. But it is done, and we're in the throes of trying to, you know, we've got pages and pages of commentary, and we have to respond to every single item, which we're doing.

CHAIR TIERNEY: So the Department of Energy had asked the National Academy to convene a committee to look at the resilience of the grid in the context of a very long-lived outage either from a cyber attack, or a physical attack, or weather events, or other kinds of things.

So that will be forthcoming to the Department before long, and we can't wait for it to be done. And I hope it's relevant for you to review.

MR. PARKS: If I could just say, I think it would be very relevant. There's a lot going on. Obviously, the Secretary has announced it, you know, very early on as one of his top priorities. That continues to be reflected in all of the discussions that we're having in house.

We're also on our side we're working on a cyber R&D plan implementation. I think the last one was done in 2011, or something like that. So that will be coming out this year as well. So I think there's an enormous amount of interest in the area, and I think it will be a timely document for --

CHAIR TIERNEY: Terrific. Yes.

MR. FELLER: In the spirit of interdepartmental collaboration in the federal government, which we all love, I would call your attention to the fact that NIST has been doing for several years some important work around cyber and physical assets, particularly urban infrastructure - energy, water, transit and transport, building systems, and they've been looking pretty intensely at the cybersecurity dimension of it. And they've done a very good job, I'd say, like A+ in reaching out to the private sector. We've been involved, and a lot of others in Silicon Valley here, have been involved. They've created clusters around different categories of work that need to be attacked by NIST. They've not just engaged big companies, but little companies, even non-U.S. companies, and they've had a lot of success in identifying innovators. They've raised a fair amount of money from various sources in the federal government to underwrite that, but they've also been tapping private funds to expand the reach of that, and this cyber physical activity at NSF, which has partly funded this NIST work, has a lot of relevancy to what we're talking about on cybersecurity when we meet about things like grid modernization, and I'm hoping one day maybe we'll have the NIST people come in here and talk about the things that they've identified around cybersecurity in their cyber physical work that has relevancy to our work here, but, also, maybe to what the Secretary and his staff are going to be doing around cybersecurity for the grid.

MR. PARKS: If I may. Thank you very much for that. That's really helpful. A lot has been going on inter-agency. I would add DOD to that, and a lot of discussion has been going on from our resilient grid, microgrid work that we've done in the past to a number of things today, so -- and we have collaborated with NIST on smart grid entities, and the cyber activities, and that relation, those relationships go back a few years, but I think, again, there's a great deal going on right now in making sure that it's well integrated and it's something we should do.

MR. FELLER: If you guys ever do a map that shows the activity in the federal government, I'd love to see it if that was available for viewing by folks like us because the mental map of all that activity is hard to track.

MR. PARKS: I'm not sure it resides in one place, but we can, we can try.

CHAIR TIERNEY: So Paul, Merwin, and Janice, and then we'll wrap this session.

MR. CENTOLELLA: So just to pick up on that, you know, we did have a very interesting discussion of cybersecurity as part of the Internet of Things Panel in the last EAC meeting. That's something you might want to look at. Vint Cerf, who, as you may know, President Bush gave the National Medal of Freedom to, I mean, you know, he's very much involved in these issues, spoke quite eloquently about some of those risks.

We dealt with this in our Smart Grid Subcommittee meetings as well. I think it'll be an ongoing topic, and, you know, the other thing I mentioned in the Leadership meeting I'll just mention it for those who went in there. I'm taking over as chair of the new Smart Grid Subcommittee, so that will be an additional way we can provide coordination across those agencies.

MR. BROWN: Merwin Brown of U.C. Berkeley. Hopefully, this isn't too much of a sidebar, but we've been talking about prolonged major outages. I was wondering if anyone is paying attention to death by a thousand cuts where there are a lot of cyberattacks that continue over a long period of time with small effects that add up and cause disruption. So does anyone know of anything going on?

CHAIR TIERNEY: I am aware that there's a lot going on, but in saying that I can't give you a specific answer. Janice.

MS. LIN: Thank you for sharing that detail on the FY '17, and my question is particularly given the significant changes in FY '18, is there any role for this group of subject matter experts to help inform or guide that process like this, which I understand is happening in real time?

MR. PARKS: So I think that a number of groups are weighing in different capacities, and so I think typically there would be more through other capacities -- your other capacities than through this board to address budget related issues. And since you have energy storage, for example, that's -- it's been active on the Hill, as we both well know, so that would be the kind of mechanism to get your points across.

CHAIR TIERNEY: Katie, thank you very much. This is the first meeting of the Electricity Advisory Council since the Trump administration has come on board, and it's really great you [inaudible].

MS. JEREZA: Thank you.

CHAIR TIERNEY: Okay. Let's get on with other topics. Anjan, you're up.

MR. BOSE: Okay. So what we have is a report in front of the EAC for your approval. It looks -- it's a three-and-half page report. It was in your email that you got, so I think this is the time when we approve it; is that right? So --

CHAIR TIERNEY: That's correct.

MR. BOSE: Okay. So now the report itself came out of the GMI working group, which has been working on this for some time, and at the last meeting, you may remember that we had a very comprehensive plan on how to produce this report, and at the end of the last meeting, I think I presented a similar Power Point which kind of outlined what will be in the report.

And what happened is by the time I got home from that meeting, the plans had already changed by I think it was David Meyer, who suggested that taking another three months to write the report, and then coming back here, and taking another three months to actually go through the FACA process and so on is too long. We needed the report right now, and we didn't need a report that was 15 pages long. We needed a report that was only about three pages long so that it would be read by people.

So we kind of online made changes in plans, but we didn't change what we were going to say. I think we just changed how we were going to say it in three pages, and so what I have -- so that's what you have in front of you is a three-and-a-half page report which basically points out why we need the grid modernization initiative even more than ever before, and that's the tone of the report.

So this will give you a very brief structure. I mean, it doesn't take very long to read the two pages, so you can do that while I'm talking, I think. Let's see here so I can get this.

CHAIR TIERNEY: Anjan, just one sec because I see a couple people looking. This was distributed by Chelsea in an email to the Committee members about a week ago. Is that right, Chelsea?

SPEAKER: (Off mic).

CHAIR TIERNEY: Thank you.

MR. BOSE: Yeah, this came in that one email from Chelsea that said here is the materials for -- which had several attachments for this meeting. Okay. So the title of this thing is, "New Technologies Require a Modern Grid." And, let's see. How am I going to do this? Okay. Here we are.

So the report structure, so that's the three pages. We have a small introduction about a half page, and observations about a grid, a few things of widening and such, such a report. The recommendation is about is a page and a half, and then a conclusion is about just a paragraph. So that's all the report is made up of.

So the introduction basically says that the grid is a critical infrastructure. It's only half a page. And what it does is it refers back to the things that have been going on in DOE about the Grid Modernization Initiative starting with the Quadrennial Energy Review in the 2015, and so on, and ending up with the Multi-Year Program Plan, and a Grid Modernization Lab Consortium that is -- which is about 88 projects that were funded a little over a year ago.

And so the main thing they observed about the grid was that we kind of focused in on the fact that the research, the Grid Modernization Initiative, was looking at the grid as a system and not the different components that make up the system. And the point is made in various different ways within this little report is that system research is quantitatively and qualitatively different from doing component research because what you're trying to do is look at the full system, the whole grid, and look at its reliability, its flexibility, its resiliency, and so on.

And so the kind of issues that we get into, or that GMI gets into, is planning operations, control, analysis, of the whole grid. Okay. Which is not to say that each of these components have their own controls and their own analytical tools, and all of those things, but this is the system thing.

The other point that is made rather strongly is that this -- the grid is a national infrastructure. It's owned by lots of different people, but the reliability of the grid, the resilience of the grid, the security of the grid from cyberattacks and so on, ends up being a public good, and so individually those entities that own pieces of the grid are not particularly incentivized to do R&D on the reliability and resiliency of the grid.

And so it falls back to the federal government to do the R&D that is needed. Now, that doesn't mean there may not be ways that pieces of it that may come out of that R&D couldn't be taken advantage of by somebody trying to make a living out of making a new analytical tool out of some research that came out of it, but the overall research thrust has to be done by the federal government, and we made that point rather strongly here.

The other point we make is that there is only one grid in the country, and it's kind of hard to do any testing of the grid in any realistic way, so much of what we have to do in R&D has to be done on simulation. And so this is a bit different from, you know, if you're going to test a new kind of battery, then you make one prototype and you can test it. But you can't test a new grid. You might be able to take a few subsystems off, or a little piece of it off and test it, but you can't test the resiliency of the grid in any realistic way without doing large-scale simulation.

So the recommendations, these are the five different pieces, and this is not -- this is very different in the recommendations you see in the multi-year program plan that the Grid Modernization Initiative has actually put out. So we don't try to kind of say that this one is important, and this piece is not important. We think all of it is very well laid out.

The main points are made just to focus in on these couple of things which I said, the simulation platforms. Well, the workforce issue is always there because who is going to do this research, but even after that, who is going to actually take care of the smart grid that requires new kinds of -- new kind of skills needed from people. So that's always an issue, but the R&D itself is we emphasize the simulation platforms for planning, operation, control of large systems, and so on, which requires -- and much of this work has already been started so it just focuses in on that as being important where you'll set up large-scale simulation centers with real and synthetic data. Real data for the grid has some implications of national security and so on, so you don't -- you can't have everybody trying to mess around with real data, real grid data, so there's also an effort trying to make synthetic data and so on.

And then these platforms have to be layered, and it can be -- it doesn't have to be, the simulation platform doesn't have to be in one place. It can be connected and so on.

Then there are testing layers where you

can do some of the subsystem testing. For example, a distribution feeder, for example, can be tested with new systems and so on. So hardware in the loop, testing and so on so you need not just computer simulations, but also actual computer simulations that can attach hardware with it to actually do some testing that way. Some things about system technologies where it says component technology is the difference in how to do that.

And then the last recommendation was to point out the fact that none of this is going to work without the right policies, and so it is up to the technical people who are doing the R&D to point out where it'll get stuck if the right regulations and policies don't come into play.

And so -- I mean, the technical people R&D are not going to make the policies, but if the policies go one way, then the -- there'll be issues involved in actual applications of these things.

So then the conclusion is just -- just

emphasizing it-- only about five sentences, and all of them are there. You can read it.

So I will -- the final sentence says the modernization of the grid is necessary because everything about the grid is changing, so the generation mix needs changing, new measurement things comes in, power electronics goes in, in a big way, and all of these have an impact on the grid, and nobody can act -- unlike many other things, there is nobody actually who can say that five years from now the grid is going to look exactly like this because they will certainly be wrong. That's the only thing we know. So the grid has to be flexible and still be resilient, be reliable, and secure.

I'll stop there. I'll take questions.

CHAIR TIERNEY: Anjan, thank you very much for shepherding this through. I'm sure it was a quick turnaround that you had to do, but you really put together what is, in essence, a beautiful executive summary for the report that you didn't have to write. So thank you very much.

MR. BOSE: Yeah, that was the only big benefit out of this. We didn't have to write the report after all.

CHAIR TIERNEY: It's perfect. Janice, is your card up for a comment? Chris, you're up.

MR. SHELTON: Sure. I wanted to comment on the -- one of the first points you had on one of the prior slides about this being a system analysis issue. I think we missed that a lot of times, so I think that's a very important thing to call out, and it really speaks to the architecture of the system. So we've had so much technological change happen to the components, but I don't think we've reimagined the architecture. So a lot of the -- a lot of the opportunity is there, and with the, you know, some of the advent of computing technology, and machine learning, and other technology coming as well, I think we're at a great time with -- because we've changed a lot of the underlying component technology capability, and we have the potential to add the smarter control layer to solve system problems, but if we don't do the analysis, and don't think about the whole system, we may not see the ways that we can apply those, and those -- some of those can be very low cost, and have orders of magnitude benefit on reliability.

CHAIR TIERNEY: Thank you. Rolf.

MR. NORDSTROM: Thanks, Sue, and thanks Anjan. I have sort of an ignorant question, and that is what scale of research or simulation gives you useful system level insights? I mean, I think the report does a nice job of saying this is among the most complicated machines on the planet, and it's a system of systems, and I think makes a good argument for why you need some sort of system level research and simulation given all the moving parts and changes to the system.

But it's not clear to me, and it's just, as I say, an ignorant question. What -- I don't know enough about how those simulations would be done. What level of system do you need to model or simulate, or research in order to have that simulation yield insights that actually do give you those system level understandings? Do you know what I'm asking?

MR. BOSE: Yep. So that's a very good question because it gets confusing. Many times a new idea can be tested on relatively small systems. I mean, you find a lot of university papers being written on relatively small systems, but the ultimate point I was trying to make in saying that we need these big simulation centers is because if you're going to change, for example, a policy that has to -- that impacts the whole instrument of connection, you have to have a place where the instrument of connection can be tested as a whole.

Now, the level of granularity that you represent the instrument of connection with is a matter of research as to figure out, but that -- the idea itself is not possible today. And it's almost impossible to have a completely different policy tested out, a policy meaning operational strategy, tested out on the eastern interconnection because nobody is going to try it and risk blacking out the system.

So you should be able to with today's computer technology be able to actually do the simulation of the whole power system. You're not going to do that day in and day out, but there will be times when you want to do that.

So the whole thing about simulation is you can do it at different levels depending on what exactly you're trying to prove.

CHAIR TIERNEY: Mark.

MR. LAUBY:: : Thank you. And, of course, I'd like to second Chris' comments, and, of course. Anjan, I know where your heart is when it comes to system analysis.

I had a few tweaks around words more than anything else, and that is that, you know, sometimes we get confused between security and reliability, and I've come to the -- in NERC we've come to the thinking that reliability and security are two equal, you know, there's the chief reliability officer, there's the chief security officer, and that we need to work together.

So when I see resiliency and security efficiency, I think liability. So I assume that you're trying to tie that in.

MR. BOSE: It's there in this -- in the (inaudible). It is written there.

MR. LAUBY:: : But one thought I did have, and it really comes to when we were talking a little bit about cybersecurity before, and one of the things we're struggling with is how do you design a system that will be more robust, more secure, from a cyber perspective, or physical -- physical is a little bit easier. How do you de-risk the system that you're building so that you can take advantage of some of these control systems you're putting in place, and you're not actually building in vulnerabilities. And for that matter, how do we measure the risk that we have on systems? We have these risk assessments. That's a high risk, that's a medium risk, that's a low risk, based on certain kind of criteria that's in our standards, but I don't think they're, you know, necessarily the best or the only.

And also, as we look at historical data, and I'll give you an example, if you have relay mis-operations, and you haven't lost any load, you haven't had major events, but I can tell you,

percent of the relays that operate today mis-operate. And the more often they mis-operate, the more chances there are for a uncontrolled cascading of the (inaudible) power system. That is to say more shots on goal.

So we need to also get an idea of what -- how to measure risks historically, as well as looking into a future system how am I increasing the vulnerability of that system so that I can start designing this piece out so I can take advantage of some of the advances that I know are there? I mean, (inaudible) enhance reliability and security of the system. So something to think about when -- thank you.

CHAIR TIERNEY: Marilyn.

MS. MARILYN BROWN: Anjan, thank you for having a recommendation specific to the grid modernization and policy setting. And I was working my way through the logic here, and want a little bit of expansion, if you might.

So you started off by saying that there are a lot of regulatory agency actions, et cetera, to do with greenhouse gas emissions, and setting rates, and policies of various sorts, and they all can affect what the grid might look like. We could use some assistance to determine metrics and mechanisms to measure these impacts.

And then you focused down on resiliency, so I'm kind of going back to what Mark had said, you know, what is the difference between security, reliability and resiliency, and were you really meaning that we need to focus especially on how easily the grid can recover and adapt? Is that the resiliency piece that you think is missing, might need to be measured and metrics provided so that policy impacts on resiliency in particular can be evaluated, or was this just an example, one of many things you could have used to illustrate --

MR. BOSE: Well, I think, Marilyn,

you're focusing in on how you write a full page report in English only, and address all the issues that Mark just raised.

I think most of us know, you know, when you read something like this that the resiliency, reliability, and security are all mentioned in there. But these meanings are dictionary meaning, and there is the meaning that NERC puts on it, which has mathematical metrics, all right, that you can measure because how would you know whether a system is reliable or not unless you have something to measure it against?

And, in fact, the big debate right now I think Sue mentioned that we're finishing up a report on resiliency, and actually everybody seems to know in general what resiliency means, but there's not a single power engineer who knows what resiliency is. So because we're in that stage where we are still trying to decide what it is.

So something that's well this would be fine, you know -- we know reliability has been defined for 30 years, so there's all these different gradations, and people like Bill Parks and Kevin Lynn, who are kind of shepherding the GMI projects right now there are whole bunches of projects which are essentially trying to define some of these things. So we I -- we tried to stay away from those kind of difficult issue because that's part of the R&D itself.

But I think the main focus of this report was to say how important it is, and it tends to -- and the fact that it tends to sort of get lost in the shuffle, this whole thing about the systems research, because we say, well, if we have the best -- if we can bring down the cost of batteries in the next year, we've solved all the problems.

Well, we haven't solved all the problems, because that's only one of the things, because once you put in a whole bunch of batteries out there, there's a whole myriad of problems that will show up that the operator of the grid will have to face. So -- and that's the whole point over here. But those things are well taken.

CHAIR TIERNEY: So I'd like the three remaining people, four remaining people who have a comment to be very precise and concise because I would like to try to keep us on schedule, and I know that we need to tee up the vote on this matter.

Oh, my goodness. My chastising did its trick. Oh, no, no. It was a joke. Merwin, go.

MR. BROWN: This is a bit of sidebar. It's an addition -- deeper discussion on the need for simulation, and stop me if I go too long. Okay?

CHAIR TIERNEY: Well, I just heard it. You said that we need to go deeper on simulation.

MR. BROWN: Okay, let me explain then what I mean. We got into this with a project we did in California that we called, what I called solving the autoimmune disease of the electric grid, which was the relay, cascading relay problem that Mark mentioned.

It's basically what we called also an N minus 20 problem. We do N minus 1 calculations.

We can sort of do N minus 2 calculations, N-3. Probably would take the best computer system close to a year to do the calculation. So how do you do an N-20 when you can't simulate a grid that way?

Number one, that calls for more simulation to be able to do more of this kind of thing. But, secondly, it calls for some work-arounds, and the work-around we used was what is done for projecting thing like flu epidemics when you can't measure everything, every flu transaction that takes place.

And what that ended up being in my simple-minded way of looking at this is, is that you use equivalencies within the grid simulation, and you supplement it with information embedded in data on the grid, and that's how we were able to do the N minus 20 analysis, and out of that we're able to determine which pathways were most likely to contribute to a cascading outage on the grid. So I was trying to add a little bit of depth, plus the fact, I think it just shows the complexity and the depth in which this subject is.

CHAIR TIERNEY: Thank you. That was pretty concise. Heather.

MS. SANDERS: So my comment is on the metrics. Metrics. And so the work you're doing in the GMLC to define the catalog of metrics I think is really essential. I don't know if we -- if it comes across well enough in this report. And what I think would be very helpful is if we started not to talk in the generic resiliency term, and start to bring in those metrics into these discussions so that when we talk about reliability, oh, I can say my SAIFI is this, my SAIDI (inaudible), is this, my MAIFI, my CAIDI is this.

When I talk about resiliency, I'm like, well, I was out for a while, but -- so the point is, is to get us thinking about what that really means, and I think that the work that you've done on that catalog of metrics is really, really valuable, and as you emerge with the case studies, it will be really important.

I'm not sure if it comes through in the

report as much as we intended, but I think that is a critical one to start training the industry on being more deliberate about what we're really talking about.

CHAIR TIERNEY: I can't wait for you to read the National Academy report on this topic too.

MS. SANDERS: Send it to me.

CHAIR TIERNEY: You'll get it first when it's hot off the press.

MR. FELLER: So a suggestion would be to take advantage of the fact that Franz from the International Electrotechnical Commission was here last, to share this with him with an eye toward understanding what the IEC is doing with some of their other national projects around grid modernization, China being one of those, the EU being another where a lot of money is being spent, and where the IEC is serving as an advisor. They're not really playing the same role with ANSI and EPRI, and NIST here, but they're more actively involved on these issues, so just a recommendation about one of those follow-ups to elicit comments.

CHAIR TIERNEY: Thanks, Gordon. Chris.

MR. SHELTON: I think the discussion of resiliency and security and reliability is very relevant to all of these -- all of our Subcommittees. I mean, these things come up all the time. It's really about design. So the resiliency word, you know, in my view and my experience is about design, right, whereas if you talk about reliability, design is one component of reliability, so it's just -- I think it's of the essence to this entire discussion.

CHAIR TIERNEY: Thank you. Who would have thought that three pages could engender such great comments from the Committee members?

I wonder if anyone would put a motion forward so that we can take a vote?

MR. FELLER: So moved.

MR. BROWN: Seconded.

CHAIR TIERNEY: Moved and seconded. Is there any further discussion?

I just want to put in a good word for

supporting the concept of the public good nature of this work. It is such an essential element of it, as is the systems part of it. So I will enthusiastically vote in favor of this report myself. Anyone else?

All those in favor?

(Aye)

CHAIR TIERNEY: Opposed?

(No response).

CHAIR TIERNEY: All right. Congratulations. Thank you. Thank you everybody who worked on this. (Applause)

We have a dual presentation from Kevin Lynn and Bill Parks on the grid modernization laboratory consortium work.

MR. PARKS: Good afternoon, and as we've done before, we're going to split this talk, and kind of tag team the opportunity -- the issues that are here. And I just want to really appreciate the ability to come back and talk about this, and, hopefully, we'll hit some of the themes that you have -- you've brought up already if I can get this thing to like me. There we go.

So what we want to do is briefly talk about the GMI. We've talked before, so we'll just touch upon that, and also the lab call (phonetic) itself, and then talk a little bit about the peer review results that we held, the peer review we held about six weeks ago, and I really want to thank three of the members that are here. Anjan, Heather, and John were part of the peer reviewers, and really gave valuable contribution, and it was a really, really great set of discussions and feedback that we had. And we'll talk a little bit, a few examples of each of the ones, with the six areas that we have.

So if you recall, we started with attributes. And in the discussion that we just heard, reliability, resiliency fit into that. One of the reports, and we'll touch on this again, is working to define how these are, and also how they interrelate, and how we want to look at this as we go forward.

This is informed work on the multi-year program plan which has six technical areas that we're working on, and the key, as Anjan and others have mentioned, is that we're taking this as a systems approach. So we're taking these six areas, and the intersections of all of those, and we'll see how they work. So concentrate on does the device integrate systems sensing and measurement, on systems operations control design and planning. How does cyber -- and cyber come into that, resiliency come into that, and then how does that relate to the institutional world around it because in this space technology, markets, and policy all combine in a real world way in real time. And we do have the multi-year program plan we put out officially a year ago January, and it's up on the DOE website.

As part of the grid modernization initiative we are working across the country. It was a three-year call that we awarded the first year, a year ago January as well, so we're into our second year of funding of that, and the peer review was really to assess what happened in the first year, and do we continue. And the majority of findings were the projects were relevant, and we'll talk a little bit about that, and that we should continue this. We are conveying that to labs of real time, and moving funds to the second year of this three-year activity on these projects.

We awarded $220 million nominally. Thirteen of our labs are involved. We awarded 80 new projects, and there are over 150 partners in this. Just an idea of the partners again who are engaged in this, and they really range -- and again, one of the neat things about this is we've got a conglomerate of universities of, states, of utilities, of different representation around organizations from suppliers, and that kind of things, as well as federal partners and groups like NIST, and NRECA, and EEI, and EPRI. So it's really a nice collection of workers on this, and coordination in those activities, and I really have to hand it to the labs for really stepping up in a new way of thinking, and working in an integrated manner on this, and we're starting to see some real successes from this. We did have our peer review (inaudible), as I mentioned, and it was a really great discussion. A really interesting finding from the peer reviewers was we held in their poster session where we had all the projects and related projects from around the programs, touching upon grid modernization, whether it was directly in OE, or in EERE, and references back to ARPA-E activities that have been going, science with high performance computing, and those kinds of thing, and the comment back was we didn't allow enough time for them -- for discussion among the panel. That they really would have liked to have seen the (inaudible) sessions going for multiple days because we had, you know, regulators going around to every (inaudible), and engaging in it saying, hey, this is relevant to what I'm doing, and it really -- an enormous amount of cross fertilization for a peer review.

So I think we feel very successful and it's something we're going to try to figure out how do we do this better. How do we even engage this a little more to bring in all of the departmental activities.

So first, we're going to walk through the six in a little bit about what things I'm going to discover too, and then I'm going to turn it over to Kevin to kind of finish and talk about the other four.

Design and planning, two findings. The idea again in this section we're trying to create grid planning tools that integrate T&D, and system dynamics over a variety of time and spatial scales to go back to the earlier questions. I think you're going to have to simulate multiple things because you're trying to do multiple things within the system.

How does that T&D interface work? What do distribution systems act like in the future? What do they look like in the future? And you have it engage into the system. And, you know, what does that say about the market structures around, and how they operate?

And one of the activities that we have is on transactive energy, and those are in different market segments and how those kind of actions as you reach into buildings, or, ultimately, the cars and things, how do they engage with the grid as well?

Comments from it all? Encourage open software. We've been working to do that. Need for an open repository to handle data.

Connections to industry. How do we even go beyond what we've done before? How do we really take advantage of all the innovation that is going on to make sure that it is coordinated, and that information is available to people as we go forward?

There are 3,000 different utilities, as you know, and they come in a lot of different styles. We are working in the activities that we're doing, working with the public power, as well as the co-ops, in addition to the (inaudible) IOUs, and we're looking, again, with working with (inaudible) within different structures. So it really makes for an engaging set of discussions, and looking for commonalities, and how do you replicate in the different kind of market structures, and those type things.

And then continue to engage with (inaudible) for NERC on issues, and have more robust planning criteria and standards, and a lot of talk about standards, a lot of talk about making sure that your definitions are the same, and communication will continue to come up throughout this, and how do we do a better job of continuing to communicate.

One project that we have going on within this section, you know, progress within each of the six sections, and again try to integrate those, this project is an interconnection seam study. It's really looking at the east and the west, and it's a wide area study on how we could look at the reliability, and efficiency for futures, leverages kind of the lab strengths, and looking at this modeling on a big scale, and engaging stakeholders like (inaudible) SPP, and so on, and Jay has been engaged in that project as well, and building on the projects that we've been doing over the past few years, five, six years, the number of building block studies that we kind of build on to really look at this, and how it can impact the system, and how can a system act in both a reliable and resilient manner. So this a really big scale project in looking at the national scale.

The second area that I'm going to talk

about is systems operation review findings. And, again, what we're trying to do is look at grid architecture here that came up with Chris' comments and others before, how do we coordinate and control millions of devices and integrate across the EMS, and what does that future really look like? How does aggregation occur? What level does it occur at?

Some of the things that we're looking at is a portfolio. Rick's pretty good for the, you know, the amount of money that we have to put into this. The MYPP, two areas not covered by what was presented are analytics and computation, and power flow. Analytics and computation at OE we do have a few projects looking at that. We've done some exploratory work with the Office of Science with NSF on the (inaudible) and those kind of things in that area. That was not highly emphasized in the project, but, again, part of what we looked at when we put this MYPP together was what are the -- where are the gap areas. Not necessarily just repeat what's in every program line energy storage, or like (inaudible), but how do we look at what's missing in the portfolio things as we look at this, and how do we kind of augment the existing programs and go beyond, especially the integration of the activities that are happening with the boundary space within programs. How do we really crosscut and cross fertilize better than we have historically as we look at other programs within DOE?

The idea of tradeoff off of

(indiscernible)large in scale really have more impact. They have great architecture we're going to talk about in a minute, but it's increasingly important, and I think the thing, again, it does back to the report, it says the number of states that are engaging in good architecture discussions. How is this thing actually constructed? You know, what do we want?

And it's not -- it's a number of states.

We're up to about a dozen states that are playing in this in one way, and it's North Carolina, and it's D.C., and it's Minnesota, not just a New York and California, Hawaii kind of thing. So it's a really interesting blend of states that are coming together and sharing information in the grid architecture space, and it's a very active area for us.

The challenge with transactive is out there a little ways in terms of how it's really going to go, and the work that we're doing is, again, interesting in that we're working with Southern Company, we're working with Ohio, we're working with Washington, the State of Washington and all, so really looking at different constructs of how it might operate, and not just a traditional ISO market arena.

And then how do we communicate more broadly again. That comes up -- and we're trying to put more face on our communications, and as we're getting more and more results on the system, and really to make sure that we're interfacing with industry as much as possible.

And grid architecture. I'm sorry. Lost my place or something. Yeah. On the grid architecture work, what this box is showing is the grid architecture project, how it relates to other projects within the portfolio so that it's a fundamental building block for what we're doing, and how it can relate to so many activities that are going on from sensing and measurement strategy to advanced control theories, to device grid integration, to support on interoperability.

So it's really we're trying to weave all this together into a systems approach, and, you know, tying in all the disciplines we need to do that, the principals, really understand the guidelines, lay that out, help the states decide which principles and activities they need, and how do we continue to work with EPRI, with the smart grid, with NIST, and with others on how all this comes together.

And I'm going to turn it over to Kevin at this time.

MR. LYNN: We just split this at about seconds ago, so the other thing I would just say about grid architecture which I think is really great, you know, as Bill probably mentioned, we have a number of programs that are kind of working together, and we're trying to pull all those programmatic activities together so we're all seeing them from the same play book. And with grid architecture as well as some of the other things actually in sensing and measurement, we're actually trying to have some of the PRS from these projects come together and sort of make sure that we're all -- whether it's the vehicles program, or the energy storage program, or the buildings program, with regard to grid architecture, let's everybody get on the same page. Let's everybody get briefed on what's the latest in grid architecture so as we build out our grid integration programs, you know, for each one whether it be through solicitations or otherwise, we can all be on the same page and be implementing grid architecture, or sensing and measurement, or interoperability in the same way, in the same fashion.

So that's one of the things that we're doing internally, which I think is just great.

So sensing and measurement. So these findings are really just sort of the big picture findings that we've got in each of the technical areas. We've got a lot of great feedback from people like Anjan, and Heather, and John on a lot of the other individuals projects, but these are just some of the big, the high-level things, and we haven't even shared them with a the labs yet, so that's probably why we're doing it on a pretty high-level.

But sensing and measurement we're really trying to -- you know, one of the -- this is one of the bigger gap areas in our entire portfolio because no one really from any individual program, especially within EERE, has just spoken on sensing. I mean, that's like a subset of buildings, or a subset of our vehicles program.

So this was -- this really came out as

one of our bigger gap areas, and so really trying to work on the devices, actually, the sensing and measurement strategies, and some of the data analytics, the communications that go along with trying to create 100 percent visibility on our system. What does that look like?

So, you know, a couple other points that came across was, hey, you know, you really -- communications is part of your MYPP, but you really didn't talk about communications at all. There wasn't a lot of projects that we're really addressing in the projects.

One of the things that came up too, which was very interesting, and it was a long conversation at the time, I happened to be sitting in this particular session when this was happening, was the conversation about building out communication elements, so when you get -- what happens -- you know, is that part of what we're working on? You know, we've had some other projects -- during the discussion that have gotten not necessarily the best data, and we might be putting together the best applications, but if we're not doing good data quality analysis, and getting good data to start with, we're going to get a lot of junk on the other end of it just as well, and how much do we need to start thinking about poor data quality on our side to make sure whatever apps we're developing, which they consider the easy part, actually comes out as the -- in the good information.

So sensor placement. There were some conversations around this. We're really trying to come up with a senor placement strategy so you can, depending on what you want to do, or what you want to achieve, you can sort of get the best sensors and put them in the best place, you know, get 100 percent visibility with the least cost and the least distribution.

Some of the things that came up as part of the discussion was really about, hey, well, a lot of times even if you have an optimized location for your sensors, no one really puts it there anyway. There's a practical application of where this stuff actually will go, and maybe you should think about that as part of your plan.

So sensor development. There's a -- I think you know, people realize -- they acknowledge that we are some very smart people at some of the national labs working on some of these sensors and sensor development, that maybe needed to think a little bit more about what the priority was, and what the context was, and are we working on the highest priority items.

And happily we had a lot -- we had been struggling a lot, a little with some of the machine learning efforts, and we've gone back to the well, going back to the well, trying to get it right, and I think we actually finally did get it right. So in the process of being able to move forward in some of our sensing and measurement activities and data analytics.

And so this was one -- I think -- the one thing that I think we really -- we -- you know, we understand that we're sort of the energy side of this, but there's a whole lot of different players like Google, like Microsoft are doing a whole lot of really interesting crazy stuff with data analytics, but we need to figure out what's our side from the energy side, and I think, you know, we finally got to pull together some use cases that sort of resonated with all of the different external peer reviewers, so we felt really good. We feel like we can move forward on this particular project, and we can sort of build off of the seed that we've developed, and maybe broaden it out a little bit more as we think more about this particular area.

I'm going to move to this next slide. Here we go. So within devices and integrated systems (inaudible) -- this is another area, one of the six areas that we're really trying to increase the amount of grid services we get from a variety of different devices that we put on the system, whether it be energy storage, vehicles, buildings, et cetera.

So one of the thing that they called us out on was there was no foundational investments in power electronics and energy storage. So we had a lot of program specific -- being foundational again is when we're all working together co-funding activities together, and program specific is where particular programs are investing their own funds in a particular area.

So there's a lot of program specific focus, and whether it was in DG inverters or energy storage, batteries, et cetera, but there was no real foundational look across power electronics or energy storage across the department, and the question was should we be looking at that.

And, you know, one could, you know, we need to do a little bit more thinking about this. We do struggle. I've been a number of sides where people ask us, hey, what are you doing in energy storage across the department, and it becomes quite an interesting picking and piecing because there's (inaudible) storage, and fuel cells, and batteries, and all the different stuff that's going on, and you're going to have a great discussion about that tomorrow, I know. But that's one of the things that we need to think about.

So the laboratory testing. That work was one of the things we talked a little about was sort of do we need to be building this broader laboratory testing network. We kind of thought maybe we needed to not try to bite off too much and really just focus on developing an open library which our grid components would go into, and I can talk more about that individually.

You know, we definitely need to get more engaged from industry on some of the standards and testing work. We've had some really good meetings, but a lot of the peer reviewers mentioned that they hadn't even heard about the meetings. We needed to do better with our communications which was broadly acknowledged across all the areas we worked in, and, you know, concentrate on early stage R&D, and looking to incorporate it into some of existing work.

You know, and then the slide I had

before, if I can go back to it -- there we go -- on interoperability. So this is another project where we're trying to all get on the same page in terms of interoperability across the department, so instead of having individual programs like vehicles or buildings, or storage, I'll try to think about what if that means interoperability to them. We're really trying to reach across all the different programs with a single voice across the department with some of the efforts that we're doing, and really engage with industry and others, and we know that this has always been a tough thing. This isn't the first time that people have been working on this, and we know there's a still a long way to go on some of this.

So with security and resilience, you know, basically, some of the high-level things was we need to have more projects. We need to think more about this. This is clearly a high-priority item. We have, basically, one project that's going for three years. Two of our other projects are going to sunset at the end of this year because they're what we call pioneer partnerships. We need to finish those. We're going to finish those up, and we're going to have one project, so we need to think about -- more about what we want to do here.

Security needs really to be incorporated in all the different projects that we do. We need to really think about even when we talk about interoperability, in our interoperability projects, we need to think about security.

We need to think about more diversity and some of the resiliency topics. We had a couple of projects with -- in Kentucky and New Orleans, and we need to really think about, hey, we're building these resilient cities, or industry campuses, how can those things apply more broadly across the country as we do it, and getting people trained was something that we need to do more -- think about a little bit more? This is one of our -- one of our exciting projects. It's actually in New Orleans, but we're trying to think about how to build a more resilient city. We're working with Rockefeller, and this is actually with Entergy, and a variety of different utilities on local thinking about a transactive system, microgrids, how do all those things build together so we can have a more resilient city as a result of any major storms that come through New Orleans.

So actually, this is going to come to an end at the end of, I think in July. It's an exciting project. It scored very well, and we're interested in building off the success we had with

(inaudible) project. Here we go. And then institutional. You know, we have a lot of great projects, good projects moving in the right direction. Metrics, very important projects, very difficult projects. We have a lot of good feedback for them on that particular one. We need to make sure that we're getting enough feedback from states, consumer advocates, and other stakeholders to make sure that what we're doing is moving in the right direction.

We, again, need to communicate what we're doing. Some of the evaluation costs and benefits of the different technologies that(inaudible) incorporate into the grid was getting good feedback, but I think we need to take further steps, and we need to accelerate some of that work, and we need to make sure that we're capturing all the lessons learned from work that we're going in places like New York REV, so we can make sure that we can help other states and other entities.

So I think with that, you know, some of the broader lessons learned, we need to make sure we communicate. Continue working with industry. Making sure people understand, you know, have expectations, especially with some of the lower technology readiness level activities if we're trying to do some projects we're looking ten years out, make sure we set the context where everybody understands what we're really trying to focus on.

Some of the projects need to be mirrored and refocus, you know, focused a little bit more. And I think we need to have a broader cybersecurity plan. You know, we have a, -- maybe -- and this is sort of across some of our other projects as well. Maybe we focus a little bit on smaller projects with a lot of labs working together, and maybe we need to think about a few bigger, higher- impact projects, and cyber might be one of those areas that we need to think about moving forward.

A lot of the, what we call the pioneer partnerships which we're working with states, we had ten projects where we're working with states and other local governments helping with their grid modernization efforts, we need to make sure that we're disseminating some of the lessons learned and experiences, whether it be with New Orleans, or Kentucky, or Alaska, or the New York REV process, California, making sure that we get some of that information out to them.

And I think that's what we have. So

we'll be happy -- Bill and I will be happy to take questions.

CHAIR TIERNEY: Thank you. I'm going to -- you've all spoken again. I have to just go in order then. So, Heather, it's great. I was going to try to find someone who hadn't spoken yet. Go.

MS. SANDERS: First of all, I really want to compliment you on the GMLC review. It was so well done. I know it was the first inaugural of it. I really appreciate the organization and the thought that was into it, especially preparing the reviewers.

What I found most impressive was the emphasis on communication in English. I have never, ever been to a forum with so many highly technical skilled engineers that were actually able to explain things. It's something I value very highly. Something I spent my whole career trying to make happen, and you did very well, and I really want to compliment you on that emphasis.

As I talked with folks in the paper sessions, I also agree more time on that would be great if you could co-locate your paper sessions with other events like ESNA, for example, or DistribuTECH, or something like that, I think it would be fabulous.

I appreciated, you know, all the people you put in front. There was no defensiveness. It was, okay, I'm going to try to explain it differently. It was fabulous. So I just -- I have to say that, you know, every day I learn I know less, and that day I learned I knew a lot less, and it was fantastic.

My question has to do with the system-to-system concept, architectures, et cetera. I hear it. I know what it means. I have had the benefit of being here as a member of the GridWise Architecture Council, et cetera, but when you go into state regulatory forums, that concept is foreign. The way we evaluate investments is point-by-point. Chris made a very good point earlier.

So my question is how do we get an evolved grid architecture adopted and implemented, and what do you see your role as in being able to do this because it is not happening as far as I can see?

MR. PARKS: Well, first of all, thank you for the accolades (inaudible), and all the people actually that worked on it.

Secondly, on the grid architecture, one thing that came out of it is that you continue to have -- it's a very solid effort. It needs to be communicated in plain English better, and it's one thing we're going to take on. We're meeting with the labs on the week of the 20th, and it's one of our activities. We are having a couple of internal discussions specifically on program interface with grid architecture, so we're hoping about a month from now having a more cohesive, easy story to tell. That's not a simple thing to do. That and metrics both. I think they're some of the hardest things that we're trying to tackle, and we're going to just continue to work on it, but it is a priority for us to do so.

MS. SANDERS: So does it ultimately get

implemented at the utilities and distribution planning? I mean, how does the grid architecture evolution get implemented?

MR. PARKS: So right now, it's being implemented at the front of we're having a lot of dialog with the regulatory world, and as I said, there are ten or 12 that we're working actively on around this space. Those dialogs are really important. Ohio happened actually the same week of the peer review. Jeff (inaudible) was in Ohio. He was called back. They had their planning, their whole effort around the framework that he presented to them. As an example, North Carolina is a recent addition as well. So it's really evolving in real time, and is building on, again, the communication between states as well, so it's -- I think it's just - - it's something that, it's just happening. And we hope to continue to catalyze.

MR. LYNN: I think I would just say just, you know, I really appreciated the comment where you said one of first places where you've gone and you've heard very smart technical people present in plain English, which that's great.

I think this is still one of those areas where we're maybe just a little too technical, and we could get it down to a little bit more plain English, and I think like Bill said that's a priority for us. It definitely came up in some of the conversations we had after the meeting, and it's definitely a priority we want to make.

CHAIR TIERNEY: So Granger, Merwin, and Paul.

MR. MORGAN: Actually, I have a very specific bit of advice if you do decide to mount something new in the cyber space. One of the areas that without prejudging our report that's about to come out, one of the areas that I've been not entirely pleased with in terms of what's out there already is what I have called in plain English, and which my technical colleagues have an allergic reaction to, cyber blackstart. That is suppose that somehow I get the system heavily infected, how the hell do I disentangle from all of that stuff, and get the old-style system up and running? I don't think enough people are worried about that. So add that to your list of things that you might contemplate as you move forward.

MR. PARKS: Great, Jim. I'm not the best one. Good timing (inaudible).

Probably not my best comment, but I will say that people are thinking about it. People are actually looking at some alternative ways to come at it, and that's embedded in the R&D plan that we're putting forward. So stat tuned.

MR. BROWN: Merwin Brown, UC Berkeley. Most of my 45 years plus in this business I find myself taking on different missions from time to time, and I've taken on kind of a new one in the last couple of years. Has to do with measurements. It's -- maybe it's not profound to other people in this room, but to me something struck me fairly recently about the significance of measurements.

And this is going to your quality of data question. The context in which this remark is made is that the grid has been operated and largely planned with physical models, and I think those days are fast disappearing where that's going to work. We have to go to a system that relies more and more on real-time measurements, and real-time analysis coming to conclusions and making decisions even for systems.

So from a data quality point of view, I hope that's in the equation, but that's the kind of data that we're going to need, and that will dictate the quality.

There's another aspect of this too. I see us going more and more towards what I call network measuring systems, and the syncrophaser measurement system that transmission is putting in is an example of that. And that has many attributes to it. One, of course, is really to measure an angle rather than estimate it. But perhaps more important, and it goes to this thing again about how do you simulate, or how do you do laboratory type research to find out system effects?

Once you get one of these network sensor systems in and working, basically every new thing that happens to that network, to that grid, is now part of a research project. (inaudible) ongoing basis measuring new things happening to that system.

So to me, that's profound. And I guess not for the rest of you, but I got excited by that concept. So I just wanted to pass that on to you.

MR. PARKS: And Merwin, thanks for that. I think that's increasing. I think what's happening in, you know, example, PNNL having been given access to all the web data, and having the ability to see all that, and then do research based on all of that is an example of things that I think are evolving, and will continue to as we go forward.

It's clearly complicated space, access to data, and how it's handled, and everything else, and then we (inaudible) the security, the resiliency issues on top of that, but those discussions are continuing to happen. I think there are some really good activity moving it forward.

MR. LYNN: I guess I would just really quickly says is just on the cyber side, I'm clearly not an expert on this, but I think your comment on data quality, and being able to do things in real-time, I mean, the faster -- we have to do things in real time making sure that whatever it is we're doing is based on good data is really important, so we have to make sure that -- I think data quality will be coming up more for us.

CHAIR TIERNEY: All right. So, Paul, Paula, Anjan, and Marilyn, and then we'll close out the session. Thank you.

MR. CENTOLELLA: Thank you, Sue. So I'm sorry I wasn't able to be at the session, because I was in Ohio, you know, with Jeff (phonetics), and he did a really nice job. My question has to do with what you mentioned, Kevin, a foundational project on power electronics. This strikes me -- the Department has done some very good work on individual power electronic technologies, but, you know, what we continue to see even as we think about architecture, and as you think about planning, and even as we think about market, we look at a system that is comparatively fixed rather than dynamic, and we have relatively little control below that 7.5-minute interval that it takes to dispatch a generator, and what power electronics is giving us is the ability to make various parts of the grid dynamic, and to switch power flows to react at millisecond levels to disturbances whether in voltage, frequency, or other aspects of the grid, and it strikes me that that is fundamentally different from the way we have thought about and operated the power system for much of the last century.

And so I'm curious about if you can say more about what your foundational project is, and how that might begin to address that question.

MR. LYNN: I don't have an answer to

that question. I mean, I agree with everything that you just said, and I agree that -- I know that we've done a variety of different power electronics work when I was in SunShot, you know, we did a bunch of work, and, you know, a big part of -- here's all the value that our power electronics can provide, but no one's paying anybody for it, so nobody cares. You know, we went through that for years. We're still going through it.

You know, I think there are some comments on the devices and integrated systems testing that maybe we should be looking at some of the work, you know, could we leverage some of the power electronics works that's going on in energy storage, and with, you know, in the solar world, and in the vehicles work.

Obviously, you know, and also AMO has an entire effort with manufacturing,

(inaudible), power electronics that's going on in North Carolina State University. There was some interest in doing some applied work there. I just think there's a lot of pieces there. I mean, really where I mean, my thinking was. -- I'd like to hear what Bill thought -- there are so many different pieces here that are important in trying to address some of the challenges that you just pulled together. It just feels like, much like energy storage it could be power electronics is one of those places where there's a lot of stuff going on. If we just pull it together, we might be able to get something bigger than just some of those small parts.

MR. PARKS: Kevin's right. We're doing work in -- and other partners are-- but he's doing work, and it's too much ones and twos in that, a coordinated thrust. And the same comment I think was made on energy storage, is we've got JCESR doing basic work, but the first five years it concentrated on automotive storage not grid storage. It's starting to pivot on that, and then relate back to the other things that we're doing beyond lithium ion as an example.

So in both areas, I think the question that was raised in the QTR, and in other areas is do we have critical mass? Is it well enough orchestrated, and I think it's something that we're continuing to work on as two areas that really could use greater coordination and effort.

MR. CENTOLELLA: I look forward to continuing to talk to you about that one that.

MS. CARMODY: So thank you for the presentation. I always -- coming from the ground level, working in the state regulatory environment, I always appreciate the information, but it also is an example of getting lots and lots of information, and don't know what to do with it.

So I'm going to harken back to kind of Heather's comment about communication back to state regulators, and actually a lot of comments that apparently were made at the peer review process.

The need for communication, because I'm there in the trenches with the Maryland state regulators, and I know they, you know, they're grappling with it, their technical staff, our agency participating in lots of very kind of specific things.

So my quick question to you is how is the interaction, say, between NARUC, the Association of Regulatory Commissioners, NASUCA is my national agency, NASEO is the state energy office, you've got the air quality agencies, you know, the Conference on State Legislators. I'm trying to figure out -- yeah, and they all operate

states, you know, five different kind of groups operating at the state level, but I'm trying to figure out how do you take those critical things -- you know, Heather was talking about grid architecture -- and start on that broad level. You've got 50 states being able to kind of communicate kind of the essential things to --

either through those national associations to see if -- it's almost like training a trainer -- so that the information can get pushed out in a rigorous but broad way to all of the states, or do you go state by state and invite all of the kind of (inaudible) groups into those states, because I have to tell you, this -- these kinds of discussions, they may be going on with particular utilities, or in particular maybe technical staff within agencies, but it is really hard to kind of bring that down to that level, number one, to see what's going on with your states, with your utilities, you know, and what folks are thinking about, and what is it about all the stuff that you're doing that you consider most essential that all of us should be, you know, get our folks and regulators to be thinking about?

MR. PARKS: So two part answer kind of broadly, and one is we do have long-term historic relationships with NARUC, with NASEO, the NCSL and NGA, and we continue -- we provide some funding to them. We put out publications with NARUC as an example over time (inaudible) transmissions just basically electricity 101 kind of things, as well as specific papers that have come out of the labs. Berkeley has been a leader in that arena. They've done a series of papers just in the last year or so on different aspects of the distribution system evolution, and those kind of things.

Having said that, that we have a strong relationship, a strong history with it, the magnitude of requests from the states have really grown in the last couple of years. And what I would say is that we are meeting those today, but we are not meeting them as robustly as we would like. I think we could really, really expand the number of things.

And, again, there's so much happening in a quick period of time that we need to really leverage all the resources around how it can be utilized.

So I see it continuing. I don't see that going away at all. I think part of what we're thinking about is how can we help make sure that you understand what's going on in those other ten or so states that were really active on grid architecture as an example, and there are other things that we're active with them on.

And another thing we're trying to do in all of this, and it came out really as part of the New York REV is we were having one lab support the governor's office, one lab support NYSERDA, and another group, you know, supporting utilities, and coordinating our responses to helping the states is really good and valuable in their process.

So it's a continuing struggle to build that, and historically we've done a lot of special events with NARUC, or with NASEO, and that kind of thing. I personally think that all of that courtesy should be expanded, and it becomes more of a critical issue over the next few years.

MS. CARMODY: And if I could say, I mean, in NASUCA - the National Association of State Utility Consumer Advocates - we've been asked to -- involved in LBNL reports, which we're very grateful of, and webinars, and in other kinds of information sectors, but they're really kind of key, and still part of it is I think the big picture questions as we tend to focus on very specific issues evaluation, electric grids, you know, electric vehicles, microgrids, but we lose kind of that system, you know, kind of sensibility.

But I did want to point out that, you know, we do appreciate, you know, DOE reaching out, you know, to us.

MR. LYNN: Couple of quick points. One is I think we're doing a little better. When we first started this, we had three different labs in New York REV. They were all doing something. They were not coordinated. And so as part of this process, we pulled all those pieces together so we had a single piece, and we're trying to make sure that we're getting lessons learned out of projects like that so we can share them broadly with states.

But I think one of the things that came out -- and Bill's right. I think, you know, we've worked with NARUC, and NASUCA, and NASEO, and sort of those lines, and together too, but I think, you know, as we get better at this, we can communicate sort of the same, and be consistent across when we communicate with all those different groups together we can sing the same song so everybody is together instead of sort of having a different perspective on what's being -- the information that's being delivered.

CHAIR TIERNEY: So Anjan and Marilyn, I will request that you be very brief. We're behind.

MR. BOSE: Okay. I don't have a question about GMLC projects itself, but rather a little news item I saw a couple days ago which said that the Secretary has appointed Alison Silverstein to write a report on the grid.

Is it related? Are you part of it? How does it fit into the picture of the grid and DOE?

MR. PARKS: I noticed that Kevin didn't jump into that one (laughter). Yes, we are both supporting that effort as well as many people within the department to put together a market study of what's happening. That'll -- you know, the due date to the Secretaries is July 23rd -- I mean, June 23rd. I won it by a month. And so we're working pretty diligently. People like David Meyer aren't here today because they're working on that kind of thing. And Alison is the kind of principal editor pulling all these pieces in.

The one thing we've done is we used the GMLC lab network to pull in the labs, and to pull in efforts from them, and we've received something between 15 and 18 papers from the labs that are specifically targeted on chapters or activities within the thing, trying to make sure that we're capturing as many viewpoints as possible within the time frame that we

(inaudible). So we're actively

engaged, GMLC is

actively engaged(inaudible) lab to really step up, and the players are working pretty hard.

CHAIR TIERNEY: Thank you. Try to keep it short.

MS. MARILYN BROWN: I was very excited to see the mention of machine learning, and a whole big data topic in the presentations. At the university, we're really at Georgia Tech, and I know at CMU, and many other places the students are so excited about the role of big data, and helping to achieve sustainability of all variety of sorts.

So they start down these various projects. They try to merge different data sets. And they realize that choosing these data sets is fraught with just insurmountable problems. Time stamps don't drive, GPS coordinates not the same. They tried to so something on EVs. You've got EV charging stations from four different vendors, and you don't know what you've got on campus. You really want to try to help, and you scrape data, you know, scrape data from all over the place. The students are incredible at what they can do, but they're so frustrated by the challenges of all of this.

And I remember when the smart grid data was made available how valuable that was to universities. Well, now we're in a whole other generation of data, and it would be just to try to add some systemization, or some rules, or something, and to make some of these data, real-time data streams available to other universities and others could give you so much.

So just try to think about how you can take it to the next step sharing of data. I know your labs really appreciate it, but the universities are just really hot to get some of this too. What do you think?

MR. LYNN: That's a really good point. I think -- we don't have the answer to that. And, you know, we continue to encourage coordination across (inaudible), and I think some of the solutions are going to require some of that data coordination, and I think it's going to have, and it's such a broad (inaudible) that it's going to be somewhat piecemeal or specific to certain kinds of situations for the things you're trying to do.

But we see enormous interest, as you do, in it, and we see enormous value in the players that are working the space, but the labs, universities actually within industry, and so we just continue to evolve in that direction. I'm not going to pretend I have the answer --

MR. PARKS: I think that recommendation (off mic).

CHAIR TIERNEY: Well, let's leave that as the final word. This was a terrific effort that you guys have shepherded, so thank you very much for your -- (applause).

We have exactly ten minutes for your break. We're going to start five minutes late because I see our panelists are here. So we'll start at 3:00 precisely.

(Off the record at 2:50 p.m.)

(Back on the record at 3:00 p.m.)

MR. MORGAN: We have a really exciting topic - gas- electric integration. My strong sense is that we'll end up substantially running over our time, but we're not going to be allowed to run over our time.

SPEAKER: Excuse me just a second, Granger. First, please take your seat, or take sidebar conversations into the hallway. We're going to get started right now. Go ahead, Granger.

MR. MORGAN: And what I'm going to do is also not have discussion after each talk. I'm going to go -- we'll go through all three talks, and when you hear something that you want to comment on, put your flag up. And then at the end, when we're all done, we will systematically back and forth across the two tables hear comments on any or all of the talks, or any observations you care to make about gas-electric integration. My fear is that probably every single one of us is going to want to make a comment about gas-electric integration, especially if you live in the northeast.

But with that, I'll ask Sue to come up and give her first talk, and there is a clicker here to advance.

CHAIR TIERNEY: Thank you, Granger. You guys will recall that the impetus for this panel was some brief overview that we had at a few sessions back. And the role that I have in today's lineup is to be the primer. I'm the basic person, and then you have two real experts following me, who will drill down into more detail on the topic.

So I'm going to talk mainly about what's different, and what's similar about these two industries. Would you raise your hand if you know a whole lot about the gas industry?

SPEAKER: (inaudible).

CHAIR TIERNEY: Okay. Some of you -- are there some people in the room who know nothing about the gas industry? Okay. That's great. Oh, let's see if I can make work the right direction. Maybe no. Oh, yes, I can. No, I can't.

So the conventional wisdom right now is that at least for the foreseeable future, and until a very urgent decarbonization agenda occurs, there will be increasing interdependencies between the gas and electric industries.

For one thing, the electric industries will become more and more dependent on natural gas for not only a percentage of its generation, but in integrative functions with integrating renewables. Golly. I hope I don't do that every single time I try to advance it.

So you probably all recognize that this is the famous chart of the amount of generating capacity that has been added each year over the last 50 or so years by fuel type, and the big yellow bars are the huge amount of natural gas capacity that has come on line since around the year 2000.

The red is nuclear. The black is coal. You can see that fleet is pretty aging, but the amount of capacity that is now natural gas, -- and, of course, renewable is in blue on this thing -- is the modern capacity that has come onto the system. And so it an overwhelming amount of capability that exists in the gas fleet.

And until a couple of years ago, the amount of capacity that came on just after in these huge (inaudible) bars after the year 2000, that capacity remained highly underutilized for a number of years as gas prices were high during that period.

And so when gas and coal prices began to change, that underutilized capacity was available already on the grid and could be dispatched up very quickly.

This is the electricity generation outlook by EIA, the most recent annual energy outlook. You can see that coal is the diminishing market share in this business-as-usual. This is, remember, an existing policy's outlook. It does not anticipate the implications of changes in policies that are not already existing in the federal and state governments.

You see nuclear is flat, and you see natural gas and renewables taking up a larger share between now and the year 2040, again, in this business-as-usual outlook.

So electricity is going to depend upon gas, and gas depends upon electricity, and I don't just mean to run the compressor stations on the system itself. But the outlook for the market for natural gas going forward is very much a function of growth on the electric side, and industrial use, and export markets.

So this is the same energy outlook, an annual energy outlook that anticipates where new gas sales will come from. You can see residential and commercial at the bottom are pretty small, and -- excuse me -- and they are flat going forward in this business as usual case.

Electric power is the growing sector along with industrial use, and industrial use is highly sensitive to price. Of course, electricity is as well. Price in this outlook is expected to be slightly higher going forward then it has been in this really low price environment we've had in the last year.

So let me talk about similarities between these two industries. Wow, this is really weird. Sorry. Both of these started about 20 years ago, 20 to 30 years ago to unbundle the functions, and in natural gas and electricity, the wires function is separated from the commodity function, as it is largely in wholesale energy markets on the electricity side.

The commodity supply in both of these two industries is market-based under most circumstances, with the transportation function on the interstate system at tariff cost of service prices. Both of them had those transportation services priced by the FERC for the most part when they are provided for other third-parties, rather as part of bundles service to consumers.

Both of the industries have a state regulated local distribution company function, and so everywhere where there's natural gas for retail consumers it's state regulated. Most of them have the majority of physical assets owned by private companies.

Maybe someone more skilled than I can do this.

SPEAKER: (Off mic).

CHAIR TIERNEY: Oh, great. I was told that there was. Both of them have systems that cross the country, and both of them have really different sub-national markets with a lot of differentiated features.

So here's the physical footprint of the two industries. For natural gas, I'll show you the picture, but the physical footprint of the interstate transmission grid basically reflects the fact that from the beginning of the industry, the gas was distant from consumers, and so you had the construction of an interstate pipeline that became federally regulated. So if you want to cite natural gas facilities, and pipelines you go to FERC, and the citing of natural gas facilities is federally preempted.

So you see that here in terms of the traditional source of natural gas down in the Gulf Coast, and Texas, and Oklahoma, and moving that gas up into consumer markets in various northern parts and western parts of the United States.

And you see with this picture the increase in shale gas production in different parts of the country, and the top of that screen is the Marcellus and the Utica Basins in Ohio, Pennsylvania, Appalachian regions.

So that geographic location of where gas is increasingly coming on line is affecting the distribution of the pipeline system of natural gas, and you see that here with a lot of new and planned expansions in the Marcellus area, moving out of Ohio, out of West Virginia, out of Pennsylvania into other gas-consuming markets.

Now, that's different than electricity. Recall that electricity grew up from a century ago with power plants, little power plants physically located to consumers, and the states control siting of transmission for the electric system, and that history is quite tied to the fact that that's just totally different than we have natural gas.

So the location and the physical developments of these two systems ended up with very different regulatory and legal structures for affording the development process of the assets themselves.

So, you know, the picture, it just shows the different locations of power plants, many of which are clustered relatively close to load centers, or in the coal country in places close to where coal could be supplied.

But the tradition in electricity was from the beginning that you moved the fuel to the load, and then you built the power plants there rather than transmitting from mine-out stations where, of course, that does exist, but it is not the norm.

So the electricity grid is more tied to the consumer centers in some sense than the natural gas grid, although as I've pulled out these maps, they look kind of similar. Okay, Sue, let's go.

So differences. Everything now toward the end of this are going to be differences in these two systems. Electricity is a network, and I think of the pipeline system as more like laterals, and that has important implications. So electricity you know it's physically connected within an interconnection, the three interconnections and power flows across a highly interconnected network of physical facilities.

But in natural gas, what you have is companies own individual pipeline systems, and they don't have a mesh network type of configuration. You are going to buy service delivered on a physical set of assets that are connected to each other with occasional drop off points, but if you're not -- if are a power plans and happen to be located next to one pipeline and not another, you're going to take your service off of one pipeline that's not gonna source its supply from a lot of different pipeline locations.

Okay. So you know the interconnections. You don't need to see that. So I've already mentioned that natural gas is developed along pipeline, and to give you an example of that -- I am so inept. Okay. These are just two examples of the point. If the middle picture is the full array, and it looks just like the electric system, it's actually made up of these individual laterals.

On the left, you see an example of Dominion Energy's pipeline system, so if you're on Dominion System you're flowing up through Dominion, basically, until you can get a tap off. By contrast, some shippers may use the Texas Eastern shift system which is in parallel to, but physically separated from the other one.

So that's the case for that system that looks like it's just like the electric grid. It isn't. They are very different.

Gosh, I hope you guys have better luck with this than I do.

So storage. We're having a whole day on storage tomorrow. The storage approaches are quite different in the two systems. So this is a picture of the storage locations for natural gas. These are underground storage for the most part. It's in salt domes, or, you know, abandoned mines and a variety of other places where there are large physical supplies of natural gas compressed underground, and it really provides a finite amount of take out of the fuel.

But it also allows for storage of fuel with really long time frames. Within a season, you can then draw down the fuel supply. We know that's really different than electricity. So electricity we do have some big storage, and this is a picture of pumped storage, so that's a situation where you know the grid operator has the ability to call upon pumped storage, but typically that is on a daily basis, an intra-day basis, not a long seasonal basis like you have on natural gas.

And the emerging technologies that we know about for storage on the electric grid will go from the nanosecond basically of frequency to longer term, but we don't have a lot of this seasonal, intra-season storage on the electric side, which is going to be a challenging attribute associated with increasing intermittency of different kinds of fuels with different patterns of supply by season, of course, within days and so forth.

So the commodity market are very different.

CHAIR TIERNEY: So natural gas. Everything on the production side is essentially unregulated for the past few decades. So the production and cleaning of natural gas, for example, is unregulated by the federal energy regulatory commission, or any other entity. There is true commodity competitive pricing that exists, and demand is highly -- excuse me -- demand is highly sensitive to price. That did work better if I push really hard.

Electricity. Of course, production is highly regulated even in places where there are market based rates that Bob would tell us that a market design operated and administered by an RTO is highly regulated by FERC. So there's a very different structure, and, of course, within the context of a vertically integrated electric utility system such as Southern Company, you have a different form of regulation for the generation side, and demand is sensitive to price, but nowhere like it is on the natural gas side.

So there are lots of other differences across the industry, and these are going to sound kind of random, but they affect the markets for the two systems.

A universal service. Natural gas does not have universal service. You could live in some location where you have no physical supply, or you can actually be a person who wants natural gas service, but unless you build the lateral, or there is available -- there is the expectation that the utility is going to build a lateral to you, that's only going to happen if it actually doesn't raise everybody's else's rates.

So it is a different model on the gas side for what areas of the country are served, and what customers literally are served, and there is no obligation to build or plan for new customers in the same way, or course, that there is in electricity.

And a natural gas delivery company has an obligation to serve its current customers, but not new ones. So that's an important distinction.

Another difference. The demand outlook. So natural gas is growing, unlike at the moment the electric industry, in terms of demand. There was a period when natural gas was pretty flat, and that was when prices were pretty high as recently as a decade ago, and local distribution system service for natural gas does tend to be pretty flat. That's because the growth is the LNG export market that doesn't go through the LDC. Growth in the power generation market, and for the most part around the United States power plants take off the high pressure system rather than go through the low pressure distribution system, and industrial customers take a direct tap off of the main pipelines as well.

So you see this difference between LDC markets being flat, and the overall market for natural gas driving pipeline -- interstate pipeline additions, or high pressure pipelines, but not necessarily -- the market doesn't necessarily see that locally.

Electricity demand is pretty flat everywhere whether it's wholesale or retail. There are, of course, some parts of the country that are experiencing growth, but unless there is a major new period and phase of electrifying transportation, industrial use, and buildings that now heat with natural gas or propane, then electricity demand is pretty flat.

So that's a big if what I said. Most of the deep decarbonization studies indicate that electrification is a pathway to lowering the carbon footprint of the economy, but to do that you have to lower the footprint of the electric system at the same time you are electrifying other sectors, and doing that, of course, affects the market for natural gas. So all of these things are a little interconnected.

Another difference is that the speed and timing, and pace of things really differs in these two markets. Natural gas moves 15 to 20 miles per hours, and electricity is measured in, again, minute fractions of a second in terms of making sure that they system operates.

There is a lot of ability on a pipeline system to change pressure, and inject into storage, and pull out of storage in order to speed up the movement of natural gas, but, in essence, somebody up in New England who needs gas tomorrow, that gas already has to have been in the system for many, many days in order to get ready for market to have deliveries occur when needed.

There's one really important element of the differences between these, and that is the presence or lack thereof of industry standards for reliability. So in natural gas, there is no NERC. There is no NERC or anything like it for assuring that the system as a whole operates according to certain standards.

Now, that's not saying there are not safety standards. That's not saying there are not operating standards and procedures. Yes, or course there are, but there is no mandatory industry-wide reliability organization that pulls in the planning functions for long-term resource adequacy, as well as the operational security issues. So there's -- it's just very different on natural gas than electricity.

And the way that those standards tend to operate on the gas side is to me more akin to the way it used to be quite a while ago on the electric side. So the gas standards evolve for the industry as a whole when there is a major cross-industry policy issue that FERC has to decide and may introduce. There is the North American Energy Standards Board which is the standard setting organization for both electricity and gas that develops through a collaborative industry process to try to address with a voting process by the members of the different industries what standards will be adopted. And sometimes when the industry can't get its act together to vote something in, that's when FERC steps in to adopt an industry-wide policy.

But the pipeline companies, for example, have had their own business practices, their own business policies that have to do with what time you might be able to call up supply; their response time; whether they are actually electronic in terms of their response to customer nominations of moving gas; or whether those are by phone. So there is a wide variety of actual practices across the gas industry that vary tremendously, according to what the owner of a system adopts.

And as you know, since 2005, after the famous 2003 black- out, Congress enacted the framework for mandatory standards. Of course, there are a lot of industry-wide, voluntary agreements to share services, and mutual assistance process across the electric industry.

States do hold for the most part resource (inaudible) roles in the electric industry with FERC adopting that role in organized wholesale markets on the east coast especially.

But these are very different functional

ways in which the industry operates, and an example is you think about the control centers of a grid operator. 24/7 the screens are all up. Everybody is operating just every single second.

The gas industry there are questions about when they should start their day, and occasionally the gas industry members will say, well, well, we can't start our gas day at 4 a.m. That means our guys would have to get up early and go out to then do something on the production side. It's just a really different, different type of system.

And the increasing interdependencies of the two systems is increasing the conversations between those two cultures in ways that require continuing effort to make sure that the integration continues to evolve.

Okay. So implications for us on the electricity side. Bob may talk about this with New England, but in the electric industry, we see a variety of ways in which utilities, so electric generators, who are interested in nominating gas for tomorrow, and making sure that there is adequate capacity on the system, there are different incentives in the markets for some companies to do that and not others.

So if you are vertically integrated, you may be able to put into your rates the firm gas transportation service that may be required to make sure that new gas pipeline delivery capacity is put in place for your use. That may not be the case on the electric side, and in fact, was not the case for many years in vertically -- excuse me -- in some of the wholesale markets where merchant generators have not had financial incentives to operate under firm transportation agreements for natural gas. Bob will describe how the market is evolving to try to address that issue.

I guess I just talked about that. Additionally, one of the issues that I think is a clear one is a chicken and egg timing problem, or a challenge for which the market structures are continuing to evolve on the electric and gas sides. So in some regions again, chicken and egg.

If you are in an organized wholesale market, or even if you're vertically integrated and you're the balancing authority for your system, you need to know how much gas you can get if you're going to be dispatched tomorrow. So you've got to know that you can get gas so that you can put your bid in, or you can be ready to be dispatched in the next day's market.

And if you're an organized wholesale market, you're actually going to structure your offer price depending whether you can get gas delivered for a particular price. But in some -- in some of those regions, the generators may not actually know whether they can get gas by the time they actually have to nominate and put a bid into the supply.

So this is a chicken and egg problems that is operating in real terms right now that I know the (inaudible) are trying to address, NAESB is trying to address, FERC is trying to address, but I think it will continue to evolve as you think about a system in which gas moves at 15 to, you know, 10 to 15 miles an hour, and you are looking for gas to be the swing of integrating highly intermittent fuels, and balancing that system.

So the dovetailing of those two things, and how they function in this real time and day ahead market is something that will continue to evolve.

So final facts. My only final facts are one of the great things about the electric industry -- I'm a cheerleader right now for the electric industry on this side of it -- is that everybody whose job it is to deliver reliable service whether it's Pasadena, and you're going to be there around the clock, 24/7, or PG&E, SCE, or ISO New England, the more you are part of the fuel delivery business on the electric side, or whatever it is, the industry has continued to solve these problems. I didn't even mentioned you, Mark. Sorry, Mark. You have a minor role to play in that. These are not surprising issues for the cops on the beat on the electric reliability side, and there is so much work to anticipate the changing transitions that are underway in the industry. So people are seeing the issues, trying to solve them, trying to address them, but there still continue to be market evolutions that need to occur in order to keep up.

And my last point is that's gonna just continue to be the case. It's going to get more complicated in the future. We don't know about the pace or timing in which we are going to be relying on natural gas in the say that I've just described, or whether or not it's going to be playing a more diminished role some decades forward. Lot of different challenges to figure out. And so continuing to stay ahead of that changing environment is, you know, inherently challenging. Lots of good minds are on it. I'm glad DOE's work is all about that. But work has to happen on both the gas side and the electric side as part of this.

And actually, I will make one editorial comment. One more final one. My -- I chaired the

NAESB gas-electrical integration process a year ago, and two years ago, and three years ago. And I encourage everyone to be as active as they can to communicating with the natural gas industry about how complicated these issues are. And that both sides of the industry sectors need to be working on a changing structure for the industry and a changing set of dynamics for the industry. And that's it.

MR. MORGAN: Thank you, Sue.

(Applause). So as said before, some of you weren't in the room, we're not going to have Q&A after each talk. Put your card up if you hear anything over the course of the talks that you want to raise, and once your card -- I mean, at the end of the three, I will simply go to all the cards that have gone up and not to any others.

And so Bob's now tell us a bit from the perspective of ISO New England.

MR. ETHIER: Good afternoon, everyone. Appreciate the opportunity to be here. Sue did a really nice job of sort of giving the big picture sort of issues going on in the gas-electrical issue -- industries.

I'm here to sort of give you more of a case study, what's happening in New England and why that's important. I think New England is in some ways the canary in a coal mine and all this. As you'll see, we are highly dependent on natural gas and getting more so, and we have very limited natural gas infrastructure. That's sort of the backdrop of all this. And as a result, we've had to do a number of things to try to improve our situation with working with the gas industry, and how our markets give incentives for folks to do the right things on the electric side, and better utilize all the gas infrastructure that we have.

So I will do my best to explain why New England matters. What it is we've learned. And what we're doing going forward to try to improve the coordination level between gas and electric.

So with that. So the ISO, we're regulated by the FERC, which currently only has two commissioners so we're not doing a lot of regulation at the current moment, and we're the reliability coordinator for New England under the North American Electrical Reliability Corporation. We're independent of all of the companies in our footprint.

We do three main things, and each of these things is pretty directly affected by the gas-electric coordination I'm going to talk about. We oversee the day-to-day operation of the power grids, so as Sue mentioned, we have a -- basically looks like an air traffic control center that's staffed 24/7 by six to eight people, and it operates the grid minute-to-minute, second-to-second, hour- to-hour.

We also planned the system, so we planned the New England transmission grid, and -- including interconnections, and we also planned new interconnections from new power plants on the grid.

And the final thing we do, and, of course, the most important because I'm an economist, is run the regional wholesale electricity markets.

And obviously I'm kidding that that's the most important thing we do, but that does seem to suck up the lion's share of the oxygen in New England when you're talking about the electric grid because the markets are the newest aspect, and the markets have a big role to play both in the operations and the new investment in infrastructure, and in the planning of the grid. So the markets have quickly gotten us sort of a center role in how the grid works, and how the grid evolves over time.

So increasing reliance on natural gas. This is maybe my most used slide. What you have on the left in the blue is fuel use in 2000. What you have on the right in orange is fuel use in -- or fuel use in -- or field production -- electricity production from that fuel in 2016. What you see is oil was 22 percent of our electricity production in 2000. Coal was 18 percent. They're now 1 percent and 2 percent, and that's only going down because on May 31st, the largest coal plant in New England shut down for good. So that coal number is going to only be lower in the future than it is right now.

So what took up the slack? Almost a hundred percent natural gas. Sure, we've got a touch more renewables, but largely it's natural gas that's taking up the slack, and we don't see that changing anytime soon.

And the reason that we don't see that changing anytime soon is for this graph, which is very similar to one that Sue showed you with the additions of capacity by fuel type. This is for New England only capacity isn't by fuel type, the only one that matters is this big blue one which is natural gas.

Sure, we're getting some other -- we're getting some other additions down here, but the lion's share is clearly natural gas. And this is -- we go to 2019. So this is largely historical, and from what I can tell, it's going to be the same going forward. This is a list of all new large-scale production facilities that are expected to come online in New England. All natural gas are dual fuel capable with natural gas as the primary resource. So lots of gas historically. Lots of natural gas going forward.

One of the issues we face is we are at the end -- literally at the end of the pipeline. So we are not -- we've talked to our follow ISOs. We've talked to PJM. We talked to MISO. We talked to SPP, and they're like gas infrastructure? We have more gas infrastructure than we know what to do with. We have, you know, that's not universally true, but generally we have a lot of pipelines crisscrossing their territory, and for the most part at least on a widespread scale, pipeline limitations are not their problems. That is not the case in New England.

The New England pipeline network was built to largely handle home heating and what limited industrial uses that we have in New

England. It is now being leaned on, as you can tell, very heavily to run the electricity grid. The pipeline expansion has not in any way kept pace with the increase in natural gas usage by the gas-fired generators in New England.

So we are leaning on a pipeline system that hasn't gotten updated. Luckily, it had some spare capacity historically that gas generators have been using, but we are starting to bump into the limits of those pipelines that we have in New England.

So this is a little bit of a digression, but one thing -- but what I want to show here is in the winter of 2014-15, this shows you the fossil fuel mix in New England which is here you've got your natural gas, green is coal, red is oil. So remember that annual average I showed you that was 1 percent oil, 2 percent coal? Well, when does that -- when did those 1 and 2 percents of generation happen? They happened in the wintertime when our pipelines get constrained. So while coal and oil make up a very small share of total energy usage, it happen at very critical times, specifically it happened in the wintertime when we have very cold temperatures, and our natural gas pipelines get constrained, and all of a sudden coal and oil are an economic merit order, and we couldn't -- we have a hard time getting more gas even if we wanted to.

So that's when the coal and oil comes online. That's what we're going to miss when it retires, and that's what we need to solve for going forward is what do we do when we don't have this coal and oil to lean on for handful of days? It makes economic sense to retire these resources right now because coal and oil units require -- in general because they're older unit they require a lot of maintenance. They require a lot of staffing, so they're expensive to keep around for a handful of days every winter, but we have to fill in this gap because nobody wants to be shedding load when the average high temperature in New England is 12 degrees.

MR. ETHIER: This slide shows you all

the units that we are losing in New England, nuclear, coal, and oil make up the entirety of the list. I'm an economist so I show constraints with prices not with quantities.

So what this graph shows are prices both on the electric and the gas side starting December 2010 and going through December 2016. Where are all the high prices? They're not in the summer like they were when I first started working at ISO New England. They're now all in the winter, and as you can see from the blue line, they're driven by natural gas.

So the high prices in New England are driven by natural gas. The high prices on the gas side, which when we first started seeing them back here, and especially here, astounded people, are driven by the constraints on the gas system, so price is highly, highly correlated with a tight gas system in New England as you would expect.

So natural gas, increasingly important in New England, increasingly important global commodity, one interesting thing about liquefied natural gas is the system isn't that flexible. So Sue talked about how pipeline gas moves at 15 to 20 miles an hour. Well, LNG moves at the speed of a tanker which is actually relatively fast but the distances that they have to travel are much longer.

So we are highly dependent on very timely deliveries of liquefied natural gas via tanker, oceangoing vessel in the winter in New England. That's been really an eye opener for our operators. Our director of operations now has an app on his phone that allows him to track all of the LNG's shipment in the Atlantic Ocean to make sure that they're on time and they're going to get to either New England or New Brunswick in time to meet our needs for electricity.

A little worrisome that he relies on an app for this but that's just sort of how the world works today. So and finally, you know, we have a whole new risk on the system which is severe weather can delay the arrival of these ships.

So some lessons learned. I sort of gave

you a few LNG lessons learned on the last slide. A whole bunch more that we've learned recently. Gas, and I've touched a lot of them, the gas pipelines get severely constrained during cold weather periods which lead us to rely on coal and oil. A lot of those are starting to retire. So we need to make sure we fill those gaps.

One thing we've also learned relying on these oil resources very intensely for very short periods of time, is actually the oil delivery system in New England is maybe under-stressed at times. It takes lots and lots of trucks to fire an oil-fired resource for any period of time. It's one thing to run a peaker for a couple of hours here, a couple of hours there. It's another thing to say I want to run your peaker for the next three days solely on oil. That's a lot of tanker trucks going through neighborhoods and being delivered.

So another important thing we are looking at the gas supplies chain, as I mentioned, is highly dependent on just in time LNG, and delivery to the three LNG facilities that are in New England that have become crucial. It's not that LNG is nice to have and we can feed ourselves from the pipelines to the west. It's entirely necessary that we get LNG to meet our peak winter loads. We cannot meet the peak winter loads without some LNG being back-fed into the system.

Another thing we've learned is New England is a very difficult place to build a power plant. You talk to the developers who build in multiple regions and they are universally say the hardest thing about operating in New England is not our markets. It's the permitting process and getting things built because there's just a lot more layers to go through and each layer takes longer in New England, at least that's what's represented to us.

And dual fuel capability is becoming harder to put in which a real problem for us because when we run the economic numbers, dual fuel is the cheapest solution to New England's natural gas dependency for very short periods of cold weather. Far cheaper than any other option that we've looked at.

Canadian hydropower. So I haven't really touched on that but we have some tie lines coming in from Canada. We rely heavily on those to meet our peak winter needs. The problem is our peaks happen when Canada's peaks happen oftentimes. And sometimes they curtail their sales to us because they need hydro power for their own needs as you would expect.

And finally, the region is vulnerable to large -- loss of large non-gas fired generators, these days largely the nuclear units. So what are we doing about it? We're doing a lot of things. We are -- have developed a lot of new situational awareness tools. We scrape data every day from the pipelines. We compare scheduled gas to the schedules of the individual gas fired generators. We communicate with the pipelines and the generators when their constrained operation is expected.

That is when we know the gas pipelines

are going to be constrained and we are going to be under high system load. And trust me our operators would like to think none of this is necessary. Their view and which I fully support is the gas fired generators should manage it and we should be able to stay out of it.

I don't think we feel that we're at the point that we can do that yet. So maybe someday in the future we can but right now we feel the need to get ourselves in the middle to make sure that there's as free as flow of information amongst all the parties as is possible.

We have stepped up our communication with pipeline operators who, frankly initially, didn't really care to hear from us very much. But over time I think that relationship has improved. We share data about maintenance coordination both on our side and on their side. We share expected dispatch which has required special changes to our information policy and we just keep in touch with them to make sure that any sort of hiccups on their side are reflected in our operating plans on our side.

We've had a winter reliability program which is primarily served to make sure that there's adequate oil in the tanks in our -- for our oil-fired facilities in New England. And that has been successful although in the long run we hope we can do away with that because as you'll see on this slide, we have changed our energy markets and our capacity market to provide better incentives for operations during times of extreme system stress.

We have implemented on the energy market side, you can see, we've implemented hourly offers which allow generators to better reflect their true cost of operating. So we ran into situations where folks had daily offers in but their offer in a given hour to operate was actually above their daily offer so that took away their incentive to run. So they can better reflect their true costs in the market now. We now have sub-hourly settlement so instead of settling a generator at an hourly average price; we do it at the five-minute level.

So if we have a five-minute price spike and a peaker comes on to hit that, they get paid appropriately for hitting that price spike. We also have increased our scarcity pricing. So now when we go short of reserves, we can have a price adder, not just the energy price, but an adder to the energy price of $20 up to $2,800. That's on top of an energy offer that can be as high as $1,000. So we could have energy prices of over $3,800 per megawatt hour during times of very high stress.

You think that would be a big enough incentive but wait, there's more. We have completely revamped our capacity market compensation structure so that it now very much depends on your performance during times of system scarcity and shortage. And the dollar amounts in the capacity market are even bigger on a per hour basis than they are in the energy market.

So we in three more years will be either paying or clawing back from generators with a capacity supply obligation up to $5,400 a megawatt hour on top of the energy price. So all told you're looking at roughly $9,000 a megawatt hour in the energy market for times of system shortage. So if it's a cold winter day we're short of reserves, generators could be facing an incentive of $9,000 a megawatt hour to deliver that energy that we asked them to deliver. If they deliver more than we asked for, they get paid that, and if they deliver less than we asked for they get charged that essentially.

So huge incentives. This is Texas style or Texas level energy market incentives that are going to be applied in New England in, I won't say wholly, but at least partially motivated by the gas-electric dependence that we see in New England and the stresses that we see in the system. So what we've done now is we've told the generators we put the money on the table. We expect you to go make the investments and sign the contracts to deliver when it's time for you to deliver. And this hasn't all sort of been in place yet. Our capacity market runs three years in advance so it'll be next June when all this stuff really sort of hits the street.

But our expectation is this is going to go a long way towards helping resolve some of the operational issues that we have seen in the past and in a sense some infrastructure investment of various types going forward. So and it wouldn't be complete, we're an ISO- any reaction to a problem wouldn't be complete without us doing some studies.

And so we are currently conducting just the latest in a series of studies on the gas-electric system and fuel security. That will be out this fall. It's going to look at a lot of different scenarios about the future and have a lot of different metrics for how short we're likely to be and how often and I can get into more of that if you want during the Q&A but the study's not done yet. I think the one thing that I will say at this point that we sort of knew going in but the study is seeming to validate is that well, on the electric system we are very careful to plan and operate to N-2 standards. We would have a hard time withstanding an N-1 problem on the gas side.

So we invest all this money to build new transmission lines so that in the event that a transmission line that's 99 percent operational goes out of service, we've got a backup that's also 99 percent operational. We don't do the same thing on the gas side. Yet, our system is entirely dependent on the gas system to run effectively. So with that, thank you very much.

MR. MORGAN: Thanks, Bob. That was great. And now finally, Alex, and remember to put your card up if you want to add questions or comments.

MR. RUDKEVICH: Thank you. Thank you for inviting me and I also want to thank two previous speakers because they pretty much did all the work and I don't need to explain why we're doing what we are doing.

So this is about the project that is

funded by ARPA-E. The project started a little more than a year ago. We started working on it in April of 2016. It's a part of the ARPA-E 2015 open solicitation. And the project, as you can see, it's a team effort. So the leading organization is my company the small business in Massachusetts called Newton Energy Group.

Then we have a heavy lifting organization with is Los Alamos National Lab. We have another small business, Polaris, which is a software company, Boston University, and AIMMS which, again, provides some optimization language tools. And we have technical expertise coming from Kinder Morgan on gas side and from PJM on the electric side.

Now which one is the, oh, this one. Okay. No, not sure, oh, okay. Very important, the disclaimer that, you know, we as individuals for what we are saying, the organizations, especially those that are not really involved in the study but mostly support and technically take no responsibility for whatever I'm going to say today.

Okay. Now am I pressing the right button? Okay, I'm not sure. Which one is the -- actually, okay, yeah, here we go. So this is the formal project title about this project and there is a website on the ARPA-E site or the page which describes it and in somewhat more details.

Now the objective of the project is actually to try to solve the problems that were pretty well described by Susan and by Bob. It's essentially improve and we look at this and we see first thing that we need to solve, we need to solve the operational problem. We need to solve what's going on, on an intraday basis. If we can solve that that going from bottom up we can solve everything.

The same way that how the electricity systems were deregulated and the pricing was introduced that you have to really solve the real time. Once you solve the real time you can build it up from that point everywhere.

So the pro -- so essentially it has

components. We're working on algorithms. We're working on software but we're also working on associated market design because we understand that none of this will work unless we put together the right incentives for the market participants to actually have this implement.

So the three elements are the modules and the software for simulating how the pipelines work and optimizing pipeline operation. And I'll talk later about this. Also the simulating the current business and operational process on the electric side, and also we need to integrate it into one system.

The other part is the market design and development of the underlying theory of granular price and mechanisms for natural gas that will be necessary to support that. And the third part is the conducting the simulations using realistic data to actually test different market design options.

So the organizations that are involved in Newton Energy Group, we are mostly a system integrator here. We provide the cloud-based platform to host all the simulations, collecting data and also we're in charge of commercialization. And we also work on the market design and dynamic pricing.

Los Alamos really are providers of the breakthrough. They really solved the problem of how can you optimize a pipeline operation dynamically, real, transient optimization of pipeline operation in a time that does really make sense. So once that is possible, everything else is just building on top of this.

And the rest is, again, components, the electric system models; the Boston University provides the inputs on market design and coordination algorithms. And we have support from external organizations.

Now somehow, okay, let me see. Is this just the delay or; okay. This is the maturational piece and I think I will be repeating everything that was said. I would just add one element which is if you look in the intraday and maybe day ahead structure; the price of natural gas drives the price of electricity. That we know.

But there is the other way. The electric generation is actually marginal consumer of natural gas. And it is the electric generation that drives the price of gas. So which Bob pointed out on his share. So essentially it's once you have a scarcity on a pipeline side, it spreads all over the system. And the consumers will be hit very bad so solving that is really critical. And you really have to work on both systems at the same time.

So that's the maturation and what we are trying to solve. Now the solution, and I'll start with what -- how we see the solution over there and then I'll go into underlying, you know, theory and R&D in the gas-balancing market. And I'll just talk about what it means.

So if we look, this is the outline of the electric day and the gas day. So and the electric day is modeled here on PJM. The time is corresponding to PJM. The gas day is essentially we have the time elimination, the evening elimination and three intraday elimination cycles. So what happens?

First before the generating companies have to bid into the electric market there is a bilateral, very vibrant, very active trading activity that is going on. And people settle on prices and the asset managers say, yes, we can deliver it for you. The price probably will be this or that. There's no guarantee.

There's no guarantee so the electric generator goes and bids into the day ahead market. They may be scheduled to run tomorrow and then they have to figure out actually can get gas at the price they think they can get. Now there is also another component of that that's not every electric and gas fired generator is actually scheduled in the day ahead market. Quick start units are scheduled in real time. And where they are scheduled in real time there is no way for them even to arrange for gas on day ahead because they don't know if they're going to run tomorrow or not.

So we are missing something. We are missing an opportunity to let people actually transact at the place where they need to. So essentially if we look from the point of okay, we schedule the -- the day ahead market on the gas it works pretty well. We schedule delivery for tomorrow. Then there are many nation cycles in the pipeline says yes we take this. We confirm your elimination and in the evening cycle nobody is even bumpable (sic) after that.

Everything that's confirmed is virtually guaranteed. But the implicit assumption that you will be taking gas in equal quantities every hour when everybody knows this is not going to happen? Now shouldn't we, at that point, say you know what? Why don't we allow people to trade, the differences between what was scheduled day ahead and what they actually need?

And if we allow them to trade it on an hour-by-hour basis, we'll have a price discovery mechanism and we'll actually solve the problem.

Now to trade that we need to create what we call a gas-balancing market. And the way we see it, it will be pipeline specific. We really don't need -- don't see the need to create, you know, a big RTO structure that would bundle all pipelines together.

The second, it will have voluntary participation. Essentially, if you're happy with the way things are, you don't have to do anything. If you want to trade your deviations from the ratable quantity because you're concerned about that, then you can participate. It will honor all the transportation rights and contracts and what it will do, as I said, it will enable trades through hourly imbalances.

But what's important, because we can put the optimization system that was developed and conceived by the Los Alamos Lab, we can pretty much guarantee that the transaction, if they're cleared, they will be physically implemented. So it will be supported by the operation of compressors on the pipeline that the deliveries that were and receipts that were scheduled could actually be done.

Now one thing is important to keep in mind. And we were talking about how slowly gas moves. Yes. It moves slowly in an intermonth, day-by-day basis. Intraday, the(pressure wave) moves with the speed of sound. So if you've done something at one point in the pipeline you can actually make a very big change across the pipe. And that plays a very important role in the way the physics of this is done and that's what underlies the pricing mechanism, too.

So at the end, we'll provide the industry with transparent pricing signals and that could actually inform various kinds of decision-making. And the utilization of the gas and the power infrastructure will be more efficient.

Now essentially what we -- the way we see it is as an example, at the end of the evening cycle we can start a forward market for -- which would cover the rest of today's gas and the entire next gas day. The first hour the settlement would be exposed but at the same time simultaneously for every future hour there would be an (X anti-settlement). So we settle the schedule of the deviations and we give the value for every place in the pipeline system. What actual value this gas has at that point in time and at that location?

And then comes the next hour and we repeat this process. And it goes from one hour to another hour to another hour. And each time you basically allow people to change their positions and once the position change, you re-optimize the pipeline operation dynamically for the rest of the optimization period. And with each of this strip, you get a strip of prices. We call the locational trade values because prices are something that form the actual day ahead.

Let's not confuse one with another. So that's the idea. What it will do, our reschedules for receipts and deliveries are either cleared on the market or there is a self-schedules. We get the hourly locational trade value of gas for every node on the pipeline and all the cleared schedules are settled at these values. When this is done, what it brings?

The -- essentially once the power plant knows forward these values that support the day ahead and real-time market behavior. So they know at their location what the value of gas that inform how to bid it. And that actually can guarantee the delivery at the price.

The gas -- purchases for the gas at faster power plants is simplified because again, you've got the hour-by-hour structure. Now what happens if you see the constraint on the pipeline that drives the price at that location for gas up which once you submit the corresponding bid to the electric system, the electric system re-dispatches the fleet and relieves the constraint.

So essentially you made these two systems work helping each other. And finally, you get a very transparent pricing signal to the electric generators because they know if you did not schedule and you didn't get a long-term firm transportation contract, you will be exposed to a very high, and very volatile price risk.

So you can now make an informed decision on how much of the firm transportation coverage you need and basically you have a transparent market in which you can actually sell the capacity that you are not using intraday which doesn't exist today. On the pipeline side, again, it relieves pipeline constraints through two things. You have a price sensitive optimization of compressors and you have the electric industry that is helping you.

It also helped pipeline customers make very informed investment decisions and for pipeline owners, they can now very precisely identify the constrained elements. They can assess the economic benefits of relieving these constraints and justify investments before annual (inaudible). So that's what the benefits would be on the pipeline side.

Now what means is happened? Two things.

The transient pipeline optimization and the LTV of natural gas. So the transit optimization, this is essentially - it's a heavy math. It's partial differential equations. On top of that, the optimization tools that Los Alamos managed to put together and it works. And it gives the dynamic operation of compressor optimized. And you essentially manage the economically optimal gas purchases and sales and the use of the line pack and the use of storage.

The methods and algorithms are scalable. You can optimize large pipeline network and the system seems to be solved in a matter of minutes. And we give economic signals that are granular in time, granular in space, and very importantly, they are consistent with the physics and with the engineering constraints on the pipeline. So conceptually where it comes from, again, we look at this as a two-sided auction which is conducted on the network. You put all the constraints in place. Your participants are buyers and sellers with bids and offers to buy and sell gas.

And the auctioneer is essentially as if it's controlled in the pipeline operation. It solves it and it guarantees the physical feasibility and it gives the valuation signals.

So this is the example of the, you know, the system in place looking at the data that Los Alamos Lab put together for Transco Pipelines on five and six. So we're looking at a very significant piece of pipeline, over 1,600 miles,

compressors and the optimization that was run for it for 24 hours took approximately 5 minutes.

The results, essentially you get time-dependent pressurization for every node. You get gas flow through every pipe and through every compressor stations. You get compressor ratios, (inaudible) pressure agents and horsepower use for each compressor. So all of the physical information you get out of this optimization.

And on top of that, you get the value. And each color, each line of different color basically show you the dynamic of the value of gas in the pipeline system hour by hour and that's what we are missing, because here's where we see that for some locations the spread is very significant. Once you communicate that and then there's essentially locations where power plants are. And once you communicate that to the electrical system, it will re-dispatch according. And it -- to the extent you can relieve constraints on the gas pipeline you will -- I mean, of course if you have a global shortage of gas, no re-dispatch would solve it. But in many cases it will -- this will help.

So the summary is that thanks to the wonderful ARPA-E program, we have the capability to develop this, think it through, and hopefully put it into work. And that gives a lot of innovation brought together because we've got the optimized intraday pipeline operation that could be possible. The gas-electric coordination that is really needed, novel market design, novel price formation mechanism, and the important part for the industry, we can actually guarantee delivery at the price.

So this is really important. We've got to do it. Thank you.

MR. MORGAN: Thank you. Very interesting. I have a bunch of questions but I'm going to resist the urge. I should, however, give the panel an opportunity to ask each other questions after which I'm going to take questions and comments two at a time. Do any of you want to ask or say anything in terms, yeah, go ahead?

MR. ETHIER: The only thing I would add is I should have mentioned this. Sue talked about the chicken and egg problem. And Alex talked about coordinating with uncertain gas prices and uncertain electricity prices. One of the things we at ISO New England have talked about is we currently have a real-time market and the day ahead market. But also have a two day ahead and maybe even a three day ahead market that would ease that transition and sort of help you resolve the chicken and egg problem over time by getting preliminary schedules three days in advance.

And then gradually have those become more and more accurate as all the system inputs become more accurate. So that may be as good as we can do on that one because there's always going to be this inherent, you know, you can't do two things at once necessarily, but just wanted to add that to the discussion.

MR. MORGAN: Okay, why don't we first --

CHAIR TIERNEY: Actually, can I just add one thing?

MR. MORGAN: Yeah, go ahead.

CHAIR TIERNEY: You guys probably know that one of the things, the phenomenon that's happening at FERC meetings is that there are active controversial protests. And they are largely around FERC's willingness to site and approve natural gas pipelines. And that in combination with questions about whether new pipelines could be introducing new opportunities for stranded costs in the future in a world in which there is not as much demand for natural gas to move across a pipeline system, the opportunity that these gentlemen have described to increase the utilization of the asset base on the gas side I think is a very compelling aspect of what they're talking about.

Making the -- whatever it is that we've already got in the ground workable for a system that really needs more gas, I think is great.

MR. MORGAN: So let's hear from Carl and Merwin and then we'll get some responses.

MR. ZICHELLA: First of all, thank you guys. I can see why Sue was so excited about this panel. It was really, really excellent from your introductions to right on down. I have a question for both Bob and Alex.

Bob, I realize that it's not here yet, but I was wondering when the new transmission is done for the hydropower resources in New England. I'm just wondering how that factors into your equation. New England clean power link has been approved by the State Department. Probably won't be in service until 2019 or something like that. I'm just curious what you -- what that means to you in terms of maybe relieving some of the pressure on this realizing that wintertime peaking means you don't get as much electricity from Canada as you might otherwise.

And then for Alex, so you can think about it, I'm just wondering who runs this gas market? It may be a pretty rudimentary question but it seems like, you know, we have this network of RTOs that run our markets for us on the electricity side. And in order to be able to make this work and to settle it hour by hour and to deal with the trades, I'm just wondering who does that and how do you envision that working?

So if you guys don't mind hitting those two points that would be great.

MR. MORGAN: Okay. Let's get Merwin's on the table as well and then we'll go ahead.

MR. ZICHELLA: Okay.

MR. BROWN: This is Merwin Brown. Two questions that come from a great deal of ignorance which is not unusual for me but one of them relates to physical operation of the gas system coupled with electric. Alex's comments raised the question. The second one has to do with increased capacity in the existing pipelines.

So the first question was you talked about this in terms of market impacts and how markets can be used to optimize the deployment of natural gas through the pipelines. But given this pressure reaction problem with very quick operating combustion turbine type systems, if you have enough of them and you're trying to get 1,300 megawatts ramping out of them, could you run into the situation where you physically, regardless of what the market thinks, may not be able to deliver that gas and have flameouts of the turbines? And there's the other question, what happens when these turbines shut off all of a sudden when solar plants come back on all of a sudden? So that's one question.

And the second question is a number of years ago there was quite a bit of work done on pipe relining particularly I believe in Europe and Japan and maybe elsewhere. That would allow raising the pressure of the existing pipeline systems using things like Kevlar type lining. And I know that's expensive but it's got to be a lot cheaper than building another pipeline.

Is there any thought going on that about the ability to increase the pressure of the existing systems and therefore the flow-through?

MR. ETHIER: Well, how about I take one and a half of those questions. The one I'll take in its entirety is the new Canadian hydropower one. Certainly, we think it can be helpful. But we're -- there's a little bit of a wait-and-see attitude as well because if they just say we will sell you opportunity energy when the price is high and when we have capacity available, those times I pointed out in the winter when we're relying on oil and coal, those are exactly the times that typically the Canadians need the power for themselves and we're unlikely to get more help.

So it might help the other 342 days a year, but for the remaining 23 days a year, we're going to be in the same boat we're in today. So that's the concern. Now if they'd say we'll sell you capacity, too, and we'll sell it to you all winter because we've invested in our generation side as well, that could be hugely helpful.

So that's one. The half is the turbine flameout issue and I'll just reflect what we've heard from the pipelines. The pipelines are happy to shut off our gas generators if they don't have firm delivery or if they're overdrawing. And they will tell the generators in advance but they will shut off the valves at the laterals if the generators are overdrawing their allotment. So they will do that to protect their residential customers which they should do because the costs on that side are extremely high of relighting all those pilot lights.

But our hope is that with all the communication that we have now and the increased awareness of the generator tab, it won't come to that. That might mean we have problems to deal with but at least we'll see those problems coming and they won't be, oh, suddenly this generator tripped offline and it's because the gas side shut them off. Hopefully, we'll have a little notice that that's happening.

MR. MORGAN: Right, but I think Merwin maybe also was raising the issue of if I can pack the line a bit more, I have more local capacity. And I mean, I presume that's what you were raising with respect to --

MR. BROWN: Well, that's the other half I think Bob wasn't answering. It was the pipe relining pressure --

MR. MORGAN: Yeah, okay.

MR. ETHIER: Yeah, my half, the half I'm not answering is whatever I didn't get to is --

MR. MORGAN: Yeah.

MR. ETHIER: -- in that half.

MR. MORGAN: Yeah, Alex?

MR. RUDKEVICH: Okay, thanks. Well, okay, answering the first question. Actually there is a market that operates in a way that is similar in some way that we were describing which is the Australia Province or Victoria Market.

That is actually runs more like an auction-based mechanism.

And but I think that it runs this even in a day ahead structure. We don't insist on that. We don't really want to necessarily start saying let's change the entire market structure. Our point is like let's add a market where none exists. And that is kind of the afterthought, the aftermarket, but where we really need this hour-by-hour is illusion transparency and evaluation.

And if we have that, well, the question that becomes on the one hand a technological question, can you handle 1,300 megawatt ramp? And whether increasing the pressure that the pipe can take would help would actually very quickly get an economically sound answer because, one, you've got the value on that. You know actually if it's worthwhile to invest in it or it's not because you see what -- how much money people are willing to pay for that.

And in terms of the, you know, can it

handle the 1,300 ramp or it can't, well, we'll find it out. But not only we'll find it out, again, we'll put it all a value to it.

MR. MORGAN: Okay. Let's hear Jeff and then John.

MR. MORRIS: Thank you. I guess I have a kind of lead in to a question. I always get a little bit concerned when I see maps that don't have Canada on them because --

CHAIR TIERNEY: You're next to it.

MR. MORRIS: -- you know, we have such an integrated energy infrastructure on the Pacific Coast, you know, 80 percent of the gas that is consumed comes out of Western Canada. And, you know, one of the things that led, in my opinion, to the California energy crisis was not -- a lot of the electricity forecasters not seeing the opening up of a west to east pipeline in Canada levelizing the cost of gas, and not having gas plants built out.

So where I'm heading with this is I think, you know, there's this construct of the

Pacific Coast that have seen states that have RPS standards and performance standards for electric generation, meaning natural gas or better as far as CO2 emissions go. And so there's this construct that's forced all the utilities down to do, you know, peaker loads because they're not regulated underneath those two regulatory schemes.

And so we've kind of compounded this problem that it's hard to go out and subscribe for pipeline capacity for peaker plants, you know, because where I'm heading to with this is that one of the things I know that the Northwest Gas Association and PNOC did was look at some of the metrics around micro LNG for peaker plants versus going to a market design. Does it make more sense to make that capex investment than to have to subscribe for capacity?

You might only need, you know, seven days a year as an alternative. So I guess that's my question is did you look at that capex tradeoff in infrastructure investment?

And then secondly, too, I think, too,

sometimes that, you know, because we don't require a thermal standard, an efficiency standard around thermal loads like they do for heating loads in California around cogen and so forth, that, you know, when there's a winter event, you know, we don't have that ancillary electricity production from requiring that type of cogen or combined cycle turbines as opposed to peaking turbines that would, again, do an inter-distribution solution versus to have to go to the -- a market to solve the problems and really treat the symptoms and not solve the problems I guess.

MR. ETHIER: On the issue of have we looked at the capex for various firming up of fuels the answer is yes, we looked at that a few years ago and that's was sort of the basis for my statement that dual fuel capability was by far the cheapest and pipeline, you know, paying for incremental pipe was hugely expensive even for a combined cycle resource on a per megawatt hour basis.

If you thought about doing for a peaker

it would be astronomical. So we did that a few years ago. Incident -- coincidentally, Sue's firm is doing a study for us right now sort of updating that and looking at some of the newer solutions, the micro LNG and I think there's also a methane solution that a few folks are looking at out there now and running the numbers on those things. And the thing they're also adding to that is firm contracts with LNG facilities to make sure they have LNG to meet the needs.

And the pipelines are pretty good about if the LNG facility is injecting right now saying, okay, you can start drawing right now even though the facility is a couple hundred miles away because -- partly because of the geography of New England. The LNG facilities are back-feeding the pipes so it works very effectively. But, you know, that study is not done yet.

But it's something we're actively looking at because we want to make sure our market -- we want to get a sense of what our market incentives will drive in terms of outcomes on the supply side.

MR. MORGAN: So John, you were going to get a shot in here. I'm sorry.

MR. ADAMS: Alex, I just want to be sure I understand. Is the vision that you'd be able to trade in your imbalance gas market on this pipeline both future hours and current hour? And if I got that right then the future hour imbalance price each hour you rerun will change, right?

MR. RUDKEVICH: That is correct. And that is true, yes. We will, envision that we will, be trading the forward current hour and future hours and each hour you will revisit that the price will change for the -- so the same hour may have multiple prices depending when the decision was made for that hour.

MR. ADAMS: Right. Very complex settlement statement.

MR. RUDKEVICH: It may be a complex settlement statement but it affects you only to the extent that you change your position from one hour to another.

MR. ADAMS: Right.

MR. RUDKEVICH: If you basically took your position and you're not changing -- in an hour in which you took it you got your price and it's guaranteed.

MR. ADAMS: Do you envision having to keep all the data to regenerate those prices? I'm just -- ISOs get into this all time. Where do you come up with those prices from? Just a thought. You don't have to answer it.

CHAIR TIERNEY: Granger, can I just add a comment on - -

MR. MORGAN: Yeah, please.

CHAIR TIERNEY: -- the capital costs or the economics of different ways to solve the problem? Satellite LNG versus pipeline addition versus dual fuel or something else.

Let me just give you a tale of a real life story in Massachusetts where there is a proposal to build a peaking unit. It was on Bob's chart. The proposal was to have that peak -- gas-fired peaker have dual fuel capability for a certain limited amount of run hours. The intervenors in the state energy facility siting case did not want to have that oil fire generation because of carbon emissions from oil.

And there was a discussion of whether or not there could be an onsite LNG satellite storage instead of dual fuel capability. I was the witness at the siting board facility proceeding and could not imagine the politics of siting an LNG, a satellite LNG. If Bob thinks it's hard to build a peaker, start building those satellite LNGs. So there is this coming context of siting facilities that and potentially locking in new assets that a lot of people are interested in not having built, ever be built.

So there's ending up these just, at least on the East Coast, really heated debate about what are these attributes and that's on top of the economics.

MR. MORGAN: Okay. We're going to go Mark and Jane.

MR. LAUBY:: Well, thank you and, you

know, that underlies my comments right there, Sue, is what NERC is really interested in is when gas does not become available. And what are some what we call single point of disruptions, we are running a study and we'll be releasing something in August around, you know, it all started with the Aliso Canyon on availability.

And of course, when you talk to the gas industry it's like don't worry. Be happy. No, it's no problems at all. The only time that ever happens if regulators get involved but, of course, it was a failure. It was a failure of safety. People getting sick and making the storage facility unavailable which was an important part of operations. And on the short term we were fortunate that, in fact, it didn't have a very hot summer.

But we also are concerned not only about storage facilities but then also natural gas pipelines which, of course, we're assured will be fixed very quickly and will never be a problem but can be a problem. And so -- and you touched a little bit on it, too, Bob, when you were talking about what happens when a nuclear plant goes down. Spot prices, eww. I mean, those units will start picking up. They're going to make up for that loss of 1,000 megawatts somehow unless, of course, they get shut off because there's not enough gas.

The pipeline itself does not have enough pressure built in. How do we plan for that and how do we operate for that? In fact, NERC standards actually call for folks to have planning protocols in place to look at pipeline failures and, you know, firm is not a panacea because if you've got it firm and the gas pipeline is not available, it's a force majeure, adios, I'm sorry that was a problem.

So it starts presenting itself more and more as an energy problem which I know that you're dealing with also, Bob, and ISO New England. We've been chatting with Gordon and the gang there. But you did mention something which I found intriguing and I'd like you to expand on it a little bit more. The difficulty of the silver bullet which is the dual fuel capability and having problems with that, is that around logistics, space, or getting to Sue's issues, she rightly mentions the problem with just building facilities overall?

MR. MORGAN: Yeah. So we'll go to go to Janice and then I think you'll hear that partly the answer is people don't want a lot of oil stored next to them but go ahead, come on, Janice.

MS. LIN: Sorry.

MR. MORGAN: I got your name wrong, I'm sorry.

MS. LIN: It's Janice, thank you. So actually I had related question to Mark which is, you know, when we -- it seems like across the country we're getting more and more into natural gas. And I'm just wondering if you all -- this is my general question, can comment on like what happens when we don't have natural gas because of the methane leakage at Aliso Canyon, very recent case in point. That's an underground methane storage facility in southern California that was the sole source of gas for 18 power plants in the LA Basin.

I think in 2011, New Mexico had this like super deep freeze and somehow the gas pipelines or something went wrong and there was a gas shortage. So I'm just curious about that big picture.

And then my more specific questions for all of you is building on what Merwin said earlier about how can we improve the utilization of our existing assets? And one way is to improve utilization of the pipeline itself through the - - this new market. Line it with that material you were talking about, but what about improving utilization on the demand side through the generating plants themselves?

My good friend here, Heather just deployed say, for example, energy storage and an existing LMS-6000. So rather than store it in gas, can you store it in electricity and get better utilization? But that kind of depends on the daily cycle of the need and I'm wondering if you can -- you said 23 days. But what happens sort of in the course of a day and is it something that energy -- electricity storage could help with?

MR. ETHIER: Well, let me try to address at least a couple of the things that have been brought up. First on the dual fuel issue. My take on it is it's -- a small part of it is local siting that people don't necessarily want anything that makes a power plant in their neighborhood dirtier. But the bigger issue, at least in New England, seems to be more they don't like oil generally.

Oil's just dirtier and even though a 7,000 heat rate light oil unit is going to be far, far less polluting than the 10,000 plus heat rate heavy oil units that they're displacing, our system is not very good. Our system broadly, not the ISO system, but the broad system is not very good at making those tradeoffs, even when to the dispassionate observer they make a heck of a lot of sense because they're win-win.

So it's really around the politics and the siting. It's not the space. It's not the infrastructure investment. It costs money but we're putting a heck of a lot of money on the table and the generators are -- that are able to seem very interested in making the investment. So that's the first issue.

On the issue of backups, what if we don't have gas, I guess is part of your question. Interestingly, well, if we didn't have any gas it would be a bad day at the office but --

CHAIR TIERNEY: You couldn't go home.

MR. ETHIER: Or wouldn't go to work, one of the two. But one interesting thing is renewables actually help with that even though they're not dispatchable. Gas because gas can be stored so readily in the pipes, anything that displaces gas use within, let's say within an operating day is helpful when you have a gas crisis.

You know, there do come upper limits on the maximum amount you can deliver in any short period of time but, you know, adding a 1,000 megawatt wind farm that runs flat out for five hours but not for the rest of the day actually does help the gas situation in a complex way but it actually does. So that's, you know, I know only a piece of your question but that's at least one thing we have discovered and sort of recognized as renewables sort of flood into our market.

MR. MORGAN: Okay, anything else? Yeah.

MR. RUDKEVICH: I would add to that, I think it's an excellent point because when we have well-integrated gas and electric system, to the extent that, I mean, gas is essentially -- is a storable and compressible media. So the storage that we may be missing or not having on the electric side could be actually by displacement obtained on the gas side when we need it.

And the tradeoff between whether it's a better gas storage or electric storage, well, that what people can find out. We can't decide ahead of time like what is the optimal configuration.

It will always depend on the current condition but I think that's an excellent point that if we have a well-coordinated intraday gas and electric system, we can take advantage of this storability of gas inside the pipeline.

MR. MORGAN: So we have three more cards up and Madam Chairman has granted us another five minutes. So why don't we do these three?

CHAIR TIERNEY: You have to ask Carl. The diurnal. And one follow up in regards to diurnal. I missed the part of the question but a follow up on that, on the -- from Janice's question. Sorry.

MS. LANEY BROWN: So I am just curious on the 23 days.

CHAIR TIERNEY: Oh.

MS. LANEY BROWN: Within the day what is the shortage? Is it certain hours of the day or is it for all 23 of those days 24/7?

MR. ETHIER: Oh, you're -- okay. So it's typically for a handful of hours, the peak hours in a day that we'll have shortages because you run out -- you get to the point where you don't have any more gas to run gas-fired generators right at that period in time because you've -- there's -- if you burn more gas then you wouldn't have any more for later in the day that sort of thing so.

MR. MORGAN: All right so let's just quickly come up along the line without any responses and then we'll wrap up.

MS. MARILYN BROWN: Okay. Two quick questions. I had noted in Alex's presentation that there was a comment in terms of articulation and value. That the design that you're working on helps articulate value to regulators and I'm just interested in how you envision that might change the conversation or how that might impact, you know, the discussion with regulators. That's the first part.

And then the second part, in Sue's presentation she talked about kind of this crisis or, you know, the significant blackout in electric industry drove a focused and regulation reliability. I'm curious if you can envision something akin to that happening with the gas.

MR. MORGAN: Yeah, or is the gas industry aware that that could happen that if they -- yeah. And that could certainly get a lot of regulatory interest.

MS. MARILYN BROWN: Yeah.

MR. MORGAN: Moving up, Gordon, do you -- is your card up? No. Chris, last one.

MR. SHELTON: Hi, one -- two question. One, both are for Bob, how are the changes that you said you're making are in motion, how are those getting exposed to the load side? And if at all in what ways? And because that seems like an opportunity based on what we're seeing in other markets. And the -- and it solves the permitting problem, so same amount of money, less permitting potentially.

The second question is what is the import, what is your sort of daily import capability in the non-peak hours during the scarcity seasons on transmission?

MR. MORGAN: Go ahead.

CHAIR TIERNEY: We thought there was one more question.

MR. MORGAN: No. No, that's it.

MR. RUDKEVICH: Okay. I can start with the locational trade value question. So as I understand the question was how is it going to help in a regulatory context. Well, I mean is -- let's say if you need to justify an investment to the regulator typically you come up with a cost-benefit study. And the costs are typically understood. But sometimes quantifying the benefits is difficult and when you have the value on what you deliver which is very granular, you can actually much better justify the benefits.

So for example, it's a lot of studies on electric side when people look at the, you know, the benefits of say, putting in a new transmission line in place. And that is often done with the nodal price in models in place, I mean, the analogies here symbol.

MR. MORGAN: But I think the corollary

to her question, Sue and Bob may have a thought as the extent to which the gas industry is aware of the fact that if you ever did get a major outage as a result of a gas shortage, Congress is not going to sit around. I mean, there'll be an action. It'll almost certainly be regulatory and so I would have thought that was an incentive to be a little more cooperative in trying to resolve these issues.

CHAIR TIERNEY: So I have a response from my NAESB experience where, again, the process at the standards board is that people in industry segments vote on whether or not they want to adopt a standard. And some of the discussion about this gas-electric issue revealed to me that there were very different senses of urgency across the divide of the two industries.

I believe I posed the question to the group exactly like you described which is it going to take actually a major disruption to get people to --

MR. MORGAN: A lot of people's pipes are

going to have to freeze.

CHAIR TIERNEY: Yeah, to light a fire, so to speak under the groups. And I actually don't -- so the -- there were assurances that that's not going to happen. I was less sure of that.

But I don't know how it would play out at the moment in this era of polarized politics in Congress around fuels. You could imagine one response would be to adopt a different set of government regulations or energy standards process. But you could also imagine people saying yeah, we told you so. We should not have gotten rid of our coal plants.

So I really don't know what -- how it would play out at the moment. It is just such a crazy controversial setting around which fuel is better or worse and who knows where we go.

MR. MORGAN: So lastly, any response to Chris's question?

MR. ETHIER: Sure. I'll do the easy one first which is what's our daily electric import capability and I think it was you were asking about electric side.

MR. SHELTON: The unused during these constrained times --

MR. ETHIER: Oh. Zero to some would be the answer. And it really depends on the weather in Canada. So if the weather is Canada is not sort of on a relative scale worse than ours, or it's somewhat better which happens, then the Canadians are more than happy to sell us electricity at $400 a megawatt hour. They love to do that and twice on Sundays.

MR. SHELTON: Yeah. I guess what I was thinking about is as it relates to Janice's question, you know, is there any opportunity to offset, like you said, if you had this five-block renewable it would -- could be valuable. I was just looking to the transmission system to do that --

MR. ETHIER: Yeah.

MR. SHELTON: -- in a, you know, vaguely --

MR. ETHIER: It's utilized pretty fully. I mean the market does a very good job of squeezing every last megawatt out of Canada when it's available. Are there certain times when it would be helpful if they had a few more generators available? Yes. It's a pretty small number of hours a year though.

MR. SHELTON: So I know we're out of time but I guess we can talk after but could you uneconomically dispatch resources so that you have more gas later?

MR. ETHIER: Okay --

CHAIR TIERNEY: He's going to ponder that.

MR. ETHIER: Yeah. My initial instinct is no because a lot of the Canadian system is hitting its limits when they're not selling it to us because they are all flat out on their end. Otherwise they're more than happy to sell it to us. So that's my initial response.

And then the slightly more challenging question was -- the slightly more challenging question was, you know, how are the gas-electric changes, and I assume you mean the pricing changes that we made, are they being exposed on the load side? And the answer is not very well. We still have peanut buttered rates and things like that so we may hit $9,000 megawatt hour. There are very few on the load side that actually face that price. So that is definitely something that could be improved and the ISO consistently states we would love to see real-time pricing and the regulators consistently don't seem to be as interested as we would like them to be so.

MR. MORGAN: So with that a final round of thank and then we're going to resume at 4:50.

(Off the record.)

CHAIR TIERNEY: Hi, Paul.

MR. CENTOLELLA: Hi.

CHAIR TIERNEY: Go ahead.

MR. CENTOLELLA: Okay. Well, that was clearly a fantastic last panel and everyone I know wants to keep talking about it, but I'm going to interrupt us and bring us back to Smart Grid

Subcommittee and we have a paper that's up for a vote in this meeting. So I am going to, you know, briefly talk about what the Subcommittee has been doing and then dig into the paper and we have both a slide summary of it and the paper is also available. We can put it up if anyone has specific things that they want to look at in it.

So overview of the Subcommittee, first of all, for those of you who may be new in the room, this is a statutory Subcommittee of the EAC. It was created in the Energy Independence and Security Act of 2007 with specific responsibilities to advise DOE around smart grid and various issues related to that.

What we have been trying to do related to where we're going in this discussion is over the last little over a year, bring together for the full EAC and for our committee a series of panels and speakers and, you know, and looks at this question of how do we begin to value and integrate DER from a variety of perspectives looking both with some good external experts, and

I'll talk a little bit about a few of those that we had early on to remind people, together with also looking at what's going on within DOE both within the Grid Modernization Initiative and more broadly which form the basis for the paper that I'll be talking about here shortly.

So we started this off a year ago March with a very good panel. Heather was on the panel talking about how you actually begin to do this in the real world and we had three other speakers which, you know, which really began to kick off this discussion. First of all, Bill Kallock from Integral Analytics who is -- that is a firm that does a lot of planning for DER for leading utilities, talked about doing this kind of layered planning looking forward about exactly where and when on a distribution grid DER would be valuable.

We also had Michael Caramanis, a colleague of Alex and mine at TCR, who talked about a report that I coauthored with Michael and others on the report looking at how you begin to value in the context of the kind of platform market that, you know, has been discussed in New York REV. You know, distribution energy -- distributed energy resources within a distribution system.

So can you calculate real and reactive DLMPs and does it matter? And it turns out that at least in some circumstances it does matter and can matter a lot. And so you know, this was done for an illustrative sort of suburban kind of grid. I show you some numbers here and it really does matter in terms of the value of different distributed energy resources. And it values also -- it matters also because this is a distribution level market that has to operate to some degree on a kind of independent, not totally independent because it's linked to it, but you're not actually going to be able to dispatch every single home with flexible generation, every single distributed generator. You've got to think about these kinds of distributed markets to make this work.

And finally, we had on that panel a professor from Georgia Tech going back to our earlier discussion of power electronics, who talked really about the role of power electronics in the distribution system. The graphs here are graphs for what you can do -- what the actual voltage profile of a secondary distribution line looks like, something we don't typically look at because we don't actually monitor it. And it's much more ragged than our models would suggest. And then what happens when you actually put some very fast power electronics on that secondary distribution circuit which enables you to flatten that voltage profile. Essentially get five to seven percent demand in energy savings by using advanced power electronics as well as potentially significantly increase potentially up to 100 percent or more of the distributed PV or other distributed resources that can go on the circuit and actually begin to support voltage in the bulk power system.

So these are the kinds of things that began to shape our discussion of thinking what does it mean to begin to value and integrate distributed energy resources in the power grid. So what we did was we developed a paper. We started with some basic facts about distributed energy resources. They are here today and they are growing.

We already have and this is largely EIA data, 14 million customers that are already supplying power back into the power grid. We have about eight percent of our total generating capacity in the US that is combined heat and power. We have nearly doubled the amount of small distributed PV from 2014 to 2017. A majority of that is residential rooftop PV.

We have some 16 million customers that are either participating in demand response programs or on some form of time-varying rates. We have -- so the figure I have is a couple of years old but about three percent of residential customers have backup generators and that's been growing at double-digit growth rates each year.

We have -- there's the last figure I have was over 500,000 electric vehicles but if we use them smartly in terms of their charging cycles would also become a form of distributed storage or distributed energy resources. And we're seeing these advanced power electronics come in and really begin to change the way we think about the distribution system.

And each of these, it's not just, you know, rooftop PV, it's not just storage system. Each of these is a form of distributed energy resource that needs to be integrated in the way we value the power system.

So if I can get this to work again, there we go. So we have here in the paper a set of findings and recommendations that basically fit into four areas. The first is in terms of valuation and market integration. So we have and we didn't get -- unfortunately we did not get ours down to the four-pagers that Anjan did but we did put in an executive summary and a brief summary of findings and recommendations at the end. And that's largely where what I'm going to talk about comes from.

So one of our findings was the need to develop tools to support more efficient markets with more granular price signals and to integrate DER into those markets and coordinate also the valuation of DER with FERC and with state regulators. So one of the real premises of what we're finding is that the value of distributed energy resources is very time-dependent; it's very dependent on system circuit location, the electrical product. It is real? It is reactive power? It is reserves?

And even- in some cases- customer-specific in terms of its value. This is something that is being looked at by states across the country in different geographic locations from different political perspectives and it's an important issue for them. We today do not do a great job of integrating distributed energy resources at a market level.

As you heard Bob talk about in the last panel, when we settle in wholesale markets the settlements that go to retail suppliers that might otherwise give them an incentive to work with their customers to efficiently integrate and operate DER, they're peanut buttered on a load zone and an hourly basis so that much of the signal that might lead to more efficient integration doesn't happen.

So we thought that there were two important objectives for the department here. One was to develop increasingly detailed, accurate, and transparent methods and tools for valuing DER in the context of planning and the consideration of DER as an alternative to more conventional distribution investments.

The second was to begin to develop increasingly granular market models so that we could begin to see DER actually play in a market context as we go forward and not have to -- and in effect be able to extend our competition policies deeper into the power system. So that led to recommendations on additional R&D from methods and tools to ensure the appropriate time, location, and product-specific valuation of DER, and system planning and operations, and on improved market models as well as continuing to work with regulatory authorities to look at policies and rate structures that would advance more efficient integration of DER.

So that was one area that we addressed. A second area is in terms of planning and operations. And in here we looked at the fact that we thought that DOE has a unique and important role to play in the development of methods and tools that relate to planning and operations of the grid. We recognize that the power grid, much as Anjan talked about earlier, involves ultra-large scale complexity. And DER only make it more distributed, more dynamic, more challenging to plan and operate.

So this is going to require some fundamental changes in the way we plan and operate the grid. It's going to require some way to understand something we don't understand today. What is the appropriate role of centralized unit commitment and dispatch together with more distributed markets together with these very fast-acting power electronics and things that happen at a much quicker level at more distributed places on the grid?

Today we know something about each of those things. We know very little about what's the appropriate balance and how they should work together. And we think that's a very important initiative that DOE needs to take on because essentially this is a -- if you're looking at this as a vendor, this is a very small and highly regulated market so that while the return to the economy might be high from doing this well, the return to a vendor for actually developing the analytics and the software is likely to be quite small.

So we think that there's continuing R&D on tools, computational methods, more dynamic and distributed models for the grid, simulation tools, all of this related to research on how you do it and how you begin to balance this interaction of centralized markets, distributed markets, and power electronics to make this work as an important priority for DOE going forward.

The next area is just one of really reaffirming that there is a role for the department with respect to both basic and with respect to what we call goal-directed applied R&D. And we think DOE has played a positive role in both of these areas both through the Office of Science and through some forward-looking applied R&D that's important for modernizing the grid. And this is an area where we think DOE in terms of grid modernization and the integration of DER has a unique role to play.

And we identify valuable programs both through the Grid Modernization Initiative that you heard about earlier but there are other things, the cybersecurity and critical infrastructure program. Some of the report -- work that goes on in OE related to standards development, some of the projects like the one you heard from Alex that are funded by ARPA-E that particularly in those areas that related to the grid-focused research.

There's been some really good work that's come out of there.

We recommended continued support for this Multi-year Program Plan related to grid modernization. We don't mean to exclude other things by saying that but we think that's an example of looking forward to where the needs are and directing a portfolio of research that is designed to meet some objectives that we need to meet in the near term.

Finally, we think there's an area here in terms of DOE using its convening authority to coordinate between entities and stakeholders to provide science-based information and to provide technical assistance. We heard a little bit about this earlier. The operation and oversight of the grid is divided between federal and state authorities, between over 3,000 utilities, 7 RTOs, and many other stakeholders and entities that have a role.

This kind of division actually has value. I mean there's -- I'm not suggesting that there ought to be one model for everybody in the grid. Having some differentiation promotes experimentation and opportunities to figure out how to integrate new technology while reflecting appropriately local perspectives. But DOE has an important role to play in coordination and providing access to critical information that not everyone will have equal capability of accessing.

So in this area we thought it was important that there be a sharing of information on the frameworks that are already under development in many places and that in thinking about this, it needs to involve both a consumer and a utility perspective of how to make this happen if we're going to get to some consensus about how to go forward.

So those are the basic elements of our report. We have some ongoing work we started at our last meeting with a panel on the internet of things. We will continue to work in that area, continuing to examine the cybersecurity concerns, looking at potential applications and benefits.

I'm sure we will also look at interoperability standards, something mentioned earlier today. And we have had an initial discussion, and I suspect we'll pick that up perhaps even at our breakfast tomorrow morning before the start about where we might go about thinking about infrastructure investment in the grid.

So that's where we are. That's at least tentatively where we're going. And I'm open for questions about the paper or anything else.

MS. CURRIE: First of all, I want to congratulate you and your Committee, Subcommittee, on this report. I think you did a very good job articulating some of the issues that we need to focus on and also I just think it's written in a way that's easily understood.

Two comments, one is I think that so many times smart grid DERs are considered synonymous with smart meters by a lot of the public. And I think anything that we can do and that DOE can do to make people see a broader understanding of what smart technology means in the electric industry is valuable.

The second thing that I want to comment and congratulate you on is the point about trying to value distributed energy resources from the consumer perspective because I think that, again, it's very important for all of us as we look at how we integrate these resources and value them and price them particularly is to be able to give consumers a sense that they are getting something. Because, you know, I think from my utility experience when you have to go and argue for the investment in the form of a rate increase, now the first thing people want to know is well, what is this doing for me?

And that sometimes is not a question that is answered quickly, easily, and succinctly. And the more you sputter around in these kinds of forums where you talk about raising rates and you can't clearly say what the consumer is getting, the more your credibility erodes. So again, I think it's very important for us to keep a focus on what is the consumer getting out of all of the millions of dollars that will be spent to bring this kind of technology, change, and functionality to our industry.

MR. CENTOLELLA: Thank you, Phyllis, and I want to say thank you to all of the members of the Subcommittee that worked on this because this really had input from a lot of people and I appreciate that.

Mark?

MR. LAUBY:: Thank you. And I would also like to congratulate the group. I thought it was well-written. A couple of things that come to my mind and I think you're touching on it here and that is that one of the key value equations is the closer you get the resources to the customers, the more reliable it's going to be if you can manage it and control it, right? And so when I thought about that and I thought about the high speed issue which scares the living daylights out of me because of what happened recently (inaudible) when we found out that inverters were instantaneously calculating frequency as opposed to being time-varying, but slow down a little please and get the right -- get the frequency right would be my message there.

But there's been some work done in Germany, I'm sure you're aware of it, where they actually have DSOs where they're managing some of this, is -- have you -- has that kind of come into your thinking here and what areas perhaps we need to really look at advancement and what things we can borrow?

MR. CENTOLELLA: So I mean it's interesting and I think it kind of touches a little bit on the discussion that we had this morning where we were talking about the interface between the bulk power system and the distribution system. And so there are now a variety of models out there beginning to think about that. Is the traditional distribution utility simply calculating what the hosting capacity for these things is? Is it trying to value it? Is it creating a platform to help facilitate transactions and services?

And ultimately, you get to the question of is there a transactive piece of this? And so we followed a little bit, for example, there are some examples in Europe where you actually have to peer-to-peer markets that are emerging with this distributed technology and I think if we get to that question here it will both operational questions. But it will also raise very significant jurisdictional questions because you now have markets that may be used to operate the distribution system that involve both retail and wholesale transactions. And I'm not sure who has authority over that and that may be a question that DOE can help FERC and the states figure out but I don't know the answer right now. And when I -- I have asked that question to a FERC commissioner before and the answer I got was it's a quilt.

So if anybody knows what that means please let me know. Jeff, I -- do you have your card up?

MR. MORRIS: Thank you. I'm wondering I

think what we struggle with in the State House is sometimes this question is having a good idea of where the precipice is for when these values should be propagated up to centralized markets, propagated out to system benefits, or propagated behind the meter like that as a service or decentralized market. Do you think that part of this concept is that identifying where that precipice is for that decision?

MR. CENTOLELLA: So I think there are two questions here. One is I do think regardless of where we go, we really have to do the research to understand what the appropriate balance is between centralized markets, local markets, and faster-acting equipment. That's part of the question.

When you get down to asking how deep into a system do you propagate these values, that's a question that you can actually model and you can decide is the difference of going the extra step significant enough that you want to make the expenditure to actually settle at a lower point in the grid. Now I guess what one of the things I would say is that there clearly are places today, and I don't know whether it's everywhere, but there clearly are places today where simply settling on a load zone and hourly basis seems to have real costs.

There's at least one RTO zone I'm familiar with where the differential on a peak day between different load nodes for hourly average prices is over $1,000 a megawatt hour. That seems to be an example of where one would clearly think one ought to go at least to the load zone, load node point and maybe go beyond that both in time and locational granularity. But that's the kind of thing that we're sort of stuck with our historical way of doing this and we ought to be asking how far we should go.

CHAIR TIERNEY: Maybe one more question from Laney? Is this card up?

MS. LANEY BROWN: Yeah. It's actually brief and it was more just a validation I think of what we heard today in regards to the GMLC report out that there's an increased need for support on regulatory and state and I think we have that, that we sort of have queued that up. So I just thought it was an interesting note that I think continues to validate one of the recommendations we put forward.

CHAIR TIERNEY: Last question I'll take.

MS. MARILYN BROWN: So we -- when you were in Atlanta last month I had posed a question. I wonder if you thought about it some more. We were discussing the ability of -- to demand response on the demand side of the meter to be able to help balance demand. And we were talking about the role of electric utilities and providing potentially internet services and the investments that might be needed in fiber optics in orders to bring quality internet Wi-Fi access to places that right now can't really support distributed demand-side resources.

And I wonder if you've had a -- you know we've got a line there about or we've got a bullet, a whole bullet, about infrastructure investments.

MR. CENTOLELLA: Yeah. So that's our future work --

MS. MARILYN BROWN: And I know we didn't weave anything, we did not weave anything about this into our current paper.

MR. CENTOLELLA: No, it's --

MS. MARILYN BROWN: It's too, you know, out there but it is a real problem. I was talking with Southern Company yesterday about the problem it's not just rural America. That's what TVA is looking at: rural poverty and small towns that can't get internet and therefore, it can't participate in any of this. It's also the city of Birmingham. It's got so much poverty that they, you know, traditional Wi-Fi suppliers won't touch it.

So they won't go there. So how do we help the microgrids of the future run if they don't have this kind of fiber optic backbone?

MR. CENTOLELLA: So I guess my short answer knowing that this is, you know, we're really running against time is that different network requirements, there are different network for different services. And so one has to think about what it is that one is trying to accomplish and then make the case. And so we can have further discussion about that but not every network is -- needs to be fiber and have the ability to deliver high bandwidth low latency. But that's a much longer discussion.

CHAIR TIERNEY: And now that's the last question. Dr. Morgan?

MR. MORGAN: So I'll vote to approve this as it is but will you consider in five continuing and expanding support for regulatory authorities blah, blah, blah, that advanced innovation and economically efficient inte -- I'm worried about promoting innovation in this space. I mean and regulatory changes could have a big impact there. I mean, if I for example relax exclusive service territories even a little bit so that I could have innovative microgrids down under the distribution system, you know, then a whole lot of private sector people could get involved and start innovating as long as only a regulated -- so it's up to you.

I mean if this is too late to contemplate -- what?

MR. CENTOLELLA: So I think he's talking recommendation number five --

CHAIR TIERNEY: Hold on, hold on, you guys. This poor gentleman has to figure out the tramped upon words. So one at a time.

MR. CENTOLELLA: So could we get the pdf up?

MR. MORGAN: Yeah, in five that advance, I mean, in the second line of five that advance innovation and economically efficient integration. Very --

MR. CENTOLELLA: I would consider it friendly. Any reaction from the rest of --

MR. MORGAN: Yeah, it would be friendly and if it's --

MR. CENTOLELLA: -- the Subcommittee? I --

MR. MORGAN: -- if -- and I'm not going to vote no even if it doesn't get put in.

MR. CENTOLELLA: Okay. I would consider it a friendly amendment. Can we go down to recommendation number five, it's about a little further down the page?

MR. MORGAN: Right to the near -- it's at the bottom.

MR. CENTOLELLA: There, you've got it.

MR. MORGAN: Right.

MR. CENTOLELLA: So advance --

MR. MORGAN: Advance innovation and --

MR. CENTOLELLA: -- innovation and economically efficient integration? And I'm thinking I will take that as a friendly amendment unless anybody objects. And if not, maybe we can have a motion.

MR. MORGAN: Thank you.

CHAIR TIERNEY: So is there a motion to approve amended?

MR. MORGAN: So moved.

MR. CENTOLELLA: All set.

CHAIR TIERNEY: I hate to ask if there's any further discussion. All those in favor? Aye?

SPEAKER: Aye.

CHAIR TIERNEY: Opposed? Great job on this. Really great job.

MR. CENTOLELLA: Thank you.

CHAIR TIERNEY: We have next up the Energy Storage Subcommittee for another work product.

MR. BROWN: Thank you. Let's jump right into this and again, I'll run into trouble using this probably. Okay, these -- I want to just briefly cover the Energy Storage Subcommittee's 2017-2018 activities and plans.

First of all, there's been a slight change in our structure administration in that Chris Shelton who's been our vice chair for the Subcommittee for a number of years, his job and his schedule is such that it was difficult for him to fulfill that particular position but he has. I want to say he's been contributing an awful lot to the Committee but this is sort of a scheduling issue. And so he was willing to step down and the -- I held some kind -- I went through a process and picked Ramteen Sioshansi as the new vice chair. So just make that for the record.

We have finished the high-penetration energy storage work product that Chris was the one who initiated and led the effort on this. I might add there were a lot of contributors in this particular effort. A lot of people put a lot of time into it. But Chris is going to discuss this in just a moment because we're bringing it to the group here for a vote.

And then some new work products we're working on, one of them is the thermal storage one that on opportunities and challenges that Ake's going to work on and this one has come about because you may recall a couple of meetings ago in, I think it was our five-year plan, but one of the reports we put out we brought in the scope of energy storage to go beyond electricity-in electricity-out storage to look at other things. And the first big one we're going to tackle there is to identify what's meant by thermal storage and how it would interact with the grid and affect the grid.

And if we have time, I'm going to go into a little more detail about some of these. The next one, another work product that we want to start work on is called rate, tariff, and regulatory design for energy storage: lessons learned. This one Ramteen has volunteered to take on with help from Tom Sloan who is a previous member of this Committee who has a really strong interest in looking at this. The bottom line is that energy storage is trying to be deployed in a number of different circumstances, some regulated, some competitive markets, et cetera. And this has led to barriers, frankly, to energy storage deployment because the confusion in this area and a lack of consistency.

And so what this is to look at what's being done in dealing with that so far to see if there's lessons learned and then things that we can pass on to DOE in the way of recommendations.

And then tomorrow we're going to be doing a lot of work on this third work product which is energy storage role in modernizing the electric grids' security and I use this term in quotes because it's really a mouthful of things such as reliability, resiliency, and security wrapped up into that. And again, if we have time in this session I'll go a little bit more into that but that's tomorrow is what that's going to be all about.

And then finally, the biannual energy storage assessment report that we have to put out as suggested by its title every two years is due in September 2018 and Ramteen has agreed to lead that effort. So with that, I want to turn the podium over here to Chris to discuss -- describe to you the report that you have, the white paper you should have, on high-penetration energy storage work product and conduct discussion leading to a vote.

MR. SHELTON: Can we pull up the other presentation or is it -- it may be present here?

Okay, no, it's a separate one. So we started on this quite a while ago and we had, if you recall, we had a panel on this subject. We had folks from the whole, you know, quite a spectrum to come and talk about high penetration of energy storage.

This started with the realization of the situation that we're in in the industry where energy storage is showing up and it's showing up in a lot of different flavors and forms. And there's a realization that this thing might actually be for real and start to scale into the industry. And that reminded me and others as we talked about it of the early days of when renewables were being introduced maybe 15 years ago as renewables started to seriously scale and solar - - wind had already to scale and solar was starting to scale.

All of the studies and work that had been, great work that was done by NREL and others to say let's imagine the future with a lot of renewables. And so all this is an effort to take that and say let's take an analogous approach to say what would happen if there were a lot of storage in the system. So it's just allow ourselves to think that that could possibly happen. And this is not a question of whether it happens.

So what's unique about this effort is it's not a question of whether it happens. It's question of how it happened, right? So you make that assumption that it happened and then you just say what does it look like. And it was Merwin's suggestion that we use scenarios to do this. It's very effective when you have uncertain futures and this is Merwin's analogy as well.

What if we catch the bus of storage? What are we going to do with it? It's kind of like the dog catching the bus story. So it was Merwin's idea to use scenarios and what this does is it allows people to have different points of view but still engage on the topic.

So we set out to do our -- the framework of our suggestions and our paper to DOE using this model of different futures, different scenarios.

And so I'm not going to go read through these but essentially what we have is what we worked on to come up with these scenarios, and we had several working sessions over the past year with two primary dimensions that would be of interest.

And these started to resonate because we found examples that match this diversity already present in what's happening with energy storage. So I'll give you those examples. So the horizontal axis that's driving our scenarios is the policy versus market intensity of the activity that's ongoing. And the vertical dimension is the integration level of that with the planning and operations process of the electric system.

So it's either tightly integrated on the top or loosely integrated on the bottom. So when you put this lens on you get some really interesting conclusions and I'll go into those in a minute. So we ended up with these four scenarios and they have very different outcomes for the electric system in terms of reliability and economic efficiency, right?

So if you end up in different corners of this you could see a lot of activity in our economy not drive reliability, right? So it may be satisfying some consumer somewhere but not driving the reliability of the electric system at the same time.

So that was the lens that we started to look at this through. We have the key assumptions. I think I already covered all of these. The last one I want to highlight here, this was not an implication on reliability. We assume an acceptable level of electric reliability in all cases. It wasn't horrible things are going to happen which would have been more analogous to the renewable case. This was an optimization consideration not a reliability- primary consideration.

So we ended up with, and we've named these, this was a difficult process of naming these but the upper right is for all intents and purposes where a large swathe of our electric system is today. We call that status quo evolved.

That's tightly integrated and primarily market driven. We do have pockets of the country that are not like this just to be clear.

The upper left is some future where you have this tightly integrated, completely policy driven system, right? It's just completely top-down controlled rollout, less market drive there.

The lower left is a case where some policy of some kind for whatever reason drove a drive toward more energy storage. But it wasn't integrated into the planning and it didn't, you know, there was no real benefit to the system in terms of its economic efficiency and reliability that you would have seen in the upper left or the upper right.

And then the last one is what we call the internet of energy. It's more like the internet itself. It just sort of organically grows and some -- it's designed for reliability. It just grows. It's not planned. It just happens, right? So those are possible futures and what's fascinating, I mentioned this a moment ago, these actually are happening. So if anyone's familiar with the self-generator incentive program in California which square is that in? It's this one, right? It was policy driven in the state of California. Huge incentives paid out to install it. Lots of storage got deployed, no visibility or control whatsoever of that equipment and no requirements for that.

So this can happen in these different ways. The upper right would be like a PJM demand side environment. The lower right is kind of where electric vehicles are. They're just getting deployed. They're not integrated into anything, right?

So I use those examples not to prescribe anything but just to kind of illuminate these are the things that we explore in the paper. So we were excited with this resonance. We thought it really shows that there is a lot of opportunity to research this. And I wanted to highlight also that it sort of, you know, all of the papers we're approving today are all directly related, right? They're all different forms or different angles of the same question.

So some key conclusions that there are significant impacts, we could -- you could have significant growth in variable renewables -- these are common things across the scenarios as well. High penetration of storage establishes a critical need to clearly define who holds responsibility for planning and reliability, some of the things I just talked about.

It reduces the need for flexible generation, obviously. So there are -- some of these are some obvious conclusions. We also did a lengthy consideration by stakeholder group which we've also included in an appendix at the end of the paper. So rather than read through these I just want to make sure we cover if there are any questions. So make sure everyone understands what we're trying to do. And answer any questions about that and then go from there.

CHAIR TIERNEY: Laney, is your card up?

Granger's trying to get his card up so you can be called.

MR. MORGAN: I'm sorry. I wanted to just get some clarification under the policymakers and regulators on page 5. It says examine conflict resolution between defector and disenfranchised customers. That's in quadrant three. I presume that includes the issues of social equity and related issues if, I mean, if I'm reading it correctly then you don't need to elaborate.

MR. SHELTON: I'm trying to get to the exact line here.

MR. MORGAN: Oh, well, it's -- I can just read it again. It's under policymakers and regulators. And one of the items is examine conflict resolution between defector and disenfranchised consumers. I'm not sure I would have used the phrase conflict resolution but I'm not proposing you change anything. I just want to make sure that, in fact, what you have envisioned there is the erosion of social equity and access to electricity.

MR. SHELTON: Right, I think maybe we -- I don't know if we want to try to do a real-time edit if --

MR. MORGAN: No, no, I'm not proposing that.

MR. SHELTON: Hopefully, there aren't too many others because we --

MR. MORGAN: I just want to make sure that's what you --

MR. SHELTON: -- but it -- so I think it would be some -- I think we're essentially saying examine disparity or something, right, rather than, I mean, it's implied that we're saying here that there's conflict. There's conflict in objectives probably so I don't know if we add a word there or --

MR. MORGAN: Yeah, but we have a -- in the electricity space at least we have a national objective of universal access.

MS. LIN: So that recommendation was in reference to scenario three.

MR. MORGAN: Yes, I understand.

MS. LIN: Which could also be the agreed defection scenario. And so the assumption was in that scenario that under a very high penetration storage scenario that at some point it would get cheap enough that certain subsets of consumers could leave the grid. And --

MR. SHELTON: And the policymakers can't control that.

MR. MORGAN: Consequences for (inaudible).

MR. SHELTON: Right? The key thing is that --

MR. MORGAN: -- the low end people who can't play.

CHAIR TIERNEY: Guys? I'm speaking up for the stenographer. Please don't talk on top of each other.

MS. LIN: And so the assumption was that there would still be a requirement to provide universal service and that a lot of that universal service would fall to the municipality creating a lot of conflict as you see there. So it's -- the idea was how do you, if in the event that that happens, how do you adjudicate and mitigate those impacts.

MR. MORGAN: Okay, understood. And I'm not proposing any change.

MR. SHELTON: Okay. We could add the word potential and then it would make it a little softer if that --

CHAIR TIERNEY: So Heather, then Mark, then Gordon.

MS. SANDERS: My question is about I don't even know how to frame this. Okay. Let me try. There are recommendations in here that go across all the scenarios and I think that's clear to DOE that that's something we're recommending to take on. And I think that you already have things in play that may be doing that.

The question I have or, yeah, the paper makes no judgment about the goodness or badness of any of these outcomes. I don't know if that's something we should take on but it seems like there's implications to each of those things. I read in a little bit about some of the badness with grid defection potentially in terms of efficiency and optimization, et cetera. But if it's too cheap to measure maybe it's okay.

I'm just wondering is there a follow-on piece of work that kind of assesses the goodness and badness and then how these come to terms? So I'm a big roadmap person. So I'm a big fan of how did you get to this point? I realize that wasn't the point of this but I'm wondering if there's a follow-on that says what causes me to end up in this future and then as I back up what are the signposts and then when do I take on these recommendations for one, two, three, four scenario that are specific. Does that make sense?

MR. SHELTON: Right, yes. I think it was not our scope. It's not generally the scope of the EAC to make the value judgments. So we didn't take that on. So but that's the benefit of DOE doing it and engaging the stakeholders in the process, right? So --

MR. LAUBY:: I wanted to congratulate the group. I really think that this is an interesting way and it's a very good way to take a look at future scenarios, future possibilities. Yeah, you can do pros and cons and you don't really have to care about how you got there. The question is what does it look like? What are the challenges? I think we're going to see even more storage facilities or batteries and different type of storage technologies coming on the system especially as we use more gas.

We saw what happened in California with the Aliso Canyon. And I know that how we got there is not important but I think you're -- it takes us to a very realistic place --

MR. SHELTON: Right.

MR. LAUBY:: -- and not many multiple --

MR. SHELTON: That was the intention was to move beyond the what if.

MR. LAUBY:: And so anyway, I'm excited about the paper and I look forward to approving it.

MR. FELLER: Even though we're not going to make a value judgment about which scenario is the ideal scenario, at least not now, although I would hope we get a chance as a follow up to debate the different scenarios even if there's a world likely to happen which has multiple scenarios happening simultaneously. I do think it would really be helpful at some stage, this is the comment about what comes next after we approve this, that states and utilities may be interested in some tool, like a report card, that says this is how we're doing on our roadmap in getting to scenario one, two, three, or four because we've chosen that.

We've discussed and debated what a world of high penetration of energy storage looks like and we think the ideal scenario for us at this utility or us in this community or us at this state level is one, two, three, or four. A roadmap helps define some of the steps but doesn't necessarily help me like a scorecard might as I'm going through those steps to see my progress.

I don't know whether that's going to be one of those options on the list of next steps after this for our group or for DOE and staff. But if I had a magic wand I'd love to see that especially if I was working at the state PUC or at the utility level.

MR. SHELTON: I think the challenge is that we -- it's -- there's a jurisdictional issue across federal to state, state to state, and federal to federal. You've got federal on federal issues. You've got state to federal and state to state. So it's always challenging when we do these to try to bridge all of those divides simultaneously. We did talk about that in the process.

CHAIR TIERNEY: Carl has the last comment.

MR. ZICHELLA: What power. I wanted to just mention this doesn't have to be sort of a value judgment about where we end up. This can be somewhat of an exercise in tracking. At the Western Electricity Coordinating Council we do scenario planning also and what we do every month is we review developments that track along the scenarios that we've done. And we try to figure out where are we headed? Which of the scenarios is the one that's actually materializing?

MR. SHELTON: Right.

MR. ZICHELLA: As you pointed out, Chris, all four of them are in play right now. But this is an embryonic point in the development of electricity storage and just as it was with solar energy, you look at the supply curves for solar, just ten years ago, and you come to a completely different conclusion about solar energy than you would come to today.

And so I would say perhaps we may want to think about a recommendation to do trend tracking about scenarios, thank you, Janice. To do sort of figure out which of the scenarios is actually coming to be because right now there's a lot of experimentation and it's not clear. So I just suggest that because it --

MR. SHELTON: So I think we could add

that as a bullet.

MR. ZICHELLA: Yeah, I think it would be a very, very helpful recommendation to do that.

MR. SHELTON: So we can add that as a recommendation.

MR. ZICHELLA: I think they probably would anyway but the fact of the matter is, I found it at WECC to be extremely helpful in trying to make some judgments about what the electrical system is going to look like overall including storage but not limited to it.

CHAIR TIERNEY: So would anyone be willing to enter a motion to approve this paper?

MR. LAUBY:: Yes.

CHAIR TIERNEY: Second?

MR. FELLER: Second.

MR. SHELTON: Does the motion include this modification?

CHAIR TIERNEY: Yes.

MR. SHELTON: Okay.

CHAIR TIERNEY: Thank you. I should -- I assume.

MR. SHELTON: I just want to be clear.

CHAIR TIERNEY: Great. All those in favor?

SPEAKER: Aye.

CHAIR TIERNEY: Opposed? You guys did a terrific job on a very insightful paper. Thank you very much.

MR. BROWN: Thank you, Chris. I'm not going to finish the presentation but just make a few -- wrap up a few loose ends here. For the record, by the way, it was -- Heather pointed out that many of the recommendations, observations, conclusions we reached were those that were robust to the scenarios and went across. And from a strategic point of view, particularly from the way Carl was talking about, you don't have to know what scenario or care what scenario comes about if you can see whatever you do to prepare for it, it works.

But the other thing we look for and we really didn't find very much of which is those things that may show up in one scenario that are have very high consequences but not likely to happen in the other scenarios. Then someone like DOE would have to make a decision do we do research to address that outcome perhaps because the outcome is so bad even though it's a low probability so to speak.

So that's another purpose of these scenarios. Regarding picking on that certainly, you know, the -- that's certainly something this group could do or anyone can do. But I again want to point out that was not our intent. These scenarios just happened so to speak by combining those axes, what those two axes did, the crossing in their various quadrants. This is the story that came out.

And so it wasn't value judgment involved at all. It wasn't this is something we want to happen. It was what the authors came up with.

Now having said that, I want to make a comment that I think prepares us for tomorrow. And that is one of the things that came out in this, if you looked at the report carefully, is that renewable generation in a lot of this, maybe all of the scenarios was a reason for deployment of energy storage. Not necessarily the only one but it was a substantial one.

And the question is that due to something that's inherent in what's going on and what we think is going to go on into the future, et cetera. In other words, it's almost an assumption that didn't get captured as an assumption. Or is it just happens to be a mindset that's prevalent right now among us or those in the authors. And therefore we kind of had blinders on as to other reasons that energy storage may go forth and I think that's what tomorrow's going to be somewhat about.

It's looking at now the role of energy storage and resiliency, security, and reliability. There's a lot of words given to that but I don't think a lot of thought and what I might call (inaudible) research, in other words where you do a lot of thought and speculation on what does that really mean and how important is it? How important is energy storage?

So maybe after tomorrow we'll have a new mindset or a broader mindset. So with that comment and I'll quit and I just want to thank everyone in this Subcommittee who put all this work in on this product as well as past products and the products that are to be.

Janice I want to thank for tomorrow in advance because I -- she's put an awful lot into making this happen. And I guess that's it. Thank you.

MR. SHELTON: Merwin, I want to emphasize again -- I want to emphasize one last time this was a highly collaborative work product so I appreciate the comments you made about that it's a good product. But it was the entire Committee practically worked on it in one form or another. It basically was like a hot potato at one point because a lot of us were tied up and so I'm sure a lot of the work product ends up that way. It ended up being a good finished product so thanks.

MR. BROWN: And I guess it was another experiment using scenario planning in one of these processes. We didn't know it would work.

CHAIR TIERNEY: Well, as John comes up I think it's really interesting that the three documents that were approved today are all very different but all highly related. And it's a terrific amount of effort that the Committees put in.

MR. ADAMS: Last man before dinner. I'll be very quick. Power Delivery Subcommittee, John Adams. Heather is our Vice Chair and Heather is doing all the work on this project, I'm so pleased to say.

What we're working on is the transmission distribution interface and what this is about is what you all heard about is we've got a lot of distributed energy resources showing up. I loved Chris' explanation on storage. It's showing up.

So that's what we've got happening. It's showing up and Paul had a lot of wonderful statistics, thank you, for on how much of it is showing up. So the question is and at least at ERCOT, I'm very -- I'm with the ISO. So as this resource is showing up on the distribution system, we have no visibility into the distribution system. We have no control activities on distribution resources.

So as it showing up there is a question about well, okay, at the interface what is going to happen in the future? So that is the question we're trying to address is, well, what is going to happen? Does the interface need to evolve? Do we need to develop more communications?

And then the other question is okay, I'm from ERCOT. I'll talk about what we don't have in Texas. But who can talk about what we don't have in California or what we don't have in PJM or what we don't have in Southern Company? So I think the interfaces are potentially different around the country.

So we thought it was an interesting question to ask, all right, how is this interface going to evolve? What do we expect to happen in the different business and regulatory situations across the country?

So that is the question we are looking at. Our objective, we had a meeting just before this meeting, is to bring awareness to the DOE and other parties of the need to evolve this interface. I think it would be great to have some type of best practice ideas that may be applicable across the country or they may all be different. What are the research gaps, who are the players, where are the seams?

I brought to this the idea that oh, the seam's at the transmission distribution transformer and discovered that oh, other people have other ideas. Maybe that's not where the seam is. So where is the seam? What are the policy tools? What are the interactions? What's the connection between the federal and state regulation?

These are the question we're trying to ask. So what are our plans? Well, let's assemble a team, assemble reference materials. We plan to copy the Energy Storage Subcommitee's successes so we're copying those. We have conducted interviews across the country with experts. So that is our form of flattery is that, hey, it works, let's copy it.

We developed a paper outline, schedule, and perform interviews. Plan to draft a T&D interface paper with findings and recommendations. We did talk about since then that didn't get on this slide is we probably ought to consult with Department of Energy personnel on hey, how does this fit with what you can do. So some consultation in the middle of this, submit it for review and we hope to present to the EAC target next June.

And I am no longer between you and dinner if you don't ask any questions.

CHAIR TIERNEY: Well, I'll just make a comment. I think this is a really exciting project that you guys are working on so thank you for teeing it up.

MR. ADAMS: Thank you.

CHAIR TIERNEY: Other comments? You're afraid I'll yell at you.

MR. ADAMS: I love being the last one before dinner. It's great.

CHAIR TIERNEY: John, thank you for your great report.

MR. ADAMS: Thank you.

CHAIR TIERNEY: Awesome. And in the three minutes that remain I want to thank Katie for staying with us. It's really nice, really glad that you were able to do that. This was a great discussion and tomorrow Janice, as Merwin said, Merwin has also put a lot of time into this project for tomorrow. And we begin at 8:00 and it's a packed agenda so I hope you're able to come on time.

MS. LIN: And we're going to have coffee.

CHAIR TIERNEY: Thanks to Janice.

MS. LIN: My treat, donation.

MR. CENTOLELLA: And for anyone who

wants to join the Smart Grid Subcommittee we will have breakfast at 7:00 in the restaurant at the Westin.

CHAIR TIERNEY: Excellent. And for anyone who is available this evening there is also dinner at 6:00 in the restaurant. And I apologize. I have to go to a different function tonight because I would love to join you. With that, thank you very much and safe travels across the street. See you tomorrow.

(Whereupon, the PROCEEDINGS were adjourned.)

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CERTIFICATE OF NOTARY PUBLIC

COMMONWEALTH OF VIRGINIA

I, Carleton J. Anderson, III, notary public in and for the Commonwealth of Virginia, do hereby certify that the forgoing PROCEEDING was duly recorded and thereafter reduced to print under my direction; that the witnesses were sworn to tell the truth under penalty of perjury; that said transcript is a true record of the testimony given by witnesses; that I am neither counsel for, related to, nor employed by any of the parties to the action in which this proceeding was called; and, furthermore, that I am not a relative or employee of any attorney or counsel employed by the parties hereto, nor financially or otherwise interested in the outcome of this action.

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