UNITED STATES DEPARTMENT OF ENERGY

# ELECTRICITY ADVISORY COMMITTEE MEETING

Arlington, Virginia

Wednesday, June 1, 2016

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SUE GANDER
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P R O C E E D I N G S

(1:12 p.m.)

CHAIRMAN COWART: For the record this is a meeting of the Electricity Advisory Committee for the U.S. Department of Energy and I will remind people that a transcript is being prepared from this meeting and that means, among other things, when you're speaking please make sure your microphone is on and when you're not speaking make sure that it's off. And for any members of the public who may be present and wish to address the Committee, we reserve time at the end of our second day of meetings, tomorrow, to hear from you. And so please sign up with the staff out in the hallway or here at the back of the room if you wish to address the Committee. We'll make this announcement again tomorrow.

Why don't we begin just by going around the room quickly and having members of the Committee introduce themselves? Can we start with you, Wanda, and work our way around?

MS. REDER: Wanda Reder, S&C Electric

Company.

MS. WAGNER: Rebecca Wagner, Wagner Strategies.

MR. ADAMS: John Adams, Electric Reliability Council of Texas (ERCOT).

MR. BOSE: Anjan Bose from Washington State University.

MS. CURRIE: Phyllis Currie, Pasadena Water and Power in California, retired.

MR. GELLINGS: Clark Gellings, independent. And Bernie didn't give me any messages to carry forward.

MS. CARMODY: Paula Carmody, Maryland Office of People's Council.

MR. ZICHELLA: Carl Zichella, Natural Resources Defense Council.

MS. TIERNEY: Sue Tierney, Analysis Group.

MR. POPOWSKY: Sonny Popowsky, retired Consumer Advocate of Pennsylvania and outgoing Vice Chair of the EAC.

MR. COWART: Richard Cowart, Regulatory

Assistance Project, outgoing Chair of the EAC.

MS. HOFFMAN: Pat Hoffman, Department of Energy.

MR. MEYER: David Meyer, Office of Electricity, Department of Energy.

MR. ROSENBAUM: Matt Rosenbaum, Department of Energy.

MR. CENTOLELLA: Paul Centolella, Paul Centolella and Associates, and also Senior Consultation for Tabors, Caramanis & Rudkevich.

MR. TILL: David Till with North American Electric Reliability Corporation.

MR. SIOSHANSI: Ramteen Sioshansi, Ohio State University.

MS. LIN: Janice Lin, Strategen Consulting and Co-Founder and Executive Director of the California Energy Storage Alliance.

MR. MORRIS: Representative Jeff Morris from Washington State.

MS. SANDERS: Heather Sanders, Southern California Edison.

MR. MORGAN: Granger Morgan from

Carnegie Mellon.

MR. ALMGREN: Ake Almgren, Orkas Inc.

MR. MOUNT: Tim Mount, Professor Meritus from Cornell.

CHAIRMAN COWART: Other members of the DOE staff present who should be introduced? Okay. Once again, and as always, let me thank our colleagues from ICF for the work that they always do in between these meetings and helping us to arrange these meetings. And there is a nice contingent from ICF in the room, but my thanks generally to all of you.

MS. HOFFMAN: Okay. All right. I'm going to go ahead and get started. First of all I thank you for all that are attending. I know some folks are at the FERC technical conference. I was there this morning and so came over here right after my panel session, but it was a very good discussion there. I also would like to thank NRECA for hosting the EAC meeting here at their facilities. It's a wonderful facility. I would also like to give my recognition to Richard

Cowart, Sonny Popowsky, Wanda Reder, and Gordon van Welie, all who are terming off of the EAC. I really, really appreciate the intellectual dialogue that you all have brought to the conversations, the movement on topics that we were allowed to address, and the constructive conversation that I think the industry needs to have. Definitely we have had some interesting debates and discussions, but I do appreciate all the support and activities that you all have supported the Committee with, especially your time and energy because I know that this can be some work in participating in the EAC and working on some of the papers and the thought products that have come out.

So I have just a couple of things that I'd like to go through and provide an update to the Committee on. First of all, related to the FERC technical conference, we did spend a lot of time talking about the transition in the electric industry, the change in the generation mix, and how we need to look at reliability going forward, what are the flexibilities that the system requires, what are some of the modeling activities that are needed for the future, and some other conversations around the economics and the cost and impact to the consumers. So I thought it was a great conversation, but that leads to where we're heading, what activities we're doing, which is the grid modernization initiative. You'll hear I think a little bit later on the Lab Consortium, but we're focusing on how can we help move forward with the grid modernization, whether it's tools, whether it's technologies, whether it's partnering with the states. We really want to focus on that and continue to support the efforts where they're needed.

So a couple of things that, you know, I'd like to highlight is that cyber security is still of increased importance for the industry and also for the Department. Given -- reminding everybody that today is June 1, hurricane season starts. We are supposed to have about an average hurricane season unless we get an El Niño, unless we transfer to an El Niño. But resiliency from that perspective is always extremely important as we look at our investment strategies, as we look at what are the risks that the industry has to deal with. So I appreciate the opportunity. Later on today we're going to do an MOU signing with the National Science Foundation. I think that's really important as you start hearing about some of the mathematical and modeling activities and some of the directions that our partnerships are going there.

Some of the other things, just to highlight, is we're diligently working the Fast Act Activities. Some significant part of the Fast Act is the Emergency Authority, which the Department can take action pre or in a recovery mode. As much as I would like to have great insight on an event that occurs on the electric grid, I cannot say my crystal ball is always that good. So I think we'll spend a lot of time figuring out what type of streamlined coordination can be done and activities and supporting the industry in any sort of event that occurs on the system.

I'm not going to go through some of the other activities under the Fast Act. If you have any questions on some of the other Fast Act responsibilities, just let me know and we can talk about that during the break or during another point in time on the agenda. But maybe one other thing that I did want to talk about is the transformer reserve, which was a requirement in the Fast Act. So everybody is aware, we do have to come up with a strategy for a transformer reserve by December 2016. We're working in coordination with FERC and the industry. We did have a technical seminar -- I want to say, what was it, a couple of days ago -- really going after what is the methodology, what is the process for evaluating the current state of transformers in the United States. We do have a very strong work team that's a partnership with Oakridge National Lab, Sandia National Lab, EPRI, the University of Tennessee, Virginia Dominion Power, and a couple of others, and we are doing individual discussions with utilities and entities to get their thoughts and their strategy. But that's the work team that's working on this deliverable and looking at what is the technical needs from the Electricity Sector Coordinating Council, the CEO's meeting. The last meeting we had with them they recommended not only that we look at the current state, but we try to look at where will the industry be five years from now. And so we are trying to get that into our thought process. But that does require a dialogue with industry to help advise us on what are they doing with respect to minimizing criticality on the system, looking at their transformer fleet, looking at where the manufacturers are heading. So I just wanted to give you an update on that.

The next thing that I would like to give you an update on is with respect to transmission I think there has been a lot of progress in the industry in moving transmission forward. One of the things that we are doing is a pre-application process for transmission and getting transmission cited and permitted, even though we're only responsible for the Presidential Permit, any interagency activities for permits. So we are trying to do a pre-application process that is working through the DOE process and system and we have a goal to get this done before the fall so I hope we can get that out and get that through.

And I guess the last thing just goes back to the emergency response activities and I want to give my appreciation to all the folks who participated in clear path exercise. It was an exercise that we did in Washington State which was an earthquake tsunami. We brought a lot of the Federal agency partners out there. FEMA, the local FEMA, the utility industry, Portland Gas and Electric, WAPA, Bonneville all participated in the exercise. But the important thing from my perspective was to educate the Federal government on what some of the processes that the electric sector does for coordination in emergency response and have them understand the process and discussions and type of information they're looking at. And then on the flipside was to have some of the industry hear the types of questions that the Federal government is asking in some of those activities. So I thought it was an extremely good dialogue with a set of recommendations that came out from that.

Just looking forward there's probably one other thing that I'd like to put on your radar in that the Federal government, the U.S. Government, is working with Canada on a joint U.S.-Canada grid security strategy. This was announced by the White House with Prime Minister Trudeau's visit with the President. And so we have an action to work with the QER to look at security baselines, but also look at a strategy with Canada for grid security. So expect that to be coming out soon, you know, most likely before the end of the year. And we'll probably have some activities resulting from that.

So those were the main things that I wanted to bring forward that's on DOE's radar for the end of the year, just so you're aware of what's keeping me busy for the rest of the time. But besides the activities I think the topics that the Committee wants to look at will be very relevant as we close out this administration and figure out what we want to achieve moving forward to make sure that we have the momentum going. But we recognize that we're in the process of a transition here with a generation fleet with the engagement of consumers and a distribution system. So I think it's going to be more important that we work together collectively and we have some more engaging conversations on the topic.

So thank you.

CHAIRMAN COWART: Thanks, Pat. Are there comments or questions to follow up from the Committee on what we've heard from Pat Hoffman? Now I know you all are not shy about asking questions, so.

All right. Well, as I think this is actually an appropriate time to recognize once again the dedication that Pat Hoffman has shown by supporting this Committee and sitting with us, you know, and being in dialogue with the Committee pretty consistently over the course of a lot of years actually. So I would congratulate you and your colleagues at the Department for being with us and not just reading our reports when we send them in. I appreciate it.

MS. HOFFMAN: Thank you.

CHAIRMAN COWART: Next on our agenda is a presentation from the Department on the EV Everywhere Challenge by Bob Graham, and he's present. Thank you. At the Leadership meeting an hour ago we were discussing the important topics that we think that the Committee should be addressing over the course of the coming year and one of the topics that comes up, has come up many times, including today, was the challenge of integrating electric vehicles into the grid and also the opportunities that integrating electric vehicles present in a world where variable renewables will be a bigger piece of the supply side. And here to wet our appetites for more on this topic is Bob Graham. Thank you.

MR. GRAHAM: Thank you, Mr. Chairman and it's a pleasure to be here. It was easier to get here today. I have to tell you that three weeks ago I was invited to go to Jefferson City, Missouri to present to the Public Utility Commission in Missouri. So I landed in St. Louis and decided I would drive out. And I saw this sign that said this is the historic route of Lewis and Clark, so I said okay, I'll follow that historic route of Lewis and Clark. So I get on Route 100 and I drive about 45 minutes and I get out to all of the sudden the road says, road closed, bridge out. Oh, okay. So take a detour. So I turn on the detour and, being a Californian and having no idea how to handle farm country in Missouri, I find myself on a dirt road, buried on a dirt road somewhere in the heart of Missouri. And finally this lady drives by in her pickup truck, and three dogs and her seven bales of hay on the back of the truck, and I flag her down. And she's probably nervous as heck, here's this city slicker out here lost, and she says no problem, just keep bearing left at the five different forks you'll see and eventually you'll hit a paved road, turn right. So I did and I finally made it to Jefferson City, Missouri. So it's a pleasure to be able to come such a short distance. (Laughter) I also have to caveat this discussion -- and all the answers that I give to all of your questions that I'm accurate on, then give Clark Gellings credit. On all the issues that I answer incorrectly, you can blame those on me, because Clark hired me in 1999 to go to work for EPRI at a time when the electric vehicle market was virtually dying and he stood behind me during an era when we were able to develop the first die down plug in hydroelectric vehicles. We were doing fuel cell bus projects in Brazil, we were doing fuel cell bus projects with Georgetown in order to keep the whole idea of electric transportation alive. Back in those days people don't remember, but it was EPRI, Southern Company, Southern California Edison, Detroit Edison, and

New York Power Authority (NYPA), who joined with the auto industry and the DOE to fund the development of lithium ion batteries. And if it wasn't for those lithium ion batteries and that investment that we made, then there would not be an electric vehicle (EV) program today. So we need to say thank you to all of us who made that happen and we've made tremendous progress, which is what I'm going to talk about. But I understand that Clark is leaving your group, but I just want to let you know just more examples. When I was looking for some guidance about a month ago to think through how to work with utility executives to engage in electric transportation, I took the time to drive down from San Francisco to meet with Clark in his home in Morgan Hill to ask questions and learn from him. Even today I'm still learning from him, so I appreciate it and I want you guys to know that.

MR. GELLINGS: Thank you, Bob.

MR. GRAHAM: So EV Everywhere. I was hired by the Department of Energy by -- Assistant

Secretary Danielson asked me a year ago, almost a year ago today, to come back to the DOE to take over the EV Everywhere program, with most of your concentration on the deployment side. So the policy, deployment, and engagement with utilities, that was the primary driver for my job back with DOE. I have some efforts in terms of research and development. I've worked with Kevin Lynn who just left and Pat's team on the grid modernization issues. I was especially focused on the linkage of cyber security between the grid and the vehicle. When I arrived, there was a lot of focus on the security around the grid and there was some focus at the auto industry around security around the vehicle. There wasn't a lot of discussion between the two. And so there now is a project, as part of the grid modernization program, that Assistant Secretary Hoffman runs that includes grid modernization and cyber security, looking at the connection between the two because we think they're important. And I can answer those questions as much as you'd like on that subject.

So I've got a very short presentation because when asked about what I should do at this discussion, it was really clear that I need to really just answer questions, and I'm here to do that. I've got a reputation that if you ask me a question I'm probably going to answer it. So feel free, and let's see what we can do.

EV Everywhere is a broad effort. EV Everywhere UP is the overarching goal of what we're doing, like (inaudible) benefits and awareness, let's people out, recognize the economic value of awareness. Workplace challenges where we know that half the charge is being done at workplaces, the rest of it's being done at home. So we do a lot of effort to get people to join workplace charging. Research and development -- I'm not as active in research and development because the Vehicle Technology Office has a team of really good people with the National Labs to be involved with that. But in certain areas, such as the movement toward 350 kilowatt, KWDC fast charging system, I work really hard to ensure that we have a program to address that as I did previously about cyber security.

I'm very focused on grid modernization, which is a subject that's dear to all of your hearts because I think we're spending billions of dollars to modernize the grid and I think it's really important for those who are thinking about electric vehicles to think about which fuel is going to be available 50 years from now that I can count on. And the answer to that question is electricity. So we're trying to get people to recognize when you make the investment in a modern grid you are also making an investment in electric vehicles and the future of electric vehicles. So it's really important to link those together. And sometimes when you get out into the Jefferson City, Missouri's of the world they don't even think about modernizing the grid, they don't even think what the benefit means. So I think we need to tell the market and then we need to link electric vehicles and that expenditure and the progress we're making around the modern grid and electric vehicles together.

State engagement is the whole effort to try to get states to engage in electrification development and appropriate plans so that states and communities can make a wise investment in infrastructure and a wise investment in what they do in terms of modification. It's really important to think carefully about what we do.

So we have a grand goal of reducing the -- getting the price down to be convenient to all. That's pretty obvious. We are being very successful in terms of the research and development driving costs out of the equation. I mentioned 1999 when Clark and I were involved with the United States Advanced Battery Consortium. When it first started, this red line would have been off the chart up to the left. Today it's down around $125 in a buy in price for lithium ion batteries. So the price has dropped -- I'm sorry, it's about $260 with a goal of getting to $125. We're making tremendous progress and some people are saying, especially when you think about

Tesla's giga factory in Nevada, that we're already achieving the $125. So cost isn't really the issue in terms of electrification any longer. The biggest issue with electrification is we have not developed a national value proposition for electric grids. So I can tell you what the value proposition is for pickup trucks. My gun rack looks really good in the back of my pickup truck. I can tell you what the value proposition is for SUVs. I sit higher up, I feel safer, I can see better. So there's value proposition. We have not developed that same value proposition for electric vehicles and we're spending a lot of time driving and we're trying to figure that out.

We spent a lot of money, as you know, because you advise these programs, on advanced and light weighting. We just recently issued an effort around $58 million dollars. So that's continuing. It continued from the Bush administration into the Obama administration, and I'm very confident it's going to continue into whichever administration we have in the future because people recognize the value of research and the value of moving into the future.

The market is strong. There's a lot of people that don't think we made much progress, but if you think about five years ago when I first drove my first Bolt that I have with roughly 45,000 miles on it now, there were hardly any electric cars in the marketplace. Even in the market today with low gas prices, while the compact car market virtually stopped with low gas prices, literally fell off the table, the electric vehicle market continued to move upward. Did it move upward at the rate we would like it to move upward? No, but it continued to grow. So there is still a very strong interest. An when you think about the 453,000 people who decided to put $1000 down on a car yet to be developed, to buy the Tesla Model 3, it just gives you an example in fact the market is very, very strong today versus what it was even five years ago, and certainly ten or fifteen years ago.

Workplace charging is spreading across

the country as I mentioned. So workplace charging is everywhere. There are over 270 companies that have signed up for the DOE program, but even more than that, that program has bred additional companies putting charge stations in. So you take an organization like Hewlett Packard, they have workplace charging in every one of their facilities nationwide. So it's a tremendous effort and tremendous growth across the country and many more beginning to do that as well. EV charge stations are all over the place. So they're being installed, they're being installed in national parks, they're being installed in front of grocery stores, in front of aquariums, they're just virtually everywhere. The key to EV charging infrastructure is making sure that there's a good business model for that. So if we do an installation in a certain area, are we doing it because we're trying to increase sales tax revenue in the community, are we doing it because we want it to be a part of our green image because it's next door to the aquarium, are we doing it because we want to attract people to our mall, what is the reason we're putting charge stations in? We need to be very wise and very careful to understand what that investment is. So far charge stations are not impacting the infrastructure, the distribution systems. We have the ability as a utility industry to understand what our load requirements are going to be. And when we are part of the solution, when we participate in the design and installation of charge stations across the country we haven't seen any issues resolving that. Should we have issues in the future, if there's a whole lot of volume on a 4 KV circuit or something, an older circuit in an older community potentially, but when I talk to people around the country I say that's not a worry. The one thing the utility industry knows how to do is to handle increased load. One thing we know how to do is install new systems and take care of our customers. We have a requirement to serve and we take care of that.

So I try to tell people who keep raising barriers that oh well, we're going to have so many vehicles that the electric distribution system can't handle, I try to just simply remind them that if they were my age they would realize that in the '50s and '60s we took care of air conditioning, we did that without a problem. So the point being is we know how to do this, we know how to build the infrastructure to take care of this. Infrastructure is not an issue. People keep talking about it's an issue, but it's only an issue when you're not communicating with the utility so the utility knows in advance what you're doing. But that would be the same whether you're building a new factory or a new welding shop, it makes no difference. So the message we try to give is involve the utility, that's part of your discussions when you're thinking about what you're going to do with electrification and charge stations. Whether they're a level 2 charge station or a bunch of 120 chargers like they put at the Portland Airport, or eventually DC fast charging that goes up to 350KW, it doesn't matter, just make sure you tell us about it and we can work with your handler.

We have a very strong relationship with the utility industry through an MOU that was signed by Secretary Moniz with Tom Kuhn from EEI. There are 10 areas of focus in that effort that ranges from education awareness to financial analysis to looking at the voids in the marketplace in terms of vehicles, such as pickup trucks and SUVs that are not electrified yet. How do we resolve those, how do we move forward to that. So in essence we're trying to identify the barriers and the concerns that deal with utilities and make sure that utilities are engaged and involved. And it is working. It's a very effective partnership. In fact we are very close, like really close to signing a partnership with the American Public Power Association as well. So we're doing everything we can to be associated with all of the utilities across the country, because as I said before, without utility engagement and proactivity, this market will not move forward.

So EV Everywhere is recognized, and probably my primary driver is that 95 percent of Americans have absolutely no idea what I'm talking about. So there is no real awareness about electric vehicles in the general populous, so we're trying to figure out how to make that happen. So we work together with our stakeholders at their request to develop an awareness campaign. And it's an interesting campaign because we are not -- we are totally trying to get the uninterested to become interested in electric vehicles. We're not campaigning to the environmental community. If they don't know about electric vehicles they're not an environmentalist. We are not campaigning to the technology community, because if you're a technology person and you haven't heard of the Tesla and lithium ion batteries you're not a technology person. So it's everybody in between. We're developing five message boards to make that happen. The message boards are based around performance and convenience. The future message boards are under development around futuristic and -- it's just a car but it's a great car, so we're developing these message boards. These were done by industry and we are asking the entire industry to get behind an awareness campaign. We're not trying to answer the questions about range anxiety or battery fires or anything else. We're solely focused on bringing attention to the market. This is an example of the first one developed around electricity + car = power that focused on performance.

When you look at the Tesla data, and the Bolt data, you will find that the four drivers behind the Tesla consumer interest and the consumer strength for the Tesla, first is performance, second is ease of recharging, third is the fancy interior, and fourth is just really a special car. But the first two drivers were performance and convenience and we're developing a campaign around that. We provide to every single organization, on a disc, this entire plan and ask them to market and get behind us. So this is -- when we say everybody -- so this is -- the NRDC is involved with (inaudible) from San Francisco, helped develop the campaign, we have California Air Resources Board, PEV Collaborative and EPA, the EEI, a number of utilities, and we have most importantly Nissan, BMW, Audi, and General Motors all participating and helping drive this campaign. So we're trying to create awareness. You get the information multiple ways, so if you have a website you just simply put a banner on if you want to have -- if you can do it for a Facebook page, and we're just providing this to everybody.

So the example of the campaign is you can change the color fonts, you can change the website -- we want you to put your own website on it -- you cannot change the messages. You can change the photographs and you can change -- if you decided that the background behind this lady with her child looks more like New England and not enough like the southern deserts then you can change the photograph and put whatever photographs you want on any of these cards. So there's a real effort for outreach that we're trying to make happen. But again we're trying to get the market to realize this market is real and it is happening.

We also used the Clean City Coalitions we have around the country as part of that education. And when you think about it we're pretty spread all across the nation, so we have a lot of avenues to reach out to consumers and customers and we're trying to use those as much as possible to move the market. So you can see we're very focused on everywhere.

The other companies would prefer that I didn't talk to Jefferson City, Missouri, they would prefer that I don't talk to Huntsville, Alabama or to Wichita, Kansas. They prefer that I spend all my time in the major megacities where the highest volume is, but the goal is to be everywhere. And if you're going to move the market across the entire country you need to do that. So when you think about charging infrastructure, think about it everywhere, think about it in countries across the entire country. So far electric transportation is a really strong bipartisan effort. We're seeing no partisan battles over electric transportation in Washington, D.C., and we're doing everything we can to continue that by emphasizing the fact that this is good for all communities and all communities across the country. So let's electrify the communities and then let's connect those communities so people can travel across the entire nation.

We have lots of data, lots of information, so I've made some websites. We're trying to get people to pay attention to it but lots of really good information has been developed, especially since 1999, that's available for individuals that want to make the decision. So people can ask and get their questions answered if they go ask the questions. So again, the campaign is to create interest and awareness and let other people answer the questions, decide what type of vehicle is best for each individual consumer, and then let the autos ask for the order, which I think is their responsibility.

So I'm here and I was asked to do this relatively quickly, which I think I just did. So I'm really pleased to answer any questions that anybody might have.

CHAIRMAN COWART: Comments or questions. I'll take them in order. Phyllis?

MS. CURRIE: Having worked in local government for a long time there is a funding issue that is emerging, particularly in California, because of the move to electric vehicles, the gas tax is being challenged in terms of the amount of money available. In any of your conversations is that coming up in other parts of the country and are you having any conversations in that area?

MR. GRAHAM: The answer is yes, it is coming up and it's extremely important. And everybody that I know, including myself that drives an electric vehicle believes there should be some form of taxes so that the roads are repaired, so I don't want my car banged up either. So we are strongly in favor of trying to ensure a broader look at gas taxes in terms of the vehicle miles travelled and that type of thing. What we're trying to prevent is having states who then adopt a special tax on electric cars where there might not be tax on other cars. Every state in the country is having an issue because as you buy more fuel efficient vehicles it's driving the amount of gasoline that's being purchased, it's driving the gas taxes down. So all of our discussions are states don't invoke special takes but work together united to make sure that we do something around a vehicle miles travelled type formula because all of us that have electric vehicles think we should be paying for it. I'm not in favor of all the discussions where we should have free tax days for electric vehicles or free parking for electric vehicles. I believe that electric vehicles should be part of the mainstream and we should pay our way just like everybody else does. And that's the message that we provide as part of EV Everywhere. But it's a good question. Pasadena has done a lot with electric vehicles by the way, done a lot.

Other questions?

CHAIRMAN COWART: Tim?

MR. MOUNT: So I didn't hear you talk about incentives. I'm an economist, you know. So can you tell us something about the issues of tax credits for purchases and also incentives? And I'm not just talking about financial things, but the likes of free parking in Manhattan or whatever, you know. There are certain things that would be attractive. So you've talked to a lot of municipal people, are there things that we could be encouraged by?

MR. GRAHAM: So the question was about incentives. So I personally am not in big favor of incentives. I do believe the way incentives are introduced today as part of a tax rebate, they would be better served if they were payable on the hood at the time of buy, which many states do today and has proven to be every effective. That definitely works to help reduce the cost down. The non-monetary incentives that work, like in California the carpool lane sticker. I mean it's a huge incentive. The cities that are providing free charging as a part of their business model to attract people into the downtown communities are doing it because it generates sales tax revenue. So that is an incentive that drives other options and other benefits.

I think it's probably going to be important in the near-term to have the financial incentives in place. And most of the people that will talk in front of you that are selling cars and selling electric equipment will tell you that they strongly support incentives that they'll last for a long time. I think we have to get to the point where, again as I mentioned earlier, that value proposition is so strong that we do not have to keep incentivizing the market to make it happen. And I think we're slowly getting there. I think the people that put the $1000 down on the

Model 3 were not really thinking about the incentives. I think they bought that car because they think it helps them be part of the next generation paradigm change.

Incentives are very important, especially state incentives today and they are working. A really good example of that is when Georgia pulled its rebate off the table and eliminated that and replaced it with a fee to cover the gas tax that was asked, the sales in Atlanta dropped off the table. So it's really important, especially now in the infant part of the market, to maintain those incentives, but in the long-run I think we need to wean ourselves off it, with the exception of things like free parking where it makes sense from a business model.

Other questions?

CHAIRMAN COWART: Pat?

MS. HOFFMAN: So I was curious, do you know where the standardization is going with electric vehicles and charges? I mean I assume there is still level 1, level 2. Is there any consistency where you see that standards are helping the process?

MR. GRAHAM: So the question of standards -- so level 1, level 2 standards, with the J1772 standard, which is a common standard for all plugs, that's really not an issue in the marketplace today, its' pretty common. All vehicles use them. Tesla even has an adapter so they can use that. Where we run into issues with standards and commonality is with the DC fast charging systems where we have an SAE standard, we have an Asian CHAdeMO standard, which are different. As we move more and more the faster charging systems, the 350KW DC fast charging systems, we're all trying to figure out a way. Can we have a single standard so that when you drive across the country you have that standard?

NYSERDA is working on trying to develop standards in order so that when you go charge at a station, you know how much you're paying for it, so you get an idea. So people aren't just charging automatically just because you're doing it, they know what that cost is going to be. So there's some standards along that. The biggest standards and issues, Pat, is the issue of interoperability across the country and making sure there's some commonality in terms of billing and there's some commonality in standards. We haven't gotten there in terms of the CHAdeMO versus the SAE, but some people think that the driving toward the faster charging DC will make a difference. It's a big issue, especially interoperability across the country.

CHAIRMAN COWART: Janice?

MS. LIN: Thanks. My question is to what extent is the EV Everywhere initiative is engaging with EV charging developers and, related to that, to what extent is the question of EV charging infrastructure ownership becoming an issue that you touch on? I know it's a big deal in California, we have a number of pilots under way and there's everything from vertically integrated models where utilities own and operate a rate base it all the way to where utilities facilitate it.

MR. GRAHAM: So the first point is easy. We engage with the charger manufacturers all the time. They're all part of the teams meeting that we've had and there's an infrastructure working group that has the charging manufacturers involved. The meeting that we had in St. Louis had charger manufacturers and I deal with Charge Point and NRG on a regular basis.

The question of ownership, we're all trying to follow the three different pilots in California. Basically what she's mentioning is in California the three filings with the California Public Utility Commissioners took three different approaches as to utility engagement and owned and operated infrastructure. San Diego engagement in simplest terms was they own, they operate, and they contract out with others to install and maintain. And Southern California Edison, they decided to do what's called make ready, so they'll install systems all the way up to the stub and then somebody else puts in the charge station itself and operates and maintains those stations. PG&E is still waiting for their final ruling, and theirs is kind of a hybrid between the two, where in some cases they would own and in other cases they would do the stub up.

I think the question that utilities and communities need to ponder is the utility has the requirement to serve all, so how do we ensure, based upon the different ownership models, that the environmental justice zones and the economically depressed communities have equal access to charging as everybody else. And so if that's going to happen, is it going to have to be a public service and who has the capability to fund that public service. The second issue where I think everybody needs to think about is maintenance of the systems, especially when we move toward large complexes of charging stations that are spread across the country and communities. Who has the ability to maintain those systems beyond the utility industry? The utility industry has a service network and the utility industry is not satisfied with a component not working. So it's really important to ask yourself the question, when we install all these systems all over the country, who is going to maintain and support those long-term? Not just next week, but long-term. And so how are we going to make that. And so you've got to debate that question. Certainly where it's good for business and a mall wants to install the charge station, they should install it and own it, maintain it, go forth, have fun with it. But if you're talking about an environmental justice zone or if you're talking about you want to be a green community, then maybe it needs to be a public owned system, and then I think the utility needs to be a partner in that.

Our official position is to look at all three models and to learn and to grow and to ensure that communities and states have as much information as possible so that they can make a wise investment in their infrastructure and their decisions. We are doing modeling and analysis, tracking, what was done in California. For example, in Massachusetts today, where we're looking at the infrastructure, where they are today, where the future vehicles are going to be in terms of longer range vehicles, in terms of higher, faster charging, in terms of different mixes of vehicles, in terms of different market penetration rates, and providing Massachusetts with its own scenarios and then letting the State of Massachusetts make that decision based upon the scenario they choose as to what investment, what approach they should take.

So we're trying to learn from the market, but I do reemphasize the importance of ensuring that electrification infrastructure is available to all, especially as we move toward second generation vehicles and used vehicles coming into the marketplace and driving the cost down. You can lease or buy a Nissan Leaf for roughly $8000 today. That's a perfectly good car. And we need to make sure that those who purchase those vehicles in the secondary market have just as much access to infrastructure as everybody else.

And then the final one is those areas that people live in multifamily dwellings that don't have ready access to electrification, how are we going to do that? We could do that by having -- if you have a workplace charging or you have a public facility and you're charging during the day, maybe we could work out a way for people who live in multifamily dwellings to charge it at night time. Or we can have DC fast chargers installed near multifamily dwelling areas. That's probably more of a public service and somebody has to be able to maintain that. Best example of that is I tried to rent a townhouse here in Washington, D.C. when I moved back and I could not do that because I couldn't find a place to plug my car in. And so I ended up leasing a house about another seven miles west of here in Falls Church and just happened to have a plug on the outside where they had the outside decorative lights. I unplugged the decorative lights, plugged in the car, and it worked like a champ. It was interesting, it actually worked through 26 inches of snow. And that was interesting because I got to buy my first snow shovel I ever bought in my entire life this last winter. So the car worked, it works at 120 and the snow shovel works, so I'm in pretty good shape.

Other questions?

CHAIRMAN COWART: I have Sue Tierney and then Paula and Ake.

MS. TIERNEY: I'm interested in hearing about what's going on, maybe as part of your program or things that you're observing with regard to the interest of either consumers and/or charger entities in having the battery be a sink for electricity and be used as part of grid integration. Is that just still in the future or are we seeing trends in the ground right now to use dynamically the batteries as part of the grid?

MR. GRAHAM: So two answers to that question. It certainly is in the future in terms of aggregating millions of vehicles together to pull energy out. And there are efforts underway. There is a BMW PG&E project looking at that. There's a U.S. Air Force at the Air Force Base in Los Angeles looking at that. So there is research being done to determine whether or not that can happen or not.

What you are seeing today, especially if you go look at what Tesla's doing, their energy source system, you're seeing today the migration out of electric vehicles of the lithium ion batteries and they're management control systems, so the system itself migrating out of the vehicles and being in stationary storage applications. And I think that's actually where the future is going to go.

I am not a big supporter of V2G, primarily because I don't believe that the individual consumer is going to benefit very much from doing that. And I believe as we move more and more toward autonomous cars and the car share car driving where the car is going to be driven more often that those cars will be more difficult to track and know where they are. And I think when you do that you add complexity to the system, add complexity to the vehicle, and the ultimate cash in the pocket of the individual I think is going to be -- I think it's probably not worth it.

In terms of fleet applications, if you had a postal fleet that went home every night to the same location and you knew where it was going to be and you knew how many vehicles, and how much energy is there, yes, V2G in that application, the (inaudible) probably makes sense in the future, but not personally, not for individual cars. So I don't really see that. I do see a tremendous movement over time of the energy storage taken -- especially with the cost being driven so low, with the energy storage for electric vehicles migrating into the distribution system because I believe -- because they are stationary, they're managed, and they're controlled. And the control systems are very, very effective today. So I think that's the direction we'll end up going. And Tesla's beginning to prove that today with that they're doing and EPS here in D.C. Is doing the same thing.

CHAIRMAN COWART: Paula?

MS. CARMODY: I just had a couple of questions related to our comment about kind of equal access, and you actually started to partially answer those. One of them has to do with kind of projections on the availability of lower cost vehicles. You mentioned the Nissan Leaf and you said $8000 and I didn't know if you were talking about a new --

MR. GRAHAM: That's the used Leafs that have come up for lease.

MS. CARMODY: Used Leafs, yeah.

MR. GRAHAM: And there are lots of them.

MS. CARMODY: But in terms of kind of newer vehicles, in terms of projections, because, you know, people are focusing on the Tesla at $35,000 as a low cost vehicle, but the reality is for a lot of people that's not a low cost vehicle because that's a base model, you're really talking in the $40s. That's not a low cost vehicle. So

I'm looking at kind of the projections. And related to that, you know, when you're looking at particularly on the east coast area, older cities like Baltimore or Philadelphia, very densely populated, lots of people are living in -- whether you call them townhouse, row house areas. I've got no off street parking myself. But, you know, lots of cities are predominantly of that model. So I know this has been identified as an issue, but is there -- you know, certainly would encourage kind of further discussion at least for those kind of areas because they do tend to be in some areas kind of skewing towards people with lower middle income kind of living in those areas. They literally have no place to charge and the notion of workplace engagement, their job opportunities may be less available, you know, for those employers to engage that way.

So I was wondering, you know, how much of a focus in that area has been on those kind of older areas which tend to be densely populated?

MR. GRAHAM: So you've actually hit on a

subject that's really important to me and I probably spend a lot more time on it than I probably should. I think it's extremely important. So that takes you to another discussion longer- term about autonomous cars and electric vehicles and the car sharing world, and that drives you to think about how many trips will become shorter, which become ideal for electric vehicles, and how those shorter trips could be with different size vehicles, which would also be lighter weight, which makes them even better as electric vehicles. The issue there though however is going to have to be the city's willingness -- when you start thinking about smart cities and smart mobility -- to eventually create charging pods or charging locations within the community so that people have access to those pods or those locations as part of their planning of infrastructure. We cannot just simply say we're going to put a few charge stations in at certain locations. We need to think through what the traffic patterns are and where the needs are and create charging pods or charging complexes at those locations.

We also need to be very careful to let people know that it's perfectly okay to use 120 charging. So because most people aren't driving longer distances. So if you live in a multi floor building, multifamily dwelling, not necessarily a townhouse, and you have access to a parking lot that has lights in the parking lot, it's really not a big issue to go in and put 120 charge stations in those locations. So most of us that are buying cars today, like I mentioned with my house, plug it into a 120 plug on the outside. We need to think more toward ways that we can provide charging locations for those individuals.

And then finally we need to be looking at dual use of systems so that when you have workplace chargers than can be used during the day for workplace and at night time it can be used by those that live in that area. So there are ways to do that. We need to think that through. It is a very big challenge. Trying to make sure that everybody has access to electrification and the health benefits from that. It's proven to be very difficult to do and we're all focused on it. I think that's the best answer I have, is to get cities to think about a charging network that includes in that charging network this pod or these locations that people can go to and recharge. And I think that's going to drive us toward more installations of fast charging systems that -- but we have to make sure that the vehicles that are available at that price range are in fact chargeable on the fast charging systems.

On the issues of the car pricing, the average American spends $31,000 for a new car. So the electric vehicles are kind of in that price range. Now does the person living in a multifamily dwelling in most part of downtown Washington, D.C. spend $31,000? No. But we need to make sure that they have that access, that ability. So as part of EV Everywhere there's a major focus, especially on environmental justice zones and the economically depressed parts of communities.

CHAIRMAN COWART: Ake?

MR. ALMGREN: There's no question that EV have reached a point of no return. It's as you showed, accumulated growing. Still, reality of the last two years, it was about 130,000 cars sold, EVs, and the total sales I think is 15 million cars. What would it take or what do you see as the main roadblock for getting at the stage where it's real growth, more exponential growth?

MR. GRAHAM: So the main roadblocks are the auto industry's willingness to market aggressively nationwide, the ability for consumers to have enough awareness of it and recognize the value, and for us to create a value proposition that makes sense to everybody to drive those consumers to cause the auto industry to want to market nationwide. For utilities nationwide to be proactive, for utilities to take the stand that we are as responsible or educating and making people aware of the benefits of electrification just like you do all the other products that you sell for electrification. We need to tell people what the grid looks like and how it's effective, how it works, how it makes a difference. That's not happening. State and cities and communities need to be proactive in terms of education outreach. When I went to Massachusetts and spent some time there talking to the team that's responsible for their program, they listed six or seven things they were doing, they have X amount of rebates, and the thing they didn't have is any education awareness. So I told them -- they said what you do think, I said I think you're doing everything right, but nobody knows what you're doing.

So it's really important that we get out the information and we talk about it. And that's got to come from the utilities, the autos, and the state agencies and those of us at DOE. So it's a real issue, but I think the biggest one is to create the demand and the demand will force the autos to sell product nationwide. Until we do that we will not overcome the price barrier and we will not overcome the issues, range problems, or

-- paradigm changes are very hard, and this is a major paradigm change. And the next paradigm change is going to be autonomous vehicles and it's going to be even harder, and we need to figure out how to do that the right way. And it's tough. And I'm travelling way too much trying to make that happen, but it is a big challenge. So what, we had 100,000 vehicles out of 15 million? We have a long way to go. But five years ago we had 2000. I'll take the 100,000 right now versus the 2000, so we are making progress.

Other questions?

CHAIRMAN COWART: So my question is coming to you -- I'm channeling a question from a conversation I had with an engineer from Toyota a week ago who was basically making the argument that we can't predict whether electric vehicles will be the selected winner in the low emission category compared with, for example, fuel cells and hydrogen vehicles. And so my question is -- I'm really just channeling this argument that I was given last week -- is what's your answer to that? Is there an alternative future? Are you on the right path?

MR. GRAHAM: So I think the ultimate answer is a little bit of all of the above. And I think I mentioned in my outset when I was privileged to work for Clark that one of the ways we salvaged the electric vehicle program at EPRI was to be very actively involved in the fuel cell vehicle technology. In 2002 I told the California Resources Board that the future is a plug in hybrid fuel cell vehicle where you take the engine out and you insert a fuel cell. And I still believe that, and there are others who are beginning to believe the same thing. In fact the Bolt was designed to be able to do that in the future. Why would you do that? Because you would have smaller fuel tanks for hydrogen and you would need less infrastructure in the marketplace.

So is the electric vehicle path the right path? If I think about autonomous cars and I think about the fact that we're going to increase the number of trips, short distance trips, which will be ideal for electrification, when I think about the fact that people are going to drive 20-30 miles a day, then I think -- and you can plug in at home -- that it's really inexpensive to use the existing infrastructure we have today for electricity. And you're all spending billions of dollars to make it even better, right? So I believe that electricity will win out long-run, but I do think there's definitely a role for fuel cell vehicles. It may be in the 18 wheeler trucks or medium-duty delivery trucks, it may be in that marketplace where you have fleet locations where you can afford to put in the hydrogen infrastructure. Can you imagine going to my house in Falls Church and installing hydrogen infrastructure versus me just plugging it into the outside plug? It's a big step to get to that point, and they're pretty expensive.

So I'm a strong fuel cell proponent. I believe strongly that we should move that direction, I just think we need to think about which vehicle applications are best for that technology. So both will win out. In the long run I think we're marching down the right path. And the final answer to that is every time we build an electric vehicle we drive the cost down for all fuel cell vehicles because they're all electric drive. And the combination of battery and the fuel cell to me is the ultimate vehicle.

CHAIRMAN COWART: Tim, Granger, and Carl?

MR. MOUNT: So I wanted to follow up on the question, and I think it was Sue who brought it up, on what I would call smart charging. You turned that to V2G which I understand, you know, does have some problems. But, you know, surely we don't want all of the cars coming in and being plugged in at 6:00 and 7:00 o'clock in the evening in California. There must be some way of organizing what I would call smart charging and ultimately one would like to coordinate with renewable sources of generation and deal with some of the variability problems.

MR. GRAHAM: So smart charging and grid integration is probably the most important topic we'll talk about today, and that is because we need to manage the charging to maximize the benefits to the grid, which means electric transportation brings benefits to all rate payers. And you do that by education, people charging at night time, you do that by price signals -- so I was just in San Diego last week and in San Diego they send out price signals to their customers and they will tell you during the day when you have the lowest opportunity for pricing those vehicles. And so people began to learn. So there's a lot of education. But the ability to manage charging is one of the benefits of electrification. And being able to make that happen wisely means that the assets we have, we utilize those assets to their maximum of our ability and that reduces cost for everybody, so therefore everybody shares.

So, no, you're absolutely correct. Most of that is going to be education and price signals to support that. The vehicles today -- like I go home tonight, I'll plug in the Bolt, its set to be charged by 6:30 in the morning. It probably comes on at 3:30 in the evening and the charge is done. When I get up and leave in the morning it's full. So we need to send those price signals, we need to work with work places to instead of everybody coming to work and charging it first thing in the morning, we need to ask the question, hey, do I have solar in the afternoon, would I be better off having solar charging in the afternoon versus in the morning and manage that charging appropriately? The technology exists to do it today, it's a matter of communicating with people and educating people. But that is a very wise question because it's extremely important to utilize the grid appropriately and we can do that with technology.

Thank you.

MR. MORGAN: So two questions. The first related to what you just talked about, namely, yes the technology exists, how do we sort of promote the adoption of appropriate regulatory and tariff arrangements to make sure that we have smart charging?

The second one though goes back to Rich's question. In the program you've just described as very much a technology promotion program, I don't have any problem with that. I'm not an economist, I'm an engineer and I think promoting promising technologies is probably an appropriate thing for the DOE to be doing, but Rich just rattled off a couple of alternative technologies. Is the DOE mounting similar promoting efforts for those sort of with a neutral position, you know, let's see which technology ultimately wins?

MR. GRAHAM: Yeah. So Clean Cities organization is very actively involved in all the above, especially natural gas vehicles. We have a major effort in looking at alternate fuels, everything from algae to different types of fuels to be used. We have an efficiency engine program, so we're trying to make tomorrow's engines more efficient. We have a major fuel cell effort that's working on especially looking at fuel cell infrastructure around the country and how to develop that and there's a team of people that I've worked with on a regular basis to support it. And when I travel across the country I talk about fuel cell vehicles, electric drive, as I just did a minute ago, where electric drive technology will drive the cost down so fuel cells can (inaudible). So I think we are trying to be as neutral as we can be.

It's really important for people to buy the right cars. So, for example, we're looking at Federal fleets, and we ask ourselves the question, which Federal fleets are ideal for electrification. Not all of them are. So in Alabama there is -- when you go and talk to the -- which I just did, so it's kind of close to my heart at the moment -- when we talked to the Army recruiters they averaged 300 miles a day driving. So they say should we get an electric car? I said no, go buy a hybrid. So buy the right car, buy the right technology.

In terms of subsidies, I think there's probably going to be a need for subsidies and incentives for a while longer. How much is a while longer? Is it five years, is it ten years? Virtually every market in the country has some subsidy. And so I think it's probably going to continue even though I personally think we have to win the battle by developing that value proposition I talked about before, and we have not achieved that. You cannot say right now what the ultimate attraction will be to attract somebody to an electric vehicle. So we have a ways to go.

MR. MORGAN: And on smart charging, how do we promote it widely, how do we get PUCs to mandate it?

MR. GRAHAM: I'm not convinced that it needs to be mandated, I'm convinced that education and awareness will achieve that effort and that's what they're doing in San Diego.

MR. MORGAN: But I don't have a time of use rate at my house. I mean I do in New Hampshire. I mean a family home I've had time of use prices since I was a kid, but I mean I don't --

MR. GRAHAM: So if we educated you to the fact that you have -- there is the -- the system itself has excess electricity between midnight and 6:00 a.m. and gave you the proper amount of information I think you would make the wise decision to plug in after midnight. If you understood that and we gave that information to you.

MR. MORGAN: Ah, but that requires me to buy some hardware that starts my charging after midnight.

MR. GRAHAM: No, it's on the vehicle already.

MR. MORGAN: All of them?

MR. GRAHAM: It's already incorporated inside the vehicle at the time --

MR. MORGAN: On all of them?

MR. GRAHAM: -- with the ability to adjust that. I just go home and adjust it to be charged at 6:30, or I can hit another button --

MR. MORGAN: So it counts on me being a public spirited person? And you think that we can solve that even with high penetration?

MR. GRAHAM: I think it's hard. And I'm travelling lots of miles to do that.

MR. MORGAN: So do I, which is why (laughter) --

MR. GRAHAM: I think it's very hard but, you know, it took -- the first car was built -- first full production assembly line was built by Henry Ford in 1917, it took the country until 1950s to build the interstate highway system. So I'm a pretty patient person. Besides I can do this.

MR. MORGAN: Yeah, but if we're going to get to be a low two degrees by the end of the century we're going to have to be a little less patient, but okay, I understand. Thank you.

CHAIRMAN COWART: All right. We've run over time, but I see that there are two cards still up. So, Paul and Carl and then that will be it for this panel. Thank you.

MR. CENTOLELLA: Okay. A short question. So one of our least well used assets is a car. I mean we operate them maybe five-six percent of the time, if that. So we're seeing in urban areas in particular more ride sharing, more young people who don't want to own cars. How does that change the value proposition for electric vehicles if at all?

MR. GRAHAM: Well, I think it increases the potential and size of the market for electric vehicles because most of those trips are short trips and those trips are ideal for electrification. I believe in the future you'll see a movement toward autonomous cars which will do the same thing, and I think what that will do is increase access to people who are -- the 20 million people that don't have driver's licenses to be able to use those vehicles and to drive those. Those are also short trips. I think you'll see car sharing continue to grow, so you'll see more and more people use car sharing and be able to get to the doctor and back for health checkups. Those are all short trips. Because those trips are typically only two people I think you'll see a difference in design of vehicles in the future, just smaller, lighter weight. If their autonomous potentially less crash worthiness even for the lighter weight and I think that will eventually grow. So all of that to me says the electric vehicle market will grow, especially in urban areas providing we provide intelligent charging systems or pods so that those car share locations. The Uber drivers of the world have the ability to go and charge and do it quickly so they stay on the road like they want to be. So I think it makes a huge positive in that direction.

By the way, utilities need to think about that too because when you're thinking about all that autonomy and all those vehicles charging, then all of the sudden the resiliency of the grid might need to be at an even higher level than it already is and the question needs to be asked, what technology needs to be developed to ensure that even increased resiliency -- so now we don't want the wind to blow it down and we want to fix it fast. Well, when you're driving autonomous cars around and that autonomous car is used to electricity providing the control and the wireless control systems, maybe we have to be 100 percent efficient. So we need to think about are there additional technology levels over and above what we have today that need to be developed while autonomous cars are coming down the road.

So that's a great question and I think it's going to make a benefit.

CHAIRMAN COWART: Carl?

MR. ZICHELLA: Thank you. I appreciate your presentation, Robert. What you just said sort of segues into what I've been thinking about. I'm also from California and seeing projections of, you know, three million vehicles or four million vehicles by 2030, I'm thinking about the geographies elsewhere in the country where we're starting to see increasing penetration of renewable energy resources, like the southeast where we might also begin then to see, consequently, a high penetration of electric vehicles. Some of the issues that we're encountering in California, it seems to me we can be heading some of that off by thinking prospectively about how we develop infrastructure to meet those needs in areas where we can reasonably expect that EV use will grow.

Have you selected, or has DOE selected certain geographies to really focus on ahead of this, sort of get ahead of the curve so to speak about these kinds of penetrations and how they might best be managed for grid stability?

MR. GRAHAM: So I mentioned the infrastructure study we're doing in Massachusetts. That's based upon an infrastructure study that was funded by the California Energy Commission in California, so we are patterning after that. The second thing we're doing is we are providing information on the three different PUC proposals and giving people information as to what those different models look like so they make the wise decision. And the other thing we're doing in all our engagement with other states is providing them information on what the California Plug In Vehicle Collaborative has developed, which the Collaborative consists of about 25 different stakeholders in the marketplace, each of them contributing information, and the reports that have been developed by that group of stakeholders are superb. So we're actually providing the PIV Collaborative website and their information to all states and all communities, saying don't reinvent the wheel, go use what was developed in California. And people are beginning to use that information. So we're trying to learn from that as best we can.

So I'll thank you very much. And I appreciate all the questions and the time you've given me. Thank you.

CHAIRMAN COWART: Thank you very much.

(Applause) Our next session is going to be managed by Anjan who will introduce the speakers.

MR. BOSE: Okay. So the next

presentation is a presentation of National Academy's report entitled, "Analytic Research Foundations for the Next-Generation Electric Grid", and we thought it would be of interest to the EAC because the report was instigated by the Office of Electricity. Gil Bindewald is sitting here and he actually wrote most of the proposal I believe for this that was given to the National Academies, and somebody from the Office of Science, which sponsors research in mathematics was also involved with this.

So the Committee that did the report was made up of half our engineers who knew something about math and the other half of mathematicians who had familiarity with the electric grid. And so the speakers today would be John Guckenheimer, who was one of the co-chairs of the Committee; he's a professor of mathematics from Cornell University, and Ralph Masiello who was on the Committee. And most of you know Ralph because he was on the EAC and works for Quanta Technology. And so I'll pass over to John.

MR. GUCKENHEIMER: So welcome. I'm definitely a mathematician and not a power engineer. Even though I spent somewhat over two years working on this project I still feel like I think that I know very little about the power industry. It's such a complicated beast that that's not really enough time to get hold of it.

So here is the membership of the Committee. As Anjan said, about half of us were mathematicians or mathematical scientists and half were power system engineers. The representation was broad, there were several areas of mathematics that were represented and the selection of the Committee was managed by the BMSA, which is a unit within the National Research Council. So advice from members of the National Academies was solicited about the membership of the Committee and there was quite a lot of back and forth discussion about the people who would be selected. My co-chair on the Committee was Tom Overbye from the University of Illinois who is a power system engineers.

We had a dual charge from the DOE. The first part of the charge was to address research areas, critical areas of mathematics and computational research that has to be addressed for the next generation of electric transmission and distribution system. And the second part of the charge was about community building. This is an area which is explained as inherently really multidisciplinary and you have two communities that have not interacted across a broad front. They've interacted a little bit, but the feeling is that things are changing rapidly enough that there needs to be much more interaction and that this interdisciplinary community needs to be assembled. So the DOE asked us to help them by giving advice about how to effectively build a community to describe what sort of mix of backgrounds are needed and how the community can be developed.

So a little bit of the context of the report is based upon a lot of things that undoubtedly you're all familiar with that come from the accelerating pace of change in the power industry. There are new power sources, primarily renewables and wind and solar, although also shifts from coal to gas. There is a lot more real-time data that's available, especially through PMUs that were funded largely through the Recovery Act after the financial crisis several years ago. And there are lots of new devices and changes in technology that are associated with the grid, both in the form of different kinds of control devices and electronics, and also the development of new sorts of storage. There's no doubt that further developments in storage, which you'll hear much more about it at your meeting, would make a huge difference in the way in which the grid operates. Finally, in the presentations about electric vehicles that we just heard and other mentions of smart meters, the changes in the grid from going from essentially a unidirectional communication in which I plug my devices into the electric sockets at home, the power is there, to a situation in which there's communication between utilities and my home, and smart meters are affecting my access to electricity is something else that seems like it is likely to cause fundamental changes in the grid.

So those are changes in the sort of physical infrastructure on which the industry is based. The organizational issues that are associated with it are we're starting from the assumption that reliability is absolutely essential. We all demand having power 24/7, minimal interruptions, no interruptions would be far better, and the control architecture of how the system operates is something that is really central. There are a lot of different scenarios about how the grid could evolve. One can imagine scenarios in which there are, at the developments of microgrids, much more storage and a sort of decreasing reliance upon the central provision of electricity through a natural grid versus the ability of the data that is coming from synchrophasors, PMUs, in order to provide tighter regulation on the tighter synchronization on a national basis. It's clear that regulations and standards matter, the way in which markets are organized, and so forth. These are things which also are subject to a great deal of change.

So as mathematicians in this, we can ask what are the key areas of mathematics that are necessary in order to help in the evolution of the industry? From one standpoint I look at the situation and ask whether the utility industry is going to go down the road of the communications industry 10 or 20 years ago and the sort of transformation of the telephone industry into our internet based communications today. And everybody tells me no, that can't really happen, but the question is what would it take in order to do that. One can imagine very different scenarios for what might happen to the utility industry.

And the Committee took a very conservative view with regard to this and viewed it from the perspective of some things are going to be necessary however the system evolves, and let's focus upon those parts of mathematics that are key to the evolution independent of the scenarios that are going to take place. So there are three areas, and these are already reflected in the membership of the Committee, that we identified as being dynamic systems essential for the reliability, and stability, and operation of the grid. Optimization, which is a key technology for the way in which markets are operated and control theory, which is just a central part of the way in which the grid operates.

So in writing the report we faced a difficult challenge in that we're really addressing these two largely separate communities and we wanted a report that was going to be usable by both communities and help to bring them together. So the first half of the report, first four chapters, provide background. The first chapter is just the description of the grid, its physical structure. This is directed in some ways primarily at mathematicians who know very little about it. The second chapter is also somewhat in this regard, it describes the kinds of regional wholesale electricity markets and the structure of having system operators that are responsible for reliability that has been put in place since the 1990s. The third chapter talks about existing tools and methods. Software computation is the vehicle by which the things operate and the existing tools and methods are extremely important on how we go forward. And I'll say much more about that momentarily. The important math research areas is the subject of chapter four and it talks about the three areas that were on the previous slide.

Then the second half of the report, chapter five, talks about different scenarios for the future, the kind of uncertainty that is there, about how things will evolve, and the challenges that take place. Chapter six deals with mathematical priorities, what are the research areas within mathematics. This is trying to specifically answer the questions that we were asked in our charge, but what sort of new mathematics do we need to help the evolution of the grid. Chapter seven gives a number of case studies to try to make that more complete. And then the final chapter is about building the multidisciplinary research community.

I'm going to go through the recommendations quickly. I'm not going to read them in all detail, but I'm going to try to summarize what the key points are in the recommendations. So the first set of recommendations revolve around software and data. And a lot of the software that is used in operating the grid is proprietary. Mathematicians don't have access to it, they don't have the funds to buy it, and even if they could buy it, they couldn't look inside to really see how the guts operate because it is proprietary and the source isn't there. So we think that DOE and the National Science Foundation should sponsor the development of new open source software for the electric grid.

Second is data. The data that is coming from the synchrophasor initiative and the PMUs is not going to be turned into something that's publicly available, partly for security reasons. On the other hand, data driven methods and data science are absolutely going to be essential in the way in which the grid evolves. So the recommendation that we make is that for research purposes, that efforts be made to create synthetic data that can be used in an alternative to the real data so that the research community can have something to work with without having to go to the extent of signing nondisclosure agreements, working with specific utilities, and sort of isolating themselves from the rest of the mathematical and computational sciences qualities.

So along these lines we think that synthetic data libraries should be established. The sort of emphasis in the software is the partition into things that are already in it towards reliability and control where the main issues from a mathematical perspective are primarily in the dynamics, and for market oriented things where the optimization software is more important. Text file formats in utilities are required by Federal regulations to establish that they are going to be able to survive outages of particular units on the systems, so called N-1 stability, but the text file formats that are used in doing those computations are something that are not always easy to find. And we think that the kind of information that allows the research community to understand what is being done in the industry, that that should be fully public.

With regard to the optimization, the critical need is felt to be what's called the implementation of algorithms that will deal with AC optimal power flow (ACOPF). The current methods all deal with optimum power flow that uses a DC approximation of what's happening on the grid and the optimization algorithms that deal with non-convexity in the optimization problems are simply not capable, at this point, of doing a full solution of the ACOPF problem, especially in a timely way that corresponds to the daily markets that are run by the system operators. We recommend that data driven approaches be applied in a number of different ways in terms of the future grid. And that methods that come from machine learning dynamical systems, in (inaudible) theory should be high priority research areas.

Dynamical systems theory, as I said, is sort of the basis if you think of the grid as an enormous electrical circuit, then the mathematical substrate for understanding, simulating, controlling the grid is something in which there are many mathematical issues that are not dealt with adequately at the current time.

In terms of community building, what we recommend is that DOE should establish a power systems research center. We're not specific as to the form that this center should take, but we think that there really needs to be an interface between the mathematical and power systems research communities, and that the creation of a center, perhaps geographically distributed, that would really bring people together from these two communities, might be able to provide an interface that would allow for a much broader set of interactions to take place. We also think that the DOE, and the way in which it uses the National Laboratories, should look to including academic and industry researchers much more in the kinds of coordination that's beginning to take place in their Laboratories.

So those are the recommendations of the report and now I'm going to turn it over to Ralph Masiello who is going to sort of talk in some more detail about some of the things that stand behind these recommendations.

MR. MASIELLO: Thanks, John.

SPEAKER: Okay. And we have an MOU that DOE is signing with the National Science Foundation. Ali, do you want to explain a little bit about the MOU just real quick while we're signing this?

CHAIRMAN COWART: It's unusual for the Committee to have a ceremony right in the middle of our presentations.

MR. GHASSEMIAN: Good afternoon. I'll

introduce myself later. As a result of National Science Foundation recommendation number 8, which (inaudible) Department of Energy and National Science Foundation should sponsor the development of new open source library of simulation software intended for the next generation electric grid research community. We agree to get in to sign the MOU between the NSF and DOE, establish intents to invest in fundamental mathematical and statistical algorithms to enhance the reliability, resiliency, security, and efficiency of the electric power grid. I'm delighted to have from DOE Patricia Hoffman, Assistant Secretary for the Office of Electricity Delivery and Energy Reliability, and also from NSF, to have Fleming Crim, Assistant Director for the Directorate for Mathematical and Physical Sciences, for signing this agreement here.

MS. HOFFMAN: Reports come out. But it shows you we are trying. (Laughter)

MR. CRIM: I wanted to compliment you on the very short timeline that you have managed to accomplish in executing the recommendation. It's very impressive. (Laughter) I mean it's almost like you're clairvoyant or something.

SPEAKER: Do we have one or two copies?

SPEAKER: Looks like one.

SPEAKER: Okay. (Applause) Don't lose this. (Laughter)

SPEAKER: Thank you so much.

SPEAKER: All right, Ralph, back to you. (Laughter)

CHAIRMAN COWART: Thank you very, very much. And, Ralph, what are you going to recommend that we will instantly accomplish?

(Laughter)

MR. MASIELLO: I'm speechless. If we could get the other slide back up. So let's see how many others can lend themselves to such quick action. So here are some of the specific challenges in power systems language. First the common data format, which has been what, a 20-25 year journey through the (inaudible), hasn't kept up. And the reason is more models to capture new things of interest in existing apparatus, new technologies like storage, new commercial software coming out, and the ease of data access is at risk. Second problem, the commercial security issues that an ISO faces, commercially privileged information, and DHS requirements on critical infrastructure, have made it very hard to get access to the databases you need. So as an example, if you're a researcher working in para system optimization and you're doing something, say semi definite programming and you'd like to test your algorithm on a representative market optimization problem, you can't get the data easily, whether it's an ISO like PJM or a vendor like Siemens or GE Austin, their hands are tied, they can't give you that data until you jump through a lot of hoops. That's one dimension of the problem.

Another one, speaking cynically, is if you're a vendor, software or systems vendor, or a national lab, or a consulting firm, and you're privileged on the inside working with one of those

ISOs and having access to the data, lack of accessibility is a barrier to competition. And so it's very hard for outsiders to come in. But we know historically the big advances come from outsiders. So this is important. Forty years ago we had the IEEE standard models that originated at AP or PTI or wherever, but, you know the 5 bus, the 47 bus, et cetera. So the recommendation is fix this problem so that researchers from other fields can jump in and help us find the breakthroughs.

Third point ties back to the first one. You get past the IEEE standards and you've got a lot of proprietary models, especially around new technologies, storage, inverters, (inaudible), et cetera. Details aren't known. It makes it extremely hard to compare results of different algorithms, different software to make advances.

And the fourth one comes back to the open source. It's always been really difficult to make money in this space, harder than ever. And if you were to talk to the vendors, they don't see a business case for putting the next $10 million in. So if our only users are at this RTO level, or at NERC, that's not a big enough user base, certainly not within North America, probably not globally. So that's a challenge. Next slide.

Okay. The curse of dimensionality is going to add a few zeros to the problem. And we've always, in power systems analyses, separated the distribution world and the transmission world, different models, different software tools. Distribution folks look at the transmission substation as an infinite bus, transmission folks look at it as a fixed load. That's about to change.

We also have segregated time domains for dynamic analysis. You had a set of dynamics modeled for a transient stability, for a small signal stability, for a long-term dynamics. The new resources, the new issues we're facing, blow all these and we need a way to have simulations that have a wider spectrum of time domains.

So here's some specific examples.

Midwest ISO is public with this, they are on the limits of performance. They no longer can guarantee closing the market within the hour and a half or two hour time window they have every day because of the number of nodes and resources in the mixed integer programming algorithm. And they're off working with PNNL and Gurobi and GE Austin to see what can be done to parallelize it, but right now MIP doesn't parallelize. Terry Boston privately to the Committee said PGM is not that far off. And depending upon who you talk to, whether it's Gurobi or IBM CPLEX, LINUX or UNIX, et cetera, there's 20-30 percent variability in this, but it says we're running out of gas with this key algorithm. And FERC has told the MISO we need you to have the market clearing window. So we've got a real challenge in the optimization. Add to that all the market operators are using a DC OPF as part of the security constrained unit commitment. And the new resources in adding VAR support or VAR support as a market function says we have to go AC. Big problem. So these are headline real problems that could stand in the way of development we'd like to see in market design.

So what other optimization math is out there? If you look inside all of the ISOs you find these same math and the same solver engineers. And the community, getting the two groups to communicate, has been a focus too.

So those are my comments.

MR. GUCKENHEIMER: Questions, comments?

CHAIRMAN COWART: Tim and then Granger? You have a question?

MR. GELLINGS: Hi, Ralph. So you talked about the thousands of points, you're absolutely correct. Can I drag you over to the world of so how do we actually integrate the overall power system in planning space from transmission through distribution to utilization? I don't think -- well, I know the math isn't all the same. The problems are different in all three of those domains. You're comments?

MR. MASIELLO: Well, you know, we have another panel -- I guess you have another panel later today on transactive energy and how resources on the distribution system will interact with the wholesale markets. Does that simplify an assumption we've got that the substation is an infinite still (inaudible), Clark? You know, that would be my first comment, right.

MR. GELLINGS: And I don't think that's been settled at all.

MR. MASIELLO: Yeah.

MR. GUCKENHEIMER: And I think from coming -- I think that it's clear that in the way in which the system is controlled, there will have to be hierarchy in the system. And the distinction between transmission and distribution is the place at which the hierarchy has been built into the system. In the future, if you want to have two way communication, the hierarchy probably has to be different, the protocols of the -- and the way in which the different levels of the hierarchy interact with one another may need to change. And that's part of the research issue, is what the structure is going to be.

MR. MASIELLO: Here's a pithier way of putting it, in 1997 when the Cal ISO was going through the market protocol detail design with stakeholders, one of the stakeholders half-jokingly said to me, you know, we're really building this market around what you guys can build. And 18 years later we're still doing that. A great example is except for the Midwest ISO, the ISOs all require combined cycle generators to bid in, taking responsibility for what configuration they'll run the plant in. And the reason is every one of those decisions about do I turn on the second CT, et cetera, add integer variable to the MIP and blow up the MIP problem. And Midwest ISO yielded to stakeholders. They started letting the stakeholders say here's the full details of my plant, co=-optimize it for me, but it adds to their computation woes. And it's just one little detail like that.

MR. GELLINGS: Thank you.

CHAIRMAN COWART: Tim?

MR. MOUNT: So I've got a couple of

questions about two interfaces, one that I don't think you were very clear about in the presentations is, where does the market start and automatic control finish. You know, in a way what should the time step of the market be? There are people who think the market should go down below five minutes. I'm somewhat skeptical myself, but I'd like your opinion.

And the second one you were just talking about, John, was the interface between distributed systems and the big grid. There are people who think that the almighty system operator should be able to control my toaster, and on the other hand, as you suggested, the hierarchal control. But I think a very important issue there is who does the person who operates the distribution system and sort of optimizes what's happening there work for. Are they working from the point of view of the system or are they working from the point of view of customers? And basically that latter is the one that we really are not using at all at the moment, or very limited amount.

MR. GUCKENHEIMER: I think the response to that I would say is that I think storage is a critical issue with regard to the future operation of the grid. If there were storage in each of our houses so that we could survive without the grid for a day or several hours, then the issues of providing tight control that extend all the way down to the customer from the national level, a lot of those issues would be far simpler. And the questions of when we produce power and the role of intermittency, and so forth.

One of the things that I tried to ask for a number of times during our Committee deliberations and did not get a good response to was what would be the value of a certain amount of storage in the system at a given price. So storage is now expensive, right, but if a little bit of the storage would create enormous economic efficiency. It might be worth it, even at its current price, and then the price would come down. That was something that we did not investigate and it's not really mathematical, it's more in the realm of economic sorts of issues that was not part of our charge. But I think that that's a really big issue that infiltrates into the mathematical issues that we did deal with.

MR. MASIELLO: Yes. And, you know, to pick up on that, we're coming at storage from our electrical perspective, if you will. But if you think about Walmart or Amazon, they're optimizing storage against consumers day in and day out and doing very sophisticated things with operations research to figure out how much inventory of what kind to keep where and how to manage the transportation logistics. The math they use isn't finding its way into the electric power sector. They're not doing it the same way we're doing it.

Another great question you asked is customer oriented. Right now our wholesale markets are pretty much single sided, meaning we have a supply curve and a number for demand. When we have all these customer resources in the market somehow, where are we going to get the demand curve? Will the ISO have to estimate price elasticity, will it require every customer to say this is how much I'll use at what price? Good luck with that one. So these are big questions.

MR. MOUNT: Neither of you talked about the market time stamp.

MR. GUCKENHEIMER: Well, the market timing again is something that is closely related to this. If you have to operate the system in real-time with load balancing demand in real-time without some sort of buffer that's placed in there, then that becomes a question of how many levels in the hierarchy are you going to include in the way in which you do that. In all of the optimization software that is used for dealing with markets is making assumptions about what the actual limits on loads are going to be. And they have to be relatively conservative. They're not doing any sort of dynamic simulation of what the grid operations are. And so if you ask whether we're being overly conservative or whether we're putting ourselves at risk, there's a kind of integration that could take place there that would also require much more powerful computational resources. We'll operate the markets with the software that we have and try to make it better, but where we want to do better and we're not capable, we'll just be conservative and do what we can.

MR. MASIELLO: There is an inter-relationship between the hourly markets, the five minute balancing market, and the four second system regulation, automatic generation control. And there already is movement in the West to move from one hour to fifteen minutes for the purpose of day ahead scheduling. By doing so, you decrease the demand on the balancing market. Similarly, if you can move the balancing market down to one minute, you'd decrease the demands on the regulation control. And you can move them the other direction as well. Technically, a one minute balancing market is feasible, except that most of the balancing resources are not under direct control from the grid operator, they get messages and then act independently to respond to those messages with five minutes or ten minutes as the criteria for response time. So the issues aren't technical as much as they're changing the way things are done.

CHAIRMAN COWART: Granger?

MR. MORGAN: So the MOU that we saw signed was for your recommendation 8, improvements in non-linear, non-convex optimization algorithms. Talk to me a little bit about recommendation six that is supporting research on extended dynamical systems theory. I mean I understand how very important understanding the dynamic property of power systems are and I was surprised some years ago, for example, to understand that degradation is often, apologies, not that slow. You sort of come up to a cliff and then suddenly fall off. If folks like Craig Miller upstairs have their way and we move towards more fractal control and much more distributed things, I presume the dynamics are very different.

I have two questions. One, what's the prospect of actually making significant progress in terms of the mathematics in this space? And, two, how interesting are these problems from the point of view of mathematicians?

MR. GUCKENHEIMER: Both good questions. My expertise is in dynamics. I've been doing it my entire career. And from the standpoint of the grid as a whole, the kinds of things that cause blackouts are in the jargon of the theory called bifurcations. And silent node bifurcation is the mechanism by which blackouts ought to occur. Now the theory sort of says that there are two kinds of co-dimensions, one, bifurcations that occur in generic systems, and this is the foundation of the way in which people think about stability on the grid.

One of the problems for the theory is that when you have switches in the system, it's no longer smooth and the theory no longer applies to these non-smooth systems. Multiple time scales also change the situation dramatically in terms of what you expect. There is a lot of research that is being done on multiple time scales and on discontinuous systems and so forth. Much more progress I think is possible in those areas and I think that it can have a large impact in the way in which the system is operated.

I'm sorry, and the second part of --

MR. MORGAN: No, that's close. I was asking both whether -- how interesting it was from a point of view of a mathematician, and I think you just told me that it could get quite interesting.

MR. GUCKENHEIMER: It's very interesting from a mathematical point of view.

MR. MORGAN: And, two, I was asking sort of how close to actually making progress on some of these problems are -- I mean I presume that one of the reasons for funding -- for this joint thing with NSF is that an assessment has been made that if one puts some money in the space, some significant progress may be achieved. I realize you can't know in advance. I mean there's no assurance of progress, but in this space what's your assessment of the prospect of significant progress if some significant resources could be found to push some of the theoretical issues a little further?

MR. GUCKENHEIMER: I think putting more resources into research in these areas will have a big impact.

CHAIRMAN COWART: The perfect answer. (Laughter) I apologize to those who would like to continue this conversation, but we need to move on to -- or move back in fact to our previous topic that we had launched. And I'll turn to Pat Hoffman to introduce the next speaker.

MS. HOFFMAN: So I'm going to try to get your name right, Ali, but it's Ali Ghassemian -- it's close enough. Ali came over to the Department of Energy on detail from FERC and has been managing what used to be Gil Bindewald's grid modeling program at the Department of Energy. And so we, number one, appreciate him coming over in detail and carrying a champion for the grid modeling activity. So if you could just give an overview of your work.

MR. GHASSEMIAN: Thank you for the introduction. Good afternoon. Because this is my first time I want to give you a quick bio so you guys remember it. So I have a Ph.D. in electrical engineering with a concentration in power system planning and operation. I have over 10 years of experience in energy management systems, working all aspects of energy management systems, from R&D advanced application to project delivery, system integration, including software and hardware. I have over 8 years of experience in regulatory environment, working on reliability related issues as well as policy making. And I've had the pleasure of managing advanced grid modeling for the past five and a half months.

Today's grid is more complex than anything we have seen before. There are many factors, such as increasing electricity demand, environmental regulation, aging infrastructure, reliability standards, and many other things, including intermittent generation and distributed energy resources, which result in a stochastic and dynamic behavior in the system. There are many things that have increased the complexity of today's grid. As a result, today's grid produces an enormous amount of data and significant challenges. It is hard to enable grid operators to make sense of such a large quantity of data in a near real-time and also to make data into actionable items for them because all of these utilities operate closer to the limits with a greater level of uncertainty as before. Unfortunately, today's technology, tools, and techniques are not presently up to the challenge to manage the uncertainty associated with the grid.

To address these challenges, in our opinion, a new faster computational and analytical algorithm is needed that can assist operators in gathering information, analyzing it, processing it, and making it to some actionable task that can be developed and executed in a timely manner to ensure, of course, reliability, resiliency, security, and efficiency of the electric system.

Anybody who has ever been in the operating system, operating room before, knows that decisions have to be made quickly or, potentially in a matter of minutes, you're facing outages. Traditionally operators rely on their experience, for the most part, to manage the system. But due to the increased complexity, this does not work at all times anymore. So they need help. This is where advanced grid modeling programs come in. This program leads R&D aiming to transform data to enable preventive actions rather than reactive responses to grid conditions. It aims to improve the reliability, security, and flexibility of the system.

Some objectives, AGM objectives, are to direct the development of advanced computational and control technologies, to improve reliability, resiliency, and efficiency, to prevent blackouts and improve reliability by providing a wide area, real-time visibility, into the conditions of the grid. Also improve the performance of modeling and computation that are the basis of the grid operation. AGM fully intends to achieve these objectives by advancing the computation mathematical methods, underpinning operator tools, and developing faster than real-time analytical tools. They will work in three main areas. These areas are data management and analytics, which focus on the way data is collected, used, stored, and archived. As an example, as you know, nowadays data is coming from different sources to the control centers and they have to be synced before they can be used.

The second area of mathematical (inaudible) and computation focuses on developing new algorithms and software libraries to address emerging mathematical and computational challenges. Third area, models and simulations, focuses on capabilities for better grid operation and planning in dynamic and stochastic environment. AGM, we have many partners from Federal programs, electric utilities, equipment manufacturers, software companies, regional, state, and local agencies, national labs, and universities. So we try to use as many people as possible, resources as possible available to us.

Let me give you a quick example of how AGM works. Modern power systems are moving toward a stochastic and probabilistic environment due to increase in random forces that modify the system behavior. Random forces such as valuable generation, demand side management, congestion, system load, outages, and even market behavior, to name a few. The existing deterministic operational practices, based on established dispatches and flow patterns, are becoming inadequate to deal with the uncertainty problem. The current practice could potentially result in an increase in the system failure.

As you can see in this picture, this is like our vision, how we picture things. We start with the operation (inaudible), which is where the current practice is. Next step would be including the dynamic data into our models. So we have better control of or better understanding of how things work. Then the next step is predicting.

Using data and data analytic to enable predictive actions. And I'm gradually moving to include to the state where it can handle cases in stochastic and probabilistic environment. In a planning area, right now the current practice is you get a snapshot of the data and run N-1 contingency and see, what are the --what if scenarios that you can deal with, and you come up with the corrective actions. We want to move this thing to the near real-time, meaning we have several massive amounts of cases and we're running these cases in near real-time and come up with the corrective actions for the operators so they can react to that in a timely manner.

As far as the data computation and visualization is concerned, we're going from high speed data technology to the integrated data platform. That's what we're hoping, we are aiming for. We are going from a high performance library to the softer architecture where the libraries can be used to develop software. We're going from the global view, which is situational awareness, to actionable views, which where the corrective actions were presented in a real-time to operators.

In order to make all this happen, a new generation of stochastic and probabilistic methods, reliability and performance criteria, tools, and business practices is very much needed to deal with this uncertainty. We believe development of effective applications requires research on measurement and data analytics, as well as mathematics and models. Advanced grid modeling, I inherited this from Gil. He has 37 projects under advanced grid modeling addressing different parts of that graph figure which I showed you. So we have pieces here and there. And I listed some of them in the next three pages. These projects are all in the area of data management analytics, mathematical methods and computations, and models and simulations.

Recently DOE announced funding of up to $220 million over 3 years for national labs and partners. The GMLC funding will support critical research and development in the AGM soft program. The concentration in AGM has been in load modeling and protection. Why load modeling and protection? We noticed -- we review our program on a continuous basis. We notice that we don't have strong foundational projects in the area of dynamic load modeling and protection system modeling. For the study and coordination of projection, devices, and approaches, to deal with the uncertainty. As a result the GMLC selected projects for AGM are in dynamic load modeling and protection modeling.

The next two slides gives you a brief description of these two areas, which I'm going to skip because they told me I have to.

(Laughter) National Science Foundation, as it was pointed out, DOE commissioned NRC to engage in a study with the following charges, and you've seen it before. One of the recommendations made in the report is recommendation number 8, which is suggesting DOE and NSF should sponsor a development of the new open source library of simulation software intended for the new generation electric grid research community. The report defines what should be included in open source software. It should include new analytics for the planning and operation of the fast evolving power grid. It should also include new mathematical and computational algorithms. These are all in line with the AGM program objectives. As a result of that, today we had a signing ceremony.

In the spirit of being proactive, we need to think ahead and see what is ahead of us. The following of the natural progress, what has been done under the AGM. So we need to define the uncertainties in the future and how they interact with each other, identify which ones should be dealt with first and how. We need to explore how the research on measurements, data, analytics, mathematics, and models be brought together to fully address the dynamic and uncertain behavior of the system. We had a lot of pieces here and there and we tried to put these all together. Need to manage the risk for a better grid operations, have planning in a larger scale, dynamic, probabilistic, and stochastic environment. Need to manage the uncertainty associated with the data, modeling, model validation, how it can be addressed so the proper set of data and model is processed, developed, used, and tested, validated.

Nobody has all the answers, we certainly don't. So we are reaching out to you distinguished people for guidance, opinions, and input on these topics.

Thank you. (Applause)

CHAIRMAN COWART: All right. Thank you very much. Questions, comments? Sue.

MS. TIERNEY: My comment I think is as much to Patricia as it is to everybody who has just spoken, including the representatives from the Committee. I think this is great that you've been doing this. I think it's extraordinary, especially because it's one of those probably really important issues that nobody hits the radar screen. So the fact that you got $200 million to support work in this area is -- oh.

MS. HOFFMAN: The 220 is for all of grid modernization.

MS. TIERNEY: Thank you for that clarification. (Laughter) I was going to ask, before seeing that bullet up there, how have you been able to develop a constituency for this techie important but really under the radar screen issue?

MS. HOFFMAN: That was (inaudible).

(Laughter)

MS. TIERNEY: I'd say we're still working on it, though it might be without encouraging any comment whatsoever with regard to lobbying. That is just really clear I'm not doing that. It would be helpful for us to understand what we might be able to do to be helpful on that, because I really do think this is really important.

CHAIRMAN COWART: Jeff, then Granger.

MR. MORRIS: Thank you. Great presentation. And I've asked the question before in these meetings about, you know, how we're transitioning from this reactive and rescue system we have to predictive and preventive systems using Bayesian algorithms. I guess my question is that I'm always surprised at the amount of resistance people get on the policy end about privacy around data sets, around the meter. You know, most of the demographics were built around census tract data, postal routes, telephony. You know, a radio arm off of a substation has no relationship to any demographic data that's out there. So is the collection of the base demographics going to be a huge problem and getting around the sense of privacy that people have around their meter, because they understand that it's attached to their house, versus not caring about what they give up over the internet in a lot of cases as far as privacy goes?

MR. GHASSEMIAN: I've only been in this position five and a half months, so probably I won't be able to answer your question correctly. From what I gather, DOE is trying to pair industry and utilities together for developing things. When they do that, coming from a vendor background, when I was at the vendor I mentioned that once before. When I did my Ph.D. I needed some data, so what I did I got a job with the vendor so I can have access to the data in order to do my work. So a lot of the utilities and vendors, we're trying to pair them off and hopefully encourage them to start doing collaborating and working on things together. That way that problem can be resolved.

MR. MORRIS: Thank you.

MR. MORGAN: So I too want to follow up on Sue's comment. And I should preface it again, as she did, I've got no personal stake in this. My mathematical skills have eroded rapidly.

(Laughter) But the fact that you're doing some of this jointly with NSF certainly suggests that you intend to go out broadly across the community, and I would argue that across many of the things that we've been hearing about. While some of the best expertise in the country resides in the National Labs, some of it resides elsewhere. And to the extent that you're able, I would urge you to pursue a strategy of go find the best actors, wherever they are, independent of whether they're in the labs or not.

CHAIRMAN COWART: Paul?

MR. CENTOLELLA: So I come at this as an observer who's neither an engineer nor a mathematician, but I'm encouraged by, you know, the Committee's report encouraged by the funding of this effort. I think, you know, we know that, for example, the advances in mixed energy programming have made the bulk power markets possible up to this point and we've continued to see advances in that area. You know, I think that without knowing the details of what you're doing, the work on dynamic load modeling can be part of a larger look at big data analytics that also could play a significant role here.

I guess I would encourage you to think about areas that have to do with how you solve the dimensionality problem as you're going further down into the distribution grid. In particular, thinking about some of the applications of things like distributed optimization, some of the things that have come out of the communications industry in terms of things like proximal messaging. And some of the things that you might think about in terms of very grid edge automation and control to manage disturbances where they occur in the grid as a way of supplementing some of what you're doing in terms of these computational capabilities as a way of trying to get at optimization and control overall.

So those would be my thoughts and, you know, and hopefully there's progress that can be made in all of these areas and I would encourage you -- because I think this -- as Sue said, this is very important work.

MR. GHASSEMIAN: Thank you.

CHAIRMAN COWART: Tim, and then I -- this will have to be the last question.

MR. MOUNT: So I also support what Sue said. You know, this is a very important area and the MOU with NSF is an important step forward. This is really just a comment that I would hope that there would be an emphasis on new methods for designing and managing distribution systems more effectively so that they really contribute to the grid. I think this is a big hole in our current capabilities. So there's been tremendous progress on the big grid, but not on the many little grids.

CHAIRMAN COWART: All right. Before we

close this out I want to make sure that John and Wanda, you had something to add to that?

MS. REDER: Mine's just short. I think the pattern of working with the National Academy to frame up multidisciplinary scopes and big problems is a best practice and something that can be further leveraged. And I also think that working across departments to advance and research where these multidisciplinary areas can be further explored is also a really good idea. So I compliment this and encourage you to do more.

MR. ADAMS: I just wanted to quickly note, you know, there's a business process issue of keeping up with changes to system and the size of the business process issue of keeping up with the distribution system is at least 10 times as large as the transmission. I think ERCOT is the only one that's doing weekly model updates to the transmission grid. It is an incredible effort to do that. So I'll just say that the dimensionality problem is not just a computational problem, it is a business problem as well.

I guess the other thing I wanted to ask about is, you know, we also said we'd talk about sharing power flow cases and data. ERCOT did that at one time in maps and stopped because of what I thought was Federal pressure on Homeland Security. So I guess the question is okay, is everyone on board with that proposal or is there more to go?

MS. HOFFMAN: It feels like I have to have some conversations with -- I don't know. So the answer is I think we better figure that out.

CHAIRMAN COWART: Thank you very much. And thanks to all the speakers on this interplay of topics here. Very important work. Thanks, Anjan, for setting that up.

We're due for a break now. We're seven minutes behind, so it's in the acceptable error bar for this afternoon. (Laughter) But we will return -- we're going to resume at 3:45.

(Recess)

CHAIRMAN COWART: We now begin our panel on transactive energy, a topic that the Committee has discussed as a future panel on repeated occasions and now the fortunate day has arrived.

Paul.

MR. CENTOLELLA: So thank you. We are privileged to have these panelists here to talk about a topic that builds on our panel from last March on the valuation of distributed energy resources and looks at this from a market perspective of how we could begin to have transactions in energy resources at different levels. And so we have four quite distinguished speakers on the panel. We're going to begin with Dr. Lynne Kiesling. Dr. Kiesling is an Associate Professor of Economics at Northwestern. She is an author of a number of books on electricity markets. She is also an advisor to the Institute for Regulatory Law and Economics, one of the better training grounds for regulators in the U.S. at the University of Colorado, and has done a lot of work on economic regulation, innovation technology change, new institutional economics, and political economic history.

Second speaker is Dr. Richard Tabors.

Richard is a colleague of mine at TCR where he's President of TCR. He is also the Co-Director of the MIT Utility of the Future Study, a Visiting Professor in Electrical Engineering at the University of Strathclyde, and one of the original team at MIT that developed the math for LMP pricing.

Our third speaker is going to focus on how transactional energy integrates with buildings. Srinivas Katipamula -- I hope I got that right, Srinivas, or close enough anyway -- is a staff scientist at PNNL. He's also an ASHRAE and ASME Fellow and he is focused on operational efficiency in commercial buildings throughout his career.

And our final speaker, Curt Kirkeby, you know, heads the work on applied R&D in emerging technologies at Avista Utilities. He was the principle investigator for Avista smart grid project and has worked on a variety of issues related to grid asset management operations and advanced metering.

So with that I'm going to turn it over to Lynne.

DR. KIESLING: Thank you, Paul, and thank you for inviting me to speak on this panel. Given the conversation that we just had, I think there's a lot of good cross fertilization to happen here.

My role on this panel is to frame out at a conceptual level and provide a definition of common framework for a discussion of transactive energy. So I'm going to stay conceptual and I'm not going to get technical, but what I hope to do by kind of setting the stage and talking about the conceptual economic concepts of transactive energy that that will create a framework and a space for having a little more technical discussion from the other panelists. Or at least that's my goal, so ask me in 10 minutes if I've achieved that.

This, just as a starting point, is my favorite schematic of our current representation of the power system. Since you all eat, sleep, and breathe this, I'm not going to go into this in any gory detail, but just so you know where I'm starting from and thinking about both the physical current flow in a fairly linear direction and the, if you will, the economic institutional and organization vertical integration from generation through the wires through the retail relationship with the end-use customer. So for me this represents both the physical and the economic value flow and supply chain. And I'm thinking about that as a starting point for thinking about transactive energy because I think one of the important aspects of transactive energy is that the innovations that we've seen over the past two decades, particularly digital technologies, enable the evolution of this electromechanical very linear architecture to change and to do other things. And part of the challenging work, as we were just discussing, is I think that both kind of the research and the computational and the modeling aspects that we were discussing go into that architectural question of what are these innovations unleashing as potential economic value creation in the distribution network, and in particular I'm going to argue around the distribution edge. And that's where transactive energy is I think a crucial and fundamental concept for thinking about forward looking value creation.

So I want to start with a couple of definitions. I don't remember if Paul mentioned this or not, but as an Emerita member of the GridWise Architecture Council, of course I went right to the GWAC website to get my definition and so I'm going to work with the definition of transactive energy as techniques for managing the generation consumption or flow of electric power within an electric power system through the use of economic or market based constructs while considering grid reliability constraints. There's a lot going on in that sentence and I want to unpack a few pieces of it. And, in particular, I think this definition fuses both the technological aspects of transactive energy and the economic concepts underlying transactive energy. And what

I'm going to do over the next couple of minutes is break those apart so that we can treat them distinctly because they are certainly complements to each other, but they are distinct and it's very important to remember that.

I'm going to focus on the economics. There's no great surprise there. So when we think about transactive energy from an economics perspective, I think it's important to think of it as focus on that word transactive, right The language matters and the word transactive is grounded in the idea of parties engaging in exchange for mutual benefit. Okay, so right back to the fundamentals. And once we start thinking about the concept of transactive, it immediately becomes a very decentralized concept. The idea of parties exchanging for mutual benefit is a very decentralized bottom up concept. It's an idea of bottom up decision making. And I think some of the projects and some of the cases that the other panelists will discuss will be really good illustrations of precisely the decentralized bottom up decision making and one of the -- if I want to -- I'm just going to put a marker in here for a complexity theory way of framing this. One of the arguments that I think you can make about transactive energy as a decentralized bottom up decision making process is -- and this is I think an open and important research question -- is to what extent do you get emergent -- what the complexity theorist would call self-organizing criticality. How do you get self-organization in such a decentralized system? And I would argue that the transactive capabilities that you get from transactive net energy enable that emergent coordination.

And in particular I think the important thing about transactive energy from an economic perspective is that what you're doing is you're using the idea that parties are going to engage in mutually beneficial exchange via transactions and that what these transactions will enable is -- and you'll notice -- and I'm very particular in my use of colors to highlight words here -- that with --

those of you who are engineers I think are more comfortable and familiar working with the idea of control, and I'm going to use a different word that's actually a different concept, which is coordination. And I like coordination. I think it's consistent with the idea that, especially as the distribution network becomes more heterogeneous in scale and scope and the nature of the agents in the system -- if you have customer generators -- I wish we had come up with a better word than prosumer, but that seems to be the one we're landing on -- that is a fundamentally different type of agent in a network rather than having, here's a generator and here's a consumer and they're going to engage in some kind of transaction.

So the nature of the agents change and the scale and scope and the diversity of the technologies also change. And so when you have that much heterogeneity in a complex system, I think the organizing principle, if you want to think about create some kind of order in the system, the organizing principle is indeed one of coordination and that transactions, price mediated transactions, enable that coordination. And obviously the kinds of activities we're thinking about are the generation and consumption of electricity, but also the use of network capacity. So when we think about the distribution grid, one way that you can model the distribution grid is as a common pool resource. Given the way current flows it's pretty hard to define property rights within the grid really well. So what we have to do is we have to come up with a set of institutions to define use rights within the grid and that's where thinking transactivity is useful to us.

As I said, I think when we think about transactive energy it encompasses two dimensions of this decentralized coordination. Dimension one is the economic, and I would argue the institutions, where we think about market design, we think about the rules that govern the exchanges into which we enter. And then the second is the technology. To give you kind of just a groundwork for at least where I think this concept started, I'm going to be a little self-serving and argue that the concept originated in the work that we did in the GridWise Olympic Peninsula Project. And this is a schematic of one of the market clearing periods for the real- time market in the Olympic Peninsula Project. And just to refresh your memory, we had 130 households split among 4 different groups, a control group that got the programmable communiqué thermostat technology, 3 contract groups that either had a fixed -- a TOU with a critical peak or a real-time price. This is a schematic of how the real-time market worked. The idea is that the steps here on the demand curve that are giving you the elasticity, those are the price responsive devices. In this case it was price responsive thermostats. So that is an example of an economic manifestation of the ability of a transactive technology. You program it so that it can respond autonomously to a price signal. And what you get as a result in the market is you get that elasticity. And that elasticity obviously has, you know, beneficial effects in terms of reducing price spikes because those devices can respond autonomously to price signals. And the different households are going to program their devices to different trigger points because different people have different willingness to pay, we're all different. And I argue that heterogeneity is the source of the resilience, the source of the decentralized coordination, the source of that self-organization. And by the way we did this in five minute market clearing intervals, which I think was a bit aggressive.

Like we were talking in the last one about doing the voltage at like five minutes, moving it down to one minute. I think this is an example of doing that same kind of logic, but not in an ancillary or voltage market, but in an actual energy market.

I just put up some examples to put this on a continuum again to just provide us with a frame of reference. I would think about kind of the standard electromechanical world with our spinny dials on the meter, on the watt hour meter. And, you know, if I split this out by institutions and technology again, you know, we start with institutions of having a regulated average priced contract. That's not very transactive. You know, it's not enabling the individual to respond in any way to any kind of price signal because it's giving you that average regulated rate.

And then moving in a more transactive direction we have things like direct load control, where the individual does not control of specific ability to determine when and how his or her devices respond autonomously to changes in price signals, which is again what I think of as the kind of transactive definition. But it is a move in a direction towards having some kind of autonomous response capability. And then, you know, the -- and I picked the picture of this thermostat because that's the one on my wall at home which I can program to a bunch of different times, but it's not price responsive in any way.

But, finally, if we think of something that's fully transactive, that's when you have devices that are themselves price responsive, and that the individual operating the device can program them to respond to price signals. From an economics perspective, the question is what is the individual operating the device willing to pay for the electricity to operate that device? And I think when we get into talking about buildings, we will have a similar but different conversation about the control systems. But at a simple level, I think this is a useful place to start.

To put this in a broader technological context, I would also just put a placeholder for the usefulness and the value I think of thinking about transactive energy with respect to the burgeoning -- the only other phrase I dislike as much as prosumers is Internet of Things, but there it is. You know, the growth of the very censor laden Internet of Things technologies, and one of the capabilities and one of the functionalities that sits in that portfolio of kind of Internet of Things capabilities is indeed energy management, and energy awareness, and energy use information generated and used around the distribution edge. And so I think the intersection of transactive energy and the transactive capability of consumers with autonomous price responsive devices and the contracts that enable them to see the price signals that is something that is very compatible with the Internet of Things. And those are very complementary and, indeed, feed into the earlier discussion of electric vehicles because, you know, the ability to have a price responsive -- I'm going to get the engineering wrong, but I'll say inverter in the garage that cannot just control my solar panels, but can also send a price signal to tell me that I, you know, set a price signal, say when it is or is not valuable to me for me to have my vehicle charged, or for my vehicle to sell power to someone else, sell energy to someone else.

Similarly, I think microgrids around the distribution edge are also a good application of the idea of transactive technology, not necessarily at the device level but much more at an aggregated level. I think we'll probably hear a little bit about that from the other panelists.

And then, finally, circling back to my initial EPRI schematic, I think the idea of transactive energy is really fundamental to the kind of heterogeneity we see in this vision of the integrated grid. With all of this heterogeneity, how can we achieve coordination of resource use across so many heterogeneous agents and technologies? Price is one of the better -- I'll go all Winston Churchill and say price is the least bad of all of the coordinating capabilities that we humans have devised, and the idea of transactive technologies is consistent with that.

I think there are some implications, obviously from an economic perspective, and there are definitely some challenges. Implications of these kind of changes. Number one, from an economic perspective, the digital technologies that we've seen grow over the past two decades have dramatically reduced transaction costs. And so that transactive capability -- achieving is now cheaper than ever, at least from kind of the edge, from the intelligence at the edge perspective. I think the challenges then come in thinking about -- and Tim eluded to this in one of his earlier questions -- thinking about the architecture and the engineering and the kind of research questions around and the dimensionality questions around how does this happen? How can we enable this and take advantage of this while having a well ordered, i.e., decentralized coordination in a stable distribution grid? And so that's where developing a transactive network becomes important. I think this intersects with our discussions about retail market design and lowering entry barriers in retail markets because now we have technologies that make it cheaper and easier for all kinds of decentralized market participation.

Some of the other challenges that I think -- and I know the other panelists are planning to discuss some of these -- is how the transactive network will interact with grid management architecture. I would like to know if there's not an actual market, how is that price signal generated and by whom? And without an actual market, without a market process, you know, what does that price signal mean? Obviously the idea of intelligence around the distribution edge, you know, reiterated a lot. And what does it actually mean to implement transactive control within buildings, how do you create a market within a building? So I think that's a really interesting set of questions. So I would conclude by saying I think transactive technology is opening up all sorts of avenues for consumption, production, and pricing beyond our real binary regulated competitive kind of categories when you think about it from an economic and an organizational institutional perspective.

One last thing that I will throw in as kind of the closing curveball, looking way down the road, and that is that there are all kinds of other technologies that might be able to serve us as market platforms, one of which is Blockchain. If you're not familiar with Blockchain, Blockchain is the open source distributed ledger technology platform underneath applications such as Bitcoin. And the idea here is that different individuals, you establish your own very individual I.D. and you carry it around with you and you're able to engage in market transactions and all of the transactions get written to a shared ledger and everyone has a copy of the ledger, and it makes the transactions very transparent and very hard to tamper with. And so when we think about things like cyber security and financial security and privacy, all of which we know are big and important issues when we think about changes to the architecture of the distribution grid, thinking about Blockchain as a technology platform can interplay with this idea of transactive energy is perhaps a large question for a couple of years down the road, but it's worth us starting to think about.

So with that I will hand it over to Richard.

DR. TABORS: Literally hand it over. Let me see if I can get a timer on here to make sure that I don't do anything terrible. What I wanted to talk about this afternoon -- and first thank all of you for the invitation -- we've been doing a fair amount of work on trying to value distributed energy resources using distributed locational marginal pricing. And I think Clark Gellings is probably the only person in this room that's old enough, along with me, to remember -- you're not that old? If I said that -- you may be close but you haven't quite made it. And if I said you had it would have been an insult and I wouldn't want to do that.

MR. GELLINGS: I'm with you.

DR. TABORS: But you're with me on this one, I know. So Clark and I were at the original happening of locational marginal pricing, called spot pricing with Fred Schweppe back in about 1979 I think, or '80 -- something like that. Long ago that I don't remember. So the discussion today in large part is that I think all of us have sort of become aware that the system is getting down deeper and deeper into the issue of the distribution system. We could have gotten there before, but we kind of broke the world in the transmission and then figured out how to do that in market sense, and then now are beginning to talk down the system. So a little bit of what we've been trying to do. You know, Paul has been part of this and Ralph has as well over the last time, and Mike Caramanis and I particularly, is really to try to understand how one could and why one would think about locational marginal pricing, basically taking it down from the transmission system all the way down to the meter, and how you can do it. And this is a horrible picture, which is fine because I didn't expect you to read the equations or want them anyway, but effectively you've got a way of in mathematics moving down and down and down. And it has in it conceptually the fact that at the end of the day there are really only three products in the distribution system that we have to worry about. And other products are combinations of these, if you will, and that sort of real power, real energy, reactive power, and then reserves. So if you think about a market and what I can buy and sell and how I would do it, effectively I have real, reactive and reserves.

Now another part of that we kind of touched on when Ralph was doing his presentation is, you know, we in the world of wholesale kind of took a little bit of a sidestep about -- now almost 20 years ago -- and we said, you know, reactive, hmm, we're going to have to deal that in a slightly different way and we're not going to worry about it in our math at this point. So if you look at it, we trade at LMP level, only real power, and we put constraints on the system to kind of make up for, if you will, some of the electrical niceties that we put off to the side. When you get down into the distribution system I can't do that anymore. So I have to go from a DC mentality into an AC mentality, and that complicates things quite significantly under those circumstances.

Very quickly, if I look at the three Rs here, the reason that we've kind of set it up this way is if I'm generating real power but I need more reactive I basically have to stop some of the generation of real to get more reactive. If what I want to do is look into the future five minutes, an hour, four hours, whatever it is, I can sell reserves at that point, but if I'm selling reserves I can't also sell real power and reactive power. So these things are, if you will, tightly intertwined and I can only do so much in the mix and match under these circumstances.

And one of the things that has become kind of a big discussion point, and again partially thanks to the State of New York and the REB process, is that there has been a question about how do I value things in the distribution system. And our argument or our thinking is you value things by thinking about distributional locational marginal prices, what you don't do is think about them -- because we've made so many mistakes in the past -- as things like LMP plus D. And so it's always worthwhile for me to lay out and say what's the difference? Well, DLMP is really a granular market measure of the value of energy at a location that we're looking at at that time. So it's LMP, but I've now moved it down and down and down into whatever location within the distribution system I'm trying to get at. LMP plus D is an administrative approach, very similar in lots of ways to sort of the old avoid at cost issue that we got hung with in standard offer cases in California and New York and everywhere else where we tried to kind of do an estimate around an administrative basis and say that's the value of having X in the system for the next 20 years. And if you want to think about Europe for the minute and think about the feed in tariffs in Europe and the impact of that, you can say that's essentially the administrative part. And I am an economist. I mean I know I have a good economist over here with me, but I'm a bad economist because

I have too much engineering in my background. But, you know, looking at this you basically say I can do it better than we did it the last time and I can learn something from the European experience.

The question is why do I care about this in the distribution system? It turns out that I care about it because the differences in the locational value of energy in the distribution system is quite dramatic as you work through the day and as you look at the different locations and as you look at having solar come on and off, electric vehicles come on and off and so on. And we did a fair amount of work on a simulation basis in New York looking at the value of the maximum -- now this is an 800 bus linear radio system, so we looked for each hour in those 800 buses. What was the minimum reactive and the minimum real? Look at the real for the moment, so the real minimums frequently were pretty darn close to zero. The maximums got up, in this case, up into the 20 set range. And you'll note there's a line in the middle, and that line in the middle, which is in this case -- I guess that's green -- I'm having trouble with this one -- green that matches the blue, but this particular line in the middle, in fact, is the LMP at the node of the substation. So in other words that's the substation point and the substation price going into the distribution system. The blue line is the lowest of any of the 800 nodes that we were looking at. And the red line is the highest of any for real power and reactive power. So you can see that it makes a tremendous difference where you are in the distribution system, and the differences are not that different from the kind of spread that we see when we look at what's going on at the wholesale level.

I have a blank screen -- hang on.

(Laughter) I may be old but I'm not quite so old to have lost all of my memory I hope. (Laughter) I think, you know, we've looked at -- and I think I've skipped a couple

of slides somehow in here which
bothers me a little bit. Let me go
back. Let's see if I lost -- did I
really lose three slides?
Probably. Well, let me -- let's
see. Okay. All right. We're
back.

One of things that we were asked to do in New York, working with the REB process, was to not only kind of look at the economic question about what's the pricing, but then kind of under the umbrella about that is, how would one build a market, what would a market look like now, being very separable. Remember, New York and California, New York wanted a market, California kind of went down the prescriptive domain of how to do this. So one of the things that we did in New York was to pick up on their vocabulary, but actually try to correct it because it was not exactly right from an economic perspective. And Jeff Parker and Marshall Van Alstyne were part of the team that then said okay, what is a platform, in economic terms how would it work, and how could we design a platform for the New York distribution utility? So part of the reason I have this up here is to simply highlight the fact that the concept and economics of what's a platform is different from the sort of generic vocabulary that we use. And in the economic sense, it's a business ecosystem that matches producers and consumers who transact directly, so a lot of what of Lynne was saying toward the end of her discussion. And we looked at that and basically said there is a value proposition in terms of how you would do a DER platform and what the market is and why. And that is that you're trying to create, if you will, the overall capability of Paul and me and Lynn being -- me being able to sell, them being able to buy the services that I have in the distribution system. So being able to trade it in the same way and in the same general logic as an Amazon or an Uber, or an Airbnb, where that transactional space not only exists between us, but there are all kinds of network externalities that go with it that really assist the process.

And so, in a sense, in the electrical side you can have it. In New York there was a desire to have eight of them, or seven of them, one for each of the utilities in New York. What became very clear very quickly in the economics of it was you might have enough activity to justify having one platform in New York, but certainly not one for each of them. So in a sense you could think of, you know, some sort of a scale issue. You need to have a regional level type of a platform for DER. Why? Well, otherwise you don't have the liquidity in the market you would need. You need to have a market operator for it, standard kind of theoretical background for how one puts together an economic market under these circumstances. We looked at it in New York and were able to say, okay, if we were going to do this, how would this work. And the answer is you would have an ex-ante market constantly rolling forward where trading was taking place bilaterally, by and large because that's the nature of the structure. If you think about it as an analogue -- ICE, you know, the International Continental Exchange, is a bilateral exchange. This is somewhat similar but a little bit broader than that.

What's clear in the electric world is I have to have a clearing market at the end or a balancing market. Can you do this? In theory you can. Would you necessarily do it that way? At the beginning, the answer is probably no. The reason, there won't be sufficient liquidity to make it go like that. Does that mean you can't calculate locational marginal prices at the distribution level? No it doesn't. I can still calculate all of those, I can still have a less liquid but, nonetheless, correctly priced market that works under those circumstances. So if you look at it and you say, what's the architecture at the end of the tunnel under these circumstances in a transition for transaction pricing? Well it's probably going to have predominantly local control and local response, you know, through automatic price response. Part of what Lynn was talking about. Intelligent prices, response of charging and discharging for electric vehicles, for just general distributed storage. And then adaptive response of and to distributed generations. So looking at it, saying buildings are the most wonderful storage unit out there, we don't use them effectively on the electric side, we need to be able to do that better. The second major thing, I think in terms of architecture, is shifting over from having a centralized market that says you must do, you bid into this and this only, to having much more peer-to-peer where, you know, we can go into the Bitcoin mentality under those circumstances and have it work incredibly effectively.

And then I think we're going to see more secure and efficient power systems operation, but we're going to see it through much more dynamic operation as we go down line. And I said at the bottom line, all of the above developments imply only minimal and generally local emergency only centralized control of distribution in the end state. If you look at it and you say decentralized is likely the way that this is going to work its way out. Now the question that I get asked over and over is, okay, that's great, now what do you do next? And the answer to what we think we do next is to have a modeling system or an analytic system, again kind of going back to the National Academy report that allows us to have one piece of analysis going on at the wholesale level, so the ISO level, and a second piece of analysis, if you will, operating in each of the distribution feeders below that. And decide where you want to break it. But that, effectively I have loops within loops so I can decentralize, I can parallelize the analytics when I'm doing it as a simulator. And in the real world I've got to think a little bit better about exactly how I do it, but with the market you can see that these things are independent.

What's the information flow? The

information flow is if you think about PGM a day ahead, there's an estimate of what the demand is at every point, I run the model, I find the price at each of the substation nodes. Step two, I take the price of each substation node and I feed it down into the distribution feeder and then I calculate given that price and my expectation of loads, what are the expectation of nodal prices inside the distribution system? For those price responsive loads they then are able to respond to that price, they come back and say this is what I want tomorrow. And what I'm feeding back up the system then is quantity. So I'm feeding price down, around the loop, feeding quantity back up. The ISO, in this case, would see a different demand structure as a function of that price, would readjust its expectation in real-time, serve the load, and then we balance afterwards. There's always got to go back and fix the over and the under as you get to the bottom end of it.

So looking at that this is our next step in analytics and our next step in being able to see how those DLMPs work and move as we go down through the system.

Okay. So I'm going to turn it over.

MR. ZICHELLA: Just a quick clarification before you walk off, Richard.

DR. TABORS: Where's that --

MR. ZICHELLA: Over here. The disembodied voice in the corner.

DR. TABORS: Yes.

MR. ZICHELLA: I assume then your last comment about the ISO, you mean the distributed system operator right?

DR. TABORS: No. The last system operator was not the DSO, it was the ISO.

MR. ZICHELLA: Okay.

DR. TABORS: Okay. Because what I'm looking at is the system as it exists today, or maybe slightly modified, where that ISO is calculating the substation LMPs to 2000 nodes. I'm taking that information and going down. Could there be a DSO at that point? Absolutely. But that DSO would be, to me at least, in the breakpoint.

DR. KATIPAMULA: Good afternoon, everybody, this is Srinivas Katipamula, I'm from Pacific Northwest National Lab. And I'm the buildings guy, so I'm going to talk about buildings and how and why buildings are critical if we have to scale transactive control or transactive energy. I'll show you some energy consumption numbers, both at the world as well as the U.S., and show you why that is critical.

And transactive control in theory is quite simple to apply, however, there are a lot of challenges. But if we overcome the challenges, there are significant opportunities to make not only buildings more energy efficient, but minimize the cost as well as increase the reliability of the grid. However, you know, there is significant infrastructure investments that potentially people have to make. And for any investment, unless you have multiple value propositions, it won't be cost effective. And I'll go into some of those as well.

If you look at world energy consumption associated with buildings, you know, we use almost 30 percent of the primary energy in buildings. That's both commercial and residential. Almost a third of that greenhouse gas emissions are associated with the energy that is consumed in the buildings. Almost 60 percent of electricity used worldwide is in buildings. If you compare that with the U.S. building stock, you now, we're slightly higher, we use about 40 percent in buildings, almost 40 percent in terms of greenhouse gas emissions contribution. And if you look at electricity, we almost use three-quarters of the electricity generated in the U.S. is actually used in the buildings.

So if we want to make the grid smarter, you know, unless we integrate these energy consuming assets that are predominantly in the buildings, it won't be successful. And there is significant opportunity in terms of reducing energy consumption in buildings. You know, obviously you can include the equipment efficiency and that has nothing to do with transactive control. However, improving the operating efficiency and adding more distributed renewable energy generation to the buildings, that's where -- those are the two areas where transactive controls has a huge play.

And then in terms of challenges to deploy transactive controls in buildings, there are a number. You know, you have to have some type of control system in buildings to actually deploy these strategies. And we learned, going back from the Olympic buildings of demonstration, through the demonstrations that you've done more recently, only 15 percent of the large commercial buildings actually have building automation systems that can easily leverage to deploy transactive controls or transactive energy concepts. And if you look at the smaller buildings, which are about 60 percent of the floor space in the U.S., they absolutely don't have any control infrastructure. The only thing you have that you can control is a thermostat, and in most cases they're not -- many of them are not even communicating, although the most recent versions of that can probably communicate. And resident is even fragmented. You know, there are a lot of standards, there are a lot of open protocols. However, there's not one single standard or protocol that is predominant. And in such an environment it's hard to deploy something. So these are the challenges that we have to work on related to hardware.

And in order for us to deploy transactive controls in buildings, we have to have models that can predict what would happen if you deploy a transactive controls strategy. What would the building consumption change or how would the building react in the next time step, five minutes, ten minutes, fifteen minute ahead? There are physical models that you can use, however, developing a physical model of every building -- you know, we have five million commercial buildings and maybe 120 residential buildings, it's not a possibility. We need some empirical models that are adaptive and learn and scale. And those are the kinds of things that we need. We are not looking for a precise number, we are looking for, you know, a reasonably accurate model that can give us a reasonable estimate of what the load or the consumption would be in the future.

And then interoperability is a big issue as well, you know, both in commercial buildings as well as in residential. There are some things that can communicate and talk to each other, but by and large it's not a given that you can interoperate.

And then you also need some reference platforms to actually deploy these transactive controls in buildings, something like VOLTTRON, that the Department of Energy has funded, or the PowerMatcher, another open source product from Europe.

And in terms of the end users that are present in these buildings, large commercial buildings like this have very complex systems. And also the loads are not heterogeneous. You know, they are lighting loads, there are heating, ventilation, and air conditions loads, there are plug loads. They're all heterogeneous. And some of them are thermostatic and some of them are not. So non-thermostatic loads are easy to control. Thermostatic loads are a little bit harder to control. And then discrete. Many loads are discrete. That means you can modulate them continuously. So there is an issue there.

And then you have multiple markets in a building. And they are interdependent. For example, in the large commercial buildings you will simultaneously be providing heating and cooling at the same time. So if we affect one of them the other one gets affected. So how do we deal with those? And then if you take just the electricity market, and that also has multiple complements that contribute to that, there's the air distribution, there's water distribution, the chillers generate chilled water or boilers generate steam or hot water, and then the fans are moving air. And these are all interdependent. If you raise one it immediately affects the other, if you lower one, it affects the other. These are all the complexities that you have to deal with in large commercial buildings. And controlled responses are not instantaneous. You know, they do take in terms of minutes and that's not a big deal because I haven't seen any market that is going into the minute. The lowest one that we saw was the five minute market that we did at Olympic Pen.

And then it's not that you -- and also you don't -- in many cases the building loads are not directly controlled other than some of them, like for example, lights can be directly controlled whereas thermostatic loads are not directly controlled. You change a set point for it to move up or down. It's not that it's not possible to do direct control. If you want to do that you have to change the entire paradigm of the building controls. It's based on currently. And then if you are talking about markets that are clearing in five or ten minutes it's not a big issue because I think we could deal with that.

Then in terms of smaller buildings and residential buildings, the loads are less complex, you know, although they're still heterogeneous. And in smaller buildings don't generally cool and heat at the same time so the market becomes a little bit easier you're only dealing with one market at a time, not both gas as well as electricity. But then most of the loads in smaller buildings are discrete, so you can continuously modulate something if you would like.

And then the last challenge. You know, without a market structure, you know, there is an incentive for buildings to participate in the transactive control or transactive energy concept. It's not going to happen. You know you have to have some dynamic rates or some type of market signals that are interoperable because if a certain region of the country operates with a certain type of a control market signal and that's not compatible with another region, it's not going to be -- vendors are not going to be able to produce controls or devices that can interoperate throughout the country. So that's a very critical aspect as well.

So, you know, I've talked about a lot of challenges. There are a lot of them. However, there are a lot of opportunities. And as I said, you know, buildings consume 75 percent of the electricity, and large commercial buildings, that's 15 percent of building stock, do have building automation systems that can be leveraged to provide transactive controls at very, you know, small incremental costs. So infrastructure is not an issue for those buildings. And we can develop empirical models that scale and can be tuned and can be adapted to provide these controls. And then there are open source scalable platforms, you know, both funded by DOE and others that can be used to deploy, that can be integrated with existing building automation systems to provide transactive controls for large buildings. And for smaller buildings they can actually be used as a control platform to coordinate the loads that exist in the buildings. And buildings have a lot of virtual capacity. There is a lot of thermal mass that can be used to mitigate short-term imbalances. And there are a lot of flexible loads in the buildings, it's just that we need to bring them all together. You know, eventually there will be consolidation on the residential protocols. You can't go on forever having 20 different alliances, right. At some point there will be some consolidation and then it will become easier.

And, as I said, there is infrastructure that needs to be invested in buildings. And if infrastructure is only supporting transactive controls or just energy efficiency or helping in mitigating the imbalance that you're generating or creating by adding this regeneration, it's probably not going to be cost effective. You have to have multiple rally propositions when you deploy that infrastructure and harvest that, and that way it becomes more cost effective and more people are probably going to use that. And buildings have a lot of opportunity for infrastructure investment that can be leveraged both to improve energy efficiency as well as grid services.

So, you know, we know 20-30 percent of the energy consumer in the buildings is excessive. And that can be avoided. And there are a number of reasons why that is the case. And then in terms of renewable energy integration, you know, if you have a lot of distributed generation in your building and if that is the solar, for example, and if that is the total load in the building, and then the utility is actually providing that, this is kind of an idealized situation. But if for some reason you get a cloud cover today, utilities will have to absorb whatever loss you get from not generating locally and the utilities are picking it up. The load still remains the same and that's the business as usual down. However, transactive controls can reverse that. Instead of passing that imbalance that you're generating to the utility, you can use the flexible loads in the buildings to provide that. And it's possible, it's just that we just need infrastructure, both in software and hardware to make it happen. And here's an example -- and this is very similar to the one that we did at Olympic Peninsula, but a little bit revised. As I said, in buildings you have both the air and the water market that you have to deal with when you're creating a market at the building level. So you have to start with the zones, and these are the thermostats that manage your diffusers on the top. And you create a market at that level and then you integrate that at the air handler, and then you integrate the chiller and the cooling tower, and then you create a market at the building. And this is possible and we've shown that it is feasible. It's just that we need to find a way to scale that so that it can be deployed on other buildings en masse.

So here's another example of how a transactive signal can actually be used to manage the peak in a building. Even under the current rate structures this is feasible because there are a lot of buildings that actually pay demand and you don't need a sophisticated transactive signal to do that. You only need to forecast what your load is going to be in the next 30 days and then figure out what your target should be to avoid whatever you want to avoid. So there are things that you could do. There is tremendous opportunity that transactive controls provide in buildings, both to improve the energy efficiency of those buildings as well as provide good services and increase the hosting capacity of the renewables. However, we need a lot of infrastructure investment, at least in smaller buildings. You know, you can probably leverage a lot of existing infrastructure in larger buildings, but then any time you make some investments, you know, unless you have multiple value propositions, you know, it's not probably going to be cost effective.

So more pilots are needed so that we can figure out how to scale them. And we are doing one in the Northwest and our hope is that, out of that, we will generate these recipes or how to guides that will be useful for utilities or other institutional buildings like campuses if they would like to deploy transactive control type of activities, how they can do that.

You know, there are other issues that we are also looking at and, you know, integration of EBs, for example, and then more penetration of distributed solar has to be dealt with as well as we integrate these buildings with the grid.

And the last one is that we can do all of these things, but if the market doesn't provide any incentive for that, then obviously no one is going to be deploying this.

So that's all I have.

MR. KIRKEBY:: So I am the utility guy, so I get to actually do this for real, which is kind of fun, maybe sometimes scary, but we've engaged quite heavily in building the infrastructure and the foundation that allows for a transactive type of signal to be leveraged. So

I'm going to give you a little bit of background on us, why you should even care that we're talking about it, and then what have we done to get to where we're ultimately visioning in a transactive model.

So Avista is up in the Northwest, we're in eastern Washington, so not Seattle but Spokane. You probably haven't heard much about it because it's five hours away, although many think you can drive between 10 minutes in between meetings. Anyway -- and Northern Idaho. And so being a part of the Northwest region we have extremely low rates. Our tariffs are from 6 and a half cents to 12. So we don't really have a lot of incentive to do much with respect to distributed resources or alternatives because we're long on power, we have the region that has very low differential between peak and off peak, but we realize that that's not an indefinite situation, and so we want to create our own future.

Why Avista? Well, Avista has had this history of innovation. I think the Northwest in general, but Avista in particular. We've created a lot of things over time, been the first to do something or have the biggest or whatever it might be. We created Itron. You've probably heard of them. And Ecova; maybe you haven't heard of them, but they're the premier utility consolidated billing company. We recently just got approval for our EV tariff. You heard earlier about EVs, so we now have public, residential, workplace, and fast chargers going in as a part of that tariff to test all the things that you heard earlier.

So I want to talk also about the importance of public-private industry partnerships because that has really allowed us to accelerate dramatically what we wanted to do in this space. So I can't emphasize more how important that has been for us to really push the envelope. So when the ARRA grants came out we got three of them, which allowed us to prepare our workforce properly and to change our work rules because a lot of things did have to change given the technologies we were deploying. The Smart Grid Investment

Grant allowed us to accelerate the number of customers that were affected, so we're -- a little over a third of our customers are being positively impacted by our investments. The Smart Grid demonstration allowed us to test transactive control and allowed us to test technologies that could be complementary to an automated distribution system.

So this is kind of an I-Chart, but -- okay, so you can see right here we were working with Battelle, so they had created an abstraction of the transmission system in the Northwest. They then synthesized a transactive signal that was over 72 hours, 5 minutes for the first few hours and then it got to a coarser and coarser granularity. They then sent something to our transactive system, which then looked at our own constraints and our own economics to decide whether we needed to do something with respect to our systems. So what would we modify? In addition, those funds placed a distribution management system into operation that runs 24/7 totally automated. Nobody operates anything. So I repeatedly hear when the operator sees. We don't want the operator in the loop because the operator is too slow to actually operate in a transactive system. So I really want to highlight that we need to get to automation and we need to test that functionality at all points so that the automation is A, trusted, and B, reliable.

So this is what our hierarchy looked like with respect to the Pacific Northwest demo. So our node -- so there was a node for every participant and there were 11 participants in the project -- so we received that transactive signal at the Avista node and then we had non-WSU feeders, so those were all primarily residential customers that had smart thermostats in their home, to which we adjusted them up or down, temperature wise, depending on what we wanted to accomplish. The customers were given $100 incentive to participate on an annual basis. We calculated a locational marginal cost to serve to each one of those customers to make a determination on whether we should or should not raise or lower their temperature as part of a particular received transactive signal. Now the key point here is this is not static, it's all predicted forward because we have to understand that if we're going to modify the temperature within a premise, we may not want to do it if it's about to drop. So there's a lot of analytics that was going on with respect to every one of those thermostats, and what was going to happen in that premise if I executed a change in temperature at that point in time. So we had very precise information about which thermostats should play and whether they would. And in fact there was no override other than somebody calling that up and hitting the actual up and down on the temperate. Most people couldn't tell at all when we executed one of those transactions.

So that worked quite effectively and our challenge was just how do we place an economic value -- so we knew the cost to (inaudible) but what were the other values? So it ended up really being just that economic value and then equating it to the signal we got, which was not an economic value. So we had to resolve what economic value the signal coming from Battelle represented. So we had to do that translation.

On the WSU campus, we had five tiers. So you just heard about buildings. Well, buildings were a very important part, in addition to backup generators. So we had three tiers of backup generators, two natural gas, and one diesel. You can imagine the diesel never ran. And then we HVAC and chillers, so there were nine chillers and there were forty three buildings with air handlers at all points in time. So every five minutes we knew how much opportunity there was with respect to any one of those assets, honoring all the constraints and the future needs with that prediction. This was all done in conjunction with McKinstry and WSU, who set up the capability. Now in this particular case, there was -- you know, this is classrooms and laboratories and places where a lot of people are so we did not automate this. I'll be up front with that. There was an operator in the loop for this so we sent the signal down and somebody actually triggered it there at WSU. And if they couldn't actually honor it, they would give us some kind of reason code as to why they were not going to honor the transaction.

So I'll say that this worked exactly the way we designed it from an economic modeling standpoint. What it didn't do, it didn't capture well enough any of the grid needs with respect to either the distribution. It did try to honor the transmission side, but I can tell you it's very complex to try and extract the entire generation portfolio and transmission portfolio to come up with a representative value. So there were a lot of challenges in trying to reconcile what was coming to us and looking at our system needs and reconciling why they looked not to be in sync. So there was a lot of work throughout the project done to try and (a) understand if they were legitimate concerns or if they were just a mismatch of the system needs at the point in time. Maybe our system had different needs for whatever reason.

So I could say it was successful, but it really just whet our appetite to do more because it didn't represent enough value. And just using economics most of the time we didn't run it. So what we created was a four quadrant valuation system using forward prediction, five minutes, constantly updating that prediction based on the actuals for that five minute period and then putting it into these four quadrants. So for any particular five minute period, was there a winner or a loser with respect to customer and utility? And obviously from a customer relationship standpoint and a utility perspective, we always wanted to be in that top quadrant, right, win-win. So those are the different tiers and the different colors, and the different sizes are the value for that particular transaction. So I would say that was what really drove us to go to the next step because we didn't get this fully automated. We got it to where it was -- we were able to run it effectively and resolve -- both reconcile the transaction and schedule the transaction, but we didn't really get to where this was constantly doing its own thing without our intervention.

So next we jumped into energy storage because if we can model an energy storage system that really allows you to model any kind of distributed energy resource that you could have, any resource actually. Because an energy storage system is just basically a hydro plant. So I can be a load, I can be a source, I can provide reactive, I can consume reactive, I can do all kinds of things. So with funding from the State of Washington and Department of Energy and partners with the lab and WSU and industry, we were able to put in this vanadium flow battery, which is the largest in Europe and North America and we've been able to look at all the different values that we could achieve with different modes of operation. So there was the three Rs, and really you can pretty much put each one of those into an R or two. I would argue that you can probably do all three of those simultaneously given the right technologies.

So you can see that if you keep stacking the values, the transactive values that you would have for an actual energy transaction could be higher. Now what's missing from here, which should be taken into account, is the avoided capital and avoided O&M costs that are pertinent to every particular location on the grid. So that would come into that locational marginal value, right. And so that's really a key component that's missing from here, which may drive particular points of the network to have much greater value. Now that's one of the things in a truly -- if this was a transactive energy services world. There's a challenge in why neighborhood A has a value of X that is 10 times the value of neighborhood B just because that happens to be the way the grid is constrained. So there are some interesting challenges when you get to how you might actually distribute that kind of value within the grid that's related to offsets.

So when we think about moving this technology forward, because now we've got this foundation that we can really leverage, you think about Uber. You know, when I flew in I see this taxi line, you know, all kinds of taxis sitting there and nobody getting in them. And across the way where it's just, you know, people, families picking people up, et cetera, here's all, you know, car after car after car with Uber on it where people are sharing. You know, the shared economy, right. So how would you drive a shared economy in electricity? And as a utility, how would we actually facilitate that? So it really gets into how can I take advantage of those distributed assets with a transactive energy service that would act in a microgrid mode. So where we're going is -- our next project, which will be launching here in about another month and a half, is what we call the micro-transactive grid. This particular concept is being deployed in our U District, which is also our Smart City

Initiative, which is part of the Envision America program. So we have a bunch of technology -- we have all that technology we put in with the ARRA grants, we have additional technology we're putting in with our Smart City Initiative, and then what we're doing here is deploying distributed resources in the form of solar and storage, in addition to ties into building management systems. So there's a number -- this is a multi-university campus, so we have Gonzaga, Eastern, Whitworth, and Washington State University all in this particular area. So we are leveraging building systems to talk with these assets in a way that if you look at -- we got a feeder coming in here and a feeder coming in here. These are switches, automatic transfer switches. So this can be isolated, this can be isolated, or any combination thereof. So in any particular mode, whether I be connected -- so at -- we don't like to parallel things, so one of these will be open at all times normally. But we could close them in the case of reliability situation or a resiliency situation, or we could just have these assets managed to those use cases. So that stacked set of use cases, we could actually deliver all of those in this little section here or this section here. And in the case of, let's say a severe storm type of thing, we might be able to rotate power around. We might be able to provide service for an hour a day or for two hours a day. All of those things then become a part of a shared economy. Because it doesn't matter if I own them or if someone else owns them. If the value can be derived, if I can determine the value of that stack, if every one of those items in the stack can have a valuation methodology, it can go into a transactive signal to actually drive the operation of assets and those assets could be anybody's. I don't really care whose they are because the value is the value, whether I put it in there or somebody else put it in there, the value is the same. So if I can understand that value -- so that's the real critical piece here, if you can understand the value, then you can deliver that value to whomever needs it within this grid. So the project will focus on creating a transactive signal between the assets that are within this grid, which includes not only the campus but some residential and some commercial space as well. So it's 770 acres, it's not insignificant, and it should really prove out how we can deliver that kind of a transactive signal and what that actually looks like, how do those valuations stack up.

So because this includes resiliency and reliability plays, it also means that it's a microgrid. It means it can be islanded, it means it has to have black start capability, whatever that means. So that means I have to have intelligence at the grid. It's been mentioned a number of times, but it's really important.

So the final thing is that we need grid intelligence that takes all the options for both the prosumer, if you will, and the utility, honors both of them, optimizes then together for maximum combined value -- and oh, by the way it just does it at the meter. So the technology that we're putting in in this project will do it at the meter. So the meter, either by itself or in conjunction with each other, will act as the microgrid controller that has the transactions. So the Blockchain discussion, should there be Blockchain on those meters that actually facilitate the transactions meter-to-meter because this technology is all peer-to-peer communication capable. So this is what we've just started into and what we're actually looking at creating, is a transactive signal peer-to-peer within this district which would honor all of the needs and the constraints and do it for those individual microgrids, the grid as a bigger picture, or just individual players that might be in there.

And I'll just close with one thing. There's often times a lot of discussion about wholesale market and bulk power system, and I think, while that's important, we keep forgetting that the distributions system is where it all starts, that's the load. If we had a perfect distribution load the needs at the bulk power system level would be a lot different. If I had distributed resources that could transact with each other to create a perfect load curve it would be a lot different world on power delivery.

MR. CENTOLELLA: Thank you to the panel. We've got I guess about 20-25 minutes, so let's take some questions. And I'm going to start over here with Janice.

MS. LIN: Thank you. I actually have a question for Curt as well as one of the previous speakers, because it's kind of the same topic. And that's to build on your last point, which was to focus on the distribution system and the load, and if it was a perfect load, you know, what would -- the implications are profound. And that's sort of related to a comment -- I believe it was Ralph who said -- I even wrote it down -- he said, what would be the value of a certain amount of storage in the system. If it created enormous economic efficiency it might be worth it even at its current price. So what I was curious about is --

and, you know, so it's sort of related to transactive energy but it's a bigger picture question -- is how would you think about setting up that analysis, that value. So it's a much more macro question of, well if we could massage load and optimize a distribution system, what is that worth to us? And transactive energy may be one of the ways to get there, storage is another way. So that's my question.

MR. KIRKEBY:: So I think the transactive piece gives the platform for players. So the importance of transactive is to provide that ability to deliver value to players that might want to invest. So that's the one aspect. So the stack you saw there, that was a $7 million investment. Some of it first time investment, so it would not be relevant to a repeat and the value stream. If you add in resiliency and reliability, which I'm not sure how you -- today we don't get to -- our tariff doesn't have a reliability component I guess would be the easiest way to say that. And people just expect us to be reliable because we have been. But if you include those two, that's about $6.2 million worth of benefits. So you can argue if you can deliver those values then it's just an economic evaluation for any player.

Now I think the key is that we don't have as an industry, we don't have a methodology for each one of those types of values, and I'm not even sure that that is the complete and total list of values. And maybe it's something even simpler, like the three Rs that you heard about. Maybe it can be boiled down to something simpler which then also has a locational value as well. But if we can get agreement on a methodology so -- that's where I would like to see work done. If the methodology could be agreed upon then the inputs can always be argued, but the methodology is there for everyone and it's a flat level playing field across transmission, generation, and distribution.

MR. CENTOLELLA: Go ahead.

DR. TABORS: Can I chip in? Again this is the two of us at this end of the table are economists and one of our heroes is Bill Hogan who has really been the LMP guy. And Bill's sort of mantra, and I have to agree with it most of the time is that, you know, if you get the prices right at least to start with and at least know where the heck those prices come from or those costs or values come from, using that term to say those are really all the same thing when you're down in the distribution system. If you get those right, then effectively you can make those comparisons and you can answer the question, if I had enough -- what would I be willing to pay to maintain the reliability of the system given system X for storage where storage was in fact a device that provided the balance in the system and guaranteed the reliability and security, and so on and so forth.

So I mean this is part of the economist diving into that swimming pool as we did back when we did the original LMP work. You know, if you get the prices right and you understand what that price value cost point is, then you can calculate the value, you can think about those investment values under those circumstances. If you don't do it, then I would argue, you know, you've got a ways to go. I agreed with Curt entirely, would like to be able to understand whether we can actually do that in the scale that you talk about when you get down to transactive energy. And these are lots and lots and lots of individual transactions that are taking place.

DR. KIESLING: I would just add to that that the important thing about getting the prices right is that that's not a bureaucratic or administrative process, that's a market process. And so any value stack that we create is going to be a set of estimates of the results that would emerge out of that market process and the valuation of individual consumers for whatever the service is.

And this is a slightly tangential observation but I think it's relevant, this is one reason why in the work I've been doing lately I've been arguing for moving away from thinking about reliability and just moving towards resilience because if I have transactive devices and I've got them set at a trigger price so that they turn off, I'm technically not getting electricity. Is my service reliable? I'm getting what I am willing to pay for, I'm getting what I asked for. So I think our definition of reliability is going to have to evolve along with this.

MR. CENTOLELLA: Sue, next question.

MS. TIERNEY: First I want to compliment you, Paul, for inviting these folks because this was a wonderful panel. It was really great. Each one of you had a different angle. And my head is spinning, and so I'm going to try and limit my questions to two.

So one of them has to do with business models issues and Curt's discussion of Avista. I am -- I have an easier time picturing that role of the utility as the platform operator and as the person in the system who is looking at the tradeoffs of dollars. And yet we heard about ones where it's really not centrally organized, and that there are transactions between two parties. That one I have such a hard time conceptualizing because of my second question.

And that is in a network, aren't there external reliability issues associated with two people deciding that well, I didn't get the -- I got the resiliency and reliability I paid for, but given the physical nature of the system, doesn't that actually have external effects on other parties in the system? So that just breaks my head when I think about it in that way. So please give some reactions.

DR. TABORS: Susan, let me take a crack at it. And that is that if, you know, just like we do in the transmission system where we talk about LMP and constraints and we calculate the value and then assume that for better or worse that we have a market that's actually taking care of some of that in the --

MS. TIERNEY: Centrally organized market?

DR. TABORS: Well, it doesn't have to

be. We happen to have it that way at the moment. But if you think about it, we call it a centrally organized market but, you know, we get to bid -- there are bids and effectively offers in that market. That's what a market is. Now could you do that down in the distribution system, where again a very significant part is your calculation of the constraints in the physical ability, if you will, to move energy? And that affects -- remember my picture with a big spread in it. That big spread is essentially affected largely by voltage.

MS. TIERNEY: But isn't there that single operator in that world, or is there not a single operator?

DR. TABORS: I don't think that there has to be. I think there could well be, but not a single operator, certainly a DSO. A single operator implies that PJM is going to run down that -- and I don't think any of us with a straight face either want to can conceive of that, but could there be and should there be a DSO who's doing that? Sure. There's a good model, and as I said I think originally, initially you have to have that. I mean initially there isn't going to be the liquidity that's required to do it and maybe the platform concept actually doesn't quite work in the electric sector. I'm a little suspicious of that.

So let me turn it over to somebody else.

MR. CENTOLELLA: I'll give a modified answer to what Rich said, that ultimately you're going to settle the transactions in an imbalanced market that reflect real power flows. And so the continuous market that occurs before that will tend to settle out based upon the expectation of what that imbalanced market looks like, which just like the real- time market at the bulk power level is based on actuals, calculated ex-poste as opposed to an ex-ante market.

MS. TIERNEY: Sorry to be so dumb, but the question is really isn't in each physical place, doesn't there have to be at the end of the day the balancing person who calculates that? And is that a utility?

So I'll stop -- now I'll stop.

MR. CENTOLELLA: So the person who can calculate the actual power flow, which may well be the utility, would provide the data necessary to calculate the imbalance price.

DR. TABORS: But it doesn't have to be -- I mean the issue is yes, somebody has to calculate that. It turns out that that is not a very difficult calculation ex-poste, which is a blessing under those circumstances, but it could be the platform operator. I mean I don't have -- you know, it could be the platform operator. It needs to be somebody at the end of the day has to say you consumed this, you consumed that. The value of what you consumed is this, and it becomes a financial transaction.

MR. CENTOLELLA: And what you need is you need power flow and you need the topology of the grid to be able to do the calculation.

Rich, next question.

CHAIRMAN COWART: I'll echo Sue because

my head is spinning also. And let me preface this question by saying I'm an ex regulator who is a fan of LMPs, a fan of time of use pricing, getting the prices right, the whole deal. But there's a part of this conversation that I think most regulators would have trouble with, and that is going to your slide, Richard, where you're showing these big differentials in cost or value, however you term it, from one small neighborhood basically, one small node to another. And that, you know, by -- and the notion that we're going to come up with a system that is charging either individual businesses or individual customers such different prices for electricity in the same moment as somebody across the street or across town is something that I think a lot of decision makers would say that's not consistent with the society we want to live in.

And I'm going to pause here and just switch to Germany where, you know, they go to the opposite extreme. As you probably know, in Germany they don't have locational marginal pricing at all, and they have one price for the whole country even though the constraints on the system are enormous. And, you know, they look at New York -- you know, the people who are thinking about this look at New York enviously and say gee, having at least two zones would be good and ten would be better. But I get it that there are some inefficiencies if you don't disaggregate.

My question is how do you deal with this question of like total disaggregation where every customer is just an Uber customer and I get told from minute to minute how much it's going to cost me?

DR. KIESLING: I'm the mid reliever, you're the closer. (Laughter) A couple of thoughts occur to me in thinking about this. One is since you said Uber, when I think about surge pricing, you know, one of the -- I was teaching at our IRLE workshop for regulators last week and there I asked -- I gave a dinner talk and I asked for people who had taken Uber, you know, what do you think the reasons are for having a surge price, you know, is that just to charge some people more money. And they accurately said the surge price sends a signal to drivers, hey, now is a really valuable time to get out there and give someone a ride. And so what does that -- and the awkward -- I guess I'll say social policy awkward aspect of our surge pricing dilemma in the distribution network is that it's physically geographical in nature and that has -- you know, when you're talking about neighborhoods. And so there's a sense in which if you always are having a congestion price in a particular neighborhood, you know, prices are signals wrapped in incentives. And so that should tell you something, right? Hey, there's some profitable investment that could take place in serving this neighborhood. And so that I think is a salutary effect, a salutary longer run effect of short run potential price spikes.

The other way that I think about that question is one of retail market design. So if you have a market that has low entry barriers and you have retail competition and you have different retail providers who are offering different contracts for different types of energy services. And so putting aside something like low income home energy assistance program (LIHEAP), but just think about the potential for retail providers to offer a portfolio of contracts and, you know, if I'm -- each individual consumer is then making a decision, you know, do I want to be on that real-time price or do I want the certainty of a fixed price. And then I think part of what for me that comes in at kind of the distribution LMP level is how do you price the grid services, right, separately from how you price the energy. And that's where I think this congestion pricing is going to come in and that's what -- that's like a third of the bill generally or.

DR. TABORS: Yes, I agree totally with Lynne. Let me add one thing or two that are twists. One is that that example that I gave with the big spreads for the 24 hour period and the 800 buses, in that example the non-responsive customers -- and we had real customer -- well, we had surrogates for real customers in there -- the non-responsive customers all gained, their bills went down by six percent in that particular example for instance. So that basically says everybody won. I mean you had somebody whose prices were higher in an hour and lower in an hour, but those people who didn't respond actually came out quite a bit ahead of where they would have been otherwise. So you're picking up good old economic efficiency along the way.

I think the other part of it on the pricing and the, you know, you look at that spread is that we allow people to have -- to run the meter backwards, so net metering. And distributed locational marginal pricing is actually the right answer for net metering. That's what it is. So if you look at it and you say how are we going to get out of net metering, which is a disaster everywhere, particularly in Germany by the way, you know, this gives you a little bit of a thought process that says is there equity? And I have a very close colleague who's now in Washington at the Department of Justice and she in a discussion last -- god, I think maybe 16 months ago, said I'm not sure that I can afford not to put photovoltaics on the roof of my house because I'm paying for all of my neighbors who are putting them on the roofs of their houses. So the inequity problem is pretty bad no matter what, but the question is, is this the better partial solution?

Picking up on Lynne's point, at the end of the day you've got to capture the wires cost and that's often far larger than the energy cost when you're operating down in the distribution system.

MR. CENTOLELLA: So this could be part of a much longer discussion, but I want to get in some more questions.

Wanda?

MS. REDER: Well, my initial question was kind of along the lines of what happens to the role of distribution utility through this as you think about some of the things Sue teed up. But, you know, there are so many things that need to be kind of adopted and contemplated in a vision of full implementation. And I was just wondering, from each of you, what do you think the top two or three key criteria or things that need to have to happen in order to fully adopt transactive energy? Just, you know, the -- Curt -- yeah.

MR. KIRKEBY:: Well, I'll get back to value. We have to be able to calculate the value. If we can calculate the value then the rest of the platform is relatively easy. And I say that as an engineer and other engineers would shoot me, but we over think a lot of these solutions, and it's really not that complex to distribute control and distribute transaction, but how you fairly represent those transactions is really the issue. And then of course you have to reconcile them but that, once again, is just a math exercise.

MS. REDER: And do you think the value often gets -- it becomes difficult because of asset class and also because of jurisdiction?

MR. KIRKEBY:: Well, yeah. So just take FERC accounting. It puts it into transmission, generation, distribution, communications. I just spoke to a group of accountants on how do we even know where to put it from an accounting perspective? So I think it's difficult just because we are -- well, (a) we bill on kilowatts, that's not what we deliver. We deliver KVA. We don't charge for KVA except to our biggest customers. Why? I just don't get that. Fundamentally that needs to change because we wouldn't then be talking about just kilowatts or megawatts, we'd be talking about what we truly deliver, which then reveals how you can resolve that problem with VAR flow, which actually causes transmission issues as well as distribution issues as well as voltage issues. So if you could get down to the value and put that value on KVA, then we'd be in a lot better place.

MR. CENTOLELLA: I'm going to keep running through questions until Rich tells me this --

DR. KATIPAMULA: Since you asked, the biggest thing is on this there is a market incentive, you know, as a customer or as a user and I don't have any incentive to do anything different from what I'm doing now.

And then beyond that, you know, you generally need some infrastructure to be able to do this in an automated way. You know, you can't expect people to go change their behavior based on the dynamic prices. So you need some infrastructure that can automatically make those changes based on the preferences that they choose, not what the utility tells them or someone else tells them. So they make the decisions.

MR. CENTOLELLA: Okay. Sonny?

MR. POPOWSKY: Yes, thanks, Paul. Thanks to the panelists, outstanding. But I would join with Richard and Sue in the head spinning category. And I think among the three of us we probably have 100 years of experience in this field and if our heads are spinning my question is sort of where's the heads of the average residential customer who has to figure this out?

So where I'm coming to is if the object is to get the price right sort of what's the default rate for the residential customer who just wants to get basic electric service? And I guess I'd ask you first, Dr. Tabors, but also, Curt, for Avista, customers who aren't interested in this, they just pay the standard rate?

DR. TABORS: You know, the easy answer to that is the customer that isn't interested just ignores it, and then at the end of the year they're going to pay an average -- they'll have ended up paying the average rate that I would have calculated as the utility for that supply. So what did they lose on the way by? They lost the ability to reduce their cost and probably haven't had much of an impact on the increase. So as today, you know, where people have time of use rates and they can, you know, opt in, if you opt in and ignore, you know, you're going to pay the expected value of that stream of consumption that you would have had.

So, you know, you say is that bad? I'm giving people an option and if they choose not to take the option that's fine.

You don't look very satisfied there.

MR. POPOWSKY: The part I don't understand about that is that if certain feeders are constrained compared with other feeders, and therefore the locational price to all customers on that feeder are higher on average than they are today, because they're averaged across the whole distribution system, then aren't those customers behind a congested substation or a congested feeder paying more in the future under this system than they would have been under a more socialized distribution tariff?

DR. TABORS: Peanut butter is a wonderful thing.

(Laughter) Spread it out --

MR. CENTOLELLA: But only if they don't respond. I mean so one of the values of having the differentiation is that you actually get people who will respond. And so I'm reminded --

you know, I don't remember which pilot it was but one of the pilots, when we were first looking at doing real- time pricing during flat rates, gave people the choice up front and two-thirds of the people picked a real-time price as the rate that they would prefer. Why would you prefer that? Well, I look at my experience on Uber a couple of weeks ago when I chose Uber rather than a taxi fare that would normally be $60 and I paid $7 to go the same distance because I happened to not be in surge pricing. And that was a pretty good deal. So people will -- and if you're in a competitive market, people will have a choice presumably that they can hand over some degree of demand management to their supplier in return for a lower flat price.

MR. KIRKEBY:: Well, I would think that if nobody responds, the utility has to spend the dollars to fix the problem and everybody gets higher. The rate base increases. So it's really more of an incentive for somebody to do something because there's an economic driver and they may be able to do it more competitively than the utility can with its normal rate base structure. If that's true, then everybody wins. Of course if they do it at a higher rate, that's why pricing is important. If pricing is not reflective then you might be incenting the wrong behavior and the wrong investments.

DR. TABORS: Again, I mean if you think about certainly, the experience we've had so far on where people put and how you put PV on the roof, you know, what we know is putting PV on people's roofs is three times more expensive than putting PV in a field someplace in a much larger block, yet we're doing it. So that's issue one.

The other side of that is there are really bad places in the distribution system to put blocks and blocks of photovoltaics on roofs. You know, now I'd like to be able to say that's a lousy place to put it. If you want it, that's fine, but you pay for the reinforcement that I have to have to do it.

MR. POPOWSKY: I'm not disagreeing with

you, by the way, on much of this.

DR. TABORS: I really wasn't challenging that.

MR. KIRKEBY:: Can I just one? So one aspect of that might be, as a utility, we might want to collaborate with developers and provide community solar, community storage options in a development. So anything that's green field we might actually want to have a different kind of design, right, so that it provides that micro transactive grid capability as a part of an investment that's already being made.

MR. CENTOLELLA: So I have four cards up, Rich. Carl, Tim, John, and Paula. Can we take them or?

CHAIRMAN COWART: I think we're doing well.

MR. CENTOLELLA: Okay. All right. Carl?

MR. ZICHELLA: Okay, great. Thanks. Terrific panel. I have an easy question and a hard question. Easy question for Srinivas -- I hope I said that correctly. You said in your presentation that we need to have some sort of standards or controls for devices so they can interoperate across geographies. And I'm just curious how big is the geography you're talking about there?

And I have another question, more related to what we've just been talking about.

DR. KATIPAMULA: There are a couple of things, you know. Interoperability of the transactive signal is critical. So that's the entire U.S. You can't have multiple signals that everyone has to be compatible with. But then there's also interoperability within the devices that are participating in the market. You know, even that, to a large extent, has to be similar across the entire geographical location.

MR. ZICHELLA: Thank you. I appreciate that. The question I wanted to ask, it sort of -- I'm like everyone else so far, trying to understand how this thing fits into and moves away from perhaps the paradigm that we've been in. But there is a certain amount of what we've done that sort of ensures a social equity that I think we've heard Sonny and Richard talk about, that we've come to rely on, and that's been a regulated construct where we've had utilities that are required to provide these services. And as we -- by the way, I'm a member of the GridWise Architecture Council, so I'm all down with the notion of transactive energy. But the thing I think that we struggle with is what's the role for the regulators, and they're struggling with this too, what's the role for operating the markets, and how do we actually do what Curt was talking about in terms of getting the prices right?

I understand, you know, we have to understand the system topology so we know where things are valuable to the system and where the system is weak. We need a variety of potential solutions for that particular problem in those locations that we want to pay people for, whether they're aggregated resources or individuals, and when we would deploy them. A couple of years ago when SONGS went out of service, Southern California Edison did this incredible analysis I was very admiring of, which looked at traunches of distribution services that they would deploy at different grid conditions when they occurred, and the metric they used was percentage of peak. So they looked at when they would layer these things in and then they would have more value the closer you got to the peak. So I think it's very understandable to look at the system topology and say here's what we would need, when we would need it, and what it's worth to the system to avoid having to address a contingency in some way.

Automation, obviously it's going to happen too fast. We do need to figure out how to make things respond, to take your point on that, Curt. But it does seem to me that there's a way that we could look at this that is less complicated. You know, the peer-to-peer stuff, I get lost in that, I have to be honest. I can understand operating the distribution system using transactive signals up to a point. Our last meeting we had a lot of conversation about how complicated we'd need to make some of this, operating the distribution system. Do we look to the feeder? We had one of our presenters say they could look deeper into the system down to the transformer. You know that gets bewildering. Talk about if you're not automated you might as well forget it. But even if you are, that's a level of complexity that may be unnecessary. So I just wanted to throw out a thought about how this might happen in a construct that doesn't toss out decades of social equity considerations that we've baked into how our system operates.

DR. KIESLING: I think, when I think about what -- and I should also say I teach antitrust and regulation and our last day of class was yesterday, so this stuff is very fresh in my mind -- when I think about regulation and what constitutes the public interest, one set of things that does not necessarily sit well together is a static notion of the public interest and technological dynamism. And, you know, 120 years ago when we were thinking about regulating -- or 103 years ago when the Kingsbury Commitment basically made Bell a regulated company, we weren't all walking around with these and able to protect ourselves. And so I think, you know, the transaction cost reducing and the dramatic decentralizing power that digital technology puts in pockets of every individual and increasingly in individuals of lower and lower and lower absolute levels of income, that to me is a very empowering thing that technology does. And so my concern is whether or not we have to think about the evolution of the concept of the public interest and what constitutes the public interest. So that's one kind of big abstract thing.

More concretely, I think we can take a lot of lessons from competition policy more broadly and, in particular, think about a state PUC model in terms of its mission and its activities more on the Federal Trade Commission where they are doing ex-poste consumer protection type review, largely, as opposed to ex-ante rate determination. So I think evolving the regulatory function into a broader consumer protection, you know, focusing on force and fraud, focusing on credit worthiness of retailers, focusing on the efficacy of the LIHEAP programs, those kind of things.

So that's one set of thoughts.

DR. TABORS: Let me do a quick one, and it's very different. And that is to say, you know, ask about what can you do as a transition. We always deal with this opt in, opt out kind of a question and, in a sense, as you move down into the distribution system that's kind of where I think the pattern and the structure goes. And I agree with everything Lynne said, I don't have any argument about that in the slightest, but I think the sort of structural part of it says, you know, at some point we need to kind of move this information in. Why? Because it's getting there anyway, you know. So the question is, you know, what do I do to provide the information that's required for people to respond in what you would call an economically rational way should they want to do that? And if they don't, then they didn't opt in and they're going to be, on average, the same as everybody else that's on average. Somebody who did opt in presumably will do better. And if you look at the dynamic of that, this is one of those things where the last man off the boat is probably not going to be the happiest one in the system, right, because he just paid for -- well, the last guy that bought the -- one of the hamburger, if you will, and when McDonalds ran out of beef just paid for the whole cow, and that may be an expensive way to go.

MR. ZICHELLA: It's quite a clearing price. It seems to me that, you know, we do have this need to serve a lot of people who aren't going to participate, can't participate, fixed incomes, older people. If the result at the end of the day is a lower cost because of that average that you discussed, and I think that might be an acceptable outcome to most people, but I think if it isn't, that's going to lead to real questions about, you know, the social equity of serving everybody.

DR. TABORS: I mean I agree. I mean that's one of the single largest questions everybody keeps asking is, you know, are we in fact achieving economic efficiency in this? And if the answer is I can do it to this level and the answer is yes, and going below that level the answer is no, then you darn well better stop above that point, which is the break- even point.

MR. CENTOLELLA: So I'll just add two points to the discussion as a former regulator, Carl. One is that when we looked at the data in Ohio, you know, low income customers tended to be less peak oriented in their usage and they did tend to respond to price changes so that, you know, yes there may be some minority of people who are low income and hurt, but the majority of low income customers were better off if we had made rates more representative of cost.

The second thing, and this is not a complete answer by any means, but the second thing to remember is that the classical notion of price discrimination is to charge a different price to people whose costs of service are the same. And if the cost of serving two people is different, charging them a difference based on that difference in cost is not what a classical regulatory economics would consider to be price discrimination.

So, Tim.

MR. MOUNT: So I just wanted to say that I thought that Curt's presentation was most impressive. This is exactly what we need to see and he I think -- DOE definitely got good value for their investment. (Laughter) In particular, showing that managing distribution systems effectively reduces resources needed for adequacy on the big grid.

There are two points that I want to add that I think that there is a simple way of dealing with reliability through market mechanisms. That if you have aggregators representing customers who are wholesale customers, a typical wholesale rate structure essentially penalizes you if you don't maintain a stable power factor. Cornell has a contract like that, they deal with all their voltage problems locally. So that's the first point. The second point is -- and you actually made this, Curt, in one of your answers -- that when you see big price differences on a distribution system, as Richard demonstrated, it's an indication you've got a pretty crappy distribution system. And that's what we ought to put our focus on. We ought to start designing distribution systems that are efficient and avoid energy losses, et cetera, et cetera.

MR. CENTOLELLA: Good comments. So, John?

MR. ADAMS: First of all, wonderful presentations. I actually buy into the Kool Aid almost 100 percent, but there were a few things said that really bothered me. You said the pricing problem was a problem of the markets, but I thought externalities was a problem unsolved by markets. In fact, you know, being from Texas we've been -- hey, coal is the greatest thing on earth, right, because it produces the most cheaply, and we dispatched it first for the last 20 years that I know of. And now we've got these people saying oh yeah, but there's this little problem, carbon pollution, that you didn't pay any attention to.

So are you confident you're getting the prices right? What about externalities?

DR. KIESLING: I hesitate to open this Pandora's box given that we're to end 20 minutes ago and my flight is at 7:20, but (laughter) -- and I will sort of circle around and say I'm on record in the public in many places as saying I think the least bad model we have in the U.S. is the Texas model. And so (laughter) just let me butter you up before --

MR. ADAMS: Hallelujah.

DR. KIESLING: However, I think if we're talking about -- if we were following a policy that was say, for example, a revenue neutral carbon tax, that would be easy to reflect in

Richard's DLMP. What I think -- and I'm not an expert in the Clean Power Plan, but at least with the two different bases and all of the concerns that folks I've talked to about how the implementation of the Clean Power Plan might cause real problems in wholesale power markets, I think getting those regulations in 111(d) reflected meaningfully in distribution level prices, that that's going to be a mess. It would be a mess. I mean revenue neutral carbon tax would be a lot cleaner.

MR. ADAMS: None of you think there are any other unknown externalities that are going to creep into this?

DR. TABORS: You mean the unknown unknowns that if I knew them I'd know them? No, there will be others that are in there, but I think the biggest one clearly, at this point, is the environmental one. By the way, environmental is not just carbon dioxide. So I mean, you know, let's face it, if you look at water quality standards in the United States, what you learn very quickly is the more we measure the more we don't like what we drink. So --

MR. ADAMS: So really getting the price right is not a solved problem.

DR. KIESLING: Well, I mean, compared to what, right, compared to what? You know, the fundamental economic question is always, "compared to what". And it is only -- I'm going to channel my inner Deirdre McCloskey -- it is only on the blackboard that we ever have perfect competition and solve all these problems. And so I think the best approach is keeping -- you know, making sure the derivative has the correct sign. We're going to do a better job of dealing with this than we used to.

MR. ADAMS: Just one more. The idea that the person who doesn't participate in the market will come out better than they are now, yeah, on average, but I think all of you know that no, not necessarily on an individual case. Because you don't know where that customer is. I think there would be customers who would come out significantly worse.

DR. KIESLING: And because we don't know those customers, shouldn't we exercise a little epistemic humility when we make decisions on their behalf?

MR. ADAMS: No argument. I just wanted to challenge the idea they would for certain come out better.

DR. TABORS: Well, you know, let's do it this way and say that those customers who don't participate will come out no worse off than they would have otherwise. In other words, if I don't change the rules and I change everybody on average -- in other words, if I haven't gone to locational pricing, right, at all then what I can tell you is that they're going to be better off with the locational pricing that some people respond to and they don't than they would have been had they stayed on the current rate.

MR. ADAMS: We'll discuss it off line.

DR. TABORS: Okay.

CHAIRMAN COWART: Paula, I'm going to

give you the last word and I'm sure you're just going to be on board with all of this.

MS. CARMODY: Yes. And once again I'm preventing everybody from going to dinner.

(Laughter) I do want to thank you all. This has been really very entertaining and I also have to say that if Richard, Sonny, and Sue's heads are spinning, mine is spinning like three times as fast, honestly. And my comments aren't going to the notion of, you know, looking at so many aspects of transactive energy and how we're moving forward with it. But I have to say, you know, a concern is with this aspect of social equity, social benefits. When you talk about Uber and Airbnb, and to some extent it amuses me. I may be the only person in here that actually kind of litigated cases involving

Uber in my State of Maryland. And I have to tell you when you're talking about public interest versus technology they very much say, Uber, we are a technology company not a transportation company. And our response continuously was no, you are a transportation company and you do need to take into account certain aspects of public benefits and societal benefits. And these involve consumer protection issues and it involved criminal background check issues and protection of the drivers and insurance issues, none of which are in the Uber calculus or the lift calculus. I think it's also kind of interesting from the driver perspective with the price surging. What seems to be happening in many states is that so many drivers are coming in, their ability to make a living off those rates, you know, ability has lessened in some respects.

But I do think there's a cautionary note here, at least with regard to residential customer. I'm just having a really hard time wrapping my -- not my head, my arms around this notion and how granular you're really thinking about ultimately with transactive energy. You know, we're already talking, we've got demand response, we've got load control, we've got smart thermostats, we've got water heaters, you know, for homes. You can kind of think of those storage -- you've got the solar panels. All of those things are out there, you can kind of see it, but you seem to be envisioning a world where things are going -- you know, would be moving towards real-time pricing, real granular, minute by minute pricing. And I think that's where the difficulty is, trying to imagine residential households dealing with that or dealing with pricing on that level and dealing with that level of risk when, you know, they're basically living on a biweekly and monthly paychecks, having to deal with stability in terms of bills that they have to pay.

So it's not really a question, but I think one of the things, as a follow up, as you're walking through those, those are not illegitimate issues. And I think a lot of times looking at kind of the economist view of things -- I'm not an economist obviously -- some of these things kind of do get lost in the shuffle and I don't know whether you responded by parsing, looking at in terms of transitional, looking at it in terms of what you're trying to do in terms of customer classes, levels, gradations.

I think, you know, sort of, Richard, you had mentioned -- there may be a point at which you go down this far and no farther, you know, whatever that is. But I think that the social equity, the issues around broadly speaking, for residential customer, what you're envisioning I think goes to this point, and at least for a significant period of time it maybe doesn't go down to that regularity. And I don't know whether you would agree or disagree with that.

DR. TABORS: I would add one thing and that is I think all of us envision that transactive pricing is as really being more -- when you get down a residential level -- being more of an automatic response kind of an issue, not an individual choice type issue. And again the question about opt in as opposed to have to opt out, but I mean think about, you know, a smart thermostat, you know, think about a smart dishwasher, think about a smart electric dryer. And these are the things that we're worried now more about, can I in fact then have them be beneficial to the system as opposed to kind of toys, which is really what they are at this point.

MS. CARMODY: Right. And the only thing I would say, you know, with regard to that in terms of home settings and you're looking at kind of appliances and their life cycles, and frankly, over the past 10 years people have been hanging onto the refrigerators, the cars, the everything else much more so than they did. But you can see the life cycle cost. So it is going to take a period of time for all of that stuff to be kind of replaced. You're really talking at this point about water heaters, HVAC systems, and then if they're introducing some distributed resources. So you're still kind of limited in how much you're going to be able to pull, I think, in terms of that Internet of Things, that digital communication.

CHAIRMAN COWART: So, Paul, let me just echo what the other people said, thank you for assembling the panel, thanks for the panelists. This is a terrific conversation and I suspect that we could continue it for months.

On our agenda right -- you have some concluding comments?

MR. CENTOLELLA: I was just going to say we should thank the panel with a round of applause. (Applause)

CHAIRMAN COWART: At this point in our

agenda, there's a space inserted for concluding remarks by the Chair. My concluding remarks are, after thanking the panel, to just remind everybody that we're having -- for those who wish to -- we're having a meal together across the street.

And I don't think we need to make any other announcements. Any other announcements? All right. We are adjourned for this evening. Thank you very much.

(Whereupon, at 5:58 p.m., 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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