UNITED STATES DEPARTMENT OF ENERGY

ELECTRICITY ADVISORY COMMITTEE MEETING

Arlington, Virginia

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P R O C E E D I N G S

(1:12 p.m.)

CHAIRWOMAN TIERNEY: Good afternoon everybody. My name is Sue Tierney. I think I know many if not all of you and it is really great to see you. We have a really great way to start the day and that's with an ethics briefing and we're going to do that even before we go around for introductions because I know that you don't want to wait a minute before your ethics briefing. So after that we'll do some ground rules and introduce new members. The first person we're going to here from is Kate Gehringer. Kate is from the General Counsel's office at the Department of Energy and as you know we are a Federal Advisory Committee and we have special duties and responsibilities including ethical behavior. So Kate, it is all yours.

MS. GEHRINGER: Thanks Sue. I know I was joking about scheduling the ethics training at o'clock, which is the post lunch sleepy time but hopefully we can do this quick and interesting enough to keep you all awake. I know that there is a mix of special government employees and representatives on this Committee so I'm thankful for the representatives sitting through this even though some of this won't apply to you. I think the overall principles are important for you to sort of be aware of. I also know that some of you have sat through this presentation a couple of times already in prior years so that is where I count on you to correct me if I'm wrong.

The first thing we're going to talk about is conflicts. We have two types of conflicts. There is a financial, conflict and one that is based on relationships. In general, the overarching principle is that federal employees including those serving as special government employees who are on advisory committees are prohibited by a criminal statute from participating in a particular matter that has a direct and predictable effect upon their financial interest or the financial interest of those whose interests are abutted to them and that means your spouse, a minor or dependent child, if you are a business partner in an organization. So we'll start with what is a particular matter and then we'll talk about how your duties here could directly affect a financial interest.

So there are three types of particular matters and we like to think of it sort of in a funnel. The first types are matters that are broad, theoretical discussions where you can't say with certainty who or what will be affected. These are generally where they are large policy issues. These don't present a conflict.

The second level, the middle of the funnel is where there are Committee matters that are more specific and you can identify a particular group of entities that will be affected by your duties. So if you are making a recommendation that will affect all national laboratories and you work for one of the labs so that's where we're funneling down and your financial interest is more affected.

The third level is where there is a very narrow focus on an entity or a person who is specifically effected by the matter. This is going to be things like a grant, a contract, things like that. If a specific grant were to come before this committee for discussion that's the kind of thing we'd be talking about there.

So we're going to go back through the funnel and say how do we handle conflicts that are presented by those. So the broad issues like I said those aren't really going to present a conflict because we can't find a direct and predictable effect on any one entity by those. For the middle of the funnel when the conflict for those that are affecting the identifiable group of entities there is an exemption for special government employees where if your financial interests is arising from your employment interest you do not have to recuse yourself from those matters. So that means that in general, if I had an outside job as a federal employee I would have to recuse myself from anything that would affect that company but you do not have to do that for these middle matters where it is sort of a group of entities as opposed to a specific entity. However, when we get down to the bottom of the funnel and we get down to those narrowly focused matters there is no exemption. So this applies to all of your financial interests including stocks and other things and also your employment. So you should be recusing yourself if anything comes before the Committee that would have a direct and predictable effect on your employer when we get down to that level.

This also we like to apply this one to representatives as well. We like to encourage you to not participate if there is something that could directly and predictably effect your employer in that very narrow bottom of the funnel kind of way.

The other type of conflicts is those based on a personal relationship. This is a regulation so it is not a criminal statute but it is basically saying that there are certain personal relationships that give rise to an appearance that you cannot remain impartial and your performance of your duties as a special government employee. The regulation calls these covered relationships and the covered relationships, there is a whole laundry list of them, I'm going to not give all of them to you. It is a person other than a perspective employer with whom you seek to do business. A person who is a member of your household or a close personal relative. A person for whom your spouse or dependent child seeks to serve or does serve as an officer, director or employee. A past employer who you've worked for in the past year or an organization in which you have been active, for example if you're an active member in an environmental group and something effecting that group comes before this committee. So this is based on this reasonable person standard that or this is based on the appearance issues. So if something comes before you where you have a covered relationship you should not participate in that matter if the person or entity with whom you have the relationship is a party or represents a party. If you run into this situation we typically ask you to recuse yourself. However, in certain limited circumstances we can authorize you to participate even with this covered relationship and that is something that, if it comes out, the feds can reach out to me and we can talk through it and see if that is something we'll be able to do.

Other ethical restrictions. Misuse of government position. You may not use your official title as an SGE or the resources that you have access to as an SGE when you're conducting any business other than that related to the work of this Committee. You cannot use your access to any of the public officials or any non-public information that you may receive for anything other than Committee work.

There is also, as an SGE, you are prohibited from making representations on behalf of a third party before the government with respect to matters you are engaged in as an SGE. So what this means is if your organization or company is going to speak to DOE about matters that you guys discuss here, you should not be the one who is talking to DOE on behalf of your organization. I know because I saw them, you all completed your financial disclosure reports. You will have to do that again next year; this is just a warning. It will be about the same time and then you will hear from me or somebody else from my office again next year. The whole point of this is to just give you a basic understanding of how financial interests and these other conflicts could come up. Does anyone have any questions?

CHAIRWOMAN TIERNEY: Just remember that everybody should use the microphone.

MS. LIN: Thanks. My question is related to the misuse of government position and would it be okay -- is it then not approved to list this role in like a public bio?

MS. GEHRINGER: That's fine because it is a position that you hold. This is more in terms of if you were trying to work with DOE or any other agency and you said I am a special government employee, I work on this commission and try to use that to give yourself increased access. It is sort of when you are using it for the gain of someone else. Does that distinction make sense?

MS. LIN: Okay great.

MS. GEHRINGER: Anyone else?

MR. LAZAR: Is there any problem listing that appointment as part of a biography like if I'm being introduced at a conference as a member of the EAC?

MS. GEHRINGER: Right and yes that's fine. What we generally do with our non-special government employees we say when you're not doing DOE related work it should be one of at least three things in your bio so it doesn't get undue precedence and undo prominence in your bio. But if you're saying you work for whoever, you've worked in the field for however many years and you're also a member of the EAC, that's fine.

CHAIRWOMAN TIERNEY: Does anybody else have any questions?

MS. GEHRINGER: One more.

MR. ADAMS: I am actually wanting to advocate that the company I represent apply for a FOA that is going out from DOE. It is nothing we've supervised, it is independent. I'm thinking there is no problem with that.

MS. GEHRINGER: Right it is unrelated to work that you have done on this Committee then you're fine.

MR. LAZAR: I've got a Hatch Act question. Does that Hatch Act apply to us? Can I serve as a precinct officer for a political party?

MS. GEHRINGER: Hatch Act applies to you when you're doing this work and the same things that when you know you're on government time you shouldn't be engaging in political activity. For those of you who don't know, the Hatch Act is restrictions on partisan political activity for federal government employees. When you're using DOE time you should not be engaging in political activity. Regardless, you're allowed to be a precinct captain as long as it is outside of here and you're not wearing your DOE shirt.

MR. LAZAR: I had a financial conflict question. My IRA holds mutual funds. Many of the mutual funds hold energy stocks. Is that diffuse enough?

MS. GEHRINGER: Right so mutual funds are treated a little differently than direct stock interest and if they are what we call diversified funds it should be fine. Where we get into a little more concern is with sector funds where if you have an electricity sector fund, but this is where having a direct and predictable effect on that fund is going to be really hard to do at the level of what I understand the work is here. To the extent that any of you have energy or electricity related sector funds I know a lot of you did disclose them on your financial disclosure reports and I've talked through the agenda for this meeting to make sure nothing is going to create a conflict.

CHAIRWOMAN TIERNEY: Great questions everybody. You get one more chance to come up with some question. Thank you very much Kate.

MS. GEHRINGER: No problem, thank you.

CHAIRWOMAN TIERNEY: For those of you who, like me, have worked for either federal or state government this is part of the privilege that we have in working for this. I know every one of you is not being paid for your service here. It is great work that you are doing and going out of your way to do that and it is with this wonderful burden that you also hold in doing this in a highly dignified and ethical way. So thank you Kate for that and thank you everybody for your service. We didn't mean to intimidate you with that but we figured we would get it under our belt.

So with that, let me welcome you really more officially. We have so new members here today. I'm just going to go around and do a couple of ground rules and explain what we're going to be doing and then let's go around and everybody introduce ourselves. Probably some people don't know everybody. Maybe even give 30 seconds on what role you play in your organization. Before doing that everything that we're saying here is publically available. This is being recorded so just keep that in mind as you're asking questions, as we're having discussions. I'm not suggesting in any way that you would change your behavior but I want you to know that that's the case. Federal advisory Committees are public entities and we are glad to know that the public has a right to come. On that note, members of the public will have a chance to make comments during our meeting so if anybody is here and would like to comment please sign up outside and we welcome that chance later on today. So that will be great. So let's do that by going around and we'll start with our one legislature who is here amongst the group. Introduce yourself, say your organization and then something very briefly about yourself.

REP. MORRIS: So I'll set the example

for brief then. I am Representative Jeff Morris from Washington State, finishing my 20th year with my political hobby. I Co- chair the National Legislative Energy Task Force. Co- founded the Northwest Energy Angels, (inaudible) the Northwest Energy Technology collaborative and glad to be here.

MS. CURRIE: Phyllis Currie. I retired last year as General Manager of the Pasadena Water and Power Department in the City of Pasadena and I'm currently on the Board of (inaudible).

MR. CASPARY: Hi, Jay Caspary. I'm with Southwest Power Pool. I'm a director in our engineering group and I've been there about 15 years with about 35 years of utility experience. I'm responsible for research development and tariff services. Tariff services are related to generation interconnections, transmission service and that is becoming a bigger and bigger challenge on our system with all these renewables so glad to be here.

MR. GELLINGS: Thank you, Jay. I'm

Clark Gellings. I have spent most of my life with EPRI, Electric Power Research Institute, retired earlier this year. Thank you.

MR. ALMGREN: I'm Ake Almgren. I work at my consulting company and I also served on the Board of PDM. My background is 25 years

(inaudible) company with everything from low wattage all the way up to HVDC. Also a background in distributed (inaudible).

MS. LIN: Thanks. My name is Janice Lin and I'm the CEO of Strategen Consulting. We do clean energy advisory work around the country and globally. I wear other hats too. I'm the co-founder and executive director of the California Energy Storage Lands and the co-founder and chair of Energy Storage North America which is a storage conference that is happening next week in San Diego and I also cofounded GESA the Global Energy Storage Alliance which is a 501 C3 facilitate collaboration and sharing of best practices on storage globally.

MS. SANDERS: I'm Heather Sanders. I've been with Southern California Edison for about a year. In that role I do a variety of things. I run our sub-transmission planning group. I run our environmental licensing group and I also do integrated grid strategy and engagement which is about furthering grid modernization investments that are needed to offer our customers the choices they are asking for. Prior to Edison I was at the California ISO for six years. I was the director of regulatory affairs for distributed energy resources and I also was the director for Smart Grid Technology and Strategy before that. The biggest contribution lately has been the road maps that are driving policy in California around energy efficiency demand response, energy storage, and vehicle grid integration.

MS. LANEY BROWN: I'm Laney Brown, vice president of Grid Modernization Strategy at Modern Grid Partners. I've been there for about six months working with utilities on grid modernization strategy in Canada and the U.S.

Prior to that I worked for (inaudible) USA as director of smart grid strategy working on both implementation smart grid but also looking at regulatory strategy and implementation.

MR. BALL: I'm Billy Ball. I'm the chief electric transmission officer at the Southern Company. I've pretty much did transmission stuff for a good long time and not as an independent thus far.

MR. ROSENBAUM: Hi I'm Matt Rosenbaum. I'm the director of Grid Technical Assistance part of DOE. As far as this Committee goes I'm the designated federal officer so I organize the Committee and bring all you guys together and hopefully it is an enjoyable experience. I've been with DOE 12 years as part of the larger 25 years in the government.

MR. MEYER: I'm David Meyer. I'm the senior advisor in the Office of Electricity at DOE. I work on transmission policy issues and grid modernization questions. Lately I've been working on a task force focused on Aliso Canyon and its implications for both the gas and electric industries.

MS. CONKLIN: Hi everyone I'm Meghan Conklin. I'm a deputy assistant secretary at the Department of Energy in our Office of Electricity. I'm the deputy assistant secretary for our division called transmission planning in technical assistance. We have a number of regulatory responsibilities for proposed transmission projects being reviewed by the DOE and also do a fair amount of work on technical assistance states. Pleased to meet all of you.

MS. HOFFMAN: I'm Pat Hoffman and I think I have a little bit of time of the agenda.

CHAIRWOMAN TIERNEY: I'm Sue Tierney. I'm just starting as the Chair of this group so if I'm growing with you that may be some explanation. I've had a couple of careers most recently as a consultant at the Analysis Group. I used to live in Boston for 35 years but I am a Colorado Rocky gal now. I served in Massachusetts government for many years in environmental and utility regulation issues and had the honor of working at the DOE for many years. I just love everything about this industry so I'll leave it there.

MR. ZICHELLA: Carl Zichella with the Natural Resources Defense Council. I'm the director of western transmission so that means I have the worst title in the environmental movement because nobody likes transmission except for seemingly me. My job there is to work on our little project of transforming the way we power the world's largest economy.

MR. BROWN: I'm Merwin Brown with the California Institute for Energy Environment. I'm employed by the University of California Berkley in that capacity. I am also chair of the Energy Storage Subcommittee of this group. My background is over

years in the electric and gas utility industries either working for utilities or national labs or now university mostly in the area of management, energy technology development and also business planning.

MR. ADAMS: John Adams I'm with the electric reliability council of Texas. My current title is principle engineer. I have worked in operations most of my career. Operations engineer up through various positions some of which supervising the transmission grid. I've moved over to market integration, resource integration within ERCOT. I did an advisory position with DOE for a year and they don't know what to do with me now that I'm back.

MS. SILBERSTEIN: I'm Pam Silberstein from NRECA. Welcome to Arlington. I hope you traveled here easily. My current title is senior director for wholesale power supply and transmission issues so I'm on that side of things. I deal with the markets and their various stages of formation and transformation. I also do a lot of work around gas electric coordination, renewables integration. I'm a former fed also. I spent a few years at FERC which I loved being at but I do want to say to the DOE folks I know you guys are in a countdown I always hated this part of the congressional year and I hope the doors are open on Saturday.

MR. ROBERTI: I'm Paul Roberti. I just took a new job so my title did change from what is on my card. I am now an executive director at Ernst and Young working in the Mexico City office on the energy reform and the electricity, natural gas and oil sectors advising the federal agencies and clients. Before that I was a commissioner for about seven years at the Rhode Island Public Utilities Commission so I've made the great transition and leap three months ago. There are a lot of things going on in Mexico.

MR. LAZAR: I'm Jim Lazar, senior advisor with the Regulatory Assistance Project and a new member, this is my first meeting. I'm probably RAP's most prolific writer. You may have seen teaching the duck to fly, renewable integration strategies, smart rate design for a smart planet and our book Electricity Regulation in the U.S. My first rate case was in 1974 as an undergraduate energy economic student. I worked a

30-year career as an expert witness. I've been with RAP since 1998. I worked all over the world with RAP but the last six years mostly in the U.S.

MS. WAGNER: My name is Rebecca Wagner and I am almost one year gone from the Nevada Commission where I served 9 years and it has been the best year of my life especially given what is going on in Nevada. Before that I worked for a geothermal developer in Nevada and now I focus on mostly regionalization of the CAISO as well as other efforts for market opportunities in the west as well as energy policy in Nevada.

MR. FELLER: My name is Gordon Feller and I'm a new member of this group. I've been in Silicon Valley for years and worked to bridge the engineering world in tech companies where I've been to the policy world so I serve on a lot of boards and work with a lot of public policy focused organizations not just in Silicon Valley. Some of you may know for instance what we're doing in clean power in the Valley through something called Silicon Valley leadership group. So at

CISCO at the executive office at the headquarters I've had a global portfolio responsible for not just inventing and developing the new technologies that we bring to utilities or non-utility partners like ITRON who are building advanced metering infrastructure and hopefully modernizing the grid in the process but also working with national governments as they try to prioritize their investments or private investors. So we work with a lot of the venture capital firms in the Valley. We participate in a lot of those venture capital investments with startups who are focused in this area that we're focused on here. One of the non-profits I'm on the board of, Meeting of the Minds, is partnered with utilities, non-utilities, Black and Veatch for instance, AT&T, University of California, Stanford and that organization which was a spinoff from the World Bank works with cities to try to help them use the grid infrastructure and their utility partners, some of whom are owned by cities of course, to try and dramatically improve the performance of the city.

That's one area I'm especially interested in right now.

MR. BOSE: Hi I'm Anjan Bose. I teach electrical engineering at Washington State University. I've worked in electric power for all my life both in industry and in academia and even in government. I spent a couple of years at DOE.

MS. MARILYN BROWN: Good afternoon I'm Marilyn Brown. I'm the Brook Byers professor of sustainable systems at the Georgia Institute of Technology where I've been for 10 years. Before that I was at Oakridge National Laboratory where I managed the energy efficiency renewables and grid program. At tech, I teach in the school of public policy and I run the climate and energy policy laboratory and I simply try to keep one half step ahead of my really smart students. So I look principally at the integration of demand side resources into electricity systems and I am also a member of the board of directors of the Tennessee Valley Authority.

CHAIRWOMAN TIERNEY: Well thanks

everybody and welcome especially to the new members, it is great that you are here and some of you only have a couple of meetings under your belt. So this is a privilege to have this very diverse and experienced group. We have the pleasure that we always do really of having Pat Hoffman here. She is going to give us an update about what it going on.

MS. HOFFMAN: Thank you, Sue and I want to thank everybody for being here today. As I will get into my talk I always value the discussions and the topics that are discussed in the EAC. Since some of you aren't aware because you are new I am the Assistant Secretary for the Office of Electricity Delivery and Energy Reliability at the Department of Energy. I spent 21 years in the Department. I started out in the materials area. Ceramics is my background. I did a little bit of work managing some R&D projects for industrial gas turbines and was asked to move over and take a look at the electrical space from a more mechanical side of things to electrical side of things. So definitely a growth and change across the Department as I've had different jobs in the Department but a wonderful and exciting opportunity.

I'd like to thank Pam and NRECA for hosting us, thank you very much. It is a great pleasure to be able to come out to Arlington and come to your facility so I really appreciate your support on that. Thank you to Sue for taking over the Chair of the EAC. It is a wonderful group to have discussions and bring out debates and have a very constructive conversation. I would like to thank all the new members. I'm not going to go over the list because you've all introduced yourselves and talked a little bit about your background but I really appreciate you supporting the Electricity Advisory Committee. One of the things that I will reiterate is that EAC provides a lot of value to the Department. We take a hard look at your recommendations. Although sometimes you may feel we're not immediate at responding and changing the Department’s bureaucracy around some of the recommendations be sure to know that we take your input, we value your input and we work it into our processes as we think about topics, as we think about papers, as we think about activities that we're moving forward. So the value that I really see is once again being able to get into the challenges that this industry is facing, talk about the pros and cons, the opportunities, what do we really need to work on, what is some of the work that the industry really needs to pull together and utilize, the Department as a facilitator whether we do it ourselves or whether we encourage other groups such as EPRI engage in an activity or other entities. We're going to do as much as possible to make sure as issues are being brought up that we try to address them in one way, shape or form. Of course budget always has a little bit of an influence of what we can or cannot cover. So I do want to thank you.

So what I thought I'd do is take a couple of minutes and talk about the timeline of what we started doing at the Department a couple of years ago, maybe seven years ago, and really looked at some of the strategic directions of where we're heading.

The first thing I thought I'd talk about is the Recovery Act and what we're trying to do in building off of that. As most of you are aware we had 4.5 billion which is an unusual number nowadays and invested in over 330 Recovery Act projects. We really wanted to look at grid modernization and investment in our infrastructure. We wanted to help utilities accelerate their investments in their infrastructure. Some of the estimates said that we helped some of the utilities accelerate some of their investment strategies by two or ten years. I think we've had numerous benefits reports that have been discussed. I know the EAC last year took a deep dive review of the Recovery Act projects and really I would say the recommendation that I agree with is it is a good foundation for us to build off of and there are still a lot of important activities to do and a lot of lessons learned. I know you'll hear from the National Academdy in their book that they put out later on in the agenda but I think there are some pretty synergistic recommendations by the Academy as well that continues to build off of the partnership and the work on the Recovery Act.

One of the things that I'm particularly proud of that the Secretary gives me a really hard time every time I talk to them is the continue to push about the information technologies, really building a stronger sensing data, being able to look at measurements and control but actually advance the information technologies in the electric grid. I think we've done that significantly with the phase and measurement units, we've done outage management systems, we've helped with the thought process. Even though it was already going on in industry we still helped and accelerate the process with respect to distribution management systems. So a lot of fundamental things that I think have gone on that have been pretty impressive and exciting moving forward.

I know that in 2014 EAC really kind of dove down on some of the technology and operational improvements that we wanted to continue to work on in electric grid and I think we're continuing to push some of those issues, as well as in March 2015 part of the Smart Grid Subcommittee looked at sensors and other intelligent electronic devices. I think those are significant things that we're trying to pull out moving forward.

Just so you're aware earlier this year we did have a synchrophasor FOA looking for tools for reliability and asset management trying to pull off some of the recommendations. Also this past spring we announced the FOA for risk and uncertainty, really looking at wholesale market operations, transmission planning and demand site participation. We also are looking at innovative designs for transformers this past -- so we're looking at advanced transformers and we had a FOA out on that I think it was June of this year looking for flexible transformers really going into the security and resilient side of things. And then this past Monday we announced a FOA for sensor and modeling approaches for observability and controllability. I usually use the word visibility but I think I'm going to switch to observability, definitely trying to go after what can we continue to do more in this area. So I think a lot of excitement continuing to really build capabilities and look at advantages of where the grid is going and how we're helping shape that movement.

Energy storage, really appreciate the Energy Storage Subcommittee. I know that the Energy Storage Subcommittee is required as part of EAC. But energy storage is fundamental to allowing for flexibility in the system moving forward. So we've been trying to build off of the work under the Recovery Act. California has had a mandate. Of course we've talked about this in some of the EAC meetings and the 1.3 gigawatts but we really want to continue to advance energy storage technologies and how we can actually get them in the marketplace and I know that the EAC report that is coming up today with some of the surveys that you all did will provide as well some insight and I think very consistent with some of the challenges that we see.

Some of the exciting things is PNNL is continuing to invest in flow batteries and they've looked at a new additive for conventional Vanadium flow batteries. They are actually expanding the operation temperature window for flow batteries and they are also increasing the energy density of flow batteries. So looking forward we're going to try and continue to build momentum. I think that type of energy storage assets looking at reducing the costs but really investing things forward.

One of the I think philosophical but I would say strategic discussions that have gone over the last couple of years really goes toward the integrated grid and I think it was EPRI's strong push of not only do we need to look at information technologies but we really need to look at the internet of things and the integrated grid. Whether you're talking about distributed energy resources, electric vehicles or other devices being connected to the grid. That is a topic that I think is going to continue to grow and evolve. I'm not going to get into a lot of details. We've had several EAC meetings really taking a look at the value of solar or looking at solar technologies, looking at vehicle technologies and I think that discussion has to continue because at the end of the day the grid is going to be more valuable based on the number of things connected to it as we look at network theory and I think it is very important to stay ahead of what is to come so we can actually keep pace of making sure we understand kind of the low profiles and what does the load look like moving forward.

One of the things that I also think was valuable to note keeping in mind moving forward is was the establishment of the Grid Modernization Lab Consortium. I know Kevin Lynn and Bill Parks have spent several EAC meetings talking about the Grid Modernization Lab Consortium but we did have over $220 million that we put forward on the Grid Modernization Lab Consortium. We have over approximately 88 projects that we've done. Why is this important, why do I bring it up is because as you all know we've had different organizations within the Department here at the EAC meetings. It is not only just the Office of Electricity Delivery and Energy Reliability but we have members from ARPA-E, we have folks from Energy Efficiency and Renewable Energy. And what we wanted to do was make sure that the Department was well coordinated in the Grid Modernization Initiative to make sure that all aspects of research that was going on in the Department added value. We recognized that the national labs have a lot of value and a lot of technology and a lot of research that they're working on. But we think and we feel that we can get a greater gain by getting everybody to work together and develop larger more integrated projects with a stronger strategy around that. So we've been pushing that very hard to make sure that the department is well coordinated, that we can come to you with one voice and really talk about what some of the priorities are and what some of the directions are. Given that there can be differing opinions on research or strategic directions in the Department. So I think that is important that we keep that going and we keep adding value so that we're actually being supportive to this industry and so I appreciate the Committee continuing to review the GMLC projects and really I hope you continue to push us hard to make sure that we pull together the projects and we keep adding value for the industry.

Probably two or three other areas I just want to touch base really quick is one is the public private partnership. Some of you are aware that under the Critical Infrastructure Protection Advisory Council we also have the Electric Sector Coordinating Council and the Oil and Gas Sector Coordinating Council. We've been trying to work very hard from the security side of things to work with the CEO's and the leadership of the industry in an emergency and emergency events. I say that our relationship is quite strong in being able to coordinate with the electric sector in moving forward looking at whether it is a hurricane, whether it is a cyber security event or whether it is another event. I think it is very important for us to have that relationship and have the capabilities to make sure that we're addressing issues and that we're able to lean forward as we look at any emergency that potentially could occur in the United States.

But not only should we think about current threats, I think we should also think about what potentially could be coming down the line. So the last Electric Sector Coordinator Committee meeting we actually had at Sandia National Laboratories and it is something that we should think about looking at, the value of the National Labs, and we did spend some time there looking at electromagnetic pulse (EMP) and some of the EMP challenges moving forward.

So as I close up here there is probably two areas that I also want to have everybody keep on their radar which I think is really important given some of the makeup. That is the regulatory structure in the United States is still going to evolve. We've had conversations of course with Audrey in the past and looking at the New York Rev process. Looking at California, I think the business models are going to continue to be challenged. I appreciate Jim, that you're here. I think as you look at rate design, as you look at a lot of other aspects we're going to have to continue to think about how to bring -- continue to have topics at least at the EAC meetings that addresses the challenges around business models and regulatory issues.

One of the things that we are pretty proud of is with LBL. We've been trying to address some of these regulatory opportunities by a group that is at LBL that is looking at the future Electric Utility Regulation Advisory Group. Those of you that aren't familiar, they've produced about six papers on different topics in the regulatory advisory. Some of them are looking at distribution systems with DER, looking at pricing issues and I do believe we're going to have a presentation tomorrow on electricity resource planning. So those papers are really neat that have come out of Lawrence Berkeley and our office and I'm pretty proud of the work that they've been doing there.

And then the last topic is just more following the lines of the national security as I think there is going to be continued growth and understanding of the importance of the electric grid for national security and economic security as we move forward. Cyber security is always an important issue. We're continuing to do research in that area to really look at cyber capabilities and how we can protect the electric grid. But I think it is a topic that is never ending. It is going to require constant diligence. But the way to get on top of this is really to have an integrated strategy with the industry on the tools and capabilities. From my perspective you can look at the aspects of the maturity model but it is really looking at continuous monitoring, situational awareness, the ability to be able to isolate, look at role based access, some of the capabilities that have already been discussed as best practices. But I want to keep that on everybody's radar with respect to a priority and a topic that I think will continue to have to be addressed in this industry.

So with that, I just wanted to close. I know that was a lot for today. I don't normally talk that much at these EAC meetings. People that are here usually know that I'm not too much of a talker. I did want to just express and tried to do a little bit of going back to some of the EAC recommendations in saying you are this group and the discussions here do really help to move our thinking but also I think it helps move the industry forward. So with that, thank you and I appreciate the time.

CHAIRWOMAN TIERNEY: Pat, I hope you'll allow me to just add appreciation for the service that you've had. Pat is one of those assistant secretaries who was a former career employee of Department of Energy. And you can tell by listening to Pat that she has such a breathed and depth of understanding of the various industries and has worked, I've seen you personally and I can't imagine the number of things that I haven't seen personally but I have seen her switch from cyber security to hurricane preparedness and response to the variety of things she said about the ARRA and she has been able to pull and build the team over the course of these eight years, which is a pretty long tenure for an assistant secretary so thank you. It was fine that you took that long.

So we have a short break unless we're all set to go with the computers. We are good to go. So let me give you a little explanation where we're going right now. We're going to hear from Christopher Clack who is the lead author on a paper from NOAA on what is going on with electric systems and climate change in a variety of CO2 emission related topics. After that we're going to have two panels or one panel, one presentation. The first panel will be on high-voltage direct current technologies and we're going to hear from some practitioners about some of the issues there. Then Paul and Clark, if Paul is here Clark is going to describe the information about the most recent National Academy panel report that has come out and then we'll have an open ended discussion at the end of the day about the types of things that you're working on that are some relevance to share with the other Committee members. So that's where we are for today and hope that most of you can join us for dinner. With that, Christopher I think you're up. Would you please introduce yourself?

DR. CLACK: Thank you. So I'm Christopher Clack. I work at the University of Colorado in Boulder in a cooperative institute with NOAA and I've been working on mathematics my whole life, (inaudible) physics mostly and then I moved into engineering and electrical engineering and optimization to look at electric grids. I tried to come at it from a perspective of if you're going to run your whole grid off weather, you need to understand a little bit about what is going on with the weather. So this is where the genesis of the project started. Dr. McDonald who is the director of ESREL put down the seed funding for it to happen and after five years, we published some of our results and I'm going to go through some of them today. Some of them for the Nature Climate Change paper and then some of them sort of extensions of them. They're not different they are just advanced from those results, which came out in January.

Because I work with NOAA it is a legal requirement to show the keeling curve. If we work from the top right downwards along that dotted line we're basically just looking at how long it took the earth to sequester the dark side. So at the top right you're around 100 million years then you go down to 56 million all the way down to the Holocene and then you follow the black line back up and that's what human activity has released back into the atmosphere. I'm one of those people that has been born into a world where I've never seen a below average month since I've been on earth and that number is just going to keep rising. So this is what sort of motivated me to do it but hopefully there is other benefits for moving in this direction as well.

So as I eluded to, weather is going to be one of the key drivers to how we can transform the grid. That is one of the reasons why we have to change how the grid is operating. At the moment all the design operation and markets are built around fuels that have been. If we're going to transition to wind and solar, which is primarily what we'll have to do to decarbonize, you have to work with the weather and you need that through all these different phases. You can have the best economic model in the world but if you tell it the wind is blowing and it is not then your economics is flawed. So the weather is the first component and what I learned when I first went to NOAA and was reading about it and from studying the sun for a long time is you take a step back and look at the bigger picture you see patterns emerge you may not otherwise see. So if you stand here today it is raining quite heavily on and off but if you go to where I'm from in Colorado it is actually really hot and sunny. And actually if you look over the whole continental U.S. there is actually a big smoothing that happens because the Rossby radius of deformation is about 1,000 kilometers across and the U.S. is over twice that width. So when you zoom out, variability actually drops really, really low over a global scale particularly with wind. So this is a logarithm from the x-axis and the y-axis we have variability and this is wind sites across the globe and if you follow it you can see as you go down as you get three orders of magnitude larger in geographic scale your variability drops by five times. So if you can get big enough to encompass these weather patterns you actually find the statement that the wind isn't always blowing and the sun isn't always shining isn't quite true, especially if you zoom out on a global scale. But this just fixes mostly on the U.S. So these are maps that you've probably all seen before. This is a capacity factor map of solar PV and what you can see is that the desert southwest is the best and the northeast and northwest are the worst. This is the same thing but for wind and these are both at 3-kilometer resolution horizontally and this tells us the hub high winds at 80 meters. What you can see is what we call at NOAA the wind triangle that goes from North Dakota all the way down to Texas and across to the Great Lakes is a huge red triangle. Naively, if you just looked at those pictures you'd go okay let's put wind in because it is a high capacity factor and let's put them all in the central plains especially the north central plains. So hold that thought in your mind as we move on when you see the results later on because this is just an average. But actually really for planning you need to think more about what is actually going on. So this is an hour by hour depiction of about 10 days in January of what the power is doing and when it is purple that means it is full power and when it is transparent that means there is no power being produced. What you'll see is that even in those areas where it is bright red and these huge capacity factors there are times where there is no power at all from these generators. More importantly, I think, is you start to see patterns. You actually realize that the atmosphere is just a huge battery that is free and also transports your energy for you so you can tap into it repeatedly as these waves propagate from west to east predominately.

So one solution is put wind turbines everywhere and extract the energy. That is going to very expensive and so where we move into more detailed things is thinking about where can we place these. So we have to build a dataset that allowed us to look at where you can start these generators based on federal lands, state lands, topology, where people live and you see again the central plains again look pretty good for wind. And for solar you get a fairly similar picture. We do also have actual wind, relieves a lot of sight to shipping and military applications. But what we see is there are lots of areas that are excluded for good reason but there are lots of other areas that actually have potential and you can map this in different units. Here we just do watts per meter squared or megawatts per kilometer squared. You can do it in total (inaudible) possible.

And so we say okay you need a big system so I'm going to jump to a different concept which as we said allow the model to have the ability to build a national grid. The HVDC is the technology that was chosen and what I want to point out is it only has the option to do this. If it is not economically viable to do it, it won't do it. It is just saying if you think, as a model, that it is economically beneficial to be able to transmit the power and you can pay for it then build it and tell us where to build it and why.

So there are two sides to the equation, we've done the supply side. The demand side, again at the bottom here is all the different regions plotted for a 10-day period and they all look messy and noisy but then when you look at the national layer, which is the top one, you see a smooth pattern emerge from all the randomness or chaotic behavior. The bigger grid allows you to also take advantage of the smoothing. You can sell to one region when it needs peak demand and when another region needs peak demand at another you can switch who you're selling it too. At the moment if you're selling wind you'll sell into a grid the whole time and you can't (inaudible) I want to sell somewhere else. And then when you zoom out even further to a much longer time period you can see there is a huger pattern emerge over a year period where summer's much higher than winter. You get the weekend notches where people aren't using as much power and winter versus summer look different too. So you have all these different things into play on top of each other that needs to be considered in the model and this is what we've put into the model.

Obviously, we're trying to look at costs and we want to look at the different cost input so we did multiple scenarios in the paper and this is the main three. So each of these has three diamonds on it and the more mature the technology, the tighter the bands go. We tested each of those different costs versus the inverse of the natural gas cost. So we had what was called low renewable cost, high natural gas cost and then high renewable cost and low natural gas cost so that we could emulate all the different scenarios that could be possible with these costs. What I want to point out is that offshore wind is cheaper than that now. Natural gas is about the same, solar is between the one and two dollars. So when we did this in 2013 costs were actually higher than they are now. Natural gas I think we all know is on the low end too.

So I've left the equations for the backup slides if anyone wants to go through them. So I did pictures instead because I get told off normally when I put too many equations. But they are all in this paper and essentially what we're trying to do is we're trying to minimize the total annual cost of this system and we have to pay for all the sunk costs, we have to pay for all the capital costs of building new generators, we have to pay for the fuel that we're burning, all the reserves that we have to hold, we have to pay for this new transmission, we have to pay for the AC transmission to bring in the remote resources as well. So we have to make this as small as possible and then unfortunately we have to provide power at the same time which is what drives the cost up. This is quite a strong model because we enforced that there is no downtime whatsoever in the model. We take into account electrical losses and power flow within the grid and through the AC grid as well. We have a bunch of other equations to do with ramping constraints, operating reserve, load following reserve, peaking reserves and also all the citing constraints and things as well.

The model was allowed to put storage but, for the nature climate study, it was never picked, it was never competitive against the transmission but it is in the model and is able to. And the other critical thing is we didn't put a carbon tax or anything in this model. This is purely economics with those prices I showed but it is in there as well if we wanted to put in carbon tax or an RPS or PTC-ITC model scenarios and it also allows for electric vehicles and things like that. But for this first study it was purely electric grid and what can we do if we have growing demand.

So build the model, run it and then this is what it plans out or what it gives as a road map in terms of generator placement. So the green here is the wind, the red is solar, the purple is natural gas but I think it came out grey on the map as the natural gas and black is nuclear and blue is hydro. So hydro and nuclear were set at

2012 levels. The model can move these up and down but we didn't want to deal with that we just wanted to look at wind, solar and natural gas. So when we do this solution we get about 20 percent wind, 17 percent solar in terms of generation and 20 percent natural gas and the rest is nuclear and hydro. The install capacity (about 30 percent) is dispatchable so 30 percent is natural gas. What we found was the average level of cost was about 10.1 cents including distribution and all this extra transmission that is going to be built. You can tell about 80 percent of your variable generation using this model. What I'll note is that the top northern region that I mentioned before is not as densely populated as you may think and that is primarily because the wind blows hardest at night in those regions, they all do exactly the same thing in those regions so they are all very correlated. So what ends up happening is as you add more and more generators in that region, you add more lower and lower value wind generation which then will push the price negative. So what it does instead is it does a blend between high valued resources in terms of power generated, energy generated and then other resources are very good at matching the cumulative load from it.

So for the transmission system this is what it decided to build. It is a lot of transmission but actually the majority of it is within the interconnects. There is only about 30 million between the interconnects themselves. So a lot of the actual upgrades is within theinterconnects themselves. But those connections as you'll see in a minute with the video are actually important to help with the variability.

So this is just the dispatch stack. So when the model is solving, it doesn't just use averages, it uses the hour by hour data so it actually dispatches and does actually operates as a system where the outputs of the generators of the least cost first and works through a dispatch stack. So on here we're just showing two weeks' worth or roughly 100 hours. Winter is at the top and summer at the bottom and it shows you how it is reacting to the different signals. What we've noticed is if you have dispatchable hydro you can actually take away some of these peaks in natural gas that are occurring but it only ever gets up to a maximum of

per cent of the load. So what does this look like when you see

it on a national scale? So I normally ask people to look at one region, your favorite region wherever you're from normally if there is wind near it and you will see at some point in this video it will disappear and go to zero but when you look at the map as a whole you're going to see all the wind vanish across the United States. That's the green, the dark circles of dispatchable generation and fossil fuels so the nuclear is the solid colors. And we'll see it is actually acting and dealing with the different changes or the variability in the load as well as the resource at the same time. It works using the weather data that is put into it.

So the second video shows the transmission moving the power about. This is hour by hour. Unfortunately, it is running fast but you get the idea you have to move power about across the United States. And what you see is theinterconnects, you are shipping power but nowhere near as much power as you're shipping around within the interconnects which is really helping with the variability of it. Those interconnect areas across the different boundaries get rid of some of your big long duration events where you have big storms that set over a large region and that allows you to bring power in from a much different time zone.

So it goes through this and turns out and then we have to work out what it all costs. So the model spits out what it costs and then we have to work out what it is in levelized terms. So on the right-hand side is four green bars and they are the model simulated runs and on the left side is historical and also projections. I also put on there the average 2015 levelized costs for the US. The diamonds are the cost that have come out from the model, which includes the cost for the transmission. The cost of the transmission is roughly 0.4 cents per kilowatt hour with that extra HVDC overlay when you levelized it. What you see is you get this big change in CO2 depending on cost scenarios but what the big thing I noticed is the coal versus the high cost renewable low natural gas. The only difference between those two runs is whether you allow really cheap coal or not and the cost difference is so small it is within the noise of the model but the CO2 is not within the noise. There is a big flip in the amount of CO2 output.

And then on the round third you have two other scenarios. So the middle scenario the mid-mid is roughly where the costs are at the moment and you can see they are all below the estimated annual average for 2015. We can break it down into the interconnect cost and show that you're not just forcing the western connect to have its price rise so the eastern connect can have a lower cost. The lowering of the cost is distributed across the U.S. You can break it down by state and have a look at each state and see what the state cost would be and the reduction in cost as well.

So this is the cheapest possible solution. This is the least cost optimized. We haven't constrained carbon but when you take the right-hand side one, this is the difference in carbon emitted from the electric grid in 2014 and 2030 with this grid. So you get a huge dramatic decrease but you've also saved dollar amounts as well. This again just breaks it down by state and there will be 12 states that emit zero carbon from this even with taking into the account the reserves that need to be on the grid as well. Along with the conducts there are also local pollutants that have an effect on the communities and so it also models and tracks hour by hour all the different emissions from the power plants. So this shows, on a nationalized scale, the difference between sulfur dioxide and nitrogen oxide emissions between 2014 and the 2030 scenario shown and something that I think is more important in the western half of the U.S. maybe but a lot less water is consumed by these power plants. So you have this water to be able to use for other resources, agriculture being the big one I think, and hopefully not wasting as much consuming for power plants.

Also from the model it tells you how many jobs are created in each state and in each region and this just shows you additional jobs that are created. So all these things are essentially free because they come at a lower cost or close to the cost today and so these things are just from transitioning from one scenario to the next. These slides are a bit denser but I wanted to go into them just quickly. So there are two columns, left and right, and if we work from left to right we go from a national system down to 256 local balancing authorities. So we didn't just test what a national system would look like, we wanted to test it against different scenarios where we don't have as much expansion in the grid, which is possibly more likely scenario. So on the left-hand side we've got in store capacity and on the right-hand side we have energy generated by those technologies. Hopefully what you'll see is there is a downward trend from left to right as you go to smaller regions. So essentially you are ending up with less generation from renewables by going to smaller and smaller regions. That is an issue only because that will increase CO2 as you can see on this slide on the top left here. There are three different cost scenarios and as you go from left to right you'll see that each of the colors trend upwards and that means there is more carbon emissions generated. But at the same time, if you look on the right, their costs go up as well. So by going to smaller systems, not only are you getting less carbon free generation, you're emitting more carbon, but you're also costing the grid more money by trying to cram more renewables into a grid that hasn't taken the weather information and said hey it might not be best to put this wind generator right next to another wind generator. This bottom one is just showing the same thing about the carbon; it is just showing the carbon free generation is going down.

One last scenario that we tested was sensitivity where natural gas is a big unknown cost and so what we did was we set the three different scenarios for renewables and then we changed the natural gas fuel cost between zero dollars, where it costs nothing, all the way up to 14. And what you'll see as you move from left to right, you'll see the renewables take off and become the largest share from left to right. If you go from the top left to the middle one, that top right one, essentially the cost of solar $2.67 would mean that hardly any would be installed compared to today's levels. What you also see is around $4 you will still install about 100 gigawatts of solar before you start pushing up or get the solar deflation devaluation problem happening. And install capacity does go up. And then this is the same plots but telling you how much energy is generated from the different sources. And so we wanted to look at different scenarios and we tried to look at different grid configurations to make sure that it is not overly sensitive to the denotal sizes as well.

So the paper tried to show that there are some realistic solutions that can get you 80 percent of the way there in decarbonizing the grid. You do need a national system to get those high levels if you don't want costs to explode. We're only using

(inaudible) existed in 2007 in this model and there is no storage used by national CCS. So the findings don't always place the generators where the most power is because it might not be useful. You want it where the most benefit to the grid is, which is a different way of thinking, you'll be thinking sort of holistically rather than localized. The large areas are better for multiple reasons. One is you've got a higher probability of finding a more valuable site, you also get to resource share, you also get load diversify as well. And when you coordinate these planning between these regions you get more efficient competition because wind or solar or natural gas plan can sell to different markets if you can get onto those HVDC highways. And then this shows 80 percent is the economic part. The last 20 percent needs another method of technology. So storage might become important, demand management might be important, electric vehicles helping might be important as well as like nuclear and hydro dispatching as well. So

I'll stop there and there is allowed for any questions I'll take any.

CHAIRWOMAN TIERNEY: So if you do have questions please feel free to put up your tent card and we'll start with Marilyn.

MS. MARILYN BROWN: Thank you very much Christopher, I enjoyed that tremendously. But it did remind me of the kind of modeling that has plagued the industry my entire career where demand side is not considered on par with the supply side and see where maximizing to meet a fixed growth and demand. Last Thursday at the Mellon auditorium I received an award for TBA's integrated resource planning modeling where we took the demand side both efficiency and demand response and built it and treated it as a power plant and gave it the same attributes that you've given in terms of capital costs, ONM, a load profile. Can you do that with what you've got? Would you please try to optimize where we're looking at all of the resources available to the nation? I'd be very interested to know if your conclusions would change if you were to attempt to capitalize on the integration of the demand side in terms of the management of targeted spatially and temporally demand management to compliment, for instance, the intermittency of renewables, thank you.

DR. CLACK: Yes, good question. We do have demand side management in the model. It wasn't in this one because we wanted a conservative estimate assuming that human behavior won't change so we said this is kind of a lower bound and you can get more from it. When we put demand side management in it as a means to change the load profiles you're actually more limited by the devices that are connected to the grid because there is only so much power that you can consume in terms of demand management because there is only so many devices you can plug in that can actually take that out and that is the limited factor at the moment--is when we put this into the model you only get about percent help because if you want to keep the economic activity as high due to demand, you're producing as much power but it is just changing when you're producing it so you get manufacturer's to change when they're doing it. There is only a certain amount that you can move these about because there is only a peak amount of power that certain plants can take from the grid. So that is a limiting factor but it certainly will help for sure. Energy efficiency is in the model and it is done regionally so we can allow air conditioners to be improved in ratings in certain regions and see how that effects it. Also heat pumps can be put in instead of air conditioners to do heating and cooling and how that would shift the demand as well. So these are all in the model, this is just the first sort of volley into what the model can do and to simplify it because there is a lot in there for the general reader to take in before you then have demand management.

MS. MARILYN BROWN: Do you have any results you can share with us that show the efficiency?

DR. CLACK: It is under review.

MS. MARILYN BROWN: Under review, okay thank you. I look forward to that.

CHAIRWOMAN TIERNEY: Great question. Jim. Jim and then John and then Anjan.

MR. LAZAR: First I noticed you had the hydro in as a flat block across all hours and hydro is an incredibly flexible resource in many cases and many places. I'm curious how much of the remaining

percent that can't be served with variable renewables could be handled by adapting the hydro resource? But in following up on the previous question, some of the demand side resources in particular ice storage air conditioning, grid integrated water heating control of water pumping and electric vehicle charging are all schedulable, controllable resources on the demand side that may be able to make up and eliminate a lot of the renewable curtailment and I'm wondering if you looked at in particular the thermal storage resource, ice storage, water storage for air conditioning and grid integrated water heating as resources.

DR. CLACK: Yes there are two parts to that, I think, and I'll take the second part first which is we looked at different technologies in terms of thermal storage but we weren't dealing with the heating with mainly the natural gas portion in this particular paper. But within the model we have modules that allow you to do thermal storage and thermal heating. Thermal storage of energy, ice and water to cool buildings to use to transfer heat and that is something that will obviously change the demand profiles. So that is in there but we don't have results for it yet because we were focusing on the electric sector. For the hydro, it does vary month by month with the changing hydrological cycle but we didn't have a hydro runoff model within the model so we didn't want to decide how much power was going to be available or how much water was going to be available in the basin because we didn't have enough data to be able to give us a big enough picture across the U.S. So what we said was we took the minimum produced for that month for each of the locations, so we said that definitely would be available and then we've done studies since where we allowed to dispatch and we got up to 90 percent because we can get away with a lot of the peaking that occurs. The hydro will definitely be very, very helpful but again we are trying to be conservative on what you can do with the hydro part.

CHAIRWOMAN TIERNEY: John.

MR. ADAMS: I've got a whole series so let me just start with what is really a regulatory question. I think you're doing hourly dispatch which means these are essentially changing flows every hour which sounds to me like you're saying okay, ERCOT is not part of an integrated dispatch for the entire United States so I think it is now jurisdictional. Is that the assumption, we've said ERCOT got moved into the rest of the United States.

DR. CLACK: I'm a scientist so I'm looking at what can technically be done with the physics.

MR. ADAMS: Let me just ask the question. Did you happen to look if ERCOT is not part of this dispatch does it still have all of these benefits?

DR. CLACK: Yes so we've done different, which is again under review in energy policy, where we've done different grid size expansions.

MR. ADAMS: Okay.

DR. CLACK: So we interconnect on their own and within the interconnect just the (inaudible) and the (inaudible) regions. So we've done various scenarios and what we show is the same thing here, which is the smaller you go the more it will cost you and the more carbon you'll emit and that's for the policy makers to decide what is the trade-off level is acceptable. How

much cost and how much carbon or
how much additional cost and how
much carbon.

MR. ADAMS: So is this hourly dispatch?

DR. CLACK: Yes.

MR. ADAMS: Okay so 8760 no inner hour.

DR. CLACK: The weather data doesn't resolution enough and the low data wasn't high enough.

MR. ADAMS: Got it. Our DC size price schedule so they're changing every hour, that's the assumption in here.

DR. CLACK: They can change every hour yes.

MR. ADAMS: And almost certainly, yes okay. Where did you get the assumptions on your generators, heat rate, start time, stop time, all those things that affect dispatch?

DR. CLACK: So we did it through EIA, NREL and we also spoke with some partners at EPRI as well on getting as much data as we could. Any public access data that we could find we used.

MR. ADAMS: Great. Hub height for your wind? You're putting a lot of new wind in.

DR. CLACK: Yes. This is 80 meters but the model can do anything from 80 to 160-meter hub height.

MR. ADAMS: Okay. Your model loses on the DC ties, are all those thing accounted for, loses through the 2007 technology on the DC ties?

DR. CLACK: Yes.

MR. ADAMS: Okay just one last, well actually two last. I didn't see any solar flocks. You said there was the natural gas in red that was going up and down but I didn't see anything else.

DR. CLACK: The red is solar.

MR. ADAMS: Okay so I misunderstood. Great. Just one last comment, I noticed where your wind went in Texas. Is where wind is going in Texas driven by economic forces so that's a positive, thank you.

CHAIRWOMAN TIERNEY: Thank you, that's great. Anjan and then Jay.

MR. BOSE: So I haven't read your paper

but you were saying that you are using models that I didn't -- I was wondering if the models were things that you developed or are these the standard models that are used by all power engineers in the country.

DR. CLACK: Yes we built the model from the ground up because of the vast amount of weather data we needed to put in and none of the models that were available when I started the project in 2010 could take the terabytes of weather data that I needed to be able to put in it. So I built it from the ground up to be able to consider the weather at really high resolutions. So now we can go down to

kilometers' five-minute resolution.

MR. BOSE: And your dispatch and your production costing method, I mean there are some very standard methods that people use. But could you compare your models with those?

DR. CLACK: Sure.

MR. BOSE: No did you?

DR. CLACK: We can do it; we haven't

done it yet. None of those commercial vendors have wanted to do that.

MR. BOSE: So the last question, maybe just a comment, you said something about the advantages of DC over AC and some people have read your paper to get the idea that we should be either replacing or putting DC on top of the existing transmission system that we have today. I think we have a panel session coming up on DC where we will hear about studies which doesn't always put DC as a better option over DC.

DR. CLACK: So the DC is just the intertie between the different states in the models. It is a third tier on the transmission. So the AC has to be there for the wind generators. The only option in this one is, if you connect, you'll be paying for the DC. So in the model you've got multiple options so you have different tiers and you can choose different ones but for this paper we really wanted to simplify it because it is a peer review journal that lots of people are going to read, you can't go into all the engineering of 800 kilovolts versus 500 and things like that. But the model allows you to have multiple choices so it might choose AC over DC.

CHAIRWOMAN TIERNEY: David.

MR. TILL: Thank you Dr. Clack, I'm David Till with North American Electric, a liability corporation. I've got a question and then a more extensive commendation more than a comment. The question is in your study and in your cost did you include reactive power needs?

DR. CLACK: So we included a numeralization of some reactive power but is a really gross assumption. I would say no in terms of properly modeling it but there are some terms in there to try to deal with that.

MR. TILL: Thank you. My commendation is as you started saying that it would cost less, and I'm thinking about a national electric system, my thoughts automatically go to a national electric system is not how investments are made and so we've always got to have a point a to point b path so I was very pleased to see that you broke it down to the state level. I've not seen that before. I may sometimes be blind but I've not seen that before in this type presentation and I really appreciate that it was in yours.

DR. CLACK: And the paper will hopefully be out soon going through the growth phase. This is sort of an end state and my question immediately is well which one first and how do you maneuver that and so it grows through the phases.

CHAIRWOMAN TIERNEY: Jeff.

REP MORRIS: Jeff Morris Washington State. I may have missed this but what accounting did you have for externalities in the example with the hydro resource in the Northwest biological operating condition for endangered salmon, that changes the way those systems are operated. So as climate changes there will be a corresponding endangered species list that grows I would assume.

DR. CLACK: Yes so because we used 2006 weather we used 2006 resources for the hydro and the nuclear so they were dispatched at conservative levels at the base of what they were dispatched in those years. So in this the idea was built that you plug and play different resources into it but in here we didn't take into climate changes its actual historical data from other models. So there are no externalities in terms of changing climates or changing habitats or things like that. That can be added as another layer on the GIS data but it is not on this one.

CHAIRWOMAN TIERNEY: Janice.

MS. LIN: Thank you. I had a couple of quick questions and then a more open ended one. I was wondering on the solar resource if you also factored in roof top solar so you're looking sort of all of the above both behind the meter utility scale.

DR. CLACK: Yes so we did, there is a whole other module on solar rooftop but when we put it in it only came up to about 4 percent of the national load when you put rooftop on every single property, residential property at 8 kilowatts on every single property which is very large and that was always more expensive than utility scale. So for simplicity again we just did it with just utility scale, everything is utility scale but in the model you can allow it all to compete. So for different regions it might be different. So this is all a national scale but you can rerun the whole model on just California or just Nevada or places like that and you can allow all the different technologies to compete and the solutions may vary.

MS. LIN: Interesting. And in terms of future load growth, what were included in the assumptions especially for your assumption of rooftop solar as a negative load impact behind the meter and also for EV growth?

DR. CLACK: Yes so there are two options of the model. For the paper what we did was we just grew it with GDP from 2006 to 2012 I believe and then 0.7 percent every year to 2030. For the second module when you've got rooftop solar you do the same thing but you take into account the rooftop solar making divots into it and again that module can include the demand management or electric vehicles and that will -- so you have two sides and those modules go into the demand side so they would alter the demand. And they are the models that can be turned on where as in this paper none of that was in there to define the scope narrowly.

MS. LIN: So my last question is I'm wondering if you could comment on the future modeling plans with this model where you plan to go from here. You mentioned that storage may be a consideration in lieu of the fossil resources so that is one area of interest and this kind of modeling I think could be really interesting at the state level and how would states be able to work with you to explore different scenarios.

CHAIRWOMAN TIERNEY: And Dr. Clack let's have a brief answer to that dissertation question because we have one more question and then we'll close it out, thank you.

DR. CLACK: Yes I want to run different scenarios, different assumptions put in to do all the sensitivities. I feel I've done sort of a really simplistic base case and we want to look at all the sensitivities that people care about from state level upwards. We've done a study with MISO looking at their grid doing a sort of road map form to put into their planning that they may talk about but that sort of is what we want to do with it. We want to use to help inform sort of inputs to much more deep studies and help the planning process going forward.

CHAIRWOMAN TIERNEY: Great. I'm going to take advantage of the fact that I am hogging the microphone to say thank you so much. That was really interesting. I think that this is a tremendous step forward in integrating the weather data at a very granular level with the production simulation and asset investment strategies. And it will really be cool when you match this up with somebody who asks the kinds of questions that John did about institutions, finance, the politics of decision making because that would be extremely powerful. This is really very informative for what ifs in a very, very helpful way. So we'll look forward to the other one too. Thank you.

I think we are going to have those slides available is that correct? And thank you for the references to where we can find the actual studies so that is terrific.

We're going to take a very abbreviated break so really only 10 minutes because I want to try to get us back on time. So 10 minutes from now we're going to start the panel.

(Whereupon, at 2:42 p.m. a recess was taken) PROCEEDINGS

(2:52 p.m.)

CHAIRWOMAN TIERNEY: Well I seem to have jumped the gun because our trusty moderator is not here. Let's see if I keep talking for a second whether he'll walk in. There he is. So thank you Anjan by helping me shepherd this panel take it away.

MR. BOSE: Actually, before I ask the speakers to come up Carl thought I should give a little introduction to HVDC even though most of you probably know more about HVDC than I do. Let me tell you what -- there is a lot of talk today about DC but we're not covering everything DC here. We're only covering DC transmission which is why it is called high voltage DC and as you know there is quite a bit of talk going on on the low voltage DC side. The big issue of course, is that many, many things that we use today are DC. Laptops, electronics, phones, whatever and everybody has tons of little chargers and the things laying around their house and you can't ever find them when you need them. One time I was in a hotel and I had forgotten my charger and I had gone down to the desk and I said do you have a charger for such and such a phone and he said oh we probably do let me check. He brings out a big box about this size and there are a few hundred charges in it and he said you're welcome to look and none of them were the ones I needed. So there's a lot of talk on the low voltage level about DC and whether there should be a DC supply in the home and so on. And then there is the sort of mid-voltage area where for example and this kind of goes somewhat on when I say mid-voltage you're talking about 10's of KV or something like that where you're maybe collecting generation say from a whole bunch of wind generators and you put them on a DC and this is what you would do if you had a whole bunch of wind generation out offshore and you just put a DC line on there. In fact, we don't have a lot of wind generation offshore but in Europe they are using that quite a bit. So we're not going to talk about that as much either. We're talking about DC transmission, high voltage connections of DC.

So here is a map of what we have in North America. So these things with green lines that means that they are the transmission line between those points which is a DC transmission line. So one of the first ones built in the U.S. was this on here from close to where I live on the Columbia River down to LA and then there was these black dots and those are back to back DC which means that there is no transmission line. The converter and the inverter are right there in the same hall or right next to each other. Where do we use those and if you look at them they have a nice pattern there between eastern and western and ERCOT connections and the one that usually people forget is a whole bunch here which isolates the hydro Quebec or the Quebec provincial connection. Now interestingly, of course there is a transmission line over there between Quebec all the way in there and that is because Quebec loves to sell power down into New England and so they use that. And then there are these little orange things and they are relatively new. One of them on the west is the Trans Bay Cable. They are so close to each other the line between the inverter and converter doesn't fit into the U.S. map but there is a line between them. The Trans Bay Cable means that it goes from east bay in the San Francisco Bay area to San Francisco. We'll talk about the technology used here but they are basically these small connections are what we call the VSC type of HVDC and they work very nicely below water or below ground which is where we use them. We'll talk a little bit about that technology but let's move on here.

Here is the European version of that same map and I hope you can see the outline of the countries there but the red ones actually exist today and the green ones are under construction and should be operational in the next couple of years. The blue ones are actually proposed. But if you look at that there is an interesting thing about this is that most of them connect across countries and not within countries and most of them are not even within one interconnection and I'll show you the interconnection in a little bit. All of you know the four interconnections but these are the interconnections in Europe and most of it is this blue thing here where everything is interconnected. And then this is Scandinavia and the islands, Ireland and this is not the UK because part of UK is in Ireland. So Ireland is an island a separate interconnection and this is a separate interconnection. Some of those connections as you saw where most of them is across from Scandinavia through the big European UCT connection and these ones are also connected by DC lines. So they use it somewhat differently than we do.

What is a DC HVDC you have something that converts AC into DC, you have a transmission line between that and then you convert it back to AC and then you connect this to the rest of this AC interconnection. So if you have one of the nice things is you really don't need the other line here you just need one line and the return current can come through ground. It is not very nice to make it come through ground because it keeps wearing away, corrodes metal things and stuff underground so usually you put a second line in there just a metal return you can put there but it is easier to do it this way where you have two lines. This one at a plus voltage, let's say plus 500 KV over here and you've got a minus 500 KV so you've a difference of a thousand KV which gives you a huge big power increase and what you can put across that line. Obviously the higher the voltage the more power you're going to get across. So the difference between these two lines is thousand instead of say 500 between here and the ground and you're going to get four times as much power through there.

There are all these different ways you can fix this. The Monopole, the one with the worse return which nobody uses as I said and then with the metal return nobody uses that either because this is the nicest one to use is two wires. You can easily tell whether a transmission line is AC or DC because an AC has three wires and the DC has two wires. So if you're looking at a pole when you're driving down the highway if it's got two wires that means it is a DC transmission line. Then the back to back we talked about. Then there is multi-terminal which I will say a few words about but the highest level of DC transmission line today is 800 KV plus or minus and about 8000 megawatts and it is in China and they've just completed one that can do actually 10,000 megawatts. So these in fact I think the five biggest or the eight biggest transmission lines in the world are in China today. Some number like that and they're going to build even more and they're building even more faster. The multi-terminal thing is kind of interesting because if you think about the DC it's got two points where you have an inverter and a converter and they're connected to the AC, the rest of it is connected to the AC side. That means that you don't have a network of DC lines. You only have one line at a time so the idea is how can you have now multi- terminal DC and what is the advantage of that. Well they are building one in India for example where they have two generating plants slightly apart that are on the east and they are trying to get all that power up into the Delhi area in the north. So they've got one terminal in the north and two terminals in the east and they've got two transmission lines going in. But the one I showed you before the one from Quebec to Massachusetts is three terminals because it comes down from all the way from Hudson Bay into southern Quebec and then into there so it is a three terminal DC line so we have them as well. But you don't have a whole bunch of these. The one proposed as a connection the Tres Amigas one in the Texas area I don't know if it -- in know that all three terminals are not working yet but maybe you'll hear about that when Jay talks about SPP. So here is the sort of brief history of the technology. The first DC lines were Mercury Arc Rectifiers in the 1950's and some of the first ones were built in Europe again.

(Inaudible) was a major commercial developer. The big problem --

CHAIRWOMAN TIERNEY: Anjan would you just speak into the mic?

MR. BOSE: Oh yes I'm sorry. The big problem with the Mercury Arc Rectifiers is they were hard to maintain if you can imagine mercury all over the place and all that so they went to solid state and they went to thyristors in the seventies. Technically they were about the same. I mean it worked very much the same way and now if you compare AC versus DC, see the cost of AC is the pole and the towers and the actual aluminum and so on and here you've got the two converters and the two amps. So you've got to add the two converter costs to that so it turns out -- but on the other hand HVDC you can get more power across without less losses and so on. The breakeven point was somewhere around 400 miles so that's why the one that was built first was the one down the west coast and that number kind of stood there and even today the long lines, the ones they're building in China at plus minus 800 and 8,000 KV, these are long lines. I think the longest one is about 1,300 miles today or some number like that in China. But what happened was they got these IGBT technology which are these electronics that came about. Much of it was developed for the drives business where you have different kinds of motors driven on the AC system that needed to be converted into DC. That was a much more controllable electronics and the biggest advantage of that was that you didn't need to filter out the harmonics, that the harmonic filtering was actually built in. So if you can think about it the original idea of the Mercury Arc Rectifiers and the thyristors is you have an AC source and the AC means, it is positive half the time and negative half the time so you have to actually make the part that is negative into a positive so you add the thyristor that would change the direction of the current but then you had this funny looking current that kept bouncing like this and so you had to have filters which flattened that out. These filters if you think about doing it at 500 KV and 5,000 megawatts, these filters took up on each side about a football size field. So these were only inductors and capacitors but they are big and there are lots of them. So the prices went down and you didn't need filters because IGBT's the filtering is kind of built into them. That's why the breakeven length came way down and that allowed you to do these things underwater and underground.

Now there is a built in advantage of

using DC cables. You need cable if you're going to put it underground or underwater. If you put it over head it is bare wire. So once you got cable you got something called line charging current because of the capacitive effect of the cables so if you have a long cable the line capacitants or the line charging current tends to swamp out the actual current that you need for putting the power across. So that was a problem, why you couldn't get long distance transmission lines under water, which is why you didn't get a lot of them across the Baltic Sea until this technology came on.

So that's why now we have these things across the Long Island Sound. You have some down the Hudson River connecting New Jersey and New England and Manhattan and then you have the one across the bay and you'll see a lot more of these VSC. The only problem is now once the technology is coming along where you can make them bigger and bigger. They are still at lower voltages and still at lower megawatt range but the technology is moving very fast. So that's why when you see this big long HVDC transmission lines being put in India and China they are all thyristor and not this VSC technology and not the IGBT technology.

So applications. The main application is of course if you want a point to point large amount of transfer. So the whole idea on the west coast was you got transfers of the hydropower from the north to the south to the LA area where the load was. That is what Hydro Quebec is doing. If you remember the couple of mine mouth plants into Minnesota from North Dakota or Montana so those were all actually generation to load centers. So if you have a point to point need, the HVDC works very, very nicely. Now the cables were of course a different -- so now there are two different kinds. Now you've got DC lines that are within the same interconnection. So they basically don't help any particular capability except for just being able to move the power from one point to the other. Now the other thing is you can have a DC line between two interconnections. So between the eastern interconnection and the western interconnection for example, which is why the Scandinavia keeps connecting to the UCT grid is because they can move some of that water power from Norway down into Germany. And that is very helpful because what it does is it doesn't change the stability of either system because all the AC systems and all the generators have to move at the same frequency. So if one generator has a disturbance then every generator feels that disturbance whereas if you're connected only by a DC wire, then that disturbance doesn't get across those converters. So the performance of the two interconnections are not affected by having the DC line. This is the major advantage of also having the back to back. The back to back's meaning that the eastern interconnection and the western interconnection can be connected without impacting the performance of either side.

The big advantage of having a DC line is of course you can fix the amount of power flowing on that and that is fixed by just setting the controller on those converters and inverters and that fixes the power. Unlike and AC transmission line which is dependent on what everything else is doing the power flow is not directly controllable. So the main thing of course is that only way to control that DC line is by shutting off and on and changing the controls on the two converters. There are no circuit breakers on the DC lines. Although they are now announced commercial circuit breakers for high voltage DC, ABB was the first to go announce one they are not in regular use yet and until they are in regular use, you are not going to get a lot of networked DC's. So this multi-terminal that we talked about, yes we have a few with three terminals but you're not going to get a 17 terminal DC network very, very soon yet. But we will hear about some of the talks on putting DC, enough DC HVDC close to each other so that it will be nice to have these circuit breakers.

So now you can look at these diagrams again with a little bit of a thought as to why these were put there, what was the purpose. The back to backs make sense because they are connecting systems with different frequencies. Another place where these things come in very handy is if there are lots of different frequencies or like in Japan where some areas are 50 hertz, some areas are 60 hertz, best thing in the world for HVDC connections.

So let me introduce the speakers. So Dale Osborn is the first speaker and I'm going to let somebody fix the slides for Dale Osborn while introduce. Now I have to find your CV Dale. Dale Osborn is a consulting advisor on policy and economic studies for MISO, for Midwest ISO, where he worked I think for many years, 15 years. Dale has got a lot of experience in this area. He worked for ABB in their HVDC area and before that with power companies and I think the first thing we ever did together was a stability study out in Nebraska.

CHAIRWOMAN TIERNEY: Thank you, Anjan.

MR. OSBORN: MISO does things

differently. We do it economically first and then reliability second and when we do the reliability we found that we could buy or build transmission to improve the economics of the region. We've been doing that since I arrived at MISO. This is a study from 2006 that shows you what happened with the impact of transmission versus the impact of transmission in wind generation. This was a 765 KV overlay over the eastern U.S. With about 26,000 megawatt wind delivery. The black line is the base condition without the wind or without the transmission and it showed that the prices went from the west to the east and they got higher as they went along. When we added just the transmission, that made the prices in the west go up and the prices in the east go down and didn't really help anybody in the middle, it was just added cost. So that is not something we wanted to build for wind resources. Then we added the wind resources simulation and made the prices go down, which they are doing today and it made the prices for everybody in the middle go down and a little bit for the prices in the east. But the thing with that is that the revenue of the wind generators also go down. The guy with the wind generator gets the least benefit out of that situation so that is not a very good situation.

The other thing, we looked at building a line from MISO north to MISO south and we get 26 percent of the benefit and 100 percent of the cost and we don't like that very well. And unless somebody is willing to say they're going to pay for it, it is not going to get built because it is not economically justifiable so that's why they are AC lines not being built across that interface.

Now if you build DC lines it gives you a completely economic picture. It will give you the same price at the point of delivery as the price of supply with the difference in losses, which is typically quite low. So the generators that get more revenue the areas that developed that would get more revenue, the people in the middle get practically nothing and the people on the ends would have most of the benefits. Now there is an AC system between the two points and there is some bleeding but if you bury the DC terminals deep enough in your system you can keep most of the benefits within your system. We found that out in the Eastern Wind Integration Transmission study.

The difference between AC and DC is DC you schedule it, you know who is using it and who you should be paying for it. More benefits are captured by the participants and the costs is proportional to benefits. So that is all the good things that FERC likes to hear and our members like to hear. The AC power is distributed according to the laws of physics and you get over a few hundred miles away and energy just doesn't flow between those points, it goes into the netherland and then it comes back and loop flows through half the system and people say well how much did you send? Well we sent this much out. Well where did it go? We don't know but it got there. So the thing in DC that we think is important is not the performance so much and all the physical part but the market flows can be separated from the HVDC or from the AC reliability flows. So if you have two AC systems and you're going to transfer power, you put it on the DC and you would have zero loop flow from that transaction on the AC system. This also would simplify new market designs. If you had a long system and you wanted to make a market, you could put DC line down the middle and you wouldn't have to cost allocate the AC lines across that system. And that completely simplifies the way that the power grid is built.

Like I said we do things differently. What we do is we figure out what is the potential for our market transaction and then we design the transmission system to capture as much of the potential as possible. In the United States there is a great deal of diversity between the west coast and the eastern time zone due to time diversity. It is load capacity diversity. It is not generation capacity diversity it is load. So it is like demand response playing hedge games back and forth. There are 30,000 megawatts of load capacity diversity between the eastern United States and WEC. We designed this system to do it. It has no DC breakers in it, no more than three terminal lines and commutates on strong AC buses so it could work with existing systems or it could be built if a DC breaker becomes economical. It has a 1.25 to 1 benefit cost ratio which would satisfy FERC order 1000 and it solves a whole bunch of other problems. But peak diversity happens just a few hours a year. Now what do you do with the other 8,700 and some hours? Well you could deliver wind and solar energy with it for about a fourth the cost of what they deliver for it today. And you would use the time multiplex the transmission you get a higher utilization out of it. That's what this system does. It costs $36 billion and has a 1.25 to 1 benefit cost ratio. It gets rid of 30,000 megawatts of gas beakers and it delivers 30,000 megawatts of renewables. And you get rid of 5,000 megawatts of frequency response. So if you add all of those up together it is a benefit. It is all based on 10 years of diversity data that we calculated. We took the worst case in 10 years and that's justified transmission. A list transmission system could be built today because the economics don't require anything about future gas prices or anything, it is just based on what is there, you can do it with a spreadsheet. And we're using this as an overlay for the NREL Seam study as one scenario. So we are going to be studying it with the NREL for the grid modernization.

If you look at it, one of the things it does is it goes through gas fields. So you could use gas fields differently. When you get up to 800 KV a 36-inch pipeline and a HVDC line have the same price delivery. But there is a difference. Gas travels at 30 miles an hour and DC travels considerably faster, about 80 percent of the speed of light. So anyway, there are ways that you could change the generation patterns of the United States and if you use those central one, you could decrease the losses on the diversity by half so there are some advantages of this. If you look at the solar, those same terminals could collect a lot of solar in the areas where the most solar is and if you look at when you could collect wind.

The other thing it does is if it would deliver 30,000 megawatts of renewables but if you added some more transmission on an independent basis you could go 60,000 megawatts and save $16 billion. So it is a savings for future people as well as the present. We looked at two business models. The one is individual like we built one day and stick at a time. You only capture a third of the benefits and you run out of money and you never get to California. You take it all at one time from top (inaudible) system you get over the entire range. That's it, thank you.

MR. BOSE: We'll go through the presentations first and then we'll do the panel. So the next speaker is Jay Caspary from the Southwest Power Pool. He's the director of research, development and tariff services and before joining Southwest Power Pool he was with

Illinois Power Dynegy. And, I guess, he spent a year with DOE in 2012, and we overlapped over there for that whole year.

MR. CASPARY: Okay, that was good. Thanks. Thank you for inviting me to be on the panel and, just to be clear, I'm no expert on DC. I need to listen to people like Dale and others. They really understand the technology, so I appreciate what he's done.

I'm going to share a little bit about one of the grid modernization studies that's being funded right now by DOE. I'm really proud to be part of that, and I think you're going to see why it's important for at least Southwest Power Pool. SPP, our footprint has grown organically over the last 10 years, grown to the north. We added Nebraska back in 2009. We added the WAPA Basin IS system last fall to our system. So our footprint grew into the Dakotas and Montana, Western Minnesota, and even into Iowa.

So this is our footprint. So we manage this grid. We have a market for this grid. We're building transmission for this grid. And on the western edge of this grid we have an opportunity. We've got some old back-to-back DC ties that have been installed back in the '70s and '80s, primarily, when the system was really weak, on the edge of the grids. And some of these devices are in pretty dire shape. They don't have spare parts. They're old technology. The people that designed them and operated them have retired. So we're losing the skillsets of people that know how to make these work. Actually, some of them aren't that reliable. People don't have a lot of commercial interest in scheduling across some of these ties because they really don't know if they're going to be there. And to me, that's an opportunity.

So we have DC ties, and these little back-to-back DC ties on the edge of our system. We also have two of them in ERCOT, and I love my friends in ERCOT. We have two strong DC ties, one near Wichita Falls and one in East Texas. Those DC ties have been either rebuilt or replaced in the last few years. So they don't have the opportunity that we have with these other DC ties on the western edge of our system now that we need to do something with. And my biggest fear is that we're going to replace them in kind in size, and we're going to end up building the transmission system around them for the next 30 years. So what we're trying to do is to get our hands around these assets, the condition of those assets, and where they're at in terms of performance and capabilities. What would we like to do with these assets in terms of performance? So this is just the statistics of the eight back-to-back DC ties between the eastern and the western grid. So North American, there's folks in Canada that have -- that participate in our markets and in our systems, in our regions. You'll notice the third line from the bottom there's another DC tie. They're up in Alberta. The Alberta electric system operator and Saskatchewan Power have had the McNeil tie for a while. They've actually recently rebuilt it and refurbished it, the controls and the cooling systems. But the other seven there are the ones on the western edge of our system in the U.S. And they're all old technology. There's limitations on how much power can flow, some dead band issues and performance issues.

But we've got an opportunity to maybe recreate that seam and before we do that, we're going to have to do some studies to at least have some confidence in what we think the ballpark value is of replacing this seam. One of the goals I have, and these assets are not the ones in SPP's edge, are not under our tariff, so we don't optimize those at all. We just schedule up to them based on what the owner/operators schedule to us. So I think there's tremendous value we could provide as a grid operator in optimizing those seven ties if we're given the opportunity to do that.

But what we are doing is following through on a study, and I'm really proud to be part of this with others. NREL is leading this study along with PNNL and Argon National Labs and Oakridge as well as others. Iowa State's helping us out, too, with some analytics. But this is an 18 month study to look at the seams and Dale pointed out one bookend, which is this HVDC overlay, which is a scenario we need to look at. The other scenario is status quo. What if we just keep these back-to-back DC ties in place and that'll be the other bookend. And the ones that I'm really interested in are the ones in the middle, the other scenarios where we're going to actually look at modernizing and optimizing the seam, maybe relocating, maybe right- sizing, maybe replacing existing back-to-back ties either with new back-to-back ties, with new capacity and new capabilities, new technology, but maybe with DC links. It might make a lot more sense to connect the greater Denver Metropolitan area into Woodward and Western Oklahoma, which is our big wind hub. We've got tremendous transmission capacity at that location, rather than try to work at the Lamar HVDC tie, which is kind of a weak connection between the two systems in Colorado and Kansas. Anyways, so we've kicked off this study and we're working forward to -- looking forward to working with this over the next year or so. I'm going share some slides that (inaudible) put together, so Dale already talked about some of the diversity we're trying to get, the wind diversity as well as the solar diversity across the U.S. as well as the time diversity and weather diversity. And we really haven't focused on those, at least from the eastern and the western grid perspective, collectively. We haven't optimized and looked at it.

The weather patterns are pretty big across the plains. The wind's always blowing somewhere in SPP because we're covering 14 states. And one of the things we have that's beneficial, I think, for our system is, wind is a pretty nice variable resource. It's not intermittent. It was intermittent when we had 18 balancing authorities chasing the wind on their wires. That was a real challenge for small systems like Sunflower Electric and others. But in an aggregate, the wind is a nice resource. Now, the solar, I think is going to be a little different animal. There's going to be some more intermittency that we're going to have to deal with. But the weather patterns, obviously, are an opportunity, as well as the time diversity. You've seen graphs like this that show where the good solar resources are in the southern parts of the U.S., particularly in the desert of the southwest.

You've seen the wind resources. You know, the highest wind quality resources are in southeast Wyoming as well as the southcentral plains of the U.S. And Dale talked about the triangle. You can see this. This is at a 100-meter hub height instead of 80 meter hub height that I think Dr. Clack had shown us earlier. But if you combine these resources and then put together where the seams are electrically between the grids, this is what we have. And you'll kind of notice that the best windmill solar resources in the U.S. are right on top of the seams between ERCOT and SPP and the WEC.

And then if you look at time zones and other things, you can probably see why there might be some benefits to being able to move power from the desert southwest into load centers, like Chicago or Atlanta, where the actual sun pattern and the power output of those solar farms would actually follow the load patterns a few time zones east. You want to move solar power east. Okay? You don't want to move it west. That's why you have duck curves and things like that. But that's another opportunity.

But I just wanted to share this data. This is just some of the facts of the people that are involved in this. I'm privileged to work with Dale as one of the leads on the TRC. These are the other labs and others that are involved in this. And what we're trying to do with this study, this is some timelines for it. Right now we're harmonizing the models, and that's the biggest challenge we've had is trying to get a western grid model and an eastern grid model that even look anything like each other so that we can time synchronize them. You know, what do you assume for gas prices? What do you assume for underlying inflation rates or economic development rates? When you have apples and oranges, we're going to get some results that we don't really want to have any confidence in to share, to take this to the next level. So we're working a lot right now on capacity expansion planning, resource planning models, as well as production cost, and then we'll do some power flow models over the next few month and end up with a report in a year. I look forward to sharing that with you.

This kind of shows what we're doing. We're looking at 2024 cases as a baseline and building out to 2038 scenarios for the models, and then running those different scenarios that we talked about, the macro grid, which is the HVDC overlay, that's one bookend. Again, the other bookend is no upgrades, just have these existing back-to-back ties that are there today. I'd hope we'd consider newer technology at least, and maybe better capabilities and performance. But reconfiguring the seam, whether with HVDC links or new back-to-back ties at the right locations or the big scenarios in the middle.

One of the things I just wanted to share with you, there's a lot of planning going on. There's a lot of really good regional planning going on, but in terms of interregional planning, that's a challenge. FERC Order 1000 focused our efforts on the existing interconnections. So FERC didn't help us any by trying to get us to optimize and share data and models and work on planning within existing interconnections. To me some of the biggest opportunities are across the seam between the interconnections when you have these old, aging devices that need -- we need to do something, anyway. We're going to spend $50 million at each one of these just to keep what we got, and we may want to spend that money differently.

But what I'm showing on this list is some of the projects that are being done in a vacuum that are building infrastructure toward the seam from the east in the eastern grid toward the western grid, but with no consideration of what's in the western grid, and then vice versa. Assets that are being built and planned as we speak in the western grid, towards the eastern grid, but again, no ties, no literal ties, not even sharing of data between the personnel. So that's one of the best things we're doing with this study is getting the people in the room that actually own these systems or the regional planners in the western grid and the eastern grid together, as well as the utilities, to talk about what we're doing and what we need and to harmonize these models.

One thing that just recently came out was a Pan- Canadian wind study. And obviously the Canadian system is tied primarily into the U.S. via some big DC lines. There's a lot of hydro exports to the south. They were looking at wind in these cases. It took them a couple years to do the work. But they did publish results. One of the things that I found of interest was some new 500 KV ties, which you might expect between the Canadian system and the U.S. system, as well as some increase in capacity of the existing DC tie that I talked about earlier between Manitoba and Saskatchewan Power. So they didn't identify a lot of benefits, but I don't know if they were looking at it kind of the way we would look at it. So we're going to maybe validate that study assumption, or maybe find something a little different. But they're going to help us do that, and that's great.

So what do we want and where we're at. So right now one of the things we're doing, which is a key value add, I think, in this process, is doing some pretty comprehensive surveys with the asset owner of all these DC ties to understand condition, to understand capability, spare parts, things like that. What keeps you up at night?

Why are you going to try to sell more service across this thing or do people have any confidence in this equipment? And they're not.

The big things that came out of our first meeting that we had in June came from Public Service New Mexico. And they said, this study is great. Look at all these DC options, but we want to look at AC, too. We want to look at just bypassing the Eddy County tie and taking advantage of that 345 KV line that's built in SPP to the tie, and getting benefits within the western system in New Mexico without the tie, bypassing the tie. And I'm hoping that we can move forward on that. I think there's a lot of interest in that. That's a supplemental thing.

The next scheduled meeting is October 4th. On the backend of that meeting is a North American Renewal Integration study. It's called NARI. Some people call it the Pan-North American study. The DOE funded that, too. And so we're taking the study and the participants, looking just at the U.S. needs on the east-west grids and now we're going to expand it to include the Canadians to the north and Mexico to the south. So we're excited about that.

This is my graphic that I want to share, and you can stare at this for about 10 minutes and still want to look at it some more. This is some really good data that NREL has pulled together. And I just wanted to talk a little bit about it.

So what this is showing is time synchronized generation, as well as transmission transfers and load. And what's going on with resources across North America on a time synchronized basis. The parts of the eastern grid is based upon the ERGIS study, which NREL did a couple years ago. It had significant solar development, as you see, in the southeast parts of the U.S. and pretty moderate by today's standards, I think, wind development in the plains, not nearly as much as probably we're projecting today based on prices and interest and queues. But what you see is -- you see the sun coming up over the east, the solar's picking up, the wind starts dying off. The load picks up. Transfers move around on the system. And then the sun's going to set. And the solar's going to away, and the wind's going to pick up.

So the solar and the wind, at least within the eastern interconnection, it's a good model. Okay? But when you look at the western grid here, that's a totally independent model. So these are just crunched together. Okay? There's no optimization at all. Actually, there's no coordination at all between these models. They're just time-synchronized and they're looking at typical high renewal scenarios in the future that are time synchronized. That's it. So I think we're going to see a little different scenarios come out of this eastern-western seam study, when you actually start looking at what you could do across the seams.

I'm very excited about this, and I appreciate your interest and look forward to the panel's questions. Thank you so much.

MR. BOSE: Okay, the next speaker is

Michael Skelly. He's the founder president of Clean Line Energy. And Clean Line Energy was the first company to obtain approval from the U.S. DOE to construct an interstate transmission line under the Energy Policy Act of 2005. Before Clean Line Energy, Michael led the development of Horizon Wind Energy, which was one of the leading wind companies in this industry. So with that, Mike.

MR. SKELLY: Thank you. Thanks very much. This is your one and only slide, so I'll expect you to commit it to memory. What I thought I'd talk about a little bit is our company's part in this vision of an HVDC grid, give you a bit of a rundown on the state of plans, some of our projects, and then talk in a bit of detail about the participation agreement, as it is called, that we've signed with DOE in late March of this year.

So, as was mentioned, I spent a lot of time in the wind energy field and we built a fairly successful company. And after that company was sort of bought and sold, a number of us at, what was it at? Horizon Wind, started looking around and thinking, what's the big problem? And should we start another wind development company? Should we do solar? And it's very easy to come to the conclusion that transmission is the biggest challenge out there. And we wanted the big challenge, so we started Clean Line with the idea of putting together a set of projects that would facilitate a lot more wind on the grid. And as we looked at the grid, it was clear that, because of a number of factors around how we structure the electric power system in this country with fairly balkanized ownership of the grid, and RTOs with let's say varying degrees of cooperation, again, this is pre-FERC Order 1000 back in 2009, it was clear that nobody else was going to sort of wander in and try to figure this thing out and try to build the projects. And we thought and discovered that on the strength of some of the other things that we'd been able to accomplish, we were able to put together the tens of millions of dollars of capital that it takes to fund an enterprise like this.

So where do you sort of start with this? So the incumbents, like -- and it's not that these aren't very smart people. They are very creative and they're thinking about the future, but Oklahoma Gas and Electric, for example, they're not set up to do decade long investments to move energy from Oklahoma to the Southeastern United States. Nor is, for example, TVA, it is not in their charter that they should reach halfway across the country to get access to these great resources. It's also, it was clear in 2009, it's even more clear today with sort of the very and different results of FERC Order 1000 that neither FERC nor the RTOs were going to force a process that created a dynamic where you had interregional, true interregional planning to sort of connect these resources and load. And that was our thought then and it's actually come true so that you look at that equation, you go, well, somebody's got to go figure this thing out. Let's go figure it out. And that's why we started Clean Line. And it's our hope that, if we're successful with one or more of these projects that we will be ultimately part of this sort of super grid that we've been hearing about in some of the previous discussions.

So why these particular projects? That's a little bit about why us, so why is it, you know, Clean Line Energy, this eight-year-old company up here or not some of the bigger utilities in the United States? They're not really set up for the task at hand. So then it's sort of, okay, which projects? How do you figure out which projects to do? And it's, the wind side of it is actually fairly straightforward because you look on the map and you go, okay, well, this is -- these are best resource in the country. Let's start here. And then where do you deliver to? And that answer is largely a function of sort of, if you look at our projects in the Eastern Interconnect, you'll see that we connect to the edges of the 765 system and we connect to the TVA system. Connecting to Entergy 500 KV system, many a developer has run aground on the shoals of that system so we didn't think it was feasible to go there, so we said we need to go all the way to TVA, why not go to Atlanta? As we looked at the -- sort of looked through all the laws and the state citing laws and bits and pieces of federal citing, we thought, okay, we got to keep the number of states to an absolute minimum here because we're going to rely on states, uh, and if the states don't work then hopefully we'll be able to avail ourselves of whatever federal authority is out there.

So then you, big threshold question, so how big can you do these lines? Can you do them as big as Dale's lines on the map or some of the other lines we've seen today? Our answer to that was, that, you know, 3,500 of injection is pretty much the max that you would get RTOs and utilities comfortable with. So 3,500 megawatts was sort of the upper limit on the delivery side, and 4,000 on the generation side. So that sort of gives you the basic sort of parameters.

And we did not want to try to do

projects that would require -- we thought it would be too hard to attract capital to a business that required changes in federal law. So it's hard to fund a business that you go to an investor and say, okay, we're going to have this, you know, ubiquitous national signing authority and let's go do projects around that. That didn't feel -- it's, believe me, it is very difficult to attract development capital to this business and that felt hopeless.

So then you look at the economics and the economics and the basic economics of our lines today is the costs with the current tax regime under two cents a kilowatt hour to generate wind out in the windy parts of the country. As TVA and others have done, solicitations and utilities in the center of the country are doing bids now, prices are coming in as low as a penny and a half. And again, that's with the production tax credit as I think you all know. And that sort of phases out over time, so add in the early 2020s, add about.3 cents a year as the production tax credit is slowly phased out.

So the economics of, you know, two cent wind or penny and a half wind, we need about a penny and a half to two cents to get it to market, so we're talking about delivered cost in the, you know, low-threes to four cents, which, you know, that feels like it hurts. And that was an important part of how we sort of conceptualized it. Right? The numbers were different back in 2009, but gas prices were higher. But that's where we are today.

So we're always sort of seven years into this, and we are -- well, I was at a dinner in Washington the other night and I looked at the sort of sponsors of the dinner, and I sort of counted up all the law firms that were sponsoring this big dinner. It was the dinner that you were honored at Marilyn, and I -- not to my surprise, I realized that every one of those law firms is working for us in some capacity. So as another friend in the electric power business joked to us early on, this is a full-employment project for lawyers and consultants. But we knew that going into it so I guess we can't really complain.

Let me just sort of give you the quick rundown on the portfolio of projects and then I'll tell you a little bit more about what's going on with our plains and eastern project for which we have the agreement in place with DOE. So our Rock Island connects, or would connect, 3,500 megawatts of new wind from northwest Iowa to the PG&M system outside Chicago. That project is in a hospice right now because we had a -- we sort of got hit by the trifecta on that project and the -- first of all you have an IOE utility board citing process which basically requires you to go get the land and get the rights-of-way, and then ask if you can get permission to build the line, which is an extremely expensive undertaking.

Then on top of that, the Iowa legislature changed the law that said, not only do you have to get the land, you have 18 months to get it. And then a few months ago we got a court decision overturning a favorable-sided decision in

Illinois, so we got our certificate in Illinois after about three years, and -- on a five-zero decision, by the way. That went a few landowners and ComEd, not Exelon, but just ComEd, appealed that decision. ComEd or Exelon or one of those companies is concerned about competition, apparently. And so they appealed the ICC decision. It went to an appellate court. The appellate court overturned the ICC decision. So we're hoping to get a hearing at the Illinois Supreme Court, not so much that we'll be able to get Rock Island out of the hospice, but we'll be able to rescue Grain Belt, which is the next project, from emergency care. Because the concern is that this Illinois decision, while not binding on all courts in Illinois, would affect -- that project would be vulnerable to a similar court challenge.

And basically what the court held, despite what we think, is very clear law to the contrary, that if you're not an electric utility in the state of Illinois, you cannot become one.

And you must own facilities and you must own customers. This becomes a familiar theme in a second. So we're optimistic and NRDC and other folks have helped weigh in and create the environment under which we believe that the Supreme Court of Illinois will take that up and hopefully reverse that court decision. But the three blows on Rock Island, again, that project is in hospice care and it's a very difficult situation.

So then on Grain Belt we have a good-sided decision from Kansas, from Indiana, and from Illinois. In Missouri we were -- our first trip to the Missouri commission, they rejected us on a split vote, on a 3-2 vote. We have filed -- we basically struck an arrangement with some municipal customers to give them a price that they couldn't resist on capacity on the line and they've signed up for capacity and we've managed to enlist the governor's support of the project. So we're optimistic that upon rehearing, or that upon -- it's not a rehearing. It's a second go at the Missouri process that we will get through the process. But we do have the Illinois court decision that obviously would affect how things might play out in Illinois, so we're very concerned about that.

So then we have, the other DC line that we're working on, and I'll just focus on the DC lines, is a project called Centennial West which would go from this phenomenal resources in Northeastern New Mexico to Southern California. We are not doing much work on that at all because if you get into a, you know, one of these multiyear federal citing processes, you need to go in, you know, armored up to the tune of probably, our guess is the permitting bill on that would be around $100 million. And that's not an investment that our company's prepared to make right now until, you know, we see how we prove out the business thesis with other projects, or another thing that would spark our interest in Centennial West would be if TransWest Express, which is another company with a DC line from Wyoming to

Vegas, they've been working on their permitting for about nine years now and they're awaiting a record of decision from the joint WAPA and BLM. So if they're successful, that would increase our interest in trying to move Centennial West along.

So where are we on plains in eastern? So let me just back up for a second and sort of -- so the configuration here is a 4 gigawatt line from the, basically the center of the panhandle of Oklahoma, phenomenal wind resource with a number of just about every big player in the electric power industry -- in the wind generation space is active in the panhandle from Berkshire Hathaway to EDF to Invenergy to Apex, et cetera, et cetera, so there's a lot of producers out there very anxious to build their projects but they can't do so because they have no way to get to market.

So our basic business model is to sell to those producers a slice of capacity on our line. And with that capacity, we'll get them either to the MISO market in Arkansas or to the TVA system and onto the southeast. And again, the line is 600 KV. It will move at the injection point. It'll be 4 gigawatts and the delivery points are 500 megawatts to the Entergy/MISO system and 3,500 to the TVA system. And our business model, again, is, so we'll sell the capacity. We take the development risk, so we spend all the money and the studies and lawyers and consultants and all that to sort of pull all this together, and then our investors will have the opportunity to invest in this $2.5 million project. So that's their interest is they'd like to make that investment and in order to do so, obviously, we have to get it permitted.

One of the advantages of this is that we're -- because, as we've pointed out earlier, in a participant- funded model, we're not reliant on (inaudible) or the federal government or anybody else to take the risk of project success or failure.

So before I get into the details on the DOE agreement, a few more sort of, where are we?

So the Department of Energy signed a participant agreement with us at the end of March. That was after a -- about a three and a half year NEPA process, several years of sort of analyzing the project in the run-up to entering into an agreement whereby DOE agreed that they would sort of look at the project. That put us into NEPA. Once we were in NEPA we had to go through NEPA, obviously, before DOE could make a decision with respect to participation. We got a very favorable EIS at the end of -- in November last year? Yeah, November of last year. And then the record of decision from DOE at the end of March.

So since then we -- that's a very important gating item for us as we think about sort of continuing to develop the project. First of all, we have a route, so we have 1,000-foot corridor within which the line must be sited, so we can talk to landowners with confidence about where the line would actually go. It would be premature to do so before we did that. So on the strength of that, we've had about 50 right-of-way agents in the field since, I guess since mid-July. We're a little over 100 miles of right-of-way today. And when I call the office this afternoon, a few more miles will have come in. So it's coming in at a pretty good clip. And I'll talk a little bit more about that, that aspect of it, in a second.

We are in discussions with all the wind generators who are active in the panhandle. We've run several open seasons and we're negotiating those agreements now. They, in turn, are talking with load serving entities, with utilities in the Southeastern United States. The utilities in the Southeast are interested in really sort of -- there's two ways they can approach this. One is to simply enter into PPAs where they pay for delivered energy. There's also interest among some of those utilities that can work this with the regulator but that would actually might have an interest in owning generation out in the panhandle, and owning part of the transmission line, and we're happy to have their participation, as well. That would be part of their rates and that's, in fact, in many instances, the most cost-effective solution for customers. So there's a bunch of those discussions going on as well.

So we recently made an equipment, we signed an MOU, with an equipment supplier to provide the -- it's roughly a 4,900 million for the HVDC equipment and we will issue a limited notice to proceed to that equipment supplier in the very near future. And shortly thereafter we anticipate making public who that supplier is.

So let's talk about -- am I going way over my time, by the way?

CHAIRWOMAN TIERNEY: Maybe five more minutes.

MR. SKELLY: Okay. So how does this DOE agreement work? Basically, the participation agreement with DOE says that DOE, subject to us meeting many, many pages of condition precedent, okay, which include that we have financing commitments for the project that we've signed, interconnection agreements that we have agreements for 2 gigawatts or 2,000 megawatts of capacity on the line, that we finished a few, sort of, other permits, Army Corps, (inaudible) things like that, subject to all those things happening, if we have attempted over a sustained period of time to reach an agreement with the landowner and we can't reach an agreement, then DOE will step in and use its authority to acquire right-of-way on the projects -- effectively on a project's behalf. The right-of-way will -- well, there's a bunch of ownership things around that, but that's sort of the basic mechanism. And so that's why we're spending a lot of time right now getting out ahead on the right-of-way front in order to -- so that we have plenty of time and don't end up in a situation where, you know, landowners feel rushed to make a decision. That's the basic architecture and I'm happy to answer questions about that after (inaudible).

Before I close out, let me just talk about what we think is the most important piece of all this, and it's really the social and human piece of siting, transmission wise. We feel a huge responsibility to get this right. We feel like it's, you know, one of the first long distance DC lines to be attempted and -- well, there's a few under development, so I shouldn't say that, but as a, sort of, the first across the line and in some, the first in some respects, I should say. We have to get this right, so we have to get the siting right. And so, prior to -- and this, for the time that DOE was sort of an early consideration of the project, we took great advantage of that time, and did a tremendous amount of stakeholder outreach. It's impossible to do too much stakeholder outreach because you're always going to get more input that's going to lead to a better project. So we did spend years on that, a lot of consultations with folks in the environmental community, county officials, open houses, et cetera, et cetera. I think we added up -- well, this is a few years ago, we added up and we had, like, 15,000 discreet meetings that we'd held over a several year period of time.

And that helps us do two things. It helps people understand why you're doing this, and why this is an important part of the nation's infrastructure. Not everybody's going to like what you're doing, but at a minimum you have to give them the opportunity to understand what we're doing. And you have to give people a voice, and you have to get all the information out there so that you can come up with the best possible route. The other thing we work quite hard at is constant communication. So we try to get out as early and as often as we possibly can to tell people what we're doing today, what's coming up, and so on.

There's a big tribal consultation piece to this, largely due to lands in Oklahoma, and so there's a formal piece to that and there's an informal piece to that, and we try to do a good job with both of those. And then finally, there's, you know, where the sort of rubber meets the road is when you actually sit down with a landowner and work out the agreement to site the line. And we pay 100 percent of fee value for a landowner's property, and then we've also borrowed a page from the wind energy notebook, so we pay -- we will pay landowners on a per tower basis. So if you have a lattice structure on your lane, you'll get $1,500 per year from now until the line is -- well, transmission lines don't seem to get removed, but if it were ever removed, then those payments would cease.

And then finally on the jobs front, organized labor will play an important role in our project and they have the best qualified workforce for the task at hand, and we also do as much as we possibly can in terms of local sourcing of business opportunities. So we do everything from, you know, sort of local business open houses to a few marquee arrangements with the tower manufacturer and a wire manufacturer. We convinced the French company, Sediver, to build their glass insulator factory in Arkansas in return for an exclusive agreement to buy insulators from them. So that's another important piece of this.

By the way, none of this guarantees that projects like ours will be without opposition but I'm absolutely certain that they would not be possible if you didn't do everything you possibly could to get these things right. So, thank you very much, and delighted to take questions.

MR. BOSE: Okay, questions? Do you want to go first, Sue?

CHAIRWOMAN TIERNEY: I get to go first. I have so many questions, but I'm going to do the most recent one, which is to Michael. How does the interstate Clean Power Plan process fold into this?

MR. SKELLY: So under CPP, even with a mass-based or rate-based -- and I know I'm in a room full of experts, so I may just not get this exactly right, but we're going to move the generation stack at the delivery point. So in conversations we've had with the EPA and state officials and so on. It's very clear that the receiving state would get the carbon reduction benefit, as it should be.

MR. ZICHELLA: Yeah, this has been a great panel and I wanted to thank you all. You know, this work is really important and to get to the kinds of penetrations of renewable energy resources we need to -- we have to think differently about the entire system and the work on the seams that you've been -- Dale and Jay have been involved with is really exciting stuff. And Michael, tenacity is your middle name. You know? I've just watched for years as you guys have slogged in the trenches on these projects and your commitment to doing the stakeholder outreach part of this, right, has been really inspiring to NRDC and the groups we work with, because we've been advocating people get ahead of that and not wait until the backend, as we used to do it.

I think this model has become more widely adopted than it ever has, and now DOE has helped produce, you know, this whole early consultation process, the pre-application process, that's just been finalized that recognizes the value of the kind of work you've been doing. So I just wanted to congratulate you and hope you'll stay tenacious and get to the finish time. And I do think it's important that at least somebody proves you can do this. You know? And I know one of the reasons I was hoping you would come and speak with us is because the obstacles are just enormous. And the patchwork of permitting authorities that you have to deal with is just stunning. And it's interesting to me that even though it was approved in the EPAct 2005, that states could form interstate compacts without having to come back to Congress for approval for the purpose of interstate transmission, nobody does it. And folks like you really wind up having to do missionary work and everything from municipal governments on up to states. So, thanks.

MR. SKELLY: Well, thank you. Thank you very much.

MR. BOSE: Jim? Jim?

MR. LAZAR: My questions is for Jay.

MR. BOSE: Do you want to turn on --

CHAIRWOMAN TIERNEY: Jim, your --

MR. BOSE: That's okay. I got it.

CHAIRWOMAN TIERNEY: -- microphone.

MR. LAZAR: My question's for Jay. During the 2000/2001 West Coast power crisis, the back-to-back DC interties flowed as much energy west as they could. The West was at a 500 to $1,500 megawatt hour market, and the East was in a 50 to $150 megawatt hour market. So there were tremendous economic opportunities. How much arbitrage goes on on a routine basis now with those back-to-back connections?

MR. CASPARY: I'm really not in operations or in markets. You know? I don't think there's as much as you might expect. I think the transactions across those DC ties are determined by the owners and the people that have the contracts and the rights across them, and they're going to use them to the extent they can to meet their own internal needs. But I really don't know. I do know that when we were setting some new wind peaks here in March and April, approaching 50 percent wind penetration in our footprint, we were basically exporting across everything, because energy was so cheap in SPP, a similar type situation to that blackout, I guess, and the system response for the Southwest blackout. I wish I had a better answer. I could probably look into it.

MR. OSBORN: I could help.

MR. CASPARY: Help, please. Dale's got the answer.

MR. OSBORN: Those ties, we've looked at them and they have about 22 percent capacity factor on them. Usually in our studies when we have DC, they run 70 to 80.

MR. FELLER: It's a question for Michael about our friends in the north and Canada, who obviously have a different regulatory system. They have different value on carbon in some of the provinces, like British Columbia. Can you comment a little bit about anything that you've seen there that was relevant to your business model or relevant to some of the assumptions that you're making for different projects, but also in that spirit, can you talk a little bit about what happens to your business when the price of carbon arrives on the scene and you're the party that enables the carbon-free producer to deliver carbon-free electrons to a customer, will you be presenting new issues, new options to your customers when the price of carbon becomes real?

MR. SKELLY: Well, so we think the price of carbon is -- I mean, different people price it different ways and value it different ways, but every utility in the country is thinking about carbon. And they're all trying to figure out how to position themselves around this and, you know, there's not a national -- you know, you can't pull up the NYMEX curve on carbon yet, but it's a big part of the equation. And I think, you know, I'm hard-pressed to think of a single utility that's not either positioning themselves around this, either as an offensive strategy or defensive, or whatever, because they know -- and the smarter ones are saying, you know, we got -- okay, we have a clean power plant and that's got these goals, but everybody knows that once we hit those goals, we're going to hit the "that was easy" button and go on to much greater goals.

And then with respect to Canada, that's actually an accident of geography. So Canadian provinces run north- south. Canadian rivers, by and large, run north-south. Utilities are all organized north-south. So you have a natural protagonistic actor to go get the resource to load. So a company like us, we would have nothing to do in Canada, because there's no, sort of, gap there. The natural incumbants are going to figure out what they have, and they will continue to figure it out, at least from a hydro perspective. And so but it's a round -- it's sort of an accident of geography and an accident of, sort of, how they've structured their electric system. So, if our states were long and flat, then the, you know, Westar or PG&E or whatever they would connect the wind with their load. That would have happened by now.

MR. FELLER: I guess the follow-up is Europe, which is not north-south. It's got, you know, in the European Union, 27 national jurisdictions and then a lot of provincial governments, all of whom have a say. There's been a lot of interconnect for renewables, and it's not just the Baltic. Were there any lessons there?

MR. SKELLY: Well, I think it's a deeper commitment to renewable energy, driven both by environmental imperatives but, you know, for a long time, you know, being at -- to this day, being at the end of Putin's pipe is not, you know, not always a great ride. So the national security imperatives around indigenous resources are, on the renewable side, I think are stronger in Europe than they are here.

MS. CONKLIN: Well, thank you for the panel. It was my division within DOE that actually led the internal review process on plains in Eastern and a lot of hard work went into the decision, so --

SPEAKER: Thank you.

MS. CONKLIN: -- it's wonderful to hear your perspective on it. I just had a comment. Pat asked that I mention a rule making which we recently completed on transmission, which Carl also mentioned in his comments a few minutes ago. Last week the Department announced the finalization of a rule called the Interagency Pre-Application Process or the IIP. This is using our authorities under Section 216(h) of the Federal Power Act to encourage transmission developers to do more work with the federal family and other interested stakeholders like the states, Indian tribes before they file an application with the federal government to encourage more upfront planning to make the backend of the process more efficient.

We've actually piloted this concept on a couple of our existing presidential permit applications, and because the developers and the Department did such a great job in their pre-planning, we actually finished the EISs on both those proposed projects in less than a year and a half. And so it just published today in the Federal Register and there's more information on our website if any of you want to hear some more about it.

Rep. MORRIS: Jeff Morris from Washington State. I have a question about whether there's any tradeoffs in permitting costs with this new, bold, overhead line design and those space conductors with this footprint versus DC, at all.

MR. SKELLY: I'm not sure. Do you understand the question?

MR. CASPARY: I think so, but I don't know.

MR. SKELLY: Then go for it.

MR. CASPARY: I think I understand the topic. I don't know if I have the answer to the question. The bold transmission is AEP's new compact, high surge impedance loading type design line that looks very untraditional. To try to get it on shorter towers and longer spans and higher capacities in the corridors, right? I mean, that's kind of the goal. We haven't seen any of that in our footprint. I think they're trying to build some of those projects and are building them in Indiana and other places. I think anywhere you can minimize the land use and increase the capacity in a corridor, whether it's through HVDC or through bold or some other design, I'd encourage that, or advanced conductors or whatever. There's ways to do that. But on the other side, you got to worry about security and having too much capacity or portions of your system in one corridor. The network needs to be resilient and able to respond and stay secure.

MR. BOSE: Janice?

SPEAKER: Yeah, Janice, go ahead.

MS. LIN: Thank you. Thanks for that presentation. It was incredibly informative and I know I learned a lot. I had two questions. My first question is, I was wondering to what extent, and this is really open to all three of you, you've considered energy storage as a means to improve the utilization of either existing or planned transmission to increase the throughput or efficiency, and then I have one more question related to non-wires alternatives. But we'll take this one first.

MR. OSBORN: We looked at the variability of wind and solar, and when you have a 300 or a 315,000 megawatt market, the California duck, instead of being sitting, he takes off and flies. So he becomes a ramp over the day and not a problem. So there's really not a storage requirement for solar, and when you put -- we had limited data on solar, but the solar that we added up, when you add it up over a large footprint, it becomes almost a perfectly smooth curve, all the variability adds up and it becomes predictable, and it flattens off on the top due to the time zones and then back down. It becomes a reasonable resource just like wind did. They told us in 2003, Jay and I were looking at wind that AWEA told us that 10,000 megawatt of wind was the most that could ever be built in the United States in our area. And we passed that three or four years ago. Just in MISO we're at 15,000. What do you got?

MR. SKELLY: We're over that now.

MR. OSBORN: Yeah. So I think when you get these aggregating resource or transmission lines, solar is not going to be a problem. Like, if you aggregate the wind from MISO, ERCOT and WEC together, you cut the variability by 50 percent in ERCOT and WEC, which means you could double the capacity there and run at the same capacity. So storage basically becomes just you just sell it in the market, but there's a point, and we think it's somewhere around 40 percent penetration where storage becomes important. But people who would have storage, would have a lot of different opportunities than they have today. It'd be just hard to put in new storage, because the market would take care of it.

MR. CASPARY: So we looked at this a lot. So assume the way we think, I mean, it's pretty clear that when you build transmission lines they fill up, and they fill up with, sort of, the cheapest alternative. And for our line, you'd actually overbuild the wind to about 4.5 gigawatts because wind dips in the daytime and if you remember the maps, we're actually on top of the best solar in the Eastern Interconnect, so in the fullness of time, there'll probably be another gigawatt of solar. The ratio is about 4:1, which, by the way, would make this the second largest power plant in the country after the Grand Coulee Dam.

When we look at it, the break over cost is around $100 a kilowatt hour, and we're at, like, $400 and at about 100 bucks it makes sense to start shifting things around, build a little more wind and then take advantage of the capacity in the line when the wind isn't blowing. So, yes, it's just a question of, you know, sort of when do we cross that price point, and then it would happen. And, again, ours is a very particular case because a lot of the cost of our overall system of generation plus transmission is actually in the transmission. So if you can put storage in, you can optimize it. But the numbers aren't there yet, but hopefully they will be in the, you know, at some point in the 2020s, we believe.

MR. OSBORN: I'd like to add one more point. We had Christopher Clack run our system for 30, 50, and 80 percent carbon reduction and one of the things that surprised us is we were seeing a colocation of solar and wind in North Dakota and those areas, and Michigan. And we thought, that can't be right. But the reason is is that, once you get transmission, it is lower cost to build solar in those areas because you already have the transmission, so you're using the transmission system more efficiently. You use the wind at night and the solar in the day. And you're seeing some of those colocations and I would expect that you would see transmission built to those --

MR. SKELLY: Did you measure the time of day (inaudible)? I'm sorry. Did you measure the time of day going east?

MR. OSBORN: What do you mean the time

of day going east?

MR. SKELLY: Because you're in the Eastern Interconnect. North Dakota is two hours west of Boston.

MR. OSBORN: Yeah, but we didn't go that far. We just, for the MISO footprint, we got colocation.

MR. CASPARY: I'd just like to add something. I think we do see storage applications now basically for wind farms that are trying to manage curtailments right now on our system. I think we have a lot of wind farms in SPP that are banking on a Clean Line project or two coming, so they get interconnected with us and participate in our market, but they definitely don't have firm transmission service, so they're waiting for other options and access to markets. I do think longer term you're going to see big storage projects to help complement these renewables and I know there's people interested in them. They're talking to us. They want to be part of these solutions and make sure that storage is part of the mix. And we'll include that.

MS. LIN: Thank you for that. I --

MR. OSBORN: I was going to say that one reason we don't have a big storage need is we've got Manitoba Hydro sitting up there with 5,500 megawatts of generation capability, and nine months of storage. And they can buy out of our system. And they're building another 500 down into our system. So they have a tariff provision called an EAR, an external asynchronous resource. They can buy and sell out of our system just like any participant without being subject to the MISO board director directives, because they're a provincial government. They have an independent board, and they can't be subject to anybody else, but they can participate in the market, and they're doing that. We haven't seen negative wind for, I don't know, years up there. They just buy it all and then they sell it in the middle of the summer for nice prices.

MS. LIN: The story of storage. My follow-up question is on the other end of the spectrum. In light of DOE's goals around an integrated grid and greater national security, how -- I guess this would be more for Jay and Dale to talk about, using maybe distributed energy resources, local renewables, local PJM storage in lieu, as an alternative, to transmission. I'm just curious how you're thinking about that.

MR. CASPARY: Sure. I'm a firm believer in the integrated grid model that EPRI's put out there and part of the EPRI leadership team supporting that. I think, you know, we don't have a lot of visibility right now, at least on the distribution and retail level. We don't know about rooftops. I mean, we're a wholesale transmission service provider, so we only see what goes through the big substations, the sub-transmission transformers and things like that. We really don't know what's going on at the load level. I think we need to know. Like, I think, because the grid supports all kilowatt hours, not just net wholesale kilowatt hours that we see on our system, so we're going to have to get more data and more understanding of those resources, and particularly down the road I think it'll become significant.

MR. ALMGREN: I think it's a clear value having a big system as you describe. And I think in Europe they looked at tying Europe together with Africa and get solar. But in reality it's really hard to get something done. And I'm thinking about how to go from (inaudible) to get something done. In reality, I think almost every system which has been built has been bilateral. Like Pacific intertie was Oregon down to California, how to get back into New England. And all the European systems, while the big plan was still there, they do the direct ties.

So one question, I will have two questions. How can we solve these few? What's in it for the states who are between point A and point B, how can they share -- get some cut in the benefits? Because otherwise I think it would be very difficult to do system covering many states or many countries. And the other question I have is that, all these siting issues, which are always a huge challenge, there's been huge progress on the cable technology. You can get a 1,000 megawatt, gigawatt cable which you can lay in the ground like fiber optics. And I think it's been illustrated in Norway Holland cable, the Norway German cable, which has been done. The Sweden Lithuania, and I also think there's cases now with offshore wind in Germany where they bring in with a DC cable, and then they continue on land with the cable. Because that's the only way to get it built in time. So that's my second question. Do you see the cable technology could solve some of the siting issues?

MR. SKELLY: Okay, so let me take the first questions that, sort of -- you're sort of posing the ABC, the middle state question.

CHAIRWOMAN TIERNEY: And, Michael, let me just do a time check.

MR. SKELLY: Yeah.

CHAIRWOMAN TIERNEY: I'd like to have responses and then one more question in a five minute period.

MR. SKELLY: Okay.

CHAIRWOMAN TIERNEY: Okay? Thanks.

MR. SKELLY: I think you have to do everything you can for every state. That's why we deliver energy to the state and identify manufacturing opportunities and (inaudible) as well, and so on. I don't think it's that easy, though. We have the project that I mentioned that's in a hospice is a two state project. This isn't an issue of, like, one state, a middle state. It's the whole equation is very, very complex. In terms of the cable technology, the reason these offshore links, that the cable works in Europe is because you have big ships that lay the cable out. And you have very few splices. And until we come up with a, you know, 800-ton ship that can go across the plains, you're not going to eliminate these splices. And it's right now the cost is, you know,

to 10 times, and there's not -- we haven't seen a lot of movement in that. But if you're doing a short connection and you have a huge willingness to pay, for example, in New England, they're going to do 50, 100 mile, you know, 80 mile lines that are underground, but the cost per kilowatt hour is the same as the cost for an overhead line of 7 or 800 miles.

So we don't see in most of the electric power markets that we operate in, a willingness to pay, you know, 10 cents to move power across the country.

MR. ALMGREN: Just a comment is, I mean, I've been amazed how quick the progress has been in the installation of the cables. If that trend continues, you think the cost would come down, make it more meaningful?

MR. SKELLY: I don't think we're close, no.

MR. OSBORN: One thing New England, their cost of lines are three times what our cost of lines are, so cable makes some sense. And cable is coming in in those areas about three to four times what the overhead is. And they can get it through, so they do it. They pay a little bit of a premium. But in our area it would take some more years before it would pay off. I mean, going through the Rocky Mountains with a cable would not be easy. But I calculated some years ago where the break off is, and when you get about 12,000 megawatts, the power transfer cable becomes, using 2008 numbers of technology. So if we built that first system I showed you, the second system may be cable.

CHAIRWOMAN TIERNEY: And, the last question.

SPEAKER: Very quickly then, so what needs to be fixed with the interregional planning and transmission development? Wave your magic wands.

CHAIRWOMAN TIERNEY: A new U.S. Constitution.

SPEAKER: We can't do that in five minutes.

MR. SKELLY: No. I think that the fundamental flaw within the regional planning, from our perspective, is that it relies on the RTOs to work well together as opposed to a project driven process where you have people who identify, (a) a demand and a supply, and then I -- for our money, we think FERC should require the RTOs to compare the cost and benefits of lines, not necessarily to pay for them, but at least to give state commissions and other governing authorities an ability to evaluate these lines. Because right now we have a situation where, like, the Missouri commission, how they're not positioned to figure out, like, what's the cost and benefit of a line, and if you ask -- sorry, Dale. If you ask MISO to show up to testify in a line siting application for a project like ours in Missouri, they'll say, yeah, these guys are going through the interconnect. They seem like nice enough fellas, but we don't know anything about the cost of benefits, because we've never measured it because we're going from SPP to MISO to PJM. So FERC, at a minimum, should say, you must evaluate these projects and just tell us what they do.

MR. BOSE: Thank you very much.

CHAIRWOMAN TIERNEY: Terrific panel. All right, Paul, you're up. And Clark. And please assume that you have until about five of 5:00, okay? You've got the same time, just shifted. And no more than that.

MR. CENTOLELLA: Okay. Clark and I were privileged to sit on a National Academy panel whose report just came out. It is capable of being downloaded for free from the National Academy website. It's called The Power of Change: Innovation for the Development and Deployment of Increasingly Clean Electric Power Technologies. This was a unique opportunity where a number of senators asked DOE to engage the National Academy, to look at how we could recapture leadership in clean energy. And the Academy's initiated the study. There were originally 17 members of the committee, including a former undersecretary of energy, a former congressman, a former FERC commissioner, a retired admiral, a former governor, and the two of us, and several academics, environmentalists, a really fantastic group of people to work with.

And we were really tasked with determining how policy could accelerate the market adoption of advanced energy efficiency and lower non-carbon polluting technologies. I'm going to give you the bottom line first, and then talk a little bit about how we got there.

So we had two overarching recommendations. First is that government should significantly increase their emphasis on supporting innovation for increasingly clean electric power generation technologies. And this was really a kind of underlying theme of the report that there's a fundamental need for important breakthroughs in innovation if we really want these technologies to be implemented at scale. Secondly, that Congress should consider an appropriate price for pollution, both greenhouse gases and other pollutants that are not internalized in a market-based system to both create a level playing field, create market pull, and expand research, development and commercialization. So those were our fundamental findings.

How did we get there? Well, first of all, we took a look at our existing mix of electric generation technologies. And while we have about a third of the capacity that is low or no emission technology, when you take away the legacy hydro and nuclear, we're really talking about only about 8 percent of electric generation is coming from these low emitting sources. And while some of these sources are seeing declines in cost, they still have a very long ways to go to get to any sort of target that we might have for a low emitting, low greenhouse gas electric sector.

We started out by asking the question, well, what are the market values that are contributing to this, and this was right on the first page of our report. You know, the identification of non-internalized costs for pollution being an important factor. Now, certainly not the only factor, but a factor that was an example of the kind of market failure that justifies government actions. And in this case, we noted that the correct intellectually simple but politically difficult answer is that governments can require market actors to price pollution into their decision making. So just as the National Academy has in past reports encouraged putting a price on greenhouse gas emissions, we reiterated that finding in this report as something that is fundamental to fix our environmental problems.

But we went on to look at the technologies themselves. So we looked at a number of different sources. This particular graph, which is in one of the appendices to the report, is based on the 2016 EIA Annual Energy Outlook. And we broke down all of the different elements of cost to look at the levelized cost of electricity for generation from different types of generating technologies coming online in 2022. And you'll see there that the least expensive in terms of a levelized cost basis, so this is forecasting what the cost will be five years from now. The least expensive is the advanced combined cycle gas units, and this particular graph has built into it a $15 per ton carbon price.

Well, we can look at and compare where these levelized costs are for different technologies relative to that levelized cost for a gas combined cycle unit. And what we see, and for this first graph, is without the carbon price built in, is that wind technology ends up being 43 percent more costly on a levelized cost basis. And this is sort of the medium case. This doesn't, you know, dispute the fact that there are places and occasions where wind or solar can be cost-effective relative to conventional resources. But when we looked at the central case form EIA, what we saw, and this was true for other studies, as well, was that on a levelized cost basis, wind is more expensive, in this case by 43 percent. Solar, and we're talking utility-scale solar here, by 74 percent and offshore wind, for example, is even more expensive, 240 percent more expensive than the cost of the combined cycle gas. And with the exception of geothermal and hydroelectric, you know, these technologies seemed unlikely at these cost points, to begin to scale in a massive way across the United States. Well, even when we begin to add in a carbon price at the kinds of levels that at least people are beginning to talk about, in this case the $15, it takes the wind price, for example, you saw on the prior slide, from 43 percent more efficient down to being 32 percent more efficient, and the solar is still 60 percent more efficient, not more efficient, more costly, I should say, than the more efficient gas combined cycle unit.

So we would have loved to have reached a conclusion that said, you know, we can simply go out and deploy these things. We just need to make a few little adjustments and we'll be great, but we really couldn't find the data to support that kind of conclusion. So this left us beginning to look more deeply at the technologies. And I think our basic recognition was that climate mitigation is a very hard problem, so that if you're trying to look at a problem at the scale of climate change, that is so large that it requires a significant switch to increasingly clean power sources, in most of the U.S., despite the fact that there are places where solar and wind may be cost-effective. In most of the U.S., even with a price on pollution, most increasingly clean technologies would lack the cost and performance profiles that would result in the levels of adoption that are required.

This becomes even more difficult when you look at the problem globally. Globally we are seeing coal being built in Southeast Asia. We're seeing, you know, other technologies that are conventional, fossil fuel technologies, often without controls, going in in the developing world. And if you want to tackle the climate problem, effective mitigation requires a transition to low carbon technologies on a global scale, potentially with a compressed time frame, so one has to think about technologies that are both globally scalable and globally affordable. And our conclusion was that the technologies as they exist today and are projected to improve in the near future, don't meet that test.

So we also looked, then, at the question of, well, what happens if we just continue to deploy these technologies? Can we get enough improvement just by sort of learning by doing, learning by deployment to begin to close this gap in a timely way? And, yes, we looked at the general kind of learning curves that you see out there which, you know, if you look at a number of technologies over history and you do a very simple association might suggest a 10 to 15 percent improvement in performance for every doubling of deployment. But we also looked more deeply at that and realized that first of all, that's an association. That's not necessarily causation. When you look at the analyses to try to break down the factors that contribute to that, the learning by doing is, at best, a 4 to 5 percent improvement with doubling, and sometimes not that; that, you know, that there are diminishing returns to that; that, you know, sometimes if you put a big incentive on deployment you may simply get deployment of current or incrementally improving technology and not necessarily the kind of fundamental shifts that are necessary to address the scale and cost problem on a global basis.

So we could not find evidence that policies that focused disproportionately on subsidizing deployment will produce the large, timely, and cost-effective improvements that are going to be required to address these problems. So that literally left us then thinking about how do you begin to improve the innovation process? So we took a rather in-depth look at the innovation process, identified market failures and barriers at all stages in that process and made some findings and recommendations about how to go forward.

First of all, and this is not all of them, this is a 320-page report and I invite you to read all of the details, but at a high level we said, it's important for the federal government to leverage regional efforts, regional markets, regional efforts in states, universities, entrepreneurs, and industries to help bridge the funding gap beyond what DOE can do on its own. Secondly, we took a look at things like mission innovation, the breakthrough coalition, and said we also need to be looking at this on an international level to develop technologies that can be clean and deployable, both in the developed world and also in developing economies. And we said the DOE should be looking at a broad portfolio of projects, not knowing, ultimately, what will produce the kinds of breakthroughs that are required.

And, also, in the course of doing that, widdling those projects down as you find out more information. The fundamental piece of R&D and innovation is that you are looking at things that are uncertain, and you are trying to resolve those uncertainties and, as you learn, you decide what the fruitful avenues are.

The report looked at the innovation process as a whole, recognized that there were significant barriers, both at a technology level and at a commercialization level. And we talk about the different stages of the innovation process, recognizing, of course, that it's not always as neat and linear as this, but nonetheless felt it was important to begin to understand the different points in the innovation process and what could be done at different points in that process. So we talked about some of the bridge between fundamental and early applied research and option creation, which is where ARPA-E is. And there is another Academy study which will focus on reviewing the work going on in ARPA-E.

We looked, then, at what could be done in sort of these middle stages where we found many of the most significant barriers exist. So we looked at the concept of roadmapping and challenge funding within DOE. We said that those roadmaps really ought to look at goals that were appropriate for the challenge of having globally affordable and scalable technology so that we begin to think not just about incremental improvements in the technologies that we have, but what kind of R&D is going to be necessary to get us to the point of solving the problems. We talked about and look at the role that inducement prizes can play as a supplement to intellectual property rights, as an alternative to grants and conventional R&D funding. We looked at the need to begin to activate things that are regional and local levels, so we talk about, for example, clusters of regional institutes and how you begin to develop clusters of innovative companies in different regions.

We recognized that venture capital has a limited timeframe, and looked at models and research that could allow a kind of limited partnership of government in those venture funds, gave some of the existing statutory authority under the SBIC to establish, you know, clean power related public-private venture funding as a way of extending venture capital. Understood that in order to accelerate technologies in this middle stage, it's important to utilize the kinds of tools that are now available and expanding a network of simulation and testbeds. Some of these are tools that exist today. Some of them are tools that will need to be developed. Some of them are testbeds that could be developed relatively inexpensively. Others, like a nuclear testbed, might take significant government funding in order to support, but we felt that it was important to have these kinds of tools available.

And finally we looked at the demonstration stage and really felt that it was important to create institutions that would allow a partnership between the federal government and regional funds at that stage. Finally, there's a discussion of how we move this into the utility industry. There's a chapter about how we begin to think about utility regulation. You know, some of the things that are covered in there is different regulatory models, you know, set aside funding for research and development, and a number of other items.

So that chapter really deals with modernizing the power system, and it has, I think, a couple of different focuses for DOE. One is that a recognition that it's going to be necessary to redesign business and regulatory models, models that will be more customer driven in this future world, and that DOE has a role in developing information and tools to assist state regulators in considering and implementing new kinds of regulatory models to meet those challenges.

And secondly, that states have a role in implementing policies that, in part, through their utility regulatory proceedings, to support innovation. And, you know, that might include, for example, set aside funding for innovation programs, and DOE might be helpful to the states in advancing their consideration of those kinds of objectives.

We also looked at the need for new business models, and specifically talked at this point about distribution system operators, and also other kinds of customer energy service providers. We identified some specific areas in which distribution system operators would need new tools. Those are laid out in a section of the report, some of them are things that DOE is already doing and some of them will be expansions of those efforts. So at this point I'm going to turn it over to Clark to talk about efficiency and technology readiness.

MR. GELLINGS: Thank you, Paul, great job. So, obviously, you don't do a study about technology as it relates to clean energy without touching on efficiency, and that's what we did here. Going back to the point Paul made earlier that the panel recognized that prices matter, and if we could, perhaps, really bear all the true costs of generating electricity and the price of electricity, some magic would happen. Prices would go up and people would respond accordingly. However, the panel did feel as though that was a valid path to take in the short-run, but in the long-run, it might not be enough to overcome market barriers and behavioral failures.

And let me spend just a moment on the behavioral side because this is one of the few places that I've seen the National Academy reports were that is specifically mentioned. So, now, I'm going to borrow a couple of numbers from my own work. This is not part of the National Academy work, but just help illustrate. If you look across the next

years, we -- it's likely that we might reduce the consumption of electricity by, say, 10 percent over what it otherwise would be. You know, you got countervailing and pressures of the economy and population growth, and so on.

But what's achievable in that regard? Well, with a really hard effort, maybe 14, 15 percent is achievable. Yet we leave a lot on the table because about 18 percent reduction might be economics. So I only mention these numbers just as an illustration here. You won't find them in the report. But what's the difference between those numbers? Well, it's behavior. So we offered, at least, that there should be some effort made on understanding what the behavioral issues are and potentially coming up with, I'll say, solutions, like we don't necessarily solve behavioral issues, but that we can point to activities, programs, and the like that would reduce the uncertainty of people actually adopting the more efficient technologies.

I would also just quickly mention the innovation side of this where, in fact, we could do a lot more with technology if just making that technology available so that when people would go into Home Depot, for example, and put their hand on the shelf to buy a lighting device or whatever, the device that's on the shelf is already much more efficient. So there's that angle of it.

But turning back to DOE and DOE has done and should do, among the most successful things that we've done in this country to reduce the consumption of electricity is appliance efficiency standards. DOE has that role now. It's in their wheelhouse and so the Committee complimented DOE on that activity and suggested that they should continue to set new appliance standards as the technologies evolve. Of course they need to be at maximum feasibility, technologically and economically justified so we don't put undue burden on our society.

The second recommendation here is really to do with building standards. The first one DOE has a role and is able to take action with regard to appliance efficiency standards, DOE cannot promulgate state energy efficiency sub-codes and building codes, but they can encourage. So what DOE has been doing is working with certain standards organizations such as ASHRAE. Many of us are familiar with ASHRAE Standard 90, and try to help them evolve information that would translate those appliance efficiency, or building efficiency suggestions, guidelines, into state standards should the states take action.

And the last one of these is with regard to government in the private sector, (inaudible) moving barriers. And there's some examples that were brought out in a discussion where, even within the federal government, it's sometimes difficult for them to make decisions and we are all or have all been exposed to actions that have been taken in governments with regard to buildings and sewage plants and what not, all where there are requirements to go to the lowest capital cost without allowing considerations for operating costs.

So the energy efficiency portion of this I think you'll find it's pretty thorough in that it does address the problems as we see them today. But I want to add one more very important one, and that is that things are changing around us and in particular things like AMI, data analytics, the edge of grid stuff, the micro synchrophasor work that Merwin has talked about repeatedly. All these things are bringing more data forward, and as we learn to use that data, and make that data available and learn how we can manage that data, there might be a fundamental shift in how we could look at the rollout of efficiency both from a technological point of view, as well as with regard to programs and activities. And the recommendation here, specifically, is that DOE should increase investments. Of course in innovative efficiency technologies, in that same 20-year period that I referred to earlier, there could be a tremendous improvement in energy efficiency, should those investments come forward. But these do take time. They do not happen overnight.

Any of the technologies we point to now as being innovative have been around for years. Wind turbine generators, we started working on those well over 25 years ago in earnest. Solar, same thing. This was going to require a sustained investment in time, and pointing back to a point Paul made earlier, we have to have the patience to live with them even through periods of dark outcomes, if you will.

All right, my final point I want to make is with regard to technology readiness levels, and this is really more to point to the report. I can't possibly cover all of the technology readiness level information that we've got in that report, but TRLs are a way for us in the technology community to measure the stages of development of a technology and the stages of development that system that we were using is actually the one that NASA developed. I made very brief titles for them here so that you'd get a flavor of it, but as you might guess, ranging from exploratory through formulating concepts, validation in the lab, early demos, and so on, all the way through to TRL 9 as we like to call it, and that is a wide scale commercial deployment. In the appendix to the report you'll find a series of TRLs on a number of technologies. I think for those of us who are in technology planning, you'll find that very useful. We grouped them a bit just to make it more palatable into these five. I won't read them to you, but you'll get a sense of them.

Between Paul and I, we've mentioned most of them here, even in this presentation. So just a quick wrap-up. Hard to wrap up, except number one, we really would like to see clean energy technologies compete, but they are rather expensive right now on the power generation side especially, given low natural gas prices, but that falls over, by the way, to the end use side. With the price of gas the way it is, it's really hard in some areas of the country to justify electric heat pumps. And yet those are the kinds of technologies that we'll need to see gain greater acceptance if we really are to get to a low carbon future. We can't just do it with generation. It'll have to be done with end use, as well. We need better technology, certainly, for power generation, for pollution control, end use, grid integration, storage, all of the things that we so often talk about and it's going to require a massive effort.

So, questions? Paul, I think we have left four minutes.

MR. BROWN: Merwin Brown with the University of California. When I worked for NREL, this is almost 15 years ago, we did a study for the Clinton White House, that should better get the time factor, on a question about what could bioenergy do in the way of helping with reducing the consumption of oil-type products. And I remember the answer came back -- you know, this is an oversimplified answer, but basically it was, you can't do it without new technology. And in some ways you just -- this study says the same thing, only in a much broader perspective. And I have to say that privately I intuitively am not surprised by the findings of this, at least in general, but looking at this study, as presented here, it seems to me that another dimension of research area needs to be added at the federal level and other levels, but it goes even beyond DOE and that is adaptation to climate change.

And so, I don't know whether that was discussed or not in this group, that if we can't find the new technologies, that we don't even know for sure what they are, maybe we better also get some contingency planning in there of technologies to help with adaptation of climate change.

SPEAKER: Well, certainly --

CHAIRWOMAN TIERNEY: Why don't you guys do this? Let's take a couple of questions --

SPEAKER: Yeah.

CHAIRWOMAN TIERNEY: -- and then you can answer them fully. So, Pat, and then Jim.

MS. HOFFMAN: So, my question is more just your thoughts. I noticed that chapter six on the electric grid chapter really did a huge emphasis on the regulatory issues, the business models, kind of the structures, and one of the comments in there was looking at a -- I think it was a customer role for the distribution system as a customer energy service provider or a distribution system operator. And I said, independent or combined? You know, I think actually the opportunity could be combined. I just wanted your thoughts on that.

SPEAKER: Hold on.

CHAIRWOMAN TIERNEY: Jim, add your question.

MR. LAZAR: The report (inaudible) --
CHAIRWOMAN TIERNEY: And then Marilyn.
MR. LAZAR: Jim Lazar from RAP. The report does talk about the need to get to an 80 percent reduction but it does not discuss the field switching of currently fossil fueled loads, primarily space and water heating, and electrifying those loads. And I'm wondering what the thought is on that as we look further ahead, sort of at the issue of retiring the gas industry.
CHAIRWOMAN TIERNEY: One more question, that's -- and then you guys can do a omnibus.
MS. MARILYN BROWN: Well, I really look forward to reading the report. Thanks so much for providing an overview of it. Just a real simple question on the social cost of carbon. I noticed that the $15 value is, like, almost outside of the range of the social cost of carbon as the interagency agreement agreed ranges go. In 2030, they -- I'm looking at a table here. In the year 2030 they range from 16 to 73. I'm ignoring 95 percent discount rate. So in the 2.5 to 5 percent

discount rate they range all the way up to 73. Fifteen dollars (inaudible) here, too, is kind of a typical value that people are using as a prediction of what the trading value will be for a carbon allowance in the year 2030. I've seen that used now on three or four publications. But, you know, there's a big difference between an estimate of the damages and an estimate of the mitigation cost or an acceptable tax range. So I just wondered, it seemed to me that if we were to put the full cost of carbon in, your conclusions, Paul, wouldn't be so negative in terms of what we could do in competing the clean options more favorably.

MR. GELLINGS: Thank you for your questions.

MR. CENTOLELLA: So, I'm going to come to Pat's last, but let me start with Jim's and Merwin's by just saying, you know, I wouldn't disagree, but I -- neither were really in the scope of what the study was doing, looking at power technologies and, you know, and how to get increasingly clean power technologies into the marketplace. So I think we would agree with both of your observations, you know, and it wasn't really something that was on the table for us as a Committee to try to reach a conclusion about.

So, Marilyn, you know, if you look in the report, you'll see the values. It's very easy to, you know, to go in and adjust the carbon value. Let me see if I can get back to that slide. Wait a second. So if you look at the carbon value, it is, for most of these technologies, relatively small. You can see it in the coal plant value. Oops, I didn't want to get the --

MR. GELLINGS: Microphone.

MR. CENTOLELLA: No, I don't. I guess I don't have a laser pointer that I can get to work, but you can see it in the conventional coal. It's the orange bar. When you go to the others, it's, you know, it tends to be relatively small. So, you know, here's, you know, advanced gas combined cycle. Even if you tripled or quadrupled that, you know, you're still going to see, you know, these technologies struggle somewhat. So I don't know that I've done the $60 calculation. I did $41 the other day because it's the forecasted price from one of the reports in New England. You still were seeing, you know, wind. I don't remember the exact figure, but 20 or some odd percent more expensive than, you know, than advanced combined cycle gas.

MS. MARILYN BROWN: So then what you also really want to do is look at the range of natural gas prices rather than the single one. And then those two together, I bet, could change your bottom line.

MR. CENTOLELLA: So at $30 wind is still percent more expensive on average than the

advanced gas combined cycle. So yes, it brings it closer, but the question is not just can you find places where it makes sense, the question is, can you get it to scale and can you get it to scale not only in developed economies where people might be willing to pay somewhat more, but can you get to scale in developing economies where emissions are going up, and the trade-off is between taking people out of poverty, or paying for cleaner technologies. You know, so that's part of what's underlying our fundamental recommendation.

MR. GELLINGS: Paul, I just want to add that while we obviously were trying to do a study which would talk in part about how we become more innovative in technology development, we were anchored in the technologies we know. And we didn't really begin to speculate very strongly on advanced technologies. In particular we didn't speculate on new electric technologies that would subsume the need, even, for a fossil fuels. We weren't even allowed to address transportation because that was apparently going to be done by another Academy study. So you'll see a lot of emphasis on power generation technologies, some on the smart grid, as Paul has already elucidated, but they're pretty much based in the technologies we now know.

Now, having said that, strong emphasis on, we need to do a lot more with innovation.

MR. CENTOLELLA: So, let me conclude with trying to respond to Pat's question. And, first of all, I want to say, thank you, Pat, for your support for the study. It was very much appreciated by the Academy and the Committee.

So at the time that, you know, that we were drafting this report, which is now several months ago, you know, we were looking at some of the early dialogues around how the business model of utilities might change. And sort of stated from some of Peter Fox-Penner's early work around this, you know, in terms of DSOs and service providers. You know, we did, however, you know, include in a -- and you'll see a list. And I mentioned it, you know, with respect to some of the capabilities that we felt a DSO might need. We talk there about distribution level markets. We talk about platforms and platform markets. We talk about, you know, the need to have operating models that extend from transmission into distribution. And we talk about some of the other specific kinds of things that DOE might be looking at, you know, as it begins to think about how these business models and the underlying technologies may evolve. So this is, as you know, a rapidly changing area. And ongoing work, some very nice work that, you know, we've been following in the grid modernization lab studies, but you know, an area we think of continued need and focus if we're really going to get to the point where these technologies will integrate in a way that is efficient, cost-effective, and reliable.

MR. GELLINGS: We never did try to resolve the issue of the interface, specifically, between transmission and distribution, recognizing that that is its own dynamic at the moment.

MR. BROWN: Excuse me. Merwin Brown, a clarifying question. On the carbon emissions calculations for the natural gas fire, did you include methane emissions as well?

MR. GELLINGS: No, I don't think that

was in there. So the answer is that the downstream emissions are included. The upstream emissions are not. So, you know, the getting the gas out of the well, that's not included in the calculation and that might --

MR. BROWN: Some people say --

MR. GELLINGS: -- that might modify, you know, how you were looking at this.

MR. BROWN: Some people say that could change it a lot.

CHAIRWOMAN TIERNEY: That was a terrific presentation. And thank you for your service on the Committee. Thank you so much. That was great. All right, we have little less than an hour before we need to break for dinner. And I'd like to suggest that for about 30 minutes, if anybody has some completely relevant, great idea, burning thing to share about something that you are working on that is relevant for the work of this Committee, and by that I specifically mean commentary that we might share with Pat and the Department of Energy. Or an idea that you would like to throw out with regard to some area of work that would be really interesting or edgy for the Department to be looking at, let's just put some things on the table. These are things that are just meant to stimulate some ideas for the subcommittees and to get to know each other better without having a full dissertation on the topic right now. But say why it's cool, why it's important, and what could be done. So, Janice, I'm going to see you first. And then Gordon. And then people can put up their stuff. So maybe just no one talks individually for more than three or four minutes. Okay?

MS. LIN: Thank you, Sue. So because you had mentioned AB-2514 in your opening remarks, I wanted to report back that Governor Brown, on Monday, signed into law a new bill that directs investor owned utilities to file applications for another 500 megawatts of storage, distributed -- distribution interconnected or customer sited storage. And this is incremental to the 1.3 gigawatt target, which is very exciting. And another bill he signed into law doubles our incentive program for energy storage. It's called the Soft Generation Incentive Program, but through programmatic reform, 75 percent of that is allocated to storage behind the meter, which is very exciting.

But the thing I wanted to talk about that -- what's significant about this, especially the 500 megawatt bill was that unlike previous legislative efforts, this one actually had very strong utility support, which was refreshing and new, and kind of exciting, and I think just underscores the importance of learning by doing. And when folks try something and they -- especially with storage, like a new -- Heather's going to want to say something, a new tool in the toolkit, and they try it and they really receive competitive offers and see how it works and get to operate it, there's much more willingness to make progress and do innovative stuff. And what we're noticing around the country is that there are utilities all over the place that would love to try storage but they're lacking the tools, planning tools, which help them with system planning and operation that would help indicate the value of storage, so it's a little bit of a chicken and the egg problem. And doing that modeling is very expensive and a real big barrier, and so my humble suggestion is that could be something that DOE could help solve.

First, it's all over the country. Maybe providing those resources, either funding to tap into existing commercially available tools, or create a tool or some mechanism where states can do this cost-effectively. Thank you.

CHAIRWOMAN TIERNEY: That's great. So first, Gordon, then Heather, then Merwin. And Jim, are you still up or not? And then Jim.

MR. FELLER: During the grid modernization discussion this morning, I suggested and I'll repeat it in a different form that maybe would be useful for some of our committees, and we talked about the six foundation projects for grid modernization in this context this morning. It would be good for some of our projects and some of our committees to make a concerted effort to reach out to startups which are largely invisible to bigger organizations like we represent, but I'm making a concerted effort in the last few years to spend a lot of time with startups. All of them, you know, young organizations led by young people who have disruptive technologies, or what they think will be disruptive technologies for our business. And some of them are focused in specific areas that we've discussed about today, whether it's in transmission, distribution or in storage or in generation or in other domains like the analytics for the smart grid. And I think there are an abundance of them who would jump at the opportunity to brief us about what they're doing without needing to sign NDAs. They're anxious to hear from us about what large organizations like the ones that we work with think about the areas they're focused on. It's not hard to do this. It's possible to do this as an attachment to something already happening, like one of the clean tech open events, or the event that we're involved in at the end of October that Berkley and Stanford are cosponsoring.

So I'm just offering this as a suggestion. I'm a resource if it's useful to identify some of the examples in different categories of well-funded or maybe even maybe not so well-funded but really promising startups that are focused on resolving some of the problems that we've identified and doing it differently than maybe we have been thinking about it, doing it, hopefully, with a lot less resources required, and a lot more speed into the market. And there are some priorities on our list that I could suggest some categories but I think, you know, over the course of the next 24, whatever number of hours we're together, we'll probably come up with a pretty good list of things that we want to see accelerating in the market, and this may be one of those paths to acceleration.

CHAIRWOMAN TIERNEY: Very cool idea. Heather.

MS. SANDERS: Thank you. Heather Sanders, Southern California Edison. I always have a lot of ideas for things that we need and we can do, as I learn, especially as I learn more about what it really takes to do this. However, you may already be doing this stuff, because I was really impressed hearing about the six foundational projects in the Grid Modernization working group, and so we offered a number of suggestions in that context. And so I think you're doing a lot of great work.

One of the things that we still need, and I mentioned this last meeting, is something that talks about equivalence. So, I'm not going to build a substation, but I'm going to use energy storage and demand response and energy efficiency to solve the same problem. And this is really hand-in-hand with what Janice mentioned about planning tools. This is about gaining confidence and understanding about what does this portfolio do that is the same as a resource that I have available 24x7 for 30 years, and I know exactly what it does. So this we really need because as we go into these discussions about, these things are not the same, you know, I wish I had rain boots, but I have these shoes. There's a problem. When I'm walking about there I slip. So there is things like this -- I didn't use animals. I should have used animals, right, Merwin?

So this is something that will be really important for us to discover. The second thing that I mentioned in the Grid Modernization working group that I believe is being taken care of is the new standard, the new way of designing distribution systems. So we have a standard now of how we design distribution systems that are radial. There are standards for deciding network systems, things about how many circuit connections you need, how many remote intelligent switches, how many things you need to achieve at a certain amount of reliability. That will vary based on where you are and who you are and what kind of penetration you have, but this is also really essential, because as we put forward our grid modernization plans, which we did in our general rate case on September 1st, we need to come back and say, why is this the right level of technology? And then, why now?

And so these questions are important for us now, and I think they'll become important, if not already, for many other areas of the country.

CHAIRWOMAN TIERNEY: Really terrific suggestions. Jim.

MR. LAZAR: I'm in the midst of a paper on the role of the grid integrated water heating in play in helping us with the storage and scheduling needs that we need to integrate variable renewables. Preliminary results are that just controlling the existing 45 million electric water heaters in the U.S. would give us the flexibility to add between 50,000 and 100,000 megawatts at variable renewables to the system with no adverse impacts on anybody.

That number is a function of some interesting things. How many of them are going to become heat pump water heaters? How many of them are in apartments where heat pump water heaters are not currently an applicable technology? How many gas water heaters will convert to electricity under a deep decarbonization scenario? Maui Electric has done a study that, if they can control 6,300 water heaters, which is about a fourth of the number they serve, they could eliminate the wind curtailment that's currently going on in Maui, so this is, you know, people are actually doing stuff with this.

And I'll end with a simple little piece of arithmetic. The average electric single family water heater uses about 4,000 kilowatt hours of electricity. If we convert it to a heat pump water heater, it uses 1,500. We've freed up 2,500 kilowatt hours, which is about the amount of electricity an electric vehicle uses in a year, and then we have hot water and mobility, and we can control when we charge the water and when we charge the vehicle. We've taken an existing, uncontrolled consumer of electricity, met two different end uses, and have a flexible load for both of them.

CHAIRWOMAN TIERNEY: Well, get on with it. That's very cool.

MR. LAZAR: My paper, I hope, will trigger a lab level of effort, which is what's really needed to prepare for this resource.

CHAIRWOMAN TIERNEY: Thank you for sharing that, Jim. Merwin.

MR. BROWN: Merwin Brown, University of California. Most of my work done at the University of California over the last 10 years has focused on transmission level activities, a lot on synchrophasor application, which got me to thinking about data needs with the transmission level. And then that project eventually faded away and we shifted attention to distribution, and we did a project for the energy commission trying to answer the question, is, what kind of data is needed on the distribution system in order to integrate a lot of renewables into distribution systems. So we did that. And now we also have a project funded by RP, which some people will gag if I use this again, but nonetheless, Clark raised that the work we're doing on micro-synchrophasors is to do to distribution what synchrophasors did to transmission, only it's a much tougher job. It's about two hours of magnitude more difficult, but we did achieve a device that will do that, will measure the angle.

Anyway, that's not my point. I'd only offer that as a way of disclosing I do have some interest, I guess, in this that I don't think is an ethical breach. But one thing is in listening to the -- well, that experience coupled with listening the foundational presentations of the grid modernization effort, I think the question or what's required, what kind of data is required to run the modern grid, and how we're going to get that data and use it, I don't think is really getting the proper attention. There is a lot focus on the analysis aspects of it, right? And rightly so. There should be. I'm not trying to detract from anything else in that effort, but I do detect, I think, maybe an assumption, not only for that study, but maybe in the industry, that if we build the analysis tool, the data will come. And I'm not sure that's necessarily true. And so I would like to see a more overt look at that question. And I realize it's also an (inaudible) effort. In other words, you got to find a need that needs the data and then you got to find out what it takes to get the data, and does the new data, like synchrophasor did for transmission, open up actually new needs by the fact you can do new things you couldn't do before? So I just wanted to raise that point.

Also, I might add, I've already raised it in other forums, and so it's a bit redundant here, but more ears are hearing it.

CHAIRWOMAN TIERNEY: Thank you. I know I have one. Oh, Heather, you already did yours. I have one, and I don't see another card, so I'll say it. And this is a topic that came up at our lunch meeting, and so it's something that I've been thinking about a lot. The issue is the growing need for the system operator, whether it's the local distribution utility or whoever is the local grid operator, and the balancing authority to have much more visibility into what's happening in terms of the party behind the meter resources. I've thought about this and some work that I worked on with SCE and ConEd where there's a big movement afoot to open up four distributed energy suppliers. The information about the utilities system, so that they can offer things in targeted ways that work for avoiding that substation, I mean, excuse me, avoiding that circuit or whatever.

But on the other hand, I think that we also need to enhance the ability of everybody else to see what's happening. And right now I think that's either limited by commercial interests of the provider say, who has a third party contract for solar panels on the rooftop and doesn't want to share that information, privacy issues of the consumer themselves, but I think that more and more when there's a two-way system, there needs to be more quid pro quo about that. And so I would love to either have us think about that some more, to hear if DOE has places or venues where you're either convening to deal with those qualitative and quantitative issues, and so forth.

And, Billy, I see you have one up.

MR. BALL: Yeah. I know Pat has to deal with this a lot in her role. It's just something that I've had to deal with quite a bit in the last few years, and it just gets to be a bigger and bigger issue, especially as we see newer technologies, really, anywhere you are in the country around -- whether it's grid operations, new generation type technologies, new devices on the distribution system, and it really comes back to physical and cybersecurity. And there's just been so many times that it's like we're dealing with the physical -- we're kind of in catch-up mode around the physical and cybersecurity issues. So you can deploy a technology, and then the questions start coming. And quite honestly, too many times the kneejerk reaction is, well, insert a dumb piece back in to the process to mitigate at least the cybersecurity threat. And while that might be a right solution, there's just a tremendous tug, I see. It's like advance the technology for all these reasons.

Then, oops, we may have gone -- just stop. Stop, stop, stop, stop. Now let's figure out how to get it back here so I can be concerned about my security issues. And then the next day it's, no, advance, advance. So I don't know, Pat, or maybe -- I don't know if in the Department's work, as you work on technology and research, if there's a specific effort in each case to also address some of those issue upfront. And I know that's, like, ridiculously hard to do well. I know that. But it's just something, and I know, Pat, you see it with some of the meetings around. It's just like a yo-yo thing. And they're both legitimate concerns, and if they can be dealt with together, I think we'd get somewhere quicker without kind of going back and forth, and which just creates more uncertainty for everybody involved in the process. So --

CHAIRWOMAN TIERNEY: Well, and it creates a --

MR. BALL: -- it's aspiration.

CHAIRWOMAN TIERNEY: -- battle attitude.

MR. BALL: Yeah, it really -- and I, I mean, as somebody who has some operational responsibilities, I, you know, you kind of get it from both ends. And I'm kind of used to that, but I just see a lot of energy, and fighting back and forth, but it's not that anybody doesn't have the same long-term goals. And so I don't know how to improve it. There you go.

CHAIRWOMAN TIERNEY: Thanks, Billy. Phyllis.

MS. CURRIE: Well, I don't know if it's an exciting topic for DOE, but I think that as you think about the technology changes that will affect the industry, and particularly when we started talking about the role of the transmission operator versus distribution. I think we need to think about how do we change the financial model of utilities, because a lot of the technologies, when they go to the end user, then they're not in the same kilowatt hour developing basis that revenues are collected on today. And also, energy efficiency, that reduces the number of units which utilities typically bill. So you see the conversations that go in and areas where a lot of solar is on the system and that energy meter room becomes a hot button issue.

I think some thought along the way as we develop various technologies, we need to be looking at, how does it change the revenue model, and then how do we communicate what the potential changes might be so that people are thinking of how to effectuate those changes before they're faced with the impact. And in some cases, utilities look up and they see that their revenue base has greatly eroded. And by that time, it's too late to really initiate some kind of strategy. So I just think some thinking by somebody, maybe you're going to decide it's not you, not DOE, but somebody has to be looking at how the revenue model for utilities is changing and will continue to change.

CHAIRWOMAN TIERNEY: Thanks, Phyllis. Clark?

MR. GELLINGS: Phyllis, I like that. I'd like to add to it. Let's also consider how we can preserve the electric utility because too much of this conversation that's going on now makes the assumption that we're going to end up essentially greatly affecting what would be future revenues, future service and delivery, putting a greater burden on certain elements of the utility as it tries to service its consumers because I'm one who believes that it ain't going away, that it's just too damn valuable. It was just too damn difficult to build it. There's just no way that we can make this broad assumption as some policymakers would like to make these days. And we've all heard these conversations. I want a microgrid. Well, do you know what it is? Well, no, not really. Do you know what you want it for? Well, no, not really, but I want one because I hear it's a really good thing. So, you know, I'd love to have some conversation, maybe just among some of us about how do we, yes, move forward; yes, adopt technology; yes, deal with the advent and proliferation of some of these resources, but why can't we do it in a way that preserves this wonderful concept of the electric utility that we have built over many years?

CHAIRWOMAN TIERNEY: Thank you. Rebecca, then Marilyn.

MS. WAGNER: Just quickly to add on to that, I probably don't totally share the same thought about saving the electric utility as it is today, but I think we need an evolution in that. And, as always, I've harped on this in meetings past. There has to be an evolution in the regulatory model with major changes in innovation. We've seen it in our time. I'm seeing it at the commission in Nevada, not knowing how to deal with storage or even a proposal of a storage procurement target left some apoplectic not understanding what that means and where storage fits and how it's defined so that innovation has to -- there has to be regulatory, I don't want to say upgrade, but evolution as technology evolves.

CHAIRWOMAN TIERNEY: Let me just go and then, so we'll continue this way around and then to that side. Hold on. Marilyn.

MS. MARILYN BROWN: All right, thank you. I'm kind of continuing with what Phyllis started. So the most in my crystal ball, I think that the electricity consumption of the traditional customer base of electric utilities is going to decline unless we rev up with a lot of electric vehicles on our highways. That's not a reflection of where our official forecasts lie, which continue to show growth. But I know we're seeing very little growth in TVA and I don't know when or why that would stop other than we take on new business lines, like, serving our EV customers. So I think it's really a shame. I was sorry to hear, Paul and Clark, that you weren't able to look at the future of the power of change and this combination of transportation and the traditional electric services provided by the utility industry because I think it's through the electrification of transportation that we're going to see a resuscitation of exciting things that will increase the profit margin or maintain the viability of our traditional electric industry. So that was one point I wanted to make. So let's continue to look at that.

But, related to that is, I was mentioning over lunch, from my visit to three weeks in universities in Europe, I just got back, the role of intermediaries, and I see this, too, at Georgia Tech with undergrad and grad student projects that are just so imaginative, where they're identifying new services that they can deliver, you know, over the Internet to fill some sort of a niche need in the electric industry. And I think this notion of intermediaries providing interesting business services, we ought to look at, just as examples of how we may be seeing transformation of the model going forward. It may not be just from the top down, but it's going to be, do they call it, the middle out, the intermediaries.

CHAIRWOMAN TIERNEY: Thanks. Paul.

MR. CENTOLELLA: So, Billy's comment made me think about a conversation that I've been having over the last week with one of the researchers from MIT. And it was a discussion about, how far can regulation go in promoting cybersecurity, and we were talking about, can regulation begin to address cyber problems at the distribution level. And, you know, the place I took that conversation, and Sue will remember some of this from some work that we did a few years ago, was that it's really important to think about governance, and that the industry itself needs to have governance institutions that bring it up to speed because regulators will never be fast enough to deal with the evolving problems of cybersecurity. Utility commissions will never know enough to be able to evaluate themselves whether or not cyber expenditures are at the right place or not.

And so, Sue and I a few years ago worked on a bipartisan policy council report that talked about creating an (inaudible) like institution for cybersecurity. I think convening regulators and industry to have a conversation about what kinds of institutional governance is needed in cybersecurity might be a really interesting role for DOE to take in this place. I don't know whether it would end up with the same place that, you know, that we ended up in, you know, in that report, but I think it's an important conversation and needs to happen between regulators and policymakers, including state regulators on the one hand to deal with the distribution side, and the industry on the other to get us to a point where, you know, we can actually begin to have greater faith in these private companies being on the front lines of defending our critical infrastructure. So that was one comment.

The other comment I want to make, and it's a comment that I always come back to and we're seeing it again on the distribution side is how do we begin to integrate markets and engineering? How do we begin to not just say, well, we're going to have X amount of distributed energy resources or X amount of storage, and then have to add on X more things that we're compensating for the inefficiencies of what we just said the first time? And, you know, at the same time recognize that once we enter the world of markets, it's not going to be so clear in the sense that, you know, it may not be a system operator who gets to dispatch every single resource. But there may have to be a forecasting and a using of data to understand, you know, what's going on in the system in a new way. And what does that world look like, and how do we begin to have that conversation, which we had 10 and 20 years ago at the RTO level, down at the level of the distribution utility and the featured distribution system operator or distribution platform?

CHAIRWOMAN TIERNEY: Cool, that's great. Carl.

MR. ZICHELLA: Folks have said a lot of

what I wanted to say, so I won't repeat it. I do think, you know, the focus on what the future of the utility might be is fertile ground. Everyone's talking about it, thinking about it. It might be a really useful role for the Department to play to help facilitate and coordinate some of the conversations around what's happening. In the interface with the regulatory system, I think is important, as both Paul and Rebecca have mentioned, you know, how's this going to come together? What is the appropriate role? What sort of dynamic are we going to have in a distribution system? Will it be more transactional? How much of that will be under the auspices of regulatory agencies, or how much of that will be peer-to-peer and we just have to understand how it's going to work and try to forecast what the system will do in response to the markets.

You know, I think this is an area of great uncertainty. It's inhibiting our ability to leverage the advantage that utilities can provide to us, and it's really an existential question for them. They're not sure what they're going to be. And I think it is that uncertainty is very inhibiting to the option of new technologies that these institutions see as threatening to them because their future business model is not very clear. So I think it's an area where the intersection of technology, markets, and regulation needs to really need a lot more thought by a lot of people.

I know a lot of conversation is already happening on it. It's not like it's not. But the Department may be able to play a facilitation or a convening role to help come to some conclusions about what might be some of the more promising avenues for the future of this industry.

CHAIRWOMAN TIERNEY: Terrific.

MS. LANEY BROWN: I just wanted to build off actually two trains of thought, maybe, and one was Gordon's comment around looking at startups and companies that are innovative. And also I think very different, but taking Merwin's question about data analytics and also articulation as I see it of value. And I think one role that is a gap, particularly in moving towards innovation, is articulation of value and serving as a translator or educator in this space, whether it's you know, utilities and innovation, you know, startup companies or utilities and regulators around innovation and new projects. And so some of the work that supported with DOE are development of tools to help articulate value and to help educate and translate in sort of a everyday way. And so maybe working on or developing those types of translations or educations that bridge, that help support innovation might be an area to explore.

And just maybe one last thing, to build off of -- you know when I think about grid modernization and what's required, people process technology, skillset development and the needs around skillset development is an area that sometimes is neglected, whether it's literally skills that need to be developed, or the development of culture. You know, how do you develop a change culture within an area.

CHAIRWOMAN TIERNEY: That's great. Heather, you're going to get the last word. Oh, Ake's going to get the last word, after Heather.

MS. SANDERS: Thank you. I hope I retain the thread. As I get older I forget stuff even --

CHAIRWOMAN TIERNEY: Oh --

MS. SANDERS: -- in the space of 10 minutes.

CHAIRWOMAN TIERNEY: Just wait, Heather.

MS. SANDERS: So I wanted to build on what Rebecca said because this is about, you know, policies and enabling policies. And what I'm wondering about, is there an opportunity for the DOE to partner with RAP or someone else focused on policy to say, these are the potential policies in the futures and these are the enabling technologies we need. This is one of those intersections where we get kind of stuck and we say, we want to enable high penetrations of DERs and then we say, we need to invest in the grid and make sure it can do this, this, and this. And they're like, oh, no. And then we're, like, but we can't do that then. So this is something that I think, if we could get those two things together that really talk about, you know, what it takes and what it means, I think, you know, similar to my equivalence idea is that, how do you really make this work?

CHAIRWOMAN TIERNEY: You did a good job of remembering that. Ake, go ahead.

MR. ALMGREN: There's one more which I think we should capture one way or the other. That's resilience. Among other things I'm changing the liability committee and PJM. And we deal a lot with physical security. We deal a lot with cyber. I think we're all this sophisticated. And I'm also very excited about all these new technologies. But in the world going forward, I mean, like, resilience is a big deal. Things will happen, and I think that needs to be addressed. And I don't know the right format for it, but I'd just like to get the word resilience on the agenda.

CHAIRWOMAN TIERNEY: Well, you'll be glad to know that the reason Granger isn't here today, because he's over chairing the resilience Committee at the National Academies where we're supposed to be. And we're here instead. So there's at least some contribution being made on that. Yes, that's your fault for putting us all on the same days.

That was great. I don't about you, but that was very stimulating to hear things that are popping around in your head and put a lot of ideas on the table. So that's great. And I don't know if you want to give some reaction now.

SPEAKER: No.

CHAIRWOMAN TIERNEY: Okay, that's great. So we have some really important things to do. We have to thank everybody for this afternoon. We have dinner for those who are participating and so that should be fun. Recall that in the spirit of working with the federal agencies, this is a no host dinner. Just like there's no coffee, there's no water, there's no nothing, this is just more of that. So it's great. But it'll be fun. Tomorrow we are starting, excuse me, at 8:00 and for those of you who are new, what we'll do is go through a number of reports from the different subcommittees. We'll lean on you, in fact, to decide which subcommittees that you'd like to participate on. In fact, I think there's a commitment to participate in at least something. And you'll find that they're very interesting.

Some of those subcommittee reports will involve proposed approvals of some work products of the committees, and there have been a tremendous amount of work that's been done on preparing papers. At midmorning we're having a panel on plug-in electric vehicles, keeping the thread that we just raised this afternoon, so that'll be great. And then we'll have public comment and wrap up, and I guess we'll be off. So with that, anything else anybody wants to add? Yes, Paul.

MR. CENTOLELLA: One logistical point.

The Smart Grid Subcommittee has been, over the last several meetings, having breakfast on Thursday morning before we start. Chelsea sent out an email on that, but I think she said we were going to meet at 7:30, which is not going to work if we're starting the full Committee with the subcommittee report at 8:00. So --

SPEAKER: Especially when it's at (inaudible).

MR. CENTOLELLA: Yes. So if those of us who, you know, who would like to join that breakfast will meet at the Westin restaurant at 7:00 so that we have at least a little bit of a chance to get some breakfast and talk a bit about where we're going on our distributed energy resource recommendations going forward while we're here in-person.

CHAIRWOMAN TIERNEY: That's great. Now, I'm just reminded that the place we're eating dinner tonight is over in the Westin Hotel. It's --

MR. CENTOLELLA: It's the same as

breakfast (inaudible).

CHAIRWOMAN TIERNEY: It's the same as breakfast. That's great. You can just spend the night there. That's great. That's different than a place that people have used frequently, and apparently that place is closed. But Pinzimini is good. So I think we'll enjoy it.

MR. TILL: So Clark doesn't get to fight with the waiter this time?

CHAIRWOMAN TIERNEY: Well, I'm sure he can. I'm sure he can. There are more servers to fight with. It's great. All right with that, thanks, everybody for your participation.

(Whereupon, at 5:52 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.

(Signature and Seal on File)

Notary Public, in and for the Commonwealth of Virginia

My Commission Expires: November 30, 2016

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