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BEFORE THE
CALIFORNIA ENERGY COMMISSION

In the Matter of:	)	Docket No. 15-IEPR-11
	)	
2015 Integrated Energy	)	
Policy Report	)	

IEPR COMMISSIONER WORKSHOP
ON THE STATE OF THE SCIENCE ON SCENARIOS
TO DEEPLY REDUCE GREENHOUSE GAS EMISSIONS

CALIFORNIA ENERGY COMMISSION FIRST FLOOR,
ART ROSENFELD HEARING ROOM
1516 NINTH STREET
SACRAMENTO, CALIFORNIA

FRIDAY, July 24, 2015
9:30 A.M.

Reported by:
Kent Odell

APPEARANCES

Commissioners Present

Robert B. Weisenmiller, Chair, CEC
Andrew McAllister, Lead Commissioner for the 2015 IEPR
Karen Douglas

Staff Present

Heather Raitt, IEPR Program Manager
Ivin Rhyne
Guido Franco
Sonya Ziaja

Also Present

Michael Picker, President, California Public Utilities Commission
Liane M. Randolph, Commissioner, California Public Utilities Commission
Scott Murtishaw, California Public Utilities Commission
Keith Casey, California Independent System Operator
Michael E. Rossi, Senior Advisor, Office of the Governor
Jim Williams, E3
Trieu Mai, NREL
Ray Williams, PG&E
Paul Hibbard, Analysis Group, Inc.
Brian Tarroja, UC Irvine
Jimmy Nelson, Union of Concerned Scientists
Duncan Callaway, UC Berkeley
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I N D E X

P R O C E E D I N G S

JULY 24, 2015 9:34 a.m.

MS. RAITT: All right; good morning. Welcome to today's IEPR Workshop on the State of the Science on Scenarios to Deeply Reduce Greenhouse Gas Emissions from California's Energy System.

I'm Heather Raitt, the Manager for the IEPR. I'll begin by going over a few housekeeping items. The restrooms are in the atrium. A snack room is on the second floor. And if there's an emergency and we need to evacuate the building, please follow staff to Roosevelt Park which is directly across the street, diagonal to the building.

Today's workshop is being broadcast through our WebEx Conferencing System and parties should be aware that you're being recorded. We'll post an audio recording on the Energy Commission's website in a few days and a transcript in about a month.

Today we'll work through the lunch hour, but plan to take a brief break at about noon. At the end of the day, there will be an opportunity for public comments and we're asking parties to please limit their comments to three minutes.

For those in the room who'd like to make comments, please fill out a blue card and give it to me. When it's your turn to speak, please come to the center podium and identify yourself.

For WebEx participants, you can use the chat function to tell our WebEx Coordinator that you'd like to make a comment during the public comment period and we'll either relay your comment or open the line at the appropriate time. And we'll take phone-in only participants at the end.

If you haven't already, please sign in. At the entrance are the materials for the workshop. Written comments are welcome and due on August 7th, and the information for how to submit comments is on the workshop notice.

And with that, I'll turn it over to the Commissioners. Thank you.

COMMISSIONER MCALLISTER: Thanks, Heather. Thanks everyone for being here on a Friday, which is not a typical day for workshops, so I really want to acknowledge the staff and we have really quite a robust and frequent workshop schedule these days and I really want to commend the IEPR staff for keeping the trains moving and doing it very well.

My name is Andrew McAllister, I'm the Lead Commissioner on Energy Efficiency on this year's IEPR, and mainly those two things are what I focus on. And I want to thank, well, this topic is incredibly important and I'll make a couple comments about that, obviously I want to first thank our other representatives here on the dais, Chair Weisenmiller and Commissioner Douglas here from the Commission, Mike Rossi from the Governor's Office and GO-Biz, Liane Randolph and President Picker's office via Scott Murtishaw from the PUC and Keith Casey from the ISO.

Really, I think the presentations and just the presence of all of us here highlights how important this topic is. I mean, climate change and its impacts are driving much of energy policy and increasingly water policy, agriculture policy, lots of -- it's really an organizing principle in the state of increasing importance and it's critical to get it right. And I think that really motivates including this topic as a central piece of the IEPR to create that solid foundation for all of our agencies and all of our efforts to be coordinated and be based on sound science. So with that, we have a heavy schedule and I want to give everyone the opportunity to speak. Thank you all for being here, both those in the room and out there on the Web. And I'll pass the dais to Chair Weisenmiller.

CHAIRMAN WEISENMILLER: Hi. I wanted to provide a few comments for context today. First, I wanted to thank everyone for their patience. We originally were hoping for a July 9th date and because we were dealing with basically the renewables stakeholder process, we had to reschedule this, and that's why it ended up on a Friday.

The other thing I was going to say was that certainly this is a very good opportunity, I guess following on Andrew's footsteps I will say I'm the Chair, I'm the Scientist on the Commission, I'm responsible for climate R&D and electricity and natural gas planning; so, anyway, just about everything in this forum today I will be heavily involved in.

First, I wanted to note just basically I think our staff, particularly Guido, are looking to the third climate assessment. What we've done, sort of a body of work over a long time that looks first at what the impacts of the emissions associated for energy production are on our climate, and we also look at the environment more generally, but this is very specific on the climate, and also looking at the impacts of our disruption of the climate on our energy system. And that's the basic message that's really come out from that. And so that's one of the real threads that this will be building on.

The other thing is that we, the energy principles, so I should say energy principles, I mean, looking around the room on who is at the dais, we have the PUC, we have the ISO, we have the Governor's Office, we have the Energy Commission, so it's certainly part of that group, some of whom were very involved in developing the Governor's Greenhouse Gas Goals, and we did that using Pathways model by E3 with some assistance from LBL. And I think if you look at the pathway model and what that exercise did nicely, it runs a bunch of spreadsheets, but it has a piece that models the power system, a piece that models the transportation system, building and appliances, certainly the fueling infrastructure, particularly biomass. It looks at the interaction among those pieces. Now, frankly it’s not a great model of any of those pieces, you know, and probably the best example is that I was at a workshop yesterday where Caltrans was meeting, with saying their 2040 transportation plan is a mainframe model that takes 10 hours to run. So, there is a transportation element in this model, but it is not at the level of detail of the Caltrans model.

Certainly if you look at the power part, it’s not at the level of PLEXOS, it’s not at the level of a commitment model, it’s not a particularly sophisticated model, but at least it can show us the interactions.

Similarly, we have a very complicated building and appliance demand forecasting model. PUC has a very complicated energy efficiency potential model. So I guess what I’m saying is we all have very complicated models; the purpose here is not to develop a model that rivals any of those complicated pieces, but to really focus on the interactions, and particularly the interactions in the climate context.

And so I think one of the things with

instruction today, I was trying to get it down to a half a day, and it’s not commenting on the importance, but part of it there’s a lot of research out already that sort of provides some of the backdrop, and certainly we encourage people to look at some of that, and that was certainly my feeling as opposed to listening to it again.

So on Pathways E3 model, there’s a lot out there. I think Mike Rossi and I at this point, after going through last year, could give the E3 presentation and we could probably also include the questions they don’t want to answer, but anyway, and certainly when you look at model comparisons there was a very good couple days of workshops at U.C. Davis comparing those models, so again I encourage people to look at that record. You know, sort of the utility perspective on the modeling, certainly the E3 40 percent study with the reflex model is a pretty good backstop on where the utilities are coming at.

So again, I tried to unclutter this by not covering some of those pieces since they’re out there, but certainly encourage everyone to look at those.

I think as we go through today's workshop, we're going to be looking for suggestions, again, the basic message though is think climate, think the impacts back and forth on climate, think about the interactions and extensions, but certainly we have no intention of redoing the Pathways work. So with that context, I hope that provides people some sense and certainly looking for suggestions; again, certainly Mike and I both have pretty strong feelings of where E3 could have gone further, and so that will be some of what we'll frame up today. Karen.

COMMISSIONER DOUGLAS: Well, you know, I'm really here out of interest and the topic and the presentation. In my world at the Energy Commission, of course, I'm very deep in planning on the renewable energy side, and so we're looking at what the footprint of renewable energy in the California Desert and other parts of the state is likely to be based on our long term climate trajectory and also in partnership with other agencies, Cal Fish and Wildlife, BLM, U.S. Fish and Wildlife Service, and more, looking at how to construct and think about a conservation framework around that so that we can match our renewable energy thinking and needs with adaptive management and conservation.

So I'm here to learn, you know, there's a lot that came out of the Pathways study that was very informative and helpful, and yet as the Chair said, you know, it's certainly not the last word and there are places to learn and to improve and continue the work, so I guess that would be my introduction. Thank you.

CHAIRMAN WEISENMILLER: Okay. I was going to say, I was going to ask, well, Mike Rossi is probably the person that the Governor relies upon the most in terms of going through complicated models and trying to find the flaws. So, Mike, do you have a few words?

MR. ROSSI: I've talked to a number of you prior to the meeting, to be sure, I had gotten enough background reading which I hadn't done, and I am fascinated by a whole series of things that people portray as being doable, and so I'll be looking forward to hearing the explanations as to why some things I can't imagine are doable are doable. So I look forward to this.

COMMISSIONER MCALLISTER: So I guess let's start maybe with Commissioner Randolph from the PUC.

COMMISSIONER RANDOLPH: Thank you. Well, I just spent the last couple weeks working on my Rules Committee Letter Response and a crosscutting theme was interagency cooperation, so I'm excited this is my first official opportunity to do that. And I am very interested in this topic and I appreciate the opportunity to learn, there's a lot of uncertainties and question marks coming, and looking at the different potential scenarios and solutions, as Mike said, is just completely fascinating. And I appreciate the opportunity to be here.

MR. MURTISHAW: And like Commissioner Randolph, I just also would like to express the fact that I appreciate the opportunity to participate in the invitation and the continuing cooperation between all of these agencies.

Obviously, the PUC plays a large role in helping to meet the state's overall GHG goals, so we follow all these areas of research with great interest.

We have several proceedings right now that directly pertain to some of the key elements and the key branches in these pathways to reaching 2030 or 2050 goals. We have the Distribution Resource Planning proceeding and applications that were just filed on July 1 with very interesting proposals from utilities.

I've had a chance to dig fairly deeply into Southern California Edison's proposal and I have to say I'm pretty impressed with how they are beginning to think about their role in facilitating Electric Vehicles and distributed generation and storage, and overall management of the Grid and planning appropriately for that.

I think in the near term we're grappling with an important choice in terms of our overall regulatory strategy for ensuring that the electric and gas utility sectors are contributing their share and pulling their weight, which is a lot in terms of meeting the state's overall goal. So the two broad approaches that have emerged and that are under consideration are something like what the utilities have proposed, a Clean Energy Standard, or an Emissions Standard for the electric utilities, which would essentially be more of a bottom up approach, allowing the utilities individually to devise their own plans for meeting a certain target versus an integrated resource planning approach, which would be a little bit more centralized and which the PUC would play a larger role in determining those choices out of the total portfolio of things that the utilities can do to reduce emissions.

But under either approach, the PUC will obviously play some role in guiding the options that are selected for getting to those goals and fundamentally what we have to do is revisit the measurement of GHGs as it applies to electric utilities. This is something that we started to do years ago when load-based cap and trade was still under consideration and it’s fundamental to have the metrics and the measurement processes in place to assign emissions to the utilities before we can do anything. So there are some key steps there in terms of just beginning the process.

I think one thing that we’re interested in, in terms of the findings from the research is knowing at what point we have to make key decisions about technological lock-in, so at what point do we have to commit to vastly expanding the number of charging stations and facilitating that. And we have applications from all three utilities now under review at the Public Utilities Commission, taking different approaches to expanding the number of Electric Vehicle charging facilities. But so we want to maintain that option value as long as we can before we know that we have to pull the trigger for better, for worse to commit to certain technology choices, so I think this kind of research will help inform those decisions. So I look forward to hearing the presentations and continuing to participate with all these agencies to make sure that we can reach these goals at a reasonable cost to Californians and set a good example for the rest of the country to follow.

MR. CASEY: I'll be brief. But first off, thank you Commissioner McAllister for including us here on the dais. I think the California ISO is kind of where the rubber hits the road on a lot of these policies, so we really appreciate the opportunity to be involved upfront in these discussions.

I think there's a common theme around the dais and that is, as we look at the next tranche of climate policies for the electric sector, we need to think of it in the broader context of the overall GHG strategy for the state and recognize the interactions between the electric sector and these other sectors, transportation being a big one, obviously.

And importantly, as we think about the integration solutions for making this all work, there are opportunities to leverage the climate actions and other sectors to help with the integration on the electric sector, and I think that's something we, going forward, really need to be mindful of and look to really maximize those opportunities, and certainly look for integration solutions that don't add to the GHGs and, you know, look to minimize reliance on the fossil fuel fleet. These are things the ISO is keenly interested in doing, so we look for creative opportunities to try to make that happen. So thank you for having us here today and look forward to the presentations.

COMMISSIONER MCALLISTER: Thank you all for being here. I'm really looking forward to your questions to the various panelists, we have a lot of expertise in the room. I'll just add a little bit of cleanup here and give a slightly different perspective quickly to keep us ahead of schedule.

On the Energy Efficiency side, you know, the interaction between demand and between supply and demand is sort of one of the key, you know, as things get more distributed and more demand-side oriented and we figure out how to apply and deploy and pay for a lot of this innovative technology that's coming on line, you know, the carbon impacts of those strategies really are front and center. And, you know, as supply and demand interact more and we see impacts and depend on a lot of different factors, it's really important to understand the very scenarios and work through that. So the modeling efforts are truly, I think, educational and informative for making better policy decisions.

Long term, you know, I'm Lead on Energy Efficiency, we're looking at the existing buildings very closely, trying to figure out strategies that they're going to work and really get scale in decreasing consumption and decreasing the carbon emissions of the demand side. You know, as the Grid evolves and as the

Grid gets cleaner, the relationship of electricity and natural gas will change, a lot of that depends on the costs of the different trajectories and, again, looking at how long term if there's some inflection point where different sets of technologies really make a difference, to Scott's point, that lock-in question is really key. So maybe there are places where technologies with a shorter life, or with a lower capital investment, actually do come to the fore as a transition strategy as we compare those to longer life technologies.

So I think we'll be asking questions from the various perspectives that we bring to the table in order to flesh this out and really keep these efforts robust and rigorous, and be able to focus them going forward. So I'll pass it back to Heather and we can get going to panels.

MS. RAITT: Okay, our first discussion area is on the Overview of Past Research Activities and our first speaker, Jim Williams, is on his way, he's stuck in traffic, so we'll move on to our second speaker who is Trieu Mai.

MR. MAI: Well, thanks everybody. This is Trieu Mai from the National Renewable Energy Lab.

Thanks for the opportunity to share some of our research findings today.

I originally was going to go into a bit of detail on our modeling capabilities, but I think I'll save that for the end because I think the research findings from these three studies that I wanted to share might be of more interest, and then we can go back to the models if there's interest there, and if there's time.

The first one is a National Scale Study that we looked at called the Renewable Electricity Future Study where we looked at scenarios with 80 percent renewable generation in the U.S. power grid, and we'll go into some highlights of that study.

The second one is more of a U.S. West focus where we looked WECC-wide and looked at integrating 30 to 35 percent wind and solar into the Western Grid.

And the last one is one that is actually not published completely yet, but I think I will share some result today and that is a California focused one. The Low Carbon Grid Study, which looks at scenarios with 55 percent renewables on the California Grid.

Okay, so starting with the so-called REF Study, this is an analysis that relied on some models at NREL, in addition to some Unit Commitment models from ABB called the GridView Model. The bottom line is transitioning from today or 2010 world that is largely fossil and nuclear focused, as we all know into a 2050 future where it is 80 percent renewables, and I define renewables as this large suite of options here, biomass, geothermal, hydro, as well as wind and solar.

What we find from that modeling exercise is that renewable technologies that are commercially available today, in combination with the more flexible power system, all of the analyses that I would discuss are on the power side, so we won't focus so much on the seams that was mentioned earlier, but that power side has to be more flexible, and I think that's a theme that you'll hear broadly today.

It's more than adequate to meet 80 percent of total U.S. electricity demand by 2050. Again, we did this on an hourly basis and that's what the evaluation was at the highest resolution that we could look at. And you'll see other results later on that zooms in on that.

Another key result from that beyond just that overall feasibility statement is that all regions in the U.S. really would have to contribute to this 80 percent U.S. future in 2050.

You can see in this particular scenario, or you might not be able to see because it's in a small font here, but California largely, to get to a nationwide 80 percent goal, is at nearly 100 percent renewables. And I could say that broadly speaking west-wide it looks like it has to contribute more than the other parts of the country by merely because of the rich resources, renewable resources that we have here out west.

Despite those regional differences, though, one theme that we did find is significant renewable deployment needs to occur throughout the country, and certainly some changes to imports and exports, as well.

Another set of results that we looked at were the environmental and economic impacts of this type of scenario. Certainly getting to 80 percent renewables compared to a business as usual perspective will reduce carbon emissions, that's no surprise. We estimate in our scenarios that emissions reductions would be achieved at 75 to 80 percent in the power sector.

And correspondingly, there is an incremental cost that we estimate with this transition, and that is shown in the shaded region here in terms of retail electricity prices, and you can see by 2050 that incremental costs in real terms would increase somewhere from $5.00 per megawatt hour on the very low end up to $30 to $40 per megawatt hour on the high end. What's interesting about this is our renewable focus pathway, that incremental cost is similar to other pathways that others, EIA and EPA, have identified using a non-renewable specific pathway. In fact, in some cases our incremental costs are lower than what these other estimates entail, given the similar level of carbon emissions reductions.

Moving on to the so-called Western Wind Study, there's actually three phases to this. The first phase looked at, again, that feasible statement, can we integrate wind and solar into the Western Grid? One of the findings from that was, yes, we can do it, however, there's going to be significant cycling and ramping of the incumbent fossil units, and that's the focus of Phase 2 is what are those cycling impacts and from a cost and emissions perspective.

Then finally, Phase 3 is a deeper dive, GE actually conducted the analysis there where if you had this high wind and solar system, this inverter-based system and there's a large disturbance, how would the system react? Would you still have that system reliability that we need to have?

I will skip over Phase 1, but Phase 2, these are some results from the Plexos modeling that was connected there. It's five-minute Uni-Commitment modeling. Just focusing on the black at the bottom there, that's the coal units in this low demand spring day where you have a lot of renewables on your system. And, yes, there is a significant amount of cycling and ramping during those periods of time.

However, what we found was that cycling in itself, if you isolate that impact from the bulk impact, has a minimal impact on emissions. You can see the relative sizes in the arrows on the left from both greenhouse gas emissions and criteria air pollutants. In addition, if you look at the wear and tear costs associated with cycling, you could see that in the lower right there in the small yellow upward arrow there, and compare that with the avoided fuel cost, which is on the order of seven billion dollars, so it's one or two orders of magnitude smaller. That's from a system perspective. We understand that from an individual plant perspective, those cycling costs can be significant, but from a WECC-wide system perspective, the cycling costs appear to be small relative to that total avoided fuel cost.

And lastly, Phase 3, we took a time period where we had very high instantaneous penetration levels, above 50 percent. And then we simulated a disturbance, a very large disturbance, where we tripped two units at Palo Verde and estimated or measured how the system might react to that from a frequency response perspective. And what we found was, there were no under-frequency load shedding events, even from this high inverter-based instantaneous penetration scenario.

And some of the other results were, if

you put frequency control equipment on your wind and solar, that of course would improve the response.

So the bottom line from that is, with good system planning, sound engineering practices, and technologies that are available today, the West can withstand that very important immediate period after a disturbance, even with high levels of wind and solar.

And finally, the last study that I will mention is the Low Carbon Grid Study. NREL conducted much of the modeling exercise for this study and it does tackle the 2030 questions on the path to emissions reductions in 2050, that's the goal of the state. Phase 1 is currently available and you can see those results on the website. Phase 2 is ongoing. As I mentioned, it will likely be published in the coming month or so.

The bottom line is, yes, the California power sector, at least, can cut its carbon footprint significantly by 2030 with minimal cost and curtailment impact through a renewable path, again, without compromising reliability.

I won't go too much into detail, but

there are a few very interesting results from this. First, just to set the stage, how we did this was we used the Plexos model and we compared a set of baseline scenarios where the baseline scenario is essentially the LTPP, 33 percent scenario, expanded through, or extended to 2030. And we compared that with a couple of target scenarios that gained at 55 percent renewable penetration, or 50 percent emissions reductions on the power side. We looked at a few different portfolios for that, one is a high solar versus a low solar scenario, and across all of these scenarios we looked at different system flexibility and we'll see what that means in a little bit, and estimated how that might impact three key metrics that I'll share today. One is on emissions. The top three are the baseline scenarios, and you could see it has greater greenhouse gas emissions from the power side at 80 million metric tons, compared to today's power sector emissions of about 91 million metric tons.

I've crossed all the target scenarios, not surprisingly when you have that level of renewables, there are significant carbon emissions reductions, and we measure those here.

Similarly, we look at production cost and this specific bar chart shows the annual production cost savings relative to that baseline scenario, so these are all Delta, where all the positive numbers are less cost than in the baseline. And we estimate across all these scenarios approximately four to five billion dollars in annual production cost savings. Just to get some grounding on what that means, in our baseline scenario, total production cost was estimated to be about $13 billion dollars. So you get some significant savings on cost, however, this is just production cost side, there is a capital cost analysis that is not readily available yet, but will be in the study.

And of course, the most important part of this one is really this slide here, where we measure the curtailment of renewables across these various scenarios. And you get quite a range and actually the range shown here drives the slight change as you see both in carbon emissions and cost because that missing renewable generation that you couldn’t use due to limits to system flexibility and other limits, then have to be replaced by fossil or other units that have higher emissions and higher costs. So this is an important one here and these are the details within this that really drive the details in potentially any policy design.

For example, we looked at a variety of different sources of system flexibility, including technological solutions, storage Demand Response, that was mentioned earlier, but we also looked at details within certain policy designs, for example, we have a proxy that measures the unbundled REC limits within California and how that might change the amount of curtailment you have in California.

We looked at somewhat some engineering, but perhaps also policy questions like local generation requirement, the amount of non-synchronous penetration that you could have at any time, and those very key questions -- import schedules, what can provide reserves? Those sets of questions can drive curtailments in a big way and therefore you lose out on potentially the CO_2 and cost benefits of renewables.

And finally, I'll end here, these are just a set of links to some of our other studies and our modeling capabilities. Thank you.

CHAIRMAN WEISENMILLER: Okay, so two quick questions. Is anyone in Washington having NREL do anything on the Clean Energy Plan?

MR. MAI: That's a good question. We have supported the Energy Policy and System Analysis Office of DOE in modeling carbon emissions reductions nationwide. We have not directly modeled anything on the Clean Power Plan. If you look at the Clean Power Plan documents from EPA, it does site some of the work that we've done, including the 80 percent renewable future study that I mentioned earlier.

CHAIRMAN WEISENMILLER: Okay, I guess the other question, I'll start with just a story, when I was in a project doing due diligence for Project Finance, there was a project in Texas which was the most efficient plant in Texas, that the contractor did a study, they did financing, they redid the study, just before it came on line six months later, it was bankrupt. And so you get to the question of limitations on these models. Part of it was they assumed no friction on transfers, basically that there were no bilateral contracts in Texas, well, there are, and so that was a billion dollar mistake. What your presumption on power flows across the West, you know, you don't have that on your renewable list, but my understanding is you guys are assuming basically a West-wide RTO, including LADWP, IID, and SMUD.

MR. MAI: That's a good question. We do the base model of how we run, for example in our Western study, the way you've characterized it is largely correct, where the amount of friction between balancing areas, trading is zero. We do often run sensitivities with respect to that friction, and in particular in the Low Carbon Grid Study. For California, we ran sensitivities where there were different import/export rules into California.

CHAIRMAN WEISENMILLER: Typically on these models one of the checks is, as you add more constraints to the models such as bilaterals, the costs go up and marginal costs go down. So have you done those sort of checks on the relationships on revenue requirements on marginal costs coming out of your model?

MR. MAI: We have not checked, at least on the revenue side. In the Capital Costs Analysis, we'll include some of that. I don't know the details of that yet. But in terms of the cost, one of the findings from the curtailment were based on that, when you apply more constraints into your system, you will have greater curtailment and therefore fewer production cost savings and overall system cost increases. So that is definitely true.

MR. CASEY: I had a couple of questions on in terms of your modeling efforts incorporating integration solutions like storage and Demand Response, I wondered if you could elaborate on what sort of investments did your model produce in those areas; and secondly, on the frequency response, I wondered if you could elaborate on where you were getting the primary frequency response from on your system, under your scenarios, to the extent you know?

MR. MAI: Sure. So the answer to the first question, it depends on the study. From the 80 percent U.S. base study, we did those decisions in terms of storage and other potential options there based on our least cost system-wide economic consideration. So we throw in storage as an option that the model could choose or not choose, based on its least cost solution compared to other solutions that it might pick.

MR. CASEY: Do you have any sense of order of magnitude, how much storage that produced?

MR. MAI: So in many of those scenarios, it was about 100 gigawatts of new storage, nationwide from now to 2050. And that's a mix of bulk, you know, compressed air energy storage, pumped hydro-like storage, as well as battery systems, as well. I should say the batteries are a hard thing for these models to capture because they are small, they are typically in the distributed size, so the decision-making is going to be different, and it's like comparing a rooftop PV to a utility-scale system. So there's some challenges with that.

Demand Response is something that is very challenging to model and it's challenging to model from an investment and planning perspective. But it is -- we have modeled that in this study and others from an operational perspective. What that means is we assume a certain level of Demand Response within limits of what hours it is able to operate and what services it can provide, and then the system optimizes that operation. So it does assume that it's part of the overall system.

So we do scenarios with and without that high level of Demand Response in there. To your second question on frequency response, I can't really answer that as GE really conducted that analysis.

COMMISSIONER MCALLISTER: So just a couple questions. I wanted to follow-up a little bit on what Chair Weisenmiller was asking. So in your scenario where you trip Palo Verde and you look at the response, so can you look at the inertia issue and, I mean, are you modeling it at that level? And does the response there and ability to maintain stability depend on the renewables mix at that moment? Or what are your scenarios that you're actually basing that conclusion on?

MR. MAI: So we don't fully look at inertia, we look at volt stability and frequency response within that area, and so essentially what we did was, from the Phase 2 Study, we found the periods that could potentially have the most problems, i.e., those highest instantaneous penetration periods, and then we modeled that using PSLFRG model, using PSLF, tripped Palo Verde, and just estimated what the frequency would be on the system. So I can't really answer which technologies were used to do that primary frequency response, but I could provide you with the folks who can.

COMMISSIONER MCALLISTER: Okay, that would be great. And then I guess I'm wondering, you mentioned that the capital costs assessment is coming. I guess are you going to be making sort of policy recommendations on the DR, you know, what Keith just asked, on mobilizing DR, making some assumptions? Is part of this assessment planned to be policy recommendations on how to mobilize? Anyway, they're different models for mobilizing that DR, and I want to sort of see what part of your team --

MR. MAI: Sure. NREL will not make any policy recommendations based on any of this. We partnered with a number of folks within this Low Carbon Grid Study and I presume that some of them may make policy recommendations. But I think the analysis itself does inform, as I show in this slide right here, that some policies, however, could have a major effect in terms of the level of curtailment and those policies should be considered in light of that.

COMMISSIONER MCALLISTER: Okay. Thanks. Mike.

MR. ROSSI: I'm the least knowledgeable person up here, so bear with me. As I look at your study and look at your website, I can't determine as to whether or not you run a model that does scenarios, then does probabilistic analysis as to whether this will or will not happen, 50 percent chance, 70 percent chance, 10 percent chance. Not having seen any of that, I have little faith in your numbers as to the real savings one gets to go to 80 percent renewables. I have little faith in your capital numbers since you don't have any, so that's fair, you're going to have those in your next study. But I'm trying to figure out, the important part of trying to balance here is understanding whether or not the models take into effect real costs to the consumer, real costs to industry, you know, when you look at Germany, I worry about their models that look similar to these outcomes, and the problems that they're having, huge problems that they're having making their goals work.

So I guess my simple question is, do you have that data so I can actually look at it?

MR. MAI: Sure. It depends on the study, so the 80 percent one that you mentioned does have all the data available, you could dig deeply into all of the assumptions that we have, capital costs --

MR. ROSSI: And do you have a range of outcomes?

MR. MAI: And then, for example, in this chart right here, we don't do a stochastic analysis within the model, the models are inherently deterministic that we use. To tackle the uncertainty question, what we do is we model a range of scenarios. Hence, this chart right here shows you the range of rate impacts --

MR. ROSSI: But you know, the problem in making decisions on that type of analysis when it comes to models, if you do what you just said, they become less valuable.

MR. MAI: So I would agree with you that if we had a better way to predict the future, we would be better informed for any policy decisions. I think there's an inherent uncertainty and the distributions of these future parameters are very hard to grasp to even do that stochastic analysis.

MR. ROSSI: It is difficult, but it is worth doing because, you know, people make lots of decisions predicated on Monte Carlo models, big casino models, all those -- and that future is no more easy to comprehend than the one we're talking about here. And when you're going to ask people to spend more money to achieve something that may not be achievable, other than at the 20 percent level, then you need to readjust what you're looking it. And it gets to your issue with your slide on curtailment.

So all I'm asking, and you don't need to do anything more for me here, is to direct me to where you do that research, and if you don't, just tell me you don't, it's that simple.

MR. MAI: At NREL, we typically do not do stochastic analysis, we do scenario analysis –

MR. ROSSI: Fair enough.

MR. MAI: -- and the sensitivities should cover a wide range there.

COMMISSIONER MCALLISTER: Anybody else? Okay, thanks very much, I enjoyed that. Do we have a status report on Jim?

MS. RAITT: He's not here yet and I don't have a status report.

COMMISSIONER MCALLISTER: Okay, you're not in mobile communication with him?

MS. RAITT: No, I'm not.

CHAIRMAN WEISENMILLER: Forecasting is hard.

COMMISSIONER MCALLISTER: Confirmation of the future is uncertain, okay. Blame it on the traffic, right? That's the --

MS. RAITT: So we can move on to the recent research findings, a look to the future, and the transition to a low greenhouse gas energy future. And the first speaker on this area is Ray Williams from PG&E.

MR. WILLIAMS: Thanks very much for the opportunity to present here. My name is Ray Williams. I work in the Long Term Energy Policy Group within the Energy Procurement part of PG&E. These days I'm spending about half my time on greenhouse gas policy in the state and the other half in D.C., and come August 3rd that might move to 75 percent Federal and --

CHAIRMAN WEISENMILLER: You may want to check the weather forecast for D.C., I think it'll be hot and muggy.

MR. WILLIAMS: You can always work remotely for a while. So we asked ICF to look at some of the policy alternatives that could come out of the proposed rule from 111(d), again, that was issued last year, and it really wasn't so much to look at whether California can comply or not, although we certainly follow that closely, it was really more about, you know, what are the impacts on the WECC generally.

So this is an interim analysis. Once the final rule comes out, we plan on updating. This is a great time for feedback from anybody because we'll be really trying to work on this once the final rule comes out. And then once I go through that, I want to talk a little bit about PG&E's engagement primarily in D.C.

So I'll just go into a little bit on the scenarios in the next couple of pages, but some of the outputs here include emissions and emissions rates, credit and allowance prices, natural gas prices, wholesale power prices, and systems costs. And again, we chose ICF, they have an IPM model, that model is national in scope, it looks at the power sector, it has regional dispatch. Obviously we're focused very much on the WECC here, it has an extensive dataset, power gen fuel mix, transmission, energy demand, fuel prices, and it also models environmental policies, you know, here we're looking at 111(d).

And you'll see here we are solely responsible for all the assumptions and policy constructs. That IPM model is also the model that EPA uses, but they have a separate staff and the staff that we work with here is walled off from the EPA, from the staff that works for EPA.

First, I just wanted to kind of ground the work here. So if you look at the form of 111(d) today, it's a rate-based form. And this has pretty significant implications for different kinds of technologies. So we tried to illustrate here. In the WECC, there are states that have very high emissions rates and there are other states like California that have very low target emissions rates. So we chose kind of a generic rate here, 1,300 pounds per megawatt hour, and we showed the impact in terms of either having to go into the market to buy credits, or to sell credits. And you can see for a coal facility at about 2,100 pounds per megawatt hour, and a 1,300 target rate for that particular state, they'd be going into the market to purchase credits if there was trading available.

For a wind facility, you can see that it's very much the opposite at 1,300 pounds per megawatt hour. They would have quite a significant amount of credits to sell. But what I think is most interesting here is looking at the gas-combined cycle, so if you look at a state with a relatively high target in the WECC, they may have an 850 pound per megawatt hour emissions rate. You see that the target rate is 1,300, they could actually sell credits at the rate of 450 pounds per megawatt hour. That same combined-cycle facility located in California, and that's the California proposed rate in 2030 at 537, would actually have to go in the market and purchase credits at a rate of 313 pounds per megawatt hour.

So you can see from this very different treatment of very similar facilities and, you know, and largely the same market, but obviously there's balancing, there's transmission constraints, there's different balancing authorities, and so forth, that this can have quite a significant impact on dispatch, on the evaluation of these facilities and on incentives for locating combined cycle facilities in states with high targets. So if there are some inefficiencies introduced here, this is I think part of what got us interested in this and maybe to look for ways to come up with maybe more of a uniform regional plan.

So we have a number of constructs here that are very focused on sort of rate alternatives. We have case names. We talk about the disposition of the Cap-and-Trade Program, the geographic trading regime, whether it's state or regional, the emissions rate structure, whether it's that state-specific rate, whether it's a weighted average rate, for example, that could be one rate for the whole WECC if you could somehow get there. And then we talk about the covered sources, as well as we just mentioned energy efficiency here, what's notable about the covered sources is that 111(d) is a state-by-state regulation, so you're really looking for each state at the dispatch of those facilities within the state, and not transfers across state boundaries.

So we tried to come up Santa and Bruce was helping me with this, and I tried to come up with some interesting names here, so the first is Patchwork Quilt, which is essentially no trading at all across state boundaries, and then you have the state specific rate associated with that.

Coming down, we go to regional marketplace and here we introduce WECC regional trading, but with the same state-specific rate. The Policy Case 3 that we have here, we have WECC Regional Trading, but here we come up with a blended rate, so this is a rate that perhaps could take out some of those inefficiencies if the regulation itself across the WECC was uniform. And then the fourth, we went back and added back in the Cap-and-Trade Program for California in those first three, we had it as inactive just so that we could see the effects of this rate program, so we added the California Cap-and-Trade Program back in, but otherwise used Policy Case 2 parameters, so California's mass-based, all the other states are rate-based. So, believe me, it can get a whole lot more complicated than what I'm showing here.

So in the time I have, I'm going to now turn to page 9. So this is kind of a check-in to see if California does well given the current construct and, you know, a lot of this depends on how you count, which was not fully settled, even in the proposed rule, but if you look at that blue line, which is in essence sort of an extension of current policy in the State of California, California would comply. But if you look at the impact of some of the modeling work for these other cases where 111(d) does come in, the emissions rate actually does go down, and that's primarily driven by some of the energy efficiency assumptions that are embedded in the modeling. But in any event, California looks like, from a compliance perspective, in a pretty good spot.

So here's a little bit of the dynamics on credit prices in California. So here you have that solid line going up and that's just a modeled allowance price in the Cap-and-Trade market. You see a credit price in California under the patchwork case going to zero, that's because California would be long, can't sell it, and the price goes to zero.

In these other cases where California is able to participate in a regional market, this is a rate-based market in this particular case, credit prices are positive, which means they would sell into the market, they're a long position, and there would be some economic benefit coming back to the state.

Okay, this one is an interesting graph and a little bit surprising. This is a national impact, not just California. The rule itself, the proposed rule, was quite stringent for parts of the country starting in 2020. This accelerated the shift from coal to natural gas. Gas supplies and pipeline infrastructure lagged behind demand for a period of time and what we see here is, you know, one dollar plus per MMBTU increase and natural gas prices, and this is actually a national effect, not just California. So this may be addressed in the final rule, but this is kind of a surprising result. And of course, this would affect the whole economy, not just the power sector. And there's IEA modeling done and they corroborate this kind of short term effect.

We'll do this one just real quickly. You can see the effect of natural gas prices flowing through to average power prices in California, they go up a little bit driven by those natural gas prices in California, they go up a little bit driven by those natural gas prices. And then they come down below a base case and, again, that's really an artifact of some of the energy efficiency assumptions that are embedded in the model.

All right, I'm going to move now with the time I have to page 14. This is looking at total system costs for California. And so let's just focus on 2030 here. You see it is lowest under a base case; you see it is highest, as you might expect, under the PC1 patchwork case. That's a case where California is long in this sense and they're not able to trade that long position back into the market, so in essence they don't get the benefit of the revenues from trading those credits.

You also see a similar effect in the case where you have a California Cap-and-Trade Program, but you're not trading with the rest of the WECC, so you do not get the benefit of being able to basically work your long position, you know, back into the WECC market. And then the two cases where there's full trading across the WECC, you get lower overall system costs. And if you go to the WECC, you see really some quite similar results, no trading, that's the patchwork case there, high cost, you get some trading but California is not participating, costs are a little bit lower, but still above the two cases in the middle here, the green and the purple case where there's full trading across the WECC.

And if you look really at emissions, and this is true for California and the WECC, and given the time I have, I'm just going to focus on the WECC here. This is almost the opposite kind of story. So under the patchwork case where there's no trading, emissions are actually the lowest and that's because there's no trading; companies that have a long position aren't making those credits available, and so as you might expect emissions overall in the WECC under that case are lowest.

The California Cap-and-Trade case where California is not participating, putting this position in, emissions are second lowest across the WECC, and then the two cases where there's full trading and everyone in essence can close out their positions, and emissions are a little bit higher.

Let me just now shift gears a little bit and get into some collaboration that we're doing going forward. So you probably heard with the Clean Power Plan there's an expectation that the final rule will be issued maybe sometime early in August at the ARB's request -- by the way, we've shared this with ARB -- and based on EPA, some signals we're getting, we're going to maybe go back and do some analysis more on a mass-based approach like a Cap-and-Trade Program, rather than rate-based.

We're also going to model the deep reductions in California, this was done before the Governor's announcement, so we're just about there with ICF in terms of modeling California and the California policy, and then trying to see what the interactions are across the WECC.

In terms of collaboration going forward, we're working with the DC office of NRDC and other utilities and other nonprofits in D.C. on a modeling exercise using the same model, a common set of assumptions, a common set of policy alternatives, and of course once that's done that will be made publicly available. We're also working with the Center for New Energy Economy. That's a dialogue with Western Regulators and utilities, ARB and the PUC were both there in the spring. There's analytical work going on, we're happy -- we shared this with them, as well -- they are working to show how compliance can be done. We actually have developed a compliance tool also to help with that and it's to the point now where it's validated; unfortunately, the final rule is coming out, so we know some change is going to need to be made to that, but that's also something in today's form that we can make available. You know, they are in part to discuss not only how you can comply as a state since there's some work to do across the Western United States, but Regional Compliance Plans, what can we do to really promote some kind of a Regional Compliance Plan?

The next large meeting is scheduled for mid-September and as a company PG&E very much looks forward to participating.

The benefits? Car markets and greenhouse gas policy can be in sync. Leakage for

California becomes less of an issue. Siting and operation of power plants, as I showed, can be more efficient. You can take some of those finance incentives that at least the rate-based approach makes for the WECC. You can expand the market for low carbon technologies. So there are a lot of benefits here to getting to some kind of Regional Plan. The EIM, I think, can help facilitate that as it moves forward. There's a couple of issues for California, there's an open legal issue with respect to imports once 111(d) comes in, then those generators outside of California will be regulated at the source. And so there's an issue with the State Regulation Cap-and-Trade whether they can also be regulated at the point of consumption. So I'm just going to call it an open legal issue. There's also an RFF blog out there and resources for the future, by the way, for those of you who don't spend much time in D.C., Dallas Bertra (ph), and he talks about some of the things that EPA in their final rule do in terms of encouraging regional approaches, and it may look like a mass-based approach, so that may also have some impact on the California Cap-and-Trade Program.

And then one last word here. So much of the work here really focuses on driving down the carbon intensity of in-state generation to help meet these aggressive goals and I would just suggest a more regional look, start looking at the carbon intensity associated with imports, you know, generation outside of California but consumed within the state. I think that's probably an area for some further analysis. So thanks for your time.

CHAIRMAN WEISENMILLER: Thanks, Ray. A couple questions. One is you said obviously this was developed for EPA, which would mean it's tied much more to basic fuel use average as opposed to marginal. But do you also automatically get the air quality emissions -- outside of greenhouse gas?

MR. WILLIAMS: I will check. I believe you do. Part of the modeling there is to address those sorts of environmental issues and not just GHG. I don't know the detail. I'd be happy to get that to you.

CHAIRMAN WEISENMILLER: Yeah. Now, it would be good, again, I think all of us obviously we're looking at sort of greenhouse gas benefits and air quality benefits, the same things emerge from there, so certainly analysis of that particularly West-wide, I think I would flag -- these are all labeled privileged and confidential and my presumption is they are now public?

MR. WILLIAMS: Yeah, they're public.

CHAIRMAN WEISENMILLER: Just checking!

MR. WILLIAMS: Yeah, we'll send you a copy. I'm sorry about that. We'll send you a copy and pull that off, yeah. I know we've shared this very widely, yeah.

CHAIRMAN WEISENMILLER: Yeah. And you mentioned, it sounds like you're doing it again more West-wide as opposed to just California utilities in this dialogue?

MR. WILLIAMS: At this point, yes. We've engaged through CNEE in that context with utilities, not direct utility to utility conversations at this point.

CHAIRMAN WEISENMILLER: Okay. Interesting because I was at the original kick-off meeting with Mary and that tended to be more Regulatory Commissions than Utilities.

MR. WILLIAMS: Right.

CHAIRMAN WEISENMILLER: So I guess I

would be encouraging you to see how well this flies with the other Utilities in the West.

MR. WILLIAMS: Hopefully I'll have a chance in September.

CHAIRMAN WEISENMILLER: Okay, good. That's all I have.

COMMISSIONER MCALLISTER: One question. Your various scenarios actually have a lot of, you know, a number of them tracking pretty closely with not a whole lot of difference in terms of the cost, and I'm wondering if that's sort of a function of the model or something else. It's a little surprising that that kind of West-wide coordination doesn't produce more benefits. And I just kind of want to get your insight on that.

MR. WILLIAMS: Well, they are in the hundreds of millions of dollars in a particular year, so they are significant. We're happy to provide the data, the tables behind this so you can see it.

COMMISSIONER MCALLISTER: Okay --

MR. WILLIAMS: In terms of the impacts on dispatch, I actually thought when we went through this that there would be more of an impact in terms of inefficient dispatch, so that's kind of an area of inquiry for us back to ICF. I think the primary impact that you're seeing here is the one around the opportunity to trade around the margin. It's in the form of credits in these scenarios.

CHAIRMAN WEISENMILLER: But that gets us back to the classic West-wide issue of are we just dealing with the trading in the last 15 minutes? Or are we dealing with actual commitment decisions, day-ahead markets? And presumably if can really affect day-ahead markets, we'll have a much bigger impact on cost and carbon.

MR. WILLIAMS: Good, yeah. That's right, got it.

COMMISSIONER MCALLISTER: And I'm really just asking, you know, the numbers are big on the left axes of some of these columns, right? So, yeah, but it seems like small changes in some of your assumptions could actually change the results quite a bit, so I guess maybe --

MR. WILLIAMS: Yeah.

COMMISSIONER MCALLISTER: -- that's kind of why I'm asking, you know, some of the scenarios are very very close.

MR. WILLIAMS: Yes, for example, I was a little bit surprised the two cases where you have regional trading, you know, one with a uniform rate and one with individual state rates, I would have guessed that there would have been a bigger difference there because you would have had not only the positive impact of credit prices, but also the impact of having maybe more efficient dispatch across the WECC because you weren't affecting running costs by those differential rates.

COMMISSIONER MCALLISTER: Yeah, exactly.

MR. WILLIAMS: So it's a good point and I think we're going to go back and look at that.

CHAIRMAN WEISENMILLER: Yeah, I mean, the fun part about modeling is that when you get results, do they make sense or not? And is either model teaching you something or is something screwed up in the model? So it's probably a good effort to try to determine which of the above is occurring.

MR. WILLIAMS: Well, you know, and I'm sure you know this, working with ICF, if you find something in their model that is a little bit of a shortcoming, given the new questions that you're asking, you know, they're willing to go in and enhance the modeling in that area.

MR. CASEY: Just a couple of quick questions. I was curious what was driving the incremental cost in the 111(D) scenarios relative to the base cost. You mentioned energy efficiency being, I think, one. So that was the first question. And the second was, you know, with regard to the scenarios where you're looking at California trading emission credits, particularly for the renewables, how do you reconcile that with the accounting on California Utilities meeting the RPS? Is there a -- I could be way off base here, but you have the counting for the renewable energy credits for meeting the RPS requirements, and then you have the emission credit that you're selling off, and I'm just wondering is there a double dipping here on the renewables?

MR. WILLIAMS: There is really -- there is no modeling or trading of RECs here in this. It was really, as I understand it, a dispatch across the WECC, and then looking at state-by-state because this is really in-state accounting for existing facilities only: where were you relative to that target?

MR. CASEY: I see.

MR. WILLIAMS: And were you short or long? If you were long, you sell, and if you're short, then you have the opportunity -- you purchase. That was really the problem that we work with in ICF to try to solve.

MR. CASEY: You're just focused on the difference in emission rates by the source under the WECC-wide dispatch versus the statewide --?

MR. WILLIAMS: Relative to their target, that's right, yeah. And then to your first question, there's probably a number of things going on there. But I suspect that it may be sort of the acceleration of the infrastructure change, so more coal being retired more quickly across the WECC, more capital coming in for combined cycle generation, you know, where it makes sense, and more capital coming in for renewables. That's my guess, but….

MR. MURTISHAW: Yeah, so just to clarify, then, excuse me, that Mr. Casey was making. So what the model is assuming is that for any renewable generator in California or elsewhere that is producing positive credits, because it's below any GHG rate, that that generator is able to sell those credits off without impacting its ability to contribute to compliance within that state for RPS.

MR. WILLIAMS: Yes, yes.

MR. MURTISHAW: Okay.

MR. WILLIAMS: Yeah. We didn't look at that RPS compliance issue at all, really.

COMMISSIONER MCALLISTER: Well, great. Thanks very much.

MR. WILLIAMS: Thank you.

COMMISSIONER MCALLISTER: Okay, so let's keep going with 111(D).

MS. RAITT: So I'm not sure, did you want to go back to Jim Williams now that he's here?

CHAIRMAN WEISENMILLER: Why don't we just do the Analysis group and swing back to Jim since this also deals with some of the Clean Power Plan types of issues.

MS. RAITT: Great.

CHAIRMAN WEISENMILLER: It seems to be relatively short.

MS. RAITT: Next is Paul Hibbard. Thank

you.

MR. HIBBARD: Thank you and good morning, everyone. And thank you, Commissioners and all of you for being interested in what's happening on the other side of the country. And I do apologize for spilling the water this morning, I'm just kind of hoping that in lieu of a $100 fine, I can ship you out some of the snow we had in Boston this past winter.

COMMISSIONER MCALLISTER: You brought that water along with you, though, didn't you? So we appreciate that.

MR. HIBBARD: That's right!

COMMISSIONER MCALLISTER: Yeah.

MR. HIBBARD: Oh, boy, we had eight feet of snow in a month in Boston and I had to drive through it every day. I didn't mean to spill the water just because I'm still angry about that, I promise.

So what I will talk about today is a study that we just did about the Cap-and-Trade Program in the Northeast, and for those of you who aren't familiar with it, we have since about the end of 2008, ten -- well, nine Northeast states have implemented a Cap-and-Trade Program on the power sector including all the New England states, New York, Maryland, Delaware, and New Jersey was in it for the first three years until Governor and Candidate Christie decided it was an economy killer.

So we did a study, it was funded by a number of foundations focused on not so much the -- there have been a number of studies leading up to RGGI as a program related to what the cap level should be, whether the program is needed, what the environmental impacts of reducing carbon within the Northeast Region and what the ancillary environmental impacts might be, all of these things have been studied in great detail both leading up to the program and throughout program and administration.

We actually did a very different study, it's really just looking at the allowance dollars, the revenues that have come to states, how they used it, and figure out how that money flows through the economy and what the impact is.

The RGGI Program, you know, at the time it began implementation I was Chairman of the Public Utilities Commission in Massachusetts, and I can assure you there was a great deal of angst amongst all of the states that were involved in RGGI, certainly on the Utility side, but also from the standpoint of consumers and others related to what the economic impact might be, what the impact might be on electricity consumers, whether or not the states could actually get together and agree upon how to do this. So ultimately we really looked at two things, we looked at the economic impact and we looked at what it implies for the states that will have to look to figuring out how to comply with the Clean Power Plan going forward. We now have six years of administration of RGGI in the northeast, it's gone through basically program design and development, implementation for six years, and ultimately a major program redesign part way through, including a lowering of the cap. So all of these things we think not only affect how it affects the economies of the Northeast states, but also what other states might consider, not so much California, you already have a major carbon reduction program, but many of the other states that will have to figure out how to comply and whether to do a rate-based program, or whether to do a mass-based program. There are a lot of lessons we think that can be learned there.

Ultimately in our analysis, we found that it has generated positive economic impacts for all of the Northeast states. And in this particular study, we focused on just RGGI's second compliance period. They have three-year compliance periods. We did a similar study for the first three years, 2009 to 2011. This study is focused on the second three years, 2012 to 2014. We found that across the region, spending about a billion dollars in allowance revenues translates to about $1.3 billion in economic value added. And it really results from the way that the states have used the money, and I'll talk about that in a bit.

I'll try not to spend too much time on this, but everything we did in the study is in this chart. The thing to notice here is what we did was we started by looking at the RGGI auctions and something that I'll talk about in a bit, the RGGI states, when they got together, one of probably the most difficult decisions they had to make were of course agreeing upon a cap and how that cap would be allocated amongst the states; 2) it was what to do with the allowances that were created by the Cap-and-Trade Program, give them away or auction them. And then ultimately all of the states agreed to auction them and auction them through a central auction which has a number of benefits from the power system side of things. But then all of the states had full freedom and flexibility to do whatever they wanted to with the money and how they spent that money also has a big impact.

So what we did was we looked at the RGGI auctions, the total amount of money spent and collected, and went through two pieces of analysis. The first one relates to the macroeconomic impacts. So we looked at the way the states spent the money directly within their states and how that affects, you know, through things like direct bill assistance, or funding for energy efficiency programs, program administration, a number of different ways that the states spent the money, and looked at what impacts the direct investment had on the states' economies.

But the other big piece of this of course is that, as I'll outline in a second, states made major investments in the energy sector. There was a commitment early on to think about, while states could do whatever they wanted with the money, and some of them did things unrelated to the energy sector, there was a commitment amongst many of the states to reinvest those dollars, those auction proceeds in the energy system through energy efficiency and renewable investments. So that has had a major impact on the dispatch of the power system in the three wholesale market regions that the RGGI states exist in. So we followed the money that was spent on energy system technologies, on efficiency and renewables, and figured out how that impacts the power system. And it impacts it both positively and negatively, of course, from an economic standpoint.

On the one hand, power plant owners have to purchase allowances, it increases their offer prices in the wholesale markets, increases prices to consumers at the time that those dollars are being reflected in power prices. But on the other hand, the investments in efficiency and renewables tend to have the opposite effect, and over time it overcomes the impact of the increased prices associated with marginal pricing of allowances.

So we ran PROMOD, we looked at all the different changes in the power system, and ultimately took those net impacts on the power system and flowed them back into the economic model, as well, so all of the things, the direct investment and the impacts on the power system run through IMPLAN as a macroeconomic model to figure out how it affected various things through the economy.

In terms of PROMOD, the way we set this up was we essentially modeled the system as it has happened with RGGI in place and with all of the investments the states are making, and then we created a counterfactual case by pulling out those investments and running the power system without those investments and generated what the differences were from the standpoint of generator revenues, fuel mix, payments by load, and difference in fuel purchases amongst the RGGI states.

Just really quickly on the numbers here, the first compliance period, 2009 to 2011, the cap was initially set, it was agreed upon by the states in 2007 and 2008, and then as soon as the program went into effect, the economy tanked, and really shale gas started playing a huge role in the cost of gas in the Northeast Region. Both of those tended to cause a huge amount of fuel switching and a reduction in demand, so ultimately the cap that was originally set was well above what emissions ended up being over that period and would have been anyway, so that the RGGI auctions were clearing and a floor price that was set by the RGGI states, and the revenues tended to decline over time, overall about a billion dollars in the first three years.

In the second three years, in 2012 the states conducted a major program review and reduced the cap by about half, and you can see that in these later years, while the number of allowances were much lower, the actual price of allowances increased once the cap had some effect on allowance prices. In the end, the second compliance period, the states collected about the same amount of revenue as the first compliance period on the order of a billion dollars.

This is the big thing that states have done that was pretty remarkable when they agreed to do it this way in the beginning and when each state individually made the decision in its own state proceedings. You could see about 60 percent of the money collected through these auction revenues is spent on energy efficiency across the states. There is a big chunk, particularly in Maryland was spent on -- these are the states in PJM and in this chart it’s just Delaware and Maryland, but this large chunk was money that went back for essentially a direct bill of rebates for low income customers, but also for other customers, as well. And then you can see that the state spent the money in various other ways related to clean tech R&D, renewable investments, and other programs to further reduce greenhouse gases from other sectors.

So how the states spent their money was hugely important and in the fact that most of the money was spent on energy efficiency had a very big effect.

The overall economic impacts across the nine states, $1.3 billion in economic value added in the region, about a billion was spent on the auction proceeds. It led to a reduction in revenues over the modeling period for generators of about half a billion dollars and reduces the amount the consumers pay on electricity and also some savings in the heating sector on the order of about half a billion dollars also. And then a big thing from the Northeast perspective is we have no indigenous resources, all of the RGGI states essentially import all of the fossil fuels that they use to generate electricity, so investing in energy efficiency and investing in renewables really reduced the amount of money flowing out of the region for purchase of fossil fuels, and that also is reflected in the economic impacts.

And the model also identifies a number of jobs, this is 14,000 jobs created over the modeling period, but those are job years, not actual -- so it could be 14 jobs a thousand years each, or 1,400 jobs for 10 years, so…. Yeah, that would be good.

I'll jump ahead to the observations in the interest of time here. So we looked at this to figure out what does it imply for the impact of the Cap-and-Trade Program over the first six years on the economy, but also, again as I mentioned, what's the implication for Clean Power

Plan compliance? The mechanism has functioned quite well in the Northeast and can deliver positive economic impacts. Obviously, as the cap level changes, as how the program is administered changes, that could change as well. But looking at the actual data from real implementation of the program over six years has generated positive economic benefits for all of the RGGI states.

It has integrated seamlessly in the power markets, all of these states are in fully competitive wholesale market regions. The ISOs in these regions, the RTOs, could essentially have no idea the program was going on. The offers that are made in the day-ahead market have built into them the assumed cost, the assumed value, the opportunity cost of allowances for all the generators that are affected by the program and all the systems have operated seamlessly in that wholesale power market context.

The states have retained full implementation authority. There was a remarkable level of agreement among states on many difficult issues that needed to be decided, but they have worked cooperatively and have worked very well for six years now, both in the original program design and when the states had to take the design back to their individual state regulatory processes, all of that happened over a relatively short period of time. Agreeing on setting the cap and allocating the allowance pool over time was, I think, a significant accomplishment. I know back when this idea first came out, all of the states including Massachusetts were saying this is crazy, we're not going to be able to agree amongst, you know, we don't even like New York, let alone have to agree the allocation of allowances that are going to affect money being spent in each of the states. But across all of the ten states that have originally designed it, they managed to do that, agree on a program design that the states all took back to the individual states and have really efficiently administered the program through regional coordination of auctioning the allowances, monitoring the market, and just administration and governance of the program for six years, including the major program redesign.

The design of the market, there are really two huge issues and I know that most of you in this state are aware of this, but that really affect the economic impacts of RGGI, one is the decision not to hand out the allowances to power plant owners, but ultimately for the states to retain that public right and transfer the right to omit to the private sector at a monetary cost, with revenues returning to the states. It prevents the transfer of that value, of course, to the power plant owners, but also allowed states to use the money in ways to advance really important public policy objectives within the states. The states have used the proceeds creatively to support their own public policy interests and allowed them to meet a wide variety of various public policy goals, including addressing budget challenges, assisting low income customers, restoring wetlands, these are just a handful of examples of the ways that the RGGI states have used those monies, but also promoting advanced energy technologies in assisting municipalities with investments in efficiency and renewables.

And of course, not to beat a dead horse here, but how the states have used the money has really affected the economic impact. The majority of money going to energy efficiency reduces consumption, particularly for participants, but it has also had a meaningful price suppression effect in all the wholesale regions and that benefits everyone, and ultimately keeps the investments and the impacts within the electric sector. But other investments have had strong returns, as well, including giving money back to people to reduce their electricity bills, and investments in job training and education within the RGGI states.

I went through this. The jobs that were created generally include the types of investments you would think it would include with the way the states have invested in the money, folks that are installing energy efficiency measures, installing boilers, folks that are doing audits, money being invested in training and education obviously is a good use of the money within the states.

As I mentioned, within the RGGI states they end up spending about $1.3 billion less on imported fossil fuels, and that’s a direct transfer of money that otherwise is going to producing regions that stays within the RGGI states for economic activity within those.

And then finally, you know, there are a number of things that we found looking at the administration of the program that have obvious lessons for states that ultimately are going to have to figure out how to comply with the Clean Power Plan, including the fact that looking back on it, while a lot of states may be anxious about the idea of joining a regional compact, it turned out to be relatively easy amongst a group of states that are politically and economically diverse, and don't necessarily like each other, to be honest, in some cases.

The state authority was of course fully preserved in the implementation of these programs. There was agreement amongst the states to do things cooperatively, but ultimately the specific program design and the way the allowance proceeds are, the way the allowances are distributed and then the proceeds used stays within state jurisdiction. And the common pooling and auction of the allowance program and the sheer governance has been accomplished very efficiently, reducing program costs compared to if every individual state was implementing its own carbon program. And the retention of the allowance proceeds, obviously, benefits states in many ways.

So all of those lessons, I think, are extremely important when you think about how all of the states are in the process of considering, "Should we be joining a regional program? Should we join California's program? Should we join the RGGI program? Should we create one of our own?" I think both the RGGI Program and what California has done create this model that can make things work much more easily for other states and point them in a direction of carbon reduction programs that can be designed in a way that can help mitigate economic impacts and mitigate the impacts on consumers.

So with that, I'm happy to take any questions.

CHAIRMAN WEISENMILLER: Yeah. I've got a couple. So first as a request, my recollection was that Sue Tierney has done some studies of the Clean Energy Plan impacts on the power grid --

MR. HIBBARD: Yeah, Sue and I have authored several studies.

CHAIRMAN WEISENMILLER: Yeah, so if you could submit those for the record, I think that would also help us.

MR. HIBBARD: I would be happy to.

CHAIRMAN WEISENMILLER: The other one was, there is a website set up by a third party that is tracking California's investments coming out of Cap-and-Trade, I don't have the cite, but we can certainly provide it later for the record.

And I was going to ask you, there's certainly some science that would basically argue that one of the first areas of impacts from climate disruption would be at the poles, and that would then affect the jet stream, which then could have resulted in our drought and your Polar Vortex. Do you have a sense of what the economic impacts have been in either New England or your state from the Polar Vortex?

MR. HIBBARD: Well, no, I don't. We haven't studied that. There certainly have been some analyses done by the system operator in New England and by others about the impact of spiking gas prices on electricity consumers that came from extremely cold weather. And so just as a really direct and obvious impact, that has had a huge economic impact within the New England Region. We're subject to pretty severe constraints on the interstate pipeline system coming into the region, so when it gets cold and those pipelines are constrained, the price of power just shoots through the roof, and that's had a huge impact. So to the extent that climate change is affecting the severity of cold weather within the New England Region, that's felt right in the pocketbooks of electricity consumers. But we haven't tried to look, you know, as I mentioned earlier, we just wanted to isolate, take a snapshot of what the effect was of the allowance proceeds, and we didn't try to estimate, you know, economic benefits or costs associated with the impact of the program.

MR. ROSSI: I'm not going to talk about the Polar Vortex. But if you would go to your slide 12 and just sort of take me through this? And also, there's an underlying assumption that through taxation and then a reallocation of those dollars that they are an economic benefit that is net to what they might otherwise have spent if they were in a consumer's hands. So, I mean, that underlying premise doesn't strike me as actually one that you would base the statement that there's economic value created. But regardless of that, on page 12, you know, $1.3 billion economic value, what is a social discount?

MR. HIBBARD: It's a three percent rate, it's something that is applied in the case of public policy programs. But we also looked at it at a seven percent discount rate, and it changes the numbers and makes them smaller in terms of --

MR. ROSSI: Considerably.

MR. HIBBARD: -- well, not considerably, it doesn't qualitatively change the results. That's all in the report if you want to look at that.

MR. ROSSI: Is it real or nominal?

MR. HIBBARD: Real.

MR. ROSSI: Yeah, and then as I drop down to your consumer savings is about equal to the reduction in revenues to power plant owners, it's a little higher, or a little lower, and I look at the fewer dollars spent on out of region fossil fuel, which is certainly a benefit, but it's equal to the cost of the $1.3 million that's been taken out of the system, brought into government, and then put back into the system at whatever real rate that is. I'm not sure that is all that great an economic input is what I'm trying to understand here.

MR. RIBBARD: You know, if you take a step back, the RGGI states are not trying to create an economic development program by implementing the RGGI Program; ultimately they agreed amongst all the states that they wanted to do something about climate change when something wasn't happening at the Federal level. So they implemented the program. The real question here is, how has it affected the RGGI states? So we make it very clear when you look at this, in the implications of this for other states, that that $1.27 billion in money not being spent in fossil fuel production is a negative economic impact on states outside of the RGGI region.

You know, what we're asked to do is say look at the RGGI states, figure out how has it affected their economies. So there are transfers involved in the economic analysis here. On your point about the money being collected, the loss of revenues from power plant owners is actually a fairly strong negative impact in our results and it moderates the positive impacts that flow from investments ultimately in energy efficiency. So it's not -- we try to account for both sides of the ledger on that. But the most important thing to recognize here is, if we did this for the entire country for the Clean Power Plan, then ultimately there would be winners and losers across states would be my guess because --

MR. ROSSI: Oh, look, I absolutely agree with you. I'm not trying to make a point other than there's not enough data here over a period of time that one can really make the statement that there's an economic benefit of sustainability, and which you even get to in a later slide where you talk about the jobs, some being temporary, some lasting three years, so I just want to be clear about that, that the analysis that happens a lot in this arena, and not RGGI, but in the renewables arena, in the impacts, and what you can do and you can't do, tends to lose a little value over time because of the lack of analysis of sustainability and prices and weak points in assumptions that lead you to the kind of stuff we saw in the first presentation. So I'm just trying to be careful here because, as Bob says, I get asked about the models all the time and what the impact is on the economy. And I think that what you've shown here for a short period of time, pretty damn interesting. We have to see what it means over time and the impacts of increase in cost basically netted against the values in your report on reductions as a result of energy efficiency.

MR. RIBBARD: Yeah and, you know, when RGGI did their redesign in 2012, they did sort of a really comprehensive forward -- they were trying to figure out where do we want to set the cap. They ultimately reduced it by about half, but when they did that, they did a forward looking analysis that looked at the impact on the power sector, they looked at the impact on the economies, and they looked at the impact on electricity consumers. What we were asked to do is say, yeah, there's only six years, but there's actually six years of real data and real impacts, just take a snapshot of that and see what it looks like the impacts on consumers are, not to forecast what the impacts will be, whether or not the program should go forward, this is a snapshot. So you're right, there's not -- I don't think anywhere in the country is there a lot of data on actual experience at the timescale of decades, but we do have six years of program implementation and it leads to one conclusion based upon what you look at here, which we try to be careful in the report to say this is not a forecast, we don't know where this goes when you change cap levels, but this is a snapshot of what has happened in the region.

MR. ROSSI: Thank you.

CHAIRMAN WEISENMILLER: Great. Thanks again for coming out, we appreciate that. Let's go back to Jim Williams now. Thanks. Actually, it's an interesting thing because I think Mike and I used to always ask Jim in Pathways how Cap-and-Trade was reflected.

MR. WILLIAMS: Can I take that one after my talk, Bob?

CHAIRMAN WEISENMILLER: Yeah, yeah.

MR. WILLIAMS: Sorry I was late this morning. My wife and I have been driving from our home in Berkeley to San Rafael a lot to take care of her ill and aging father, and when I came to awareness behind the wheel, I was in San Rafael. In my internal Google Maps, I had typed in SA and gotten San Rafael instead of

Sacramento, and so sorry about that.

Okay, so I was given the modest charge of talking about deep de-carbonization pathways in California, the U.S., and the world, and talking about research directions in the process in 12 minutes, so….

I think most people here are probably familiar with the work that E3 has been doing in California over the years, and so I actually won't talk about it, just to say that the sort of results and methods for the three studies shown here are available on the E3 website.

People might be a little less aware that we've been involved in something called the Deep De-carbonization Pathways Project, which is sort of an NGO activity chartered by Secretary General Ban Ki-moon, and it involved as of last year 15 countries, there's more now with about three-quarters of global emissions all the big industrialized countries, all the big developing countries, and basically what they've been doing is figuring out how in each one of their countries they could achieve emission reductions consistent with keeping warming to two degrees or less. There was a report last fall that over the next month or so there are going to be individual country reports from 16 countries coming out, there will probably be some press that you'll see about that.

At COP-21, there is an effort going on to make De-Carbonization analysis part of the UNFCCC process. And the reasons for that are basically, as it says, to improve the policy discussion and encourage cooperation. A big part of what doesn't normally happen in the international process is people putting their cards on the table: what are the assumptions? What are your real intentions? What kind of benchmarks for progress are out there?

By what's been demonstrated in the DDPP is that unofficial research teams have put their cards on the table, that there's mutual instruction and mutual learning going on. The nature of the dialogue shifts the focus away from abstractions about policy mechanisms and debates over equity and burden sharing to actual kind of problem solving around an energy system transformation. And also more focus on mutual benefits, less treatment of climate policy as a dead weight loss, and more as something that might be beneficial. A lot of eyes are on California in this process and it won't surprise anybody to know that.

And then there's identification to market opportunities, and I'm going to show something on that in the next slide. One of the things that E3 is doing is developing the Next Generation Pathways Model, it's in Python, and it's going to be cool in a lot of ways, some of which are relevant to my research recommendations at the end of this presentation. But for the purposes of the DDPP, it's basically making a common modeling tool available for all countries that want to participate, it's not necessarily to exclude other modeling frameworks, but there does need to be ways to improve comparability of results as, again, as part of sort of better transparency and putting cards on the table.

Now that point about identifying market opportunities, this was an analysis that we did using a simple one-factor learning curve, but basically what this is showing is what happens with key low carbon technologies in transportation, in power generation, and so forth, if each country essentially goes it alone and is buying off their own market based on sort of current assumptions about what costs will be versus what happens if big global markets develop in those same technologies, and so the gray lines are what the costs would be for, for instance, EVs or Fuel Cell Vehicles, versus the colored lines which show what they are where this learning takes place. And I think this has an implication for California and other leaders.

We're not really a big enough tail to wag the global dog in terms of what we do with our own emissions, but if part of what we do is to catalyze the creation of big technology markets that brings down the cost, that can have a very large global effect on feasibility. Also in the equity question, you bring the cost of clean technologies down to a level where developing countries can afford them, that really changes the terms of the equity debate.

Okay, so one of the studies that was produced for the DDPP was this one here, some people I think have seen it, that asks the question what it would take for the U.S. to achieve 80 percent greenhouse gas emission reductions below 1990 levels by 2050. And it asks the question, is it technically feasible? I'll save you the suspense, the answer was yes. What would it cost? On the order of one percent of GDP plus or minus a bunch. What physical changes are required? We'll talk about that in a second.

And then there is a supplemental report with a lot more sort of granular detail at the regional level, the sub-sectoral level, and so forth that we've been working on lately and also been sort of trying to spell out some of the policy implications. So that will be coming out in a month or two.

There's no time to show lots of charts and graphs. I find it may be easier to relate the results for our U.S. study in terms of three seeming paradoxes; the first is the physical energy system itself, it's a big change going from a fossil fuel-based system to one that isn't, but there's relatively little change in energy service required; that is, the implication is you're still driving, you're still washing and drying your clothes, etc., etc., to decarbonize the system does not necessarily require that we create Utopia.

The deeply decarbonized energy economy, well, there's a big change in where money goes in that economy, what it gets invested in. I think what we just saw from Paul is sort of an indicator in a short-term and historical kind of way what we see looking forward, you're not spending a trillion dollars a year on fossil fuel purchases in the United States, you're spending something comparable to that on basically equipment and infrastructure instead, it's more of a manufacturing-based energy economy than a fuel-based energy economy. It's more of a capital cost-based energy economy than a variable cost-based energy economy.

But from the standpoint of how those all net out, it looks to us like the change in consumer costs, things that you're paying for transportation and for heating your homes and so forth is relatively small.

And finally, there's a deeply decarbonized macro economy, as we say, on the order of a percent of GDP. We currently spend for energy seven or eight percent of GDP, so this is not necessarily a huge change. But there are some benefits for the macro economy that may belie the scale of the net impact when you think about relative price stability, the predictability of sort of an equipment-based energy economy as opposed to one that's sort of fuel-based like the oil economy we have now.

In brief, how do you get there from here? There's three pillars, the economy, the energy end use needs to become much more efficient, electricity needs to be greatly decarbonized, a factor of about 30 below of the current average rate, and there needs to be a lot of fuel switching to electricity and electric sources as to say things like hydrogen that you're producing from electricity also count in that, and across all the scenarios that we did more than half of end uses are either being met with electricity or electricity-produced fuels.

These findings are robust across all our cases for the U.S. and they're also robust across all the cases that we've seen in the DDPP for the rest of the world. Eventually everybody has to go essentially in these same directions. That is how you decarbonize the modern economy.

As a sort of general proposition, I'm thinking about the design of systems, there are sort of five factors that interact with each other. You can come up with a whole lot of different scenarios, we did four for the United States, but there's many others that are possible. Those were whether CCS is in the picture or not and how it gets used, how much sustainable, that is, low carbon biomass you think you have and how you apply that, what your generation approach is, and then from the generation approach what you do for electricity balancing, which is obviously different than, say, a high renewables case than it might be in a high CCS case. And then finally what your fuel switching strategies are. All of these sort of directions and pathways that jurisdictions might want to go in to meet these decarbonization goals are going to involve permutations of these different things. And so what sort of faces us as analysts and planners and policy makers is sort of figuring out what works best in our own bailiwick, and these are sort of the general findings we have from looking across the levels from California on out to the global level of what deep decarbonization, that is, getting to something compatible with two degrees is going to require from policymakers.

And this sort of implicitly assumes that there's not one magic ring to rule them all, that there is in fact a policy patchwork quilt and that's fundamentally going to be sectoral by nature and that things are going to have to be figured out. So you need to know what policy must accomplish. You need to have a plan, so for what policy has to accomplish basically means what is the sort of physical and financial requirements of achieving the kind of transformations, that you're talking about having a plan means doing the necessary sort of anticipatory coordination among sectors, across sectors, and so forth, have a business model means that if your policies don't provide incentives for investors to invest, businesses to do businesses, and consumers to take up technologies, then it's not going to work. And then finally, prepare a strategy for future choices.

And so just one quick example from our studies of each one of those to know what policy must accomplish. One example is that there has to be timely replacement; that is, the sort of lifetimes of the equipment and infrastructure that has the most to do with carbon emissions is long compared to the time remaining between now and the middle of the century. And so for most things you don't have a lot of shots at it before something has to change. Your policy has to sort of deal with that, otherwise you either won't make your emissions level, or you're going to end up with early retirement stranded assets.

Secondly, have a plan. So integrating supply and demand-side planning and procurement in the electricity sector, for example, this is showing the WECC in 2050 in our model, and the upper figure is the generation side, the lower figure is the load side, this is a high renewable system, and a high renewable system is going to need a lot of demand side participation, it means a really different kind of wholesale market from the one that we have at present. A lot of things need to be figured out about how you sort of jointly coordinate the roll-out of large amounts of flexible load, in this case for instance hydrogen production, where the load could be on the scale of something like 30 percent of total system load. We don't have that sort of bidirectional sort of equal treatment of loads and generation in our system now, that's a planning problem going forward that would have to be addressed.

Business model, well, to get the kind of level of transformation of light-duty vehicles that is going to be needed, and this is just one particular scenario, so the proportions between battery and hydrogen, this changes depending on what approach you want to take, but what is true is that the uptake rates that you're seeing here are very rapid. And if you don't have a plan for how manufacturers are going to manufacturer those and what sort of incentives consumers are going to see that are going to make them want to sort of do that kind of uptake, then you don't really have a policy that's going to work.

And finally, prepare a strategy for future choices. I talked about planning, I talked about having business models, but things are going to change, there's going to be market discoveries, there's going to be technologies that don't work, there's going to be new ones that we don't anticipate. And we know already in California that there are a bunch of big sort of multi-billion dollar, very consequential future transformations where there are choices, where there are going to be forks in the road, and a lot of these are going to be decided in the next decade if we really pursue the policies that we're committed to. What's our strategy toward electricity balancing? What is the future of the distribution level natural gas pipeline? Is it going to be an EV or a Fuel Cell, or some kind of Hybrid approach on LDVs? How is biomass going to be allocated? Is it going to be for transport fuel? If so, is it going to be for Ethanol? It doesn't look like a particularly good idea from our standpoint. Or is it going to be used in the pipeline to sort of decarbonize the pipeline? And depending on the fate of the pipeline, are you going to electrify building loads or go with very high energy efficiency and maintain gas in buildings? So these are all very consequential questions that we don't necessarily know enough now to answer. And so what can we do to sort of prepare to be able to answer these questions later on?

So this was my fun slide. So I think there's sort of three steps in charting our course: is deep decarbonization possible? That's work we've been doing over a few years. And what pathways can lead us there? We can identify those, California has already sort of narrowed down certain options, I can say with some confidence that we're not going to go the high nuclear route in California, okay, so that may not be the case everywhere.

But then how do we navigate along the way? And so I sort of see California being at this stage between having identified some pathways and actually being in the middle of all of the implementation problems. And so I have a Mars Rover there and I guess that's my take home as I propose sort of an anticipatory research agenda, is that we need sort of a Mars Rover that helps us orient ourselves and figure out what kind of information we're going to be needing in order to answer those questions about this technology path or that technology path that I was just describing. So we need a robust analytical framework with advanced sensitivity and uncertainty methods for assessing forks in the road, what are the points of no return? What's the timing of major investment decisions?

What are the risks to costs on emissions levels? And the path dependency of technology choices. What rate in timing of consumer adoption is needed? And how does changing that change outcomes? What information is needed to make good decisions? How can it be obtained? And how do external factors -- this is from the California perspective -- like Federal policy, regional integration, oil prices, and global technology markets effect outcomes?

And so that is my proposal as something that we need to do collectively. It's sort of meta, this all relates back to those Pathway choices, and it relates to sort of what the obligations of policymakers and analysts are in order to be able to make update plans and to sort of refresh and inform our business models and so forth, we need to anticipate that these sort of questions are going to be revisited constantly, as long as we're along the path. All right, thank you.

CHAIRMAN WEISENMILLER: Thanks. No, I certainly also was going to thank your focus on International, again, I think we all go back to the basic facts that California is one percent of the world's greenhouse gas emissions, and we can certainly lead through leadership, but at the end of the day if we're not changing things in the rest of the west, changing things on a global basis, it really won't matter what we're doing here. So again, I really appreciate your focus on the UN project.

MR. WILLIAMS: Thank you, Bob. Maybe I'll make one quick announcement while we're at it. So one little addendum to next steps for the deep decarbonization pathways project is that I was asked to become the Director of it, so I'm not directing the project. The previous director, Emmanuel Garant, is now the Assistant to Minister Fabias and the French Ambassador for Climate Change, Laurence Tubiana. And so he's been very busy preparing the Cop (ph). So I was asked to step in. So if people have questions about the DDPP, the buck stops here.

CHAIRMAN WEISENMILLER: Okay. Great. So just bringing back for a second to talk about the Pathways stuff that we looked at last year, what happened was we ran out of time and money, we ultimately closed things up. And one of the things that really was obvious at the time was, I don't remember the precise oil price forecast you had, but it was sort of what everyone believed roughly a year and a half ago, and just as you flip the button on print, you know, prices just fell through the floor. And so one of the things I know Mike and I focused a lot on was what did that mean in terms of risk assessment which gets to the broader question. In your slide, you had that one slide on, I think it was commercialization risk. So it was a pretty limited spectrum of what the risks are for these plans, and in that frankly most of it was renewable integration, you had this sort of series of technologies that might help, but none of them were quite there. And the sort of heat pumps commercialization. So that was sort of the other one which was like, who knows what we're getting into there? But having said that, there does need to be a need to really do that systematic type of risk assessment and certainly we did some stuff with you on oil prices, most of that I don't think has been shared with anyone but Mike and I, but that generally we do need to have a more systematic approach on what are the key variables, what's the risk assessment, how do you mitigate that? And again, we both concluded as, well, it was a complicated model, there were always a lot of pluses or minuses, frankly, with the reduced oil prices. But a lot of the mitigation strategies for that frankly are national, not global in nature, California is not well-positioned to mitigate oil price drops and what that might mean here. So I don't know if you have ideas on how we can better approach risk assessment?

MR. WILLIAMS: Well, I'll tell you how we're doing it, and this is sort of methodological, so forgive me. But there are two things, both of them have to do with sort of our current updates to the Pathways tool. Those in the state who have looked at the Pathways tool are probably profoundly aware of some of the limitations of Analytic, including run time, and so that's why we're building it in Python and making sort of much better sort of input and output, but also we're down to about one minute run times now. And what that means is that you can do sort of a lot of parallel runs and that you can start doing -- see, one of our premises is we don't like to do optimizations because optimizations typically imbed relationships that especially over these kinds of timelines of decades, it’s just foolish to say that you’re going to have the same structural relationships and economy 30 or 40 years from now that you have right now. And so that’s why we have always chosen the path of an accounting tool essentially, but then you get to the question of how do you deal with uncertainty in the accounting tool, and the last version we were able to sort of look at high and low input values and so forth, but the holy grail there I think is to be able to do the sort of complete charting of estate space without being constrained by optimization and what it assumes about relationships and decision variables that we have no way of knowing about. So the idea here is having a model that continues to be an accounting tool that really only involves physical and sort of direct cost relationships, but where you can sort of multiply vary all kinds of things and chart out entire state spaces what you can do because it runs fast and you can look at a whole lot of things in a relatively short period of time. So that’s sort of our methodological approach.

And in terms of sort of one advantage of being involved in the DDPP and doing the modeling at different levels, sort of all the way from cities up to global, is if you do those on the same platform, then the linkages and assumptions and boundary conditions are starting to look similar. So that all sounded a little grandiose, especially compared to how much work is involved in making that happen, but that is sort of our aspirational goal.

CHAIRMAN WEISENMILLER: Well, certainly I think the one thing we've all learned is that, again, we're talking scenarios as opposed to a forecast, and the beauty of scenarios is that you can try to map out the uncertainty space better. Otherwise you're left -- single-point forecasts have never been particularly accurate in the energy area, at least in my 30 years.

COMMISSIONER MCALLISTER: Mike, do you have any questions? No. You asked all your questions previously, I guess. So this is really helpful, I think the engagement around these questions, you know, despite some of the gaps and holes and limitations on resources and time, you know, it's helpful to have it highlight the key questions and think kind of creatively at some level, at a high level about how we might really engage with these issues and it's difficult, so we need that.

And I also appreciate your highlighting your distilled lists here, both of the choices, the needs, and also the research agenda I think is helpful, you know, at a high level, and I appreciate your highlighting in particular the question on electrification on the one hand, and high energy efficiency on the other, and it's a bit of a tradeoff, but there are a lot of different scenarios there and technology questions, so really I'm thinking a lot about that.

Your fourth recommendation -- yeah, that research agenda is about what information data we need to engage with these issues, and this is a really high priority of mine. Ever since I got here at the Commission, I'd see the constraints around our ability to get the right information to do the right analysis, to make the most informed policy decisions we can, and I guess you know, drilling into that a little bit, sort of a plan just on that actually at some level would be interesting and I wanted to just put it out there and not just to the audience and the record, but to the people who are here on the Dais that, again, I think that it's really important to figure out to best leverage our authority most effectively and really figure out how to navigate the tricky kind of regulatory and statutory issues to get where we need to go, and inform that kind of analysis to answer the questions that we really need to answer. So I think drilling into that item of the research agenda, not necessarily putting that on E3's plate, but I think that's just a priority to work through in a very collective and intentional way across the agencies and with the Governor's Office.

And then I guess, you know, any observations you have about that would certainly be welcome. You know, the international stuff is really interesting, you know, I have a lot of sort of experience across different countries doing this kind of work, and our particular context here in California is that we have a very robust democracy and a lot of stakeholders, and this uptake question, consumer response, you know, business model, even just within our regulatory processes, getting to workable solution that's actually doable in the marketplace by somebody who can make some money and actually move it forward and scale it, you know, whatever particular thing we're talking about is. It's not -- we ain't China, right? We can't sort of say, "Okay, this is Dichtung (ph)." So that has to be workable and I think the challenge that we have here is making sure that our stakeholder groups are both manageable, it's a big big tradeoff. If our stakeholder groups are manageable, then we can move forward in the timeframe that's necessary, this urgency. But also have it be broad enough that we actually do end up with some consensus that's workable and we actually do have comfort out there that, yes, if these investment decisions are made, they're actually going to pay off, and we're basically on the same page with this broad swath of stakeholders for any given issue. And certainly at the macro level here, there's just thousands of stakeholders in the state.

So I want to just hold up that as sort of something to think creatively about, as well.

And it’s more of a policy agenda, a research agenda, than a technical or even scenario-based, but it really is a key key, I think, area that we need to work on.

MR. ROSSI: I couldn’t resist, Jim. There are two things that occurred to me as I was listening to what was just said. The one percent GDP cost is not flat, it has to ramp up. And if that’s global, the peaks will be higher in regional economies. So along with the point that was just being made, is that one percent doesn’t sound like much, it just depends on where you are. It’s that old adage, on average it’s fine if you’re walking across the stream that’s three-feet high and you just happen to fall into that particular hole that happens to be 12-feet deep, right. So as you and I discussed in the past, I think we need to have more thought process around the phasing of these things in order not to end up with the law of unintended consequences slapping us in the head, which actually leads me to your page 5, or slide 5? Policies that could result in getting larger marketplaces and dealing with these initial expenses to drive these efficiencies, or this innovation, seem to me to be something we don't do well, whether it's because of a robust democracy. Or even the Chinese don't have a very good handle on it, beyond their own country. So as you look at that, that for me is a very interesting area to explore from a policy perspective because if you could really drive the cost down in the percentages that would appear here, it changes the game dramatically. All the rest of the pages you can throw away. If you could do this, you'd change the game unbelievably dramatically.

MR. WILLIAMS: I couldn't agree more, Mike. And as to your first point, the upcoming supplement that will be coming out in September for our U.S. work is going to show a lot more sort of at the U.S. Regional and Sectoral levels than our first report did. And what Paul said a minute ago is absolutely true, there are winners and losers, there's no question that there are winners and losers if you're going to follow this pathway. But the argument that I would make is that it looks like the losers are more concentrated in certain industries and uncertain regions, and the potential winners -- and since this is manufacturing-based and that's something of a trade policy, an industrial policy issue, you can't really say categorically how that's going to work out, but there is the potential for winners to be very widespread. There's sort of a democratization effect on the energy economy, or there could be, and this is sort of counter to the losers because there will categorically be losers in this world, too.

MR. ROSSI: Well, there are losers in this world as it exists, that's what at least free markets are all about, winners and losers. I don't think that ought to drive anyone's policymaking decision, or certainly protectionism of one thing or another, progress is not going to stop because of that particular thought process, right? We all know that. We may not like the rapidity at which progress changes, but it does change, or moves, and it does move. But getting back to something Bob had said earlier, the issue of identifying as you fill out all of these scenarios, those things which are the most important to drive the change, what is the volatility aspects of those things happening? And we don't see enough of that and analysis done in this arena. It's a huge conceptual issue in trying to decide what the policy ought to be. So I think it's important for us, Bob, as we have our conversations, that we constantly focus on the issue -- and this sounds great, but these three things have to happen, and as I looked at -- just looking there, the idea that we're going to drive that many sales of Electric Vehicles as we sit today is just not realistic. So that means it has to happen, but the probabilities of it happening as we sit today are hard to envision without other things happening in a major way. So it's that kind of analysis that is much more helpful than running a bunch of scenarios without any sensitivities and running sensitivities without any probabilities when you're talking about actually talking about people's lives.

CHAIRMAN WEISENMILLER: Actually I guess one follow-up, too, is obviously we get a lot of questions from the Legislature about impacts across our society, you know. At this point a lot of our programs are really influencing the early adaptors who just happen to be relatively high income. And trying to see going forward where the impacts are going to be across our society, particularly in terms of the disadvantaged communities, just trying to make sure that, again, we -- I think part of it comes to having just as we need mitigation strategies for risk, we need mitigation strategies for some of those impacts.

COMMISSIONER MCALLISTER: I was going to -- I was thinking as you were talking also just sort of about highlighting no regrets type strategies. That seems really important and to disadvantaged communities and low income populations, you know, having a different sort of cost benefit profile privately and individually, but may actually fall -- there may be ways to frame it such that they actually are in and no regrets, they end up in a no regrets type of approach that is good for many many reasons, not just for even carbon or energy policy. But I agree, I mean, this issue of consumer uptick in a voluntary environment is hugely difficult because when you offer a carrot it's to whoever can eat the carrot, and that's who is going to participate. And so how do you then scale that up and use that opportunity to get to the massive market and create value for everybody who couldn't afford that, who couldn't take advantage of that program, or eat that carrot? So there are lots of program design issues I think that really are in a lot of ways where the rubber hits the road, we've got to decide on the policies, but then get the program initiatives done in a way that really works with reality, and pushes in the right directions.

MR. WILLIAMS: Yeah, and I would just add to that, you know, the question of conditionality, if you're in the quadrant, the quadrant that I think Mike Rossi worries about, of being in a high interest rate at low oil price world, you know, you're going to be walking a more narrow path, but what is that path going to be contingent on? That kind of information becomes more important in that world than it is in the opposite world where we continue to have low interest rates and higher oil prices.

CHAIRMAN WEISENMILLER: Okay, thanks for being here and certainly thanks for your work at the U.N.

MS. RAITT: All right, thanks. Our next speaker is Brian Tarroja from U.C. Irvine.

MR. TARROJA: Good morning, everyone. So my presentation is going to take a bit of a different flavor than a lot of the ones that have gone before it in the fact that there are no dollar signs in this presentation anywhere. So I'm not going to be talking about economics at all, there's –

CHAIRMAN WEISENMILLER: I think Mike Rossi just fell asleep.

MR. TARROJA: Oh, yeah, well he's seen this. But mine is going to kind of take a step back and really start to consider more directly the air quality implications of a lot of these deep greenhouse gas reduction strategies, right?

So air quality is something we have a long history of in California and, you know, I don't want to say that's been kind of put to the side, but definitely more attention has been given to greenhouse gas in terms of climate change in the global scale. So the title of my talk is Transition to a Low Carbon Economy: The Air Quality Considerations.

So just some context. It actually was good that Jim went before me because this sets it up quite nice. Transitioning to a low carbon economy is hinged on increased use of carbon as primary energy resources, and that means electricity, right, a lot of the stuff, the work that Jim has done and the stuff he's talked about shows that electricity kind of has this central role in making this low carbon economy possible, right, electrification of services that have historically not relied on electricity is something that you're going to have to do to a large extent.

And however, for greenhouse gasses, we've really focused a lot of our attention on the electricity and light-duty transportation sectors. There's some reasons why I think that has occurred, but that's kind of what we look at because it's a large portion of greenhouse gas emissions, it's something that you can somewhat uniformly address, right? Light-duty transportation as opposed to heavy-duty transportation, the latter of which is much more diverse, right?

So in California 2013, light-duty transportation and electricity, about a little over half of the greenhouse gas emissions, right. And as we know, much of California is not in attainment of Federal or State Air Pollutant Concentrations Standards. So the main question that I want to hopefully give some insight into here is how does deep greenhouse gas reduction strategies impact air quality? And how does it help or hurt our progress towards meeting standards for air pollutant concentrations, which most of California doesn't meet?

So this is just a little bit of background, you guys are all familiar with this, this is from the Scoping Plan. We've done pretty good in getting our greenhouse gas emissions down toward 1990 levels by 2020 and, you know, that's all nice and good, but we're going to have to do much better as we move forward, and that means meta transformations, things that people have talked about here. And there's also the history of air quality. I don't know if any of you guys are old enough to remember this, this is in 1948, I'm obviously not, but -- so he knows -- right, been there, so air quality really has become, it really was like *the* major focus for quite a while and then we kind of got done pretty well as far as that goes, even though we don't meet the standards, we don't have this kind of deal going on down in Southern California where I'm from. But we still have a lot more to go, right? So this is a bit old, this 2009, but even if you look in more recent charts, it's about the same. And that's basically the counties in California that are designated nonattainment. Basically the Air Pollutant concentrations of four or five of the National Ambient Air Quality Standard Pollutants are too high. And almost all of those are in California, actually only the red ones are *only* in California. And there's Orange County where I'm from.

So what I'm going to do here is I'm going to do a little bit of an exercise. I have some deep greenhouse gas prediction strategies from a grid integration study that I did for electricity and light-duty transportation. I'm going to walk you through that and show you kind of the cases that are able to meet the "goals" that we set for it, and then we're going to see whether that helps air quality, right?

So let's start with these, saying the light-duty transportation sector, by 2050 we have a 90 percent penetration of alternative vehicles, that's very ambitious, but this is kind of a bounding scenario. We look at 100-mile BEVs, 200-mile BEVs, and Fuel Cell Electric Vehicles, and then the remaining 10 percent are just advanced gasoline vehicles that meet the CAFE Standards. We look at sensitivities to charging location, whether there's charging available at home and work, and basically whether charging is dispatchable or not, and for hydrogen electrolysis we assume that it's centrally operated and dispatchable.

And then we couple all those vehicles with a very renewable electric grid, right? We install a very large capacity of renewables, this actually ends of becoming more than we need, so just look at these numbers here, right? It's mostly solar and we install energy storage to make sure that we can use a lot of solar, or solar and wind, and so on. And we run this through our Grid Balancing and Reliability Model called High Grid, which I'd like to talk to Jim about after, and basically just see, you know, we'll have a parallel goal of 80 percent reduction because that's what everyone seems to use, and 80 percent reduction in those two sectors as a 41.8 percent reduction in the total state emissions, right.

So I just want to talk about charging.

We have immediate charging where everyone just charges right when they get home, then you can kind of see this doesn't necessarily align with renewables. You can mitigate that using energy storage where you store excess generation and shift it to discharge one people of charge, or you can just use Smart Charging, well, their charging is dispatched to align with renewables directly.

So at 255 gigawatts for renewables, which is enormous, like I said, I heard some people talking when I mentioned that number, you look for these different vehicle types, there are some vehicle and infrastructure configurations that do meet very significant greenhouse gas reductions.

So a 2010 actual is way over here. If you just use all advanced gasoline vehicles in 2050, you get down to here, but then you still need to go quite a bit further to get this "eighty percent" reduction. So BEVs are able to meet it with a bunch of storage. BEVs that are more efficient with less mileage can meet it with less storage. You can install more renewables, some of the Fuel Cell cases start to meet it. You can install even more renewables, more cases start to meet it, right? So this isn't surprising to anybody.

But what does that mean for air quality, right? So basically all I wanted to show that for is that there are a lot of ways that you can get deep greenhouse gas reductions, as Jim said it's possible, right, there are many different ways that it's possible, that's not the issue, and especially for electricity and light-duty transportation. But what does that impact, what does that have on air quality? So the way that we did this is we took a lot of those scenarios, we had their spatial and temporal distribution of emissions, right, but it doesn't stop there, this is kind of a key point I want to make here, is we put them in an Air Quality Simulation Model that takes into account the atmospheric chemistry interactions and climate, and so on. And that's actually a very important step because a lot of the discussions around air quality stop at the emissions level and, you know, it kind of doesn't necessarily give you the resolution needed to determine whether you get air quality benefits in the areas that you need it the most and whether it's actually making a big difference in terms of the actual concentration of air pollutants. Because that's what we're chasing, right? I mean, the amount of NO_x is somewhat correlated with that, but this is kind of what we're chasing.

So we used the CMAC Model in combination with our Grid Balancing Model and Transportation Model, and we look at ozone concentrations and particulate matter, 2.5 concentrations in this case, although we can do 10 also.

So let's also focus on two main basins that have degraded air quality, right? South Coast Air Basin where I live, yes, the air quality is very bad, also the Bay Area up in the North, which you guys are a bit more familiar with, they don't tend to meet the ambient air quality standards either. So we're going to look at two kind of pollutants, we look at ozone and in this case it would be one hour, although we could also do eight hour, and the standard for California set at ARB is 90 PPB, Parts Per Billion. In SoCAB nowhere anywhere in SoCAB meets that, although some places in the Bay Area may meet that, but many places do not.

For particulate matter, the standards set by

ARB is 50 micrograms per cubic meter, some places meet that in SoCAB, although most places don't, and I couldn't find a spatial solution for San Francisco Bay Area, but it seems on average they do not, right?

So I'm going to show you a couple plots of air pollutant concentrations. What I want you guys to understand about these plots is they show a spatial map of the change in air pollutant concentrations in California from a business as usual case for these two pollutants, right? These were simulated over 60's which tend to have the worst air quality typically from year to year, July 7 through 13, and basically positive means bad; negative means good. Right? A little bit flipped there.

So remember those numbers that I said, 90 PPB is what you want to get to, SoCAB is 95 to 160 something, just as an example, similar thing for San Francisco Air Basin. So let's take the most aggressive case that we have in greenhouse gas emissions, this is like way more renewables than we need, right? And we're able to use all of it and we're using very efficient battery electric vehicles, we're using a lot of renewables to meet the stationary load, and what do we have here? So let's look at ozone. The maximum reduction that we get in ozone actually occurs up in San Francisco, and then we get a little bit better in SoCAB, but the maximum reduction is around 4.75 PPB. So remember what I said, say in SoCAB we're at 95 to 100 and something, right? And we want to get down to 90. This is an extremely aggressive greenhouse gas reduction strategy, right? We have lots of renewables, we've electrified most of the vehicle fleet, we have storage, we have Smart Charging, everything is Bueno, and we like don't even get to meet the standard, right? San Francisco Air Basin may in some areas, SoCAB no way. The maximum reduction is 4.75, right? For PM215, it's a similar thing, right? We threw all this stuff at greenhouse gas emissions reductions, and we do get a benefit, but it's still kind of small, 4.19.

So if we do Fuel Cell Vehicles, it's a similar thing, similar for PM, but just a little bit, not as good for ozone, but it's the same principle, right? We throw all these strategies at greenhouse gas reduction, but it doesn't necessarily give you proportionally equal benefits in air quality. And that's kind of a main takeaway from here, is you kind of can't use greenhouse gas emissions kind of as the sole metric of like sustainability, which is kind of how it's been talked about, right? You really have to do this kind of multi-faceted sort of assessment.

So here we go. Some of the strategy has reduced greenhouse gases by 41.8 percent or more, some of them went below that "2050" goal, and the reductions in ozone, you know, three to five percent reductions of PM2.5 maximum reduction, there is a spatial resolution element to that. You know, six to 10 percent. And this happens because light duty transportation is already relatively clean as far as criteria pollutant emissions go, right? It's a relatively minor contributor to emissions such as NO_x because we've done a very good job in California of making those emissions regulations strict, right?

And also for power plants, power plants that are in degraded air basins are subject to very strict emissions regulations. If you wanted to install a power plant in SoCAB, South Coast

Air Quality Management District will subject you to all kinds of Regulations and all kinds of like stringent constraints that you have to meet. So if they're able to be installed, they're pretty clean; if they're not installed in areas that have air quality problems, then it doesn't contribute to as much of the air quality issue, right, because they're in remote areas which doesn't have high concentrations to begin with. So that's the main takeaway I was talking about, is deep greenhouse gas reduction strategies do not necessarily provide proportionately deep air quality benefits. So if you want to tackle air quality, you have to bridge renewable energy, or clean energy with sectors that have high air pollutant emissions, as well as greenhouse gas emissions.

So this kind of sums up a little bit of what I'm talking about. This is from the South Coast Air Quality Management District, right. Electricity and Light-Duty transportation accounted for very large amounts of greenhouse gas emissions. This is the breakdown of NO_x emissions in South Coast Air Quality Management District in SoCAB, right? Large stationary, which includes power plants is right about here, light-duty cars, and there's a lot of cars in SoCAB, we love to drive down there, there is a lot of cars -- right here, right? So the large contributors to carbon are not the largest contributors to air pollutant emissions.

So what are the largest contributors to air pollutant emissions? And, you know, you did see an emission profile there, so you can kind of guess, but we'll do a little bit of an exercise, this is based off of an EPA project that our lab had where what happens to the one-hour ozone if we just remove all the emissions from different sectors? Right? How do we get from having 95 to 163 PVB, you know, to below 90 or even better? So different subsectors in transportation. And here you can kind of see why. If we removed all the light-duty emissions, you get the benefit of 4 PVB; if we remove all the electric power emissions in California, you get 2.5. So this is not really where you want to be focusing if you want to look at air quality. However, if we look at the heavy-duty sector, heavy-duty transport, right, on-road diesel trucks and so on, 12.9; off-road, which is like mining equipment and tractors and construction equipment, things of that nature, which don't really have much emissions regulations on them, 11.8. And Marine and Rails, especially because we have a lot of ports down in Southern California, you guys have a few up here also, 20.6 maximum reduction. And this is kind of just an example of that spatial distribution. So note this colored scale was capped at minus 4, but it really does go to minus 11.8, and you can kind of see you get really good reductions basically everywhere and deep reductions where you need it, in the San Francisco Basin, in SoCAB.

So basically you really have to bridge these heavy-duty sectors with renewable primary energy resources to obtain an air quality benefit, right? That's kind of its own issue that does have some synergies with greenhouse gases, but it's not encompassed by greenhouse gases.

So kind of just to sum it up, right, large contributors to greenhouse gas emissions are not the largest contributors to air quality pollutant concentrations; greenhouse gas reduction strategies don't provide a proportionately strong reduction in air pollutant concentrations; and you really have to start connecting not just the electricity and light duty transportation sector, which I believe we're doing because it's a bit of low hanging fruit. But you really have to start branching that renewable electricity out into basically everything that you could branch it out to, especially in the Heavy Duty sectors.

And kind of as a final point here, is air quality assessments kind of have to be included as a separate metric when you're talking about sustainability, right? You can't just say like, oh, we reduced greenhouse gas emissions, like everything is cool. And by extension, there are other things associated with sustainability that have to be considered also, right, waste and water quality and water resources and so on. So that's kind of all I have, these are references for some of the stuff I have in here. And does anyone have any questions?

CHAIRMAN WEISENMILLER: Yeah, just following up on a couple things. Yeah, I was going to say certainly Barry Wallerstein always has this chart that shows his targets of dealing with stuff, and power plants are not that much of an issue, it’s always Heavy-Duty Vehicles.

MR. TARROJA: Yeah, because we don’t use much coal here.

CHAIRMAN WEISENMILLER: Yeah, no, I mean, you always hear a lot about power plants and pollution, but it’s really the cars and trucks on the LA freeways. But one issue for LA is that 20 percent of your economy is goods movement.

MR. TARROJA: Yes.

CHAIRMAN WEISENMILLER: So you have a huge economic dependence, you know, you have various air quality plans that have to go in place to meet, as you said, huge reductions.

MR. TARROJA: Yeah.

CHAIRMAN WEISENMILLER: And so, again, I think the challenge for all of us is how do you decarbonize the heavy-duty vehicles, you know, and certainly if you can do passenger cars, that’s great, but as you said, there are certainly co-benefits, but somehow that’s one of our major areas is Heavy-Duty Vehicles, otherwise you’re back to what happens with the economy down there, you know, if you shut down the ports and goods movement.

MR. TARROJA: And I think it’s interesting, too, because kind of decarbonizing light-duty transportation, it’s a bit more uniform, right? Everyone has kind of the same drive train. You take that drive train out, you replace it with another single drive train, but then when you start talking about drive trains for ships and tractors and diesel trucks, they’re all like different and they all have different duty cycles, and different feasible technologies, it starts to get a bit more complicated.

CHAIRMAN WEISENMILLER: It does, and certainly when you talk to the train folks, I mean, they’re not going to have electric trains in California that stop at the border and then flip over to other systems. It’s got to be something that’s more of a national solution.

MR. TARROJA: Yes.

CHAIRMAN WEISENMILLER: I guess the other thing, looking at -- you know, it was really interesting to see the air quality piece here, but one of the things that comes out strongly from the research Guido has been doing is that temperatures are going up, you know, and certainly substantially in various areas, and also you have the heat effect, I'm not quite sure we quite factored that in, but for example I guess most recent Scripps is saying Sacramento we're talking about the minimum temperatures going up four degrees (*Sic*), maximum going up two degrees. So anyway you're going to have a much hotter atmosphere there in some areas of Los Angeles. So my presumption is that's going to accelerate dramatically the kinetics of some of these reactions.

MR. TARROJA: So for certain pollutants, higher temperatures will mean that ozone would be worse. For particulate matter, it's a bit more complicated than that. But definitely for ozone, the impacts of increased temperatures is going to make it worse, so this would actually be -- it actually makes it more urgent, right?

CHAIRMAN WEISENMILLER: No, it does. And the other aspect obviously, I think it's like 30 percent of the particulates come from China, so certainly Jim's work there and my work there is important, and for LA's air quality.

MR. TARROJA: Yeah.

COMMISSIONER MCALLISTER: That's interesting. Let's see, so the air quality aspect of this is, you know, key and interesting. I guess I'm wondering where your -- you came in with a presentation with an assumption that, oh, everybody sort of talks about greenhouse gas and sort of assumes that there are these co-benefits with air quality and, you know, your sort of effort here was to dispel some of that and make it more clear what's really going on there, which I very much appreciate. I guess are there policy recommendations that really don't come from the carbon world, that can just attack these without a whole lot of linkage between those? I mean, you know, the cars, we have the catalytic converter, which is kind of an instrumental technology for getting NO_x down and solving some of the Ozone problem and cleaning up the air down there. And so I guess I'm wondering is it necessary to only consider policy instruments that sort of have both of these benefits, or are there options that you're looking at advising ARB on, and stuff, for the Heavy Duty fleet that are more targeted to the air quality and not so much on the energy front?

MR. TARROJA: Right. So it's not necessarily that you only consider policies that have co-benefits, right? I mean, some of these things are much more separated than others, but at a minimum, though, you do have to be aware of what the interactions between these policies are, right? Because you know, you could inadvertently set policies that can kind of just shift the burden of reducing air pollutant emissions or greenhouse gas emissions to a different sector and, you know, kind of get these interferences that kind of hurts all the policies going forward, right? So it's not necessarily to say that every policy needs to be fully integrated and so on, but you have to be aware of what you are and what you are not getting out of each of your policies, right?

COMMISSIONER MCALLISTER: I guess on the goods movements, and particularly the ocean freight, I mean, there are huge air quality issues there, and one of them is obviously an increase in electrification, so that's a place where you'd really have to work those together.

CHAIRMAN WEISENMILLER: -- ships.

COMMISSIONER MCALLISTER: Well, he's at Irvine, I mean, that's not ARB's bailiwick I don't think. But, yeah, so I guess anyway I appreciate that sort of help and this elucidates some of these cross issues.

MR. TARROJA: Thanks.

MR. MURTISHAW: Actually, I have just a couple of quick questions. This is Scott Murtishaw from the PUC. I would be interested in just knowing a little bit more about the disaggregation of off-road equipment and your slide 15.

MR. TARROJA: Right.

MR. MURTISHAW: So what would be the largest contributors? What would be some examples of the types of equipment within that category?

MR. TARROJA: So I don't know exactly what the largest contributor is, I'd have to go back into the data to look at that, but some examples would be like construction equipment, right, or tractors, or things of that nature, like large heavy duty -- that's kind of the main thing that I think about as far as off road goes. You know, cranes and tractors, mining, I don't know if we do too much mining in California, but, yeah, things of that nature.

MR. MURTISHAW: Okay and do you know

anything about what technologies are either in development or on the shelf already that would allow us to substantially reduce NO_x emissions from those kinds of activities? I mean, what are the options on the table? And in what way could electrification -- I have a hard time imagining electrification -- many of those uses are possibly cranes since they tend to be stationary, but do you have just off the top of your head some sense of --

MR. TARROJA: So I actually do not know of what's out there right now because it's a little bit convoluted and hasn't received as much attention as light-duty, but conceptually I would say cleaner fuels, maybe use of like hydrogen for heavy-duty-type deals because of the need for the energy density and just kind of their duty cycle. Electricity may or may not work for many of these applications, especially if they're very energy intensive and, as you said, not stationary. So that's kind of -- I don't have a sense for what the technologies that are on the shelf right now that are being looked at.

MR. MURTISHAW: Okay and similarly I'm just interested in whether you have breakdown for the ocean-going vessels category, how much of that would be while the ships are in transit versus idling at Port?

MR. TARROJA: So a lot of it is while they're at port, although they're working on that with port electrification, right. A lot of it also comes -- so you're talking about just the ships, or are you talking about the ports as a whole? Because there's a lot that goes from like drayage trucks and those vehicles which are idling, which is actually one of the larger contributors.

MR. MURTISHAW: Okay, well in the chart the category is labeled as ocean-going vessels, not necessarily ports, per se.

MR. TARROJA: Oh, in the AQMD chart? This one?

MR. MURTISHAW: Right.

MR. TARROJA: Yeah, 15. So as far as what proportion of that is in transit or is not, I don't know that off the top of my head. I can get back to you on that, though.

MR. MURTISHAW: Okay, I would just be curious to know how much cold ironing (ph) for the ships at Port would contribute to reducing those sources of emissions.

MR. TARROJA: Right. So that measure in particular was something that we looked at in one of our EPA projects. I could ask for permission to send that along to you if you wish.

MR. MURTISHAW: All right, thanks.

CHAIRMAN WEISENMILLER: And if it’s public, if you can put it in the record, that’s great; if it’s not public, just give it Scott.

MR. TARROJA: Okay, for sure. Thanks.

COMMISSIONER MCALLISTER: Thanks very much.

MR. TARROJA: Thank you.

COMMISSIONER MCALLISTER: All right, the final pre-lunch -- pre-break, sorry, not pre-lunch, sorry.

MS. RAITT: So next is Jimmy Nelson from the Union of Concerned Scientists.

MR. NELSON: Hello. So it’s an honor today to speak at this event about some work that I’ve been doing over the past year and a half with the Union of Concerned Scientists looking at California and a 50 percent Renewable Portfolio Standard, and kind of the flexibility challenges and solutions to those challenges that we might explore.

So when I kind of thought about what I was going to do at the Union of Concerned Scientists when I started about two years ago, there were a couple important studies that came out that really led me to ask a question. And what I noticed in those studies, including E3's relatively famous 50 percent Renewable Portfolio Standard work is that there were a lot of hours during the day, especially during spring days, when you were seeing a lot of gas generation at the same time that you were seeing renewable curtailments.

So you were on one hand throwing out really valuable renewable energy and, on the other hand, spending a lot of money to generate electricity from natural gas. And so there has to be reasons for this and in the modeling tools there are definitely reasons, but in my kind of estimation it seemed like this is a situation to be avoided, kind of at all cost.

So to this end, my supervisor and I, Laura Wisland, who couldn't make it today, we created our own version of the duck curve to try and kind of explain what we saw as one of the biggest challenges. And so our version of the duck curve addresses the over-generation challenge in the middle of the day that you might have too much electricity around, and you might have to curtail renewables.

Well, why would this be the case? It could be the case because natural gas generators, when they're providing energy, sometimes they also provide a number of important Grid reliability services. And so you might get into a situation where you need the reliability from a natural gas generator, or perhaps a hydroelectric generator, as well, but you don't necessarily need the energy because you have renewables kind of going gangbusters in any given hour, especially in the middle of the day.

So the orange part with lines kind of shows you the renewable energy that you might have to curtail or get rid of to maintain grid reliability. And Jim Williams set me up pretty well, I'll use some of his data from the 2012 science study. You know, I kind of wanted to bring it back to this discussion about long term climate goals because if we're going to have to have natural gas, dispatchable natural gas power plants on line in every hour of every day to provide reliability, I don't think there's any way that we can really get from the kind of baseline scenario to the mitigation scenario, I don't think there's any way we can go really deep on reducing carbon emissions. And this is especially important given that the power sector, as the title of the paper says, is very pivotal, it has a pivotal role in reducing emissions. And so if we can't shut off the gas plants in the middle of the day, in the long term, in the 2030, 2040, 2050 timeframe, it's going to be really hard to meet our goals.

So just a tiny bit on the modeling work that we've been doing. So I have to acknowledge a few folks first, E3 gave us some great datasets and kind of the renewable profiles and portfolio that we got, or that we used are from E3. And obviously I have to thank my organization, Union of Concerned Scientists, for supporting me. And we talked to various folks at NREL and Plexos. And we sent the report out for review to a number of folks who provided fantastic comments, some of whom are in the room.

And so what did we do? We looked at

three different RPS targets in California, a 33 percent, a 40 percent, and we really focused on the 50 percent RPS target because that's the one that's kind of currently in the discussion.

The geographic scope of our analysis is the CAISO footprint, so 80 percent of electricity demand in California. And we chose the timeframe 2024, we thought this was kind of an interesting timeframe to choose. So if you think about the Governor's overarching economy-wide greenhouse gas goals of getting to 40 percent emission reductions by 2030, we might need to go really relatively quickly on renewables to get to those goals. And we might need to go more quickly than would be envisioned in a 50 percent RPS by 2030, so we chose to model 2024 to see if we could do it quicker. And the punchline is that we could in terms of Grid flexibility. But we still think our results are relevant to a 2030 fifty percent RPS policy discussion.

So we used kind of the industry standard Plexos Electricity Production Cost Model; you know, it's been used by NREL and E3 and the CAISO and Southern California Edison and others to look at the challenges of integrating more renewables into the Grid. We did not perform an investment model, this is kind of different than the work that I performed in graduate school for the CEC, so it's a bit of a departure in that respect. So we really wanted to just kind of drill down on electricity operations. So we used the Plexos model. But we did not, you know, optimize the renewable mix or solutions to try and address integration challenges.

So the Renewable Portfolio that E3 generously gave us and the hourly profiles for this portfolio are for a relatively diverse mix of renewables. So as you go out to 50 percent, you still see a lot of solar energy, but our portfolio ends up ramping up wind and baseload renewables to some extent.

And, you know, I think this is because in large part the benefit of portfolio diversity, we know that makes renewable integration challenges a little bit easier, but I think that's a discussion that needs to be had further.

So we weighed our portfolio heavily towards instate resources, in large part because that's what the current RPS policy does, and I think there's a desire at least on the part of many in the state to keep some of the renewables in the state. And we don't count behind-the-meter PV towards the RPS for the same reason we're just kind of maintaining the current policy structure the way the RPS works currently.

And I should also mention that we don't simulate a lot of expanded regional coordination, so this is kind of CAISO balancing its own renewables and I can talk to what I would think might change a little bit if we did something differently, but I think a lot of the results are going to qualitatively remain the same.

So the first set of results are kind of no surprise to most people in this room, so I'll go through them quickly. As we increase the amount of RPS, but don't really make a lot of effort to integrate those renewables into the Grid in an intelligent manner, just kind of shove them onto the Grid, and curtail them when we can't maintain the reliability, we do see greenhouse gas emission reductions, so a relatively large maqnitude. And then most of your cost to produce electricity is just you're spending money on natural gas fuel, so you see reductions there, as well, although of course we didn't do an optimization or even a quantification of capital costs. So this isn't the full picture on costs, I'm not meaning to say that it is.

And then similar to other studies, we see that renewable curtailment actually starts to really go up when you get towards the 50 percent Renewable Portfolio Standard and we see about five percent of renewables would be curtailed at a 50 percent RPS.

So I think a lot of folks tend to jump at this and think, wow, this is a massive problem, we're curtailing five percent of renewables, but I'd just like to point out that there's the other 95 percent, so we put 50 percent renewables on the Grid and we got 95 percent of them accepted without really trying to do a lot of complicated integration. So I think we're already at a good starting point and the point of the modeling, though, is to investigate how we could go further and reduce this curtailment and also reduce GHG emissions.

So one of the most interesting things that I found when doing this study, and I kind of alluded to it earlier, is that reliability requirements can cause a lot of renewable curtailment. These are things that we shouldn't kind of forget about when we're thinking about integrating renewables.

So I'm going to show you the next slide in which, in this study with our specific assumptions, we found that reliability requirements can cause up to 80 percent of the renewable curtailment that you observe. So this is different than I think a lot of people's intuition of why curtailment might happen, which is that we just have too much solar energy, let's say, in the middle of a spring day, and not enough load to sop it up, right? That's one idea of why you might --

CHAIRMAN WEISENMILLER: Yeah, but your portfolios are very balanced. There's not much solar in the portfolio. So that's not a great example.

MR. NELSON: So I do think that that effect would be a bit mitigated by having a less diverse portfolio, but I still think that the qualitative result that reliability requirements can cause curtailment is going to stand. So, you know, you don't have to believe my exact numbers, but kind of take away the qualitative message, perhaps.

So we removed two sets of reliability requirements from the model, not to suggest that they're not important, but to highlight kind of areas for further analysis. And the big result that we found was downward balancing on the sub-hourly timescale can really make a big difference. And so if you're familiar with electricity operations, the two reliability requirements that were kind of the most important were load following and regulation specifically in the downward direction. So this is to deal with imbalances of supply and demand of electricity on when you might have too much supply, or too little demand, so turning down resources. And the reason that these cause curtailment is because kind of the default way that we've run the Grid in the past is that you might hold natural gas power plants above its minimum generation level in preparation to be able to turn it down on the sub-hourly level. And what you're doing when you do that at really high renewable penetrations is you're causing hourly blocks of renewable curtailment because you're trying to prepare for sub-hourly fluctuations of renewables and load. And then we found also that another set of reliability requirements, which Trieu also kind of briefly I guess showed on his slides, can cause additional renewable curtailment, the Regional generation requirements. I'm not going to go into those more.

So we looked into the question of what works and what doesn't to increase operational flexibility at a 50 percent RPS, you know, given that we have a relatively diverse mix of renewables and we're focusing kind of on instate balancing to some extent. So we looked at three different options, operate the renewables more flexibly, increase the flexibility of the natural gas power plants, and then kind of a basket of three other options, add non-generation flexibility, so storage, Demand Response, exports.

And we found that operating renewables kind of very flexibly can have large benefits. The reason is that you can avoid a lot of curtailment by actually curtailing renewables very nimbly on the sub-hourly scale, and you can avoid kind of blocky larger chunks. So this represents renewables starting to contribute more and more to reliability and balancing of the system and that can actually help you avoid curtailment, even though having renewables provide reserves, you have to curtail some. With that amount that you curtail, as shown by the rate plot, is less than the amount that you curtail if the renewables weren't contributing as intelligently the system balancing.

So what about kind of more of the usual suspects, I call them? Things that people generally say are going to help out the problem of renewable integration? We certainly find that these non-generation sources of flexibility can really help, so increasing the amount of electricity storage, Demand Response, and exports, and I should note here it's advanced Demand Response, so either increasing or decreasing electricity demand. So the X axis here is one gigawatt, or like three gigawatts on the X axis is one gigawatt of storage, one gigawatt of Demand Response, one gigawatt of exports, we just deploy them in equal ratio as a tool to show how they could work together, and you definitely see you can get curtailment down to very low levels, and you can also reduce greenhouse gas emissions. So these solutions, of course, work if you can get them and get them at a relatively reasonable cost. But we didn't perform a cost tradeoff.

So one of the more interesting things, I think, from this part of the analysis is that providing downward flexibility from these sources is pretty important. So you can start to turn off natural gas power plants if you can have a storage device kind of ready to provide that downward flexibility, and you don't have to have that storage device producing electricity to provide that grid reliability service, whereas with a natural gas plant you do need to have it on line and generating.

And then the last thing that we looked into was, what are the operational characteristics of natural gas that would be helpful and maybe not so helpful? There's a big discussion about what we need to do with our gas fleet, do we need to modernize the gas fleet to really successfully integrate more renewables? And so we performed a few sensitivity runs where we modified either one or many different aspects of the natural gas fleet, so we took just as kind of a bookend the entire CAISO gas fleet and made these changes to every single gas unit. So if you double the ramp rate, if you look at the left two bars, if you double the ramp rate of all of the gas generators in the CAISO, you don't really reduce curtailment by a large margin at all. And in kind of modeling terms, that's because the ramp rate isn't the binding constraint, it's not the thing that's causing the curtailment. On the other hand, if you reduce the minimum generation level, or the minimum power level of the combined cycles, you do see some benefit because you are starting to address at least in this study what the binding reliability constraint is, which is providing downward reserves.

And if you then combine the two things on the left, the minimum power level and the ramp rate modification, and you add some more flexibility to the gas fleet, you see not much additional benefit, and I should say that greenhouse gas emissions generally track the curtailment numbers here, so if you see reduced curtailment, you see reduced greenhouse gas emissions, so kind of in both.

So really, we find that the central thing for gas plants that might be helpful is reducing the minimum power level of combined cycles. That being said, we didn't look at installing clutches on gas power plants, so that could be an interesting thing that we could discuss later.

But in the context of the duck curve, I think this has some important implications. So the duck curve highlights two challenges to renewable integration, both the evening ramp as the sun is going down, and the belly of the duck, the over-generation problem. And at least this study highlights the belly of the duck as much more important for causing renewable curtailment than the neck. So it mostly solves the neck by turning on combined cycle power plants as the sun goes down, but the belly of the duck really kind of addresses the question of how do we operate a reliable grid that doesn't need a heck of a lot of conventional generation on line and generating when we also have renewable production.

So I think in the interest of time, I'm going to just kind of skip to kind of one thing that I thought was important kind of like as the model, or performing this modeling, what I kind of took out of it, which is that I think at a 33 percent RPS, I think we've thought of renewables, or even before we got to a 33 percent RPS, we've thought of renewables as these kind of inflexible, intermittent, variable, uncertain generators. And while that is all true, I think there's a lot of potential to understand them at a 50 percent RPS as actually active contributors to the balancing of supply and demand. And so, I mean, to really start being able to turn off natural gas power plants in the middle of the day, I think you have to start operating renewables somewhat more like a natural gas power plant. I'm not advocating for curtailing a lot of renewable generation to do this, but I think the message is that a little dispatchability goes a long way. So with that, I'll just kind of leave you with the key findings and take questions.

CHAIRMAN WEISENMILLER: Yeah, I had a couple. First, Keith and I were at an event in Germany, U.S. State Department and German Ministry on Energy and we were trying to figure out their Grid and their Grid issues, and the really common factor across all was the shift from hourly dispatch to 15 minute and five minute made a huge difference in reserves. It sounds like you've modeled, or you're presuming when you talk about having gas plants held at a certain level for an hour, you're assuming an hour dispatch, and it's really 15-minute or five, and hopefully getting shorter. And that makes a huge difference on the ease of getting renewables into the system and also in terms of the amount of reserves you have to have.

MR. NELSON: Yes.

CHAIRMAN WEISENMILLER: So, I mean, that's part of the message, I think, which I keep telling the POUs is they have to wake up and get out of hourly dispatch down to 15-minute, five-minute, one minute, whatever it's going to take because that's going to really reduce the reserves quite a bit.

MR. NELSON: Yeah, so if we can kind of successfully bridge between our like day ahead hourly schedule and a more fine grain, closer to real time dispatch, you might be able to like, when you resolve some of the uncertainty that you had in the day ahead, you might be able to start turning off gas plants.

CHAIRMAN WEISENMILLER: Well, I mean, again that’s a different issue. So one issue is there’s a huge difference on that part, certainly the German experience was the people who did the detailed modeling there for the Germans said shortening the dispatch period had a huge effect on reserves.

MR. NELSON: Uh-huh.

CHAIRMAN WEISENMILLER: And that’s certainly been our experience with the new CAISO system here, so that’s part of the messaging for people is that shorter and shorter dispatch periods are going to be huge -- and dependent. Now, the other part, though, I mean, when I look at your duck curve part, again, a lot of the qualitative stuff holds, it’s just the quantitative stuff I don’t believe. So on the qualitative -- when I look at your duck curve, you have a very flat renewable generation and you have a very balanced portfolio. When I look at ISO today, which I do every day, you see very pronounced solar generation at mid-day, you see the net as reduced substantially from that. So it’s a tougher situation which probably explains why your curtailment forecasts are much less than the ISO's forecast. It's very hard to forecast curtailment in either case, I don't necessarily believe either number, but the bottom line is yours should be much smaller.

But I think my last question would be, you talk about flexibility, but that's the flip side of curtailment, right?

MR. NELSON: Uh-huh.

CHAIRMAN WEISENMILLER: I mean, it seemed like the only real difference is whether we're paying the renewables for curtailment or not under flexibility, but many of their contracts have 180 hours, 200 hours of curtailment built in, so why double-pay?

MR. NELSON: So I guess I've thought of it as maybe you don't even need to address this question with the existing renewables, I think you can address -- and I've submitted testimony to the LTTP that says you can address a lot of the flexibility challenges by just making sure you're including kind of dispatchability and proper payments in the new contracts. Let's see, what was -- your other point was on baseload --

CHAIRMAN WEISENMILLER: Yeah, the shape.

I mean, again, I look at your duck curve and I look at ISO today and it doesn't match very well.

MR. NELSON: Yeah, so I think it's an uncertainty of the future how much kind of we're going to address the flexibility challenges by building a different renewable mix, or by installing devices and operating the grid differently. So, you know, how much does the least cost, best fit actually get us to procure more baseload resources --

CHAIRMAN WEISENMILLER: No, best fit doesn't appear to be very optimal at this stage.

MR. NELSON: Yeah, and I mean --

CHAIRMAN WEISENMILLER: It should be, but it's not.

MR. NELSON: So as I say, it's an ongoing discussion, definitely.

MR. CASEY: Yeah, Jimmy, first off great presentation and, you know, I certainly agree with Bob in terms of the takeaways, you know, and appreciate your acknowledgement about the reliability requirements are real, that's not something we can just say, well, if you get rid of the reliability requirements, problem solved. Well, that's great except the lights don't stay on. So those have to be addressed and, you know, minimizing reliance on the fossil fleet to address them is spot on and we need to do that, so I fully support that. But I think, to Bob's point, you know, your analysis is optimistic in terms of the diversity of the renewable fleet and, as a consequence, suggests that if you could just address these reliability requirements by not relying on the fossil fuel, the over-gen issue is de minimus. And I think the reality would be we'll have much more solar than you've assumed here and it's going to require an all of the above solution where we're going to have to get after this flexibility in the gas fleet, but we've got to be looking at the regionalism to find homes for those renewables that would otherwise get curtailed, as well as storage. So I guess that's my only major concern with this, is it gives the impression that this is a silver bullet, that if we get this solved, the curtailment issue is really not an issue.

MR. NELSON: Yeah, no, understood. And I think that was in large part the point of, you know, this part of the analysis to also show there are other pathways and certainly in different renewable portfolios you're going to want to pursue one pathway more than the other. A lot of my focus on kind of the reliability requirements is because I thought they were kind of an under-discussed aspect of the integration challenge, so that's why I focused on them primarily here. But there's a lot of other work to be done in all these other areas, and I didn't mean to diminish that work at all.

COMMISSIONER MCALLISTER: So I just wanted to follow-up a little bit. I wanted to ask the ISO if this sort of dispatch discussion matched your reality and I guess I don't quite feel like I have a full answer to that yet, but some level of comfort.

So, you know, it seems like basically what you're saying is to sort of, if we can make that marginal gas, that sort of layer of marginal gas along the load shape, or the supply curve basically thinned out and replace some of it with renewables, that's basically what you're saying, you know, minimum loads on the gas and sort of make that, even though we still depend on gas at the margin, that can be thinner and smaller. And I guess, is there a technical issue there? You sort of alluded to one and I want to sort of -- you know, what's part of your idea of what that would take in terms of investment and infrastructure versus sort of having it be purely a management issue?

MR. NELSON: Yeah, so I mean I think we're still understanding that to some degree. I think there's definitely a need, and we've discussed this with the ISO to some extent for kind of more active power controls to be either installed or enabled at renewable generators so that you can have the ISO send dispatch instructions, you can intelligently curtail them. And at least in preliminary discussions with renewable developers, that doesn't seem to be a very expensive thing to do at all. I think a lot of current wind plants, or at least new wind plants that are being installed already have the capability to be controlled. But I think it's going to take a lot of understanding and kind of modeling of a grid with reduced kind of thermal spinning mass-based generation to really understand the important limits. And I think part of the point of this work is just to tee that discussion up, not to necessarily answer all the question, but, yeah, there is some infrastructure that you need to maybe modify on renewables to make them more active participants in supply and demand.

MR. CASEY: I could elaborate on that a bit. I think certainly the active power control, I think most of the new projects have active power control, and it’s worth noting that today, you know, we are in the spring months experiencing the need to do renewable curtailment and almost all of it is based on resources that economically bid in the market, so we are getting economic bids to be dispatched down and that’s very encouraging. But, you know, one of the big drivers for having, at least today, gas generation on line is the frequency response obligation that you need really fast moving machines that can respond almost instantaneously if we have a major disturbance on the system; renewables can do that, but they need more than just active power control, they need the inverter technology that will enable them to basically have a Governor signal that can instantaneously respond to a frequency disturbance. And, you know, that technology is there, but the extent to which renewables have it, we don't have a good sense of what's there. Similarly with reactive power control, if we need reactive power support, renewables can do it. How many of them have that regulation management capability? We've not been able to get good insights into that. So these are the kinds of things that need to get addressed. And getting more flexibility out of the existing gas infrastructure that's there, there's a lot of plants, we have a representative from Calpine here, that they can do a lot with their combined cycle units to retrofit them to be more flexible, but the question is, is where is the revenue going to come to do that? What's the business model to fund those kinds of changes?

So I guess as a general matter, you know, when we put out the duck curve and the concerns over generation, you know, it's not just to scare people, it's to have discussions like we're having right now is, well, how do we avoid that? What has to happen, when, where and how? And those are the kinds of things that it's better to shine a bright light on it than to assume all this stuff is going to happen and there's no problem, and then there's no urgency to get it done. So just as a general commentary, you know, the duck curve and the over-generation are being put out there to really get actions happening today on what we're going to do to avoid those kinds of outcomes.

MR. NELSON: Uh-huh, certainly. Yeah, I guess one other thing on the frequency response, I think a lot of times I also think of getting frequency response from the storage devices in the times when we're really curtailing renewables. If we're going to curtail renewables to maintain proper frequency response, we probably have our storage devices charging. And so you can get at least a lot of upward frequency response from just not charging the storage as much. So I think that's one other way that we can go in the future for that.

MR. CASEY: And of course you're going to need lots of storage.

MR. NELSON: Yeah, certainly.

CHAIRMAN WEISENMILLER: And you're going to need lots of fast ramp storage and long live, so there's a whole bunch of optimization questions there that will keep people going for a while. Thanks.

MR. NELSON: Thanks.

COMMISSIONER MCALLISTER: So we are running a little bit behind time here, so, Heather, why don't you read everybody the Riot Act and about the break time?

MS. RAITT: I think we're going to take a 15-minute break, so we'll be back here at 1:00.

(Break at 12:44 p.m.)

(Reconvene at 1:02 p.m.)

MS. RAITT: Okay, so we'll get started again and our next speaker is Duncan Callaway.

MR. CALLAWAY: Thank you very much to the organizers, it's a pleasure to be here to talk a little bit about some of the research that happens in my group at U.C. Berkeley where I'm an Assistant Professor.

Before I dive into the topic of today's discussion, I just wanted to give a very quick overview of some of the work that happens in my research group at Berkeley. We're predominantly approaching problems with engineering methods and tools, looking at strategies for accommodating higher penetrations of renewables from an operations and control perspective into power systems.

We do a fair bit of data driven and machine learning-type work using solar PV data and Smart Meter data to investigate various problems in renewables integration.

We're also working on some projects that look at the value of energy storage and large scale energy systems, taking a view and commitment-based strategy, and also have some work on value of distributed PV and distribution systems. These are things I won't actually be talking about today, but I just wanted to sort of give a flavor about the things that we do.

In the first bullet, one of the things that we do some work on is Demand Response. And so what I'll talk about today is really an effort undertaken by my students and I to ask the question, how important is it for us to be doing work in this particular area? That is, trying to harness Demand Response for renewables integration.

So I'm going to basically look at two elements of this question in the talk, specifically thinking about system level issues like ramping, load following, and frequency regulation, and an end-use focus of residential thermostatically-controlled loads. So I'll talk about water heating, air-conditioning, refrigeration, and space conditioning. The purpose for thinking about thermostatically-controlled loads, the motivation for us is that this is a resource with a lot of thermal inertia, so potentially something like a large virtual battery is a way to think about these devices. And residential because, maybe this is largely an academic motivation, but I think it's actually deeper than that; you have millions of virtually identical devices that you can develop scalable control strategies for. So given the right models, you can just sort of pick those up and move them around very quickly to manage aggregations on large scale.

So the specific things that I want to try to talk about today to give you some insight into is the size of the residential thermostatically controlled load resource for Demand Response for providing those system level services that I mentioned, starting to look at little bit into whether we can actually avoid building other forms of generation capacity with this kind of a resource. And it's something that I think we need to do more to look at, but I can talk a little bit about it today.

And then lastly, and I think this is really the punchline of the talk, is in what conditions do the economics actually make sense, sort of on a per customer level, could we make a strategy like this work.

So there's been a little bit of work on this from other groups, from Lawrence Berkeley Lab, NREL, and a few others, have looked at similar kinds of questions. We're taking a slightly different approach by using bottom up models that I'll talk to you about in just a minute, which really focus on capturing the end use performance of the loads, and I'll talk a bit more about that.

We also did a little bit of sort of checking of our work using a totally different approach with Smart Meter data that we got from Pacific Gas & Electric, and I'll talk a little bit about that.

In both cases, we're grounding the approach on understanding the end use impact as a fundamental part of doing the simulation work, so that we know are we still ensuring the same end use service to customers that they would have if they weren't actually participating in the DR.

Okay, so let's see, I had one other note that, right, so what I'll talk about today, I don't have a figure on this, although we've looked at this a little bit, so for the most part we're not going to speak specifically about correlation with the demand for renewables balancing, but I'll hint at that a little bit.

Okay, so this bottom up model, I just want to very quickly walk through how it works, the basic idea is that -- this is one of the reasons I think residential thermostatically controlled loads are interesting, and light commercial for that matter -- most of them today, until we get bigger roll-out of variable speed compressors, most of them operate in just this on/off fashion, so this figure here you can see this would be, for example, for an air-conditioner or a refrigerator where, when it's off, it warms up in temperature which is measured on the X axis, and then when it's on it cools back down. And so we think of this just as a hysteresis loop, or bang bang control is what the control people would call it. And so when we do our assessments of resource potential, a fundamental assumption that we make in the work is that all of the control action will keep the loads within their original dead band of temperature; that is, we’re not going to compromise the end use service at all, we’re just going to change the timing of when these things operate.

So we use a variety of different data sources to get at this sort of statewide potential question, the Residential Appliance Survey, CEC forecasts for a number of households by climate zone, a number of different weather forecasts, we got from Lawrence Berkeley Lab a water heater demand profile. And then, as I’ll talk about very briefly, actually in this part here we used EIA Residential Energy Consumption Survey Data to basically tune our model to make sure that we were getting as close as possible to what we believed were the right answers. So the way that that tuning happens is that there’s some parameters for these thermostatically controlled loads, so we could just estimate based on just sort of engineering judgment what’s the typical capacity of an air-conditioner, what’s its coefficient in performance. But the harder things to estimate are the things that govern really how fast you move through this temperature space, what's the thermal inertia of a device?

And so we basically tune those measures, those parameters, so that our results match up to what the EIA RECS Data would predict at the State level for annual energy consumption.

So here is one of the punchlines of the talks, so this is looking at over 8,760 hours of the year in 2014, how much power capacity comes from just the residential thermostatically controlled resource. And the various striking thing, and what people sort of their eyes pop out a lot when we show this, is that we say the peak is 44 gigawatts of potential DR capacity. And the way to think about that is this is non-coincident load, essentially. So this is if we stacked up, if we put all the air-conditioners and all the refrigerators, all the water heaters on at the same time, we'd have roughly 44 gigawatts of capacity. So how much of that is actually on line and operating at any one point in time, that you could curtail to do the sorts of things that Jimmy was talking about earlier, is on the order of 15-30 percent of these numbers here. So for example, if you think about down here we have refrigerators and electric water heaters summing up to a total of about 10 gigawatts of capacity, it's going to --

CHAIRMAN WEISENMILLER: Yeah, you realize California doesn't have electric water heaters, they're very small, a very small fraction.

MR. CALLAWAY: No, no, no, I totally understand --

CHAIRMAN WEISENMILLER: Okay, fine.

MR. CALLAWAY: -- but this is taken from the RAS data, it's about 10 percent.

CHAIRMAN WEISENMILLER: Exactly.

MR. CALLAWAY: Right, yep. No, that's all baked into the analysis, yeah. I'm going to talk a little bit more about that in just a second.

So maybe one of the more striking things, though, is that there is a -- and this is something that by using this model we can get at how much energy storage capacity is in this aggregation of devices, and you can think of this basically as a virtual battery of devices. And the peak is around 12 gigawatt hours according to this way of thinking about things, but at its minimum it's on the order of about eight, and that's coming from the fact that water heaters and refrigerators are constantly in operation and, by the assumptions of the model, available to be moved around in that temperature dead band.

So this of course is just a technical potential, right? So we're just saying how much is actually out there and what's possible. Okay, so then also we looked at a scenario because electrification is obviously something that people are talking a lot about for greenhouse gas mitigation, we looked at a scenario where we electrify 10 percent, an additional 10 percent, of furnaces, so we moved to an air-source heat pump on the furnace side, and then an additional 10 percent of water heaters, so getting up to about 20 percent statewide for electric water heating. And in that case, as you would imagine, the numbers go up in terms of the resource capacity. And probably the most interesting thing, as you would expect, but this is sort of driven by temperature records and this thermostatically controlled load model, you can see that the heat pump addition to an air-conditioner provides something that starts to become a much more uniformly available resource, but it’s still not available across all hours.

I think a really important thing that we didn’t capture here that is worth thinking about and maybe some others have in this heating electrification space, of course if you electrify, if you provide somebody with a heat pump, you also provide them with the potential to cool in the summertime. And there are some implications I think to that in terms of overall energy consumption, but that’s not something that we looked at here.

We did do -- I just want to very quickly talk about some of our work with Smart Meter Data where we just wanted to sort of benchmark the numbers that we were getting on air-conditioning. So we have a sample of 30,000 Smart Meter interval meter accounts from PG&E, randomly sampled from PG&E’s service territory. And we basically did a disaggregation exercise to work out in what hours is air-conditioning operating for these loads, and basically what’s the temperature response of all of those loads, like how many watts per degree Fahrenheit of increasing outside air temperature. So there's a lot to talk about in that study, but the one thing that I wanted to talk about here is that if we think about what the -- and this would be a curtailment potential. The peak resource just in PG&E is on the order of 3.8 gigawatts, that's peak and that would be on the hottest day of the summer, which would if you extrapolate it out to the state, it's -- and this is a big assumption – the same penetration of air-conditioning across all of the utilities -- that would work out to about a 10 gigawatt resource. So from our simulations we saw something on the order of 30 gigawatts, but this is actually pretty much what we would have expected because that 30 gigawatt number from air-conditioning was basically the non-coincident load from all of the devices in the state, and this 10 gigawatts is the coincident peak.

One thing, actually I think one interesting point to make, something that is nice that we can do with this PG&E data is that we can look to see, if we basically rank customers by how big their DR potential is, we see that about five percent of customers hold about 41 percent of this air-conditioning Demand Response resource potential. So I want you to keep that in mind when I talk about the economics in just a second. But it suggests at the very least maybe some targeting is useful for the purpose of trying to get DR, providing value at the system level.

Okay, so then finally I want to come back to some of the results that we have from working with this bottom up model, the simulation model of thermostatically controlled loads. So we took data from the ISO from their Ancillary Services markets, in particular frequency regulation, both non-spin and spin. And basically, just given the time of availability that we get from the model, timing of availability of these resources, we just bumped that up against what the prices are that we see, and then backed that out and say, “Okay, what’s on a per device basis? What’s the value of these resources?” And this kind of really cuts to the bottom line, I think, in terms of whether or not this is an interesting area or a useful area for us to be pursuing as a means for mitigating renewables variability. What we see is that on a per device basis, using today’s prices for these ancillary services -- a really important caveat -- the numbers are probably inconsequential to a typical energy consumer. It is interesting to note that if you have a combined heat pump air-conditioner, at the maximum, and I forget in exactly which climate zone it was, the best value you could get is on the order of $56.00, this is per year. And then if we add that to spin value, something approaching $60.00 per year.

So a couple of things, just to think about the context of this. If you think back to that figure that I had showing the cumulative distribution of customers, there are some customers that the value could be quite large for, and that’s something that we can’t capture with the bottom up model, but we can at least hint at with the Smart Meter data that I was talking about before.

So it could be that you could get a significant amount of DR potential providing ancillary services if we target the right customers, and it could be economically interesting for those customers.

What I’m staying silent on here is the cost to actually do this. So this is just the value to the system. And so what it would actually cost to do is a whole other question, and it's not something that we've looked at in a lot of detail in our own work. I think just because these are very difficult things to estimate, we are actually trying to do some pilots where we start to try to get a handle on for one given way of doing it, what it would cost.

But I think one important thing to keep in mind is that there are a lot of complementary value streams, whether it's the equivalent of resource adequacy, or sort of targeted distribution circuit level demand response, there are other ways that it could make sense or there are other things that we could stack on top of this for it to make sense, but these numbers alone I think suggest that maybe there are bigger fish to fry for providing ancillary services.

One thing I will say, just sort of an interesting little side note, is that one of my colleagues has been running a pilot in Con Ed in New York where they're actually running a lottery, or raffle system, where instead of just paying everybody the flat payment for DR, they get basically credits to put into a lottery. And then some people get a big payout. And he's actually finding that the response for the people that are participating in the lottery is significantly larger than those that don't.

Okay, so getting back to just recapping things. How big is this residential thermostatically controlled resource? Very large from a technical perspective. From an economic perspective, though, I think the answer is very unclear. Can we actually avoid building other forms of capacity? I think yes if we use water heaters and refrigerators, perhaps that's something that you knew the answer before coming into this talk, but even with water heaters and refrigerators we see that there is a very large resource in terms of megawatts or gigawatts potential. And then just sort of recapping this part about the economics, it looks like the value is small on a per device basis, but there are complementary value streams, maybe you could run a raffle of some sort to try to get additional participation, so I wouldn't completely rule out the idea of doing this type of ancillary service provision, but I do think from an economic perspective it's going to be challenging.

And that's all I have to say.

CHAIRMAN WEISENMILLER: Thanks. A couple questions and observations. The first one was, when I got here we started asking about Demand Response, and the things that amaze me was we don't have much fast acting Demand Response. You know, PG&E I think I asked someone if they had a 2,000 and how much could you get in 10 minutes? Two megawatts. SDG&E when San Onofre went out was 71 megawatts. How much of that could you get, you know, in 10 minutes? Zero. How much could you get in 16 hours? Some. Most was 24 hours. So in terms of trying to move -- Edison is a little bit better, they have pool pumps --

MR. CALLAWAY: Yeah.

CHAIRMAN WEISENMILLER: But, again, the question on, particularly if you're trying to use this as ancillary services, it can't be 24 hours from now you're going to do something.

MR. CALLAWAY: Of course, yeah. So --

CHAIRMAN WEISEMILLER: And so that gets to the institutional stuff, the potential is there, the institutional stuff, the last time I think when all the parties came before the PUC with a settlement proposal on Demand Response, is people pointed out this is going to take longer than World War II to get to any results. So again, we're still, I've been here five years trying to push this along. Certainly at this point, you know, again, it's a long time. But in terms of -- this is great potential, but it's sort of frustrating not seeing it move. The other thing, but probably more in terms of your research, the one interesting question was if you go back to the Resnick Report on the Grid, you know, from a few years ago, one of the things they point out is that the ISO systems deal hundreds, maybe thousands of transactions; now, when you look at a future where you could be saying, "Okay, you've got millions of water heaters, you've got millions of vehicles, you've got millions of storage, you know, you have all these millions, the softwares don't like the scale. And you could also have some really funky results that, if you have every water heater suddenly flipping on or off at a given time, so there's a lot of interesting control strategy sides on the software as we move from what's been very much a wholesale focus to much more on the distribution circuits.

MR. CALLAWAY: Yeah, and that's in many respects what draws us to working on these problems, so a lot of our research focuses on how do we think about sort of hierarchical control schemes that will stick an aggregator in the middle and make it so that the ISO is not seeing millions of devices showing up in their system, they just see one controllable resource.

On the sort of speed and response time issue, in many respects that's just sort of a communications infrastructure problem, right? And one that you can resolve if your signaling pathway is broadband internet, but I think there are a lot of reasons to focus on signaling pathways that go over AMI because, you know, that infrastructure is there, the utilities own it, they'd like to find additional value for it. And it's possible to do. So AMI is very slow for pulling information back. But the Silver Spring meters here, or in PG&E, are not as well suited for this, but a number of utilities have meters that you can broadcast information to very quickly. And so if you're distributing broadcasting information to all of the devices at the same time, and they locally decide what to do with that information, you can get I think an adequately fast response. But you would still need a little bit of additional infrastructure to basically listen to that broadcast and decide what to do with it locally.

CHAIRMAN WEISENMILLER: I think the other thing I should -- it was just mentioned, I'll channel Picker for a moment, in that one of the things that President Picker, you know, everyone runs into his office saying storage is the answer, Demand Response is the answer. And it's like could people start thinking about packages more? And certainly whether more interesting preferred palettes took demand response, but also coupled with storage. So for a number of large commercial buildings that you had the combination of the two technologies, but certainly much more interesting and powerful than the individual silos.

MR. CALLAWAY: Yeah, no, that's an interesting thought and I think that what we see here, what we can get at with some of these approaches that we're taking is what is the energy storage capability of this aggregation of loads, and it turns out that, you know, you get a C Ratio of like one-fourth, which is -- it's not very good, as you might think a battery would be. So it's more maybe like a flywheel, let's say. And so maybe there's a similar coupling that you can do, or the faster stuff you're going to use DR for, which is a little paradoxical, or at least they're counter to the way we think about it now, and then energy storage providing longer timescale balancing.

MR. CASEY: Duncan, first off, I think it's great you're looking at this, but I think there's some value proposition in the wholesale market that you're not capturing here, that if you did I think might change the answer, at least I hope it would. And that is, you know, with regard to the integration challenge we have.

MR. CALLAWAY: Yeah.

MR. CASEY: And the need to not rely on gas resources for the balancing. When you look at the duck curve, you know, that's a very predictable frequent thing, it's not like a contingency on the system that happens once a year, we're going to be dealing with it every day. And traditional demand, you know, the basin

Interruptible Programs are not the right animal to get after this, it has to be something the customer doesn't even see or feel.

MR. CALLAWAY: Right.

MR. CASEY: And these are the types of loads that if we can aggregate them to scale, and the good news is we do have an aggregation model in our market that will allow just that, you know, the ISO doesn't want to be controlling water heaters, we allow aggregation up to 500 kilowatts as kind of the minimum size for our market. And we have a product called a Flexible RA product –

MR. CALLAWAY: Right.

MR. CASEY: -- that the utilities have to procure, it's a huge revenue source for resources that can provide economic flexibility in addition to whatever reserves they might earn, as well, in the market. So I would just note that, you know, we're really hopeful that with that requirement the economics of this can really pencil out.

MR. CALLAWAY: Maybe I can use this opportunity to ask for the services of the ISO because we actually -- so we did this work before, basically there's some shadow prices that are available in this Flex E Ramp, that are available now, that we didn't have access to before, but I had a student that's been, all last spring basically, trying to pull the data down from Oasis on the shadow prices of the Flexible Ramping outcomes, and it was very difficult and tedious for her to get those data. So we'd like to be able to work with those kinds of data to do these kinds of studies in the future.

MR. CASEY: Yeah. What you're referring to is something different, which is this flexible ramping constraint we enforce in the market --

MR. CALLAWAY: Right.

MR. CASEY: -- that has a pricing element to it that can be captured. What I was referring to is within the context of the RA requirement that we have in California, we just this year added a flexibility requirement where a certain amount -- so when the utilities go out and procure capacity on a year-ahead basis, a certain amount of that capacity has to be flexible and that's a bilateral revenue source that is available.

MR. CALLAWAY: Okay.

COMMISSIONER MCALLISTER: So I really

enjoyed your presentation, Duncan. I'm really happy, again, that you're looking at this. And this is very close to my interests and I feel like these conversations haven't happened as much as they really need to, and even if this is sort of a nascent idea, I think it has a lot of potential to figure out how to be relevant in the new kind of distributed multi-polar system that the Grid is becoming. So I feel like it's very relevant.

So just a couple questions. I really like the temperature response analysis based on the AMI data and I think that opens up some pathways for discussion. I guess, you know, I like this idea of pre-identifying which customers have the potential so that we can set the system up to go after those, you know, harvest those savings cost-effectively, aggregate those, and not sort of be distracted by all the other stuff where there's not potential.

So this is an analytical issue, but it's also a program issue, and I kind of want to, while we've got multiple agencies up at the Dais, I think it's an opportunity to kind of raise that question about program design in terms of how we go out and really do it effectively and get what we want, and then know that we're getting what we want, right? So there's an analytical, but there's also a program and they're very related.

You've assumed sort of voluntary participation? Or I guess maybe I'm sort of reading that in your presentation, but you know there is rate design going on, there is this appreciation that individual customers impose cost on the Grid, and that can be built into the rates discussion, I think, without actually treading on any PUC or POU specifics here, but I think it doesn't have to be voluntary and so I think this targeting and requiring is at least an option down the road if we figure out, okay, well, you know, go ahead.

CHAIRMAN WEISENMILLER: Actually, I would point out when we were looking at requiring programmable thermostats, that at the Commission Business Meeting several Commissioners went over to talk to the Governor about it and we dropped that requirement.

COMMISSIONER MCALLISTER: Yeah, no, there have been mixed experiences with that, for sure, yeah. But you know, in terms of what services a customer is actually paying for, it does matter, so it might be by region, it might be by climate zone, there might be lots of ways to think about this and to really target effectively. So I guess I'm leading up to a question: have you had interactions with, say, some of the vendors on this, like the trains and carriers and the water heater manufacturers, and kind of like looked at sort of pragmatic issues about implementation? You know, certainly it's not rocket science, and we've got the AMI data that we can leverage, and communications that you can leverage, but I'm wondering if you've drilled into sort of some of the details of how it might actually work?

MR. CALLAWAY: Yeah, we've reached out a little bit and had a bit of trouble getting traction, finding the right parties to talk to, you know, as you can imagine Trane is a big organization to try to penetrate. We have been getting a little bit more traction talking to a couple of DR aggregators that are focusing on commercial loads, and are now interested in getting into the residential space, and so we're actually just putting in a proposal to the DOE to do exactly that, to try to do some development work there. But any resources that you can point me to, I'd be happy to follow-up on.

COMMISSIONER MCALLISTER: Thanks. Anybody else? Okay, let's go on to the next presentation. Thanks very much for being here. Thanks a lot, Duncan.

CHAIRMAN WEISENMILLER: Thanks for your participation today, I appreciate it.

MS. RAITT: All right, thank you. Our next speaker is Solomon Hsiang from U.C. Berkeley.

MR. HSIANG: Hi, thank you very much for having me. I should say upfront that I was asked to come here and speak about how sort of a lot of work in economics can help inform the modeling exercise that many people here are engaged in. And in particular, a lot of work that I've been involved in is thinking about how the economy in a larger sense is going to evolve as the climate changes. And so if we're moving forward to a world where not everyone is mitigating as deeply as California is, the climate might be changing and those economic consequences should then be fed back into how we think about modeling our energy future. So the work that we're doing to a large extent is trying to detect how different changes in the environment, or changes in policy are having implications on the energy system. And I read through some of the analyses that came out of the last round of IEPR funding and was trying to think of the ways in which Applied Economics could make contributions and help sort of push the envelope further.

So on the left here are just a couple of ideas for why Applied Economics today could be useful for collaborations in the future. A lot of work in Economics is statistical and a benefit is it allows us to simplify very complex economic processes, sometimes captured in just a few key parameters that then could be fed directly into some of the modeling exercises here. And in particular, a lot of work in economics has focused specifically on causal inference, so understanding how Policy A or how change in the Environment A affects some outcome, B. Okay, so there we can make really strong statements about what's going on.

I also think it's useful for sort of implementing -- imposing reality checks on some of the modeling assumptions, so I was reading through some of the reports and trying to understand the numbers that are going into the models, and in a lot of cases real world behavior generates things that are different than what is assumed in the models, and I'll show you some examples of how we've now used empirical estimates to calibrate models, and then produce projections based on that. And so I think that's a big dimension for future action. And in particular, also, a lot of research now a days is pointing out that people's behavior is often very sub-optimal and a lot of these large-scale modeling exercises assume a high level of optimization, but people are subject to all sorts of behavioral biases and we're learning what those look like, and those actually can be incorporated into these types of models in the future.

And then finally, one of the biggest benefits of thinking about things from this economic standpoint, I think, is that it points to various interlinked markets. So for example, I will make the case to you very briefly that figuring out where people migrate and settle throughout California in the future is probably going to have zero order impact on future energy demands, and that to a larger extent is going to be affected by land prices, the job markets in the large cities and in the Central Valley, and so if we don't think about what the land markets are doing, we're going to be getting the energy projections off by a large amount.

On the right, there are some weaknesses of working with Economists like myself, so first of all, like I said, the statistical approaches are simplifying things that are very complex, so on the one hand it lets us simplify things, on the other hand it forces us to simplify things in cases where that's not always appropriate. There are also just a lot of gaps in our knowledge, we don't know how elements of the economic system behave and we have to be sort of forthcoming about that, I will point to a few things, but many things are still unknown.

And then the next two points are important. Everything that we're pulling out of the data is based on historical data and historical behavior. And so there's many aspects of the future that might differ in very fundamental ways from what we've seen historically. And so we can only make projections based on sort of these types of calibrations to the extent that the future looks anything like the past in terms of people's behavior and in terms of the environment that people are faced with.

Similarly, if we discover breakthrough technologies, those are going to be unprecedented and those will not be captured by any sort of pre-amortization based on historical experience. And also, many of the markets that are linked may not be captured by the stylized way in which we approach these problems.

So I want to go through just a couple of the recent contributions from the literature just because I think the ways in which they are immediately applicable is quite obvious. So for example, here is a calibration of what demand from millions of users throughout California is on a daily basis based on the temperature of the day, okay, and so this is very recent, like very cutting edge work by Max Auffhammer, my colleague at Berkeley, and what you see is unsurprising, CDDs and HDDs increase electricity demand. What's nice here is that this is accounting for what the people on the ground are actually doing. And it's removing all sorts of unobserved differences between individuals. Now, this is useful and can be plugged directly into the projections that are currently being pinned down by parameters that are assumed. But importantly, in very closely related work, you know, not all CDDs are the same. And in the current models that were being projected there was an assumed relationship between CDDs and energy demand that was believed to be held fixed. But of course, individuals are living in hot and humid environments, they're going to have many more air-conditioners than people who are living on the coast where it's generally cool. And you can see that very clearly in the data. So, for example, if we look in Fresno, warming leads to a very steep increase in electricity demand, whereas if you look at San Diego, for example, temperature has effectively no effect on electricity demand because no one has air-conditioners to turn on.

And so thinking about this, what we Economists call the Extensive Margin, how people are going to be adopting more air-conditioners in the future as the climate warms, is going to affect not just how many CDDs there are, but what is their effect on the energy system. And that's something that we now have reliable, real world estimates for, that have been used to think about how in the future this curve might evolve, okay, so Max Auffhammer's work has sort of shown us that, especially on the hot side, you can see that as the state warms, we can now project how people will adopt more air-conditioners, and then what that effect will be on the intensive margin, how much energy they're using. And some of Max's projections here are pointing out how this correction, correcting for the number of new ACs that are adopted throughout the state, is going to substantially affect demand projection. So in his estimates, the additional demand from climate change in the future is actually 50 percent larger once you take into account the fact that a large number of individuals will be purchasing new air-conditioners that they wouldn't have purchased had the climate remained the same.

Now, these types of numbers are purely simple empirical statistical relationships, but in some recent work with colleagues we released a

Risky Business report, which is actually the national assessment of the economic risks of climate change, and in that work we took numbers that Max actually had produced, that I was showing on those previous slides, and we hooked them up to a large engineering model to develop projections. So what I'm showing you here is just one result from that analysis which is actually looking at energy demand nationally across the United States, and there's a large probabilistic component to thinking about the future, thinking about climate change. There's discrepancy between different scientific models about what the climate is actually going to do, and there's also statistical uncertainty about what we've seen in the past. And when you combine those things together, you get distributions that look like this about what things might happen in a specific climate scenario. So this is sort of business as usual scenario and time here is moving vertically, and you see that as we move towards a warming environment, even if the population is held static, demand shifts to the right and, importantly, the distribution of potential demand outcomes also increases, so there's a large amount of uncertainty imposed by these changes that emerges from both a statistical uncertainty and the climate uncertainty.

One reason I point you to this is that it's a coupling between these sorts of empirical estimates from the economics and the engineering models on the other side. Okay, and that work was actually recently -- we drilled down into it to produce estimates just for California, which might be of interest here, looking at different regions and, as many of you know, one of the things that really matters most is the fact that everyone throughout the state is demanding on the same days because the temperature is going up, and so we turn on the peaker plants and prices rise dramatically. So for example, based on these empirically calibrated estimates here in the Sacramento Valley, the energy costs are expected to rise. There's a two-thirds probability that it's going to be in that green band, which is just increasing costs by 10 to 30 percent, based on nothing but warming alone.

Another important factor that's emerged in the literature quite recently is that individuals' income seems to be tightly linked to the environment. And so income is going to affect people's ability to build larger homes that may be more or less energy efficient, it will change their demand for cooling systems, and so in this graph what you see is results from a national study. As you move to the right, you see people's daily income decline substantially, okay, on hotter days. And we have done a variety of simulations suggesting that warming in the future is going to substantially cause the income trajectory of individuals to diverge from what it would have been had the country not warmed. So we're counting for that divergence. It will be important for thinking about the demand for various types of infrastructure and energy services.

And in particular, I think one of the key vulnerabilities of California is thinking about all of the agriculture that's at stake, so when you look at people's agricultural income, which is the right panel here, what you see is that a hot day is leading to a reduction of income of roughly $20.00 per person in the United States Counties across the country.

This is going to affect the structure of the labor market across the country and, if anything, what we've seen in the past is climatic disturbances in agriculture lead to a lot of migration towards cities. And so there's going to be populations that are moving, they're going to be trying to find better jobs for themselves, but when they move they're going to create energy demand in those new locations and, importantly, their energy demand in the new location is going to be based on the climate they face in the new location.

So if people move to San Francisco, they might demand less energy because it's going to be relatively cooler, but if people are moving towards sort of the cheaper regions where land is a lot less expensive, it also is much warmer and they're going to have heightened energy demand. So that leads us to the point that, you know, in a lot of these projections we're estimating there's going to be 40 million more people in California by the end of the Century, where are they going to be? If they end up in the regions that are hot and are getting hotter, as we move into the future, we're going to dramatically increase overall energy demand just based on individuals, alone. And if we can steer those people to locations that are substantially cooler, that's going to reduce the effects on the energy system. And so I think accounting for what we know about people's mobility is going to have first order effects on how we project demand throughout the state going forward over the next several decades.

Finally, the last points I want to make in the last minute is just that there's been a lot of other recent studies that can be used to parameterize other elements of the model, so for example, Meredith Fowlie and other colleagues at Berkeley have done recent studies not in California, but pointing out that sort of weatherization activities have been less effective than is sometimes assumed by some engineering models, and now I think the right reaction to those types of studies are to adopt some of these numbers and just incorporate them into engineering models. In many cases, the reason things are less efficient are because individuals on the ground make a lot of decisions that were just not in the Engineering models, and that's a reasonable first cut, but we need to iterate on the process and provide feedback to the engineering models.

And then finally, there's also a lot of work on how the different markets are interlinked and so, for example, this is also not thinking just about California or even future climates, so this was my colleague Reed Walker was studying the Clean Air Act Amendment and trying to understand the cost of compliance, and what we actually saw at that point in time is that, as noncompliant plants were closed, individuals had to go look for work elsewhere, and in that time when they were looking for work elsewhere there were foregone earnings, they were basically not making money that they otherwise would have, and we can actually measure that using Social Security data.

So there are many estimates that help us think about how the labor market, for example, is interlinked with these type of regulations and can give us better estimates of what the true cost to society is of certain regulations because in some cases they might also be benefits, okay, I don't want to be pessimistic here.

Finally, the very last point is that one of the recent developments is pointing out around the world the largest emissions of greenhouse gasses in the future are not going to come from California, they're not even going to come from the United States. They're going to come from emerging economies, places like Brazil, Mexico, China and India, and what we're seeing in these different regions is that as populations get higher incomes and are better able to achieve standards of living similar to what we have here, they demand tremendously more energy. And so to the extent that we can design systems that are scalable and even exportable, we can look for innovations that can be sent elsewhere in the world, we will amplify the impact of those innovations because it will be mitigating greenhouse gasses in some of the fastest growing carbon markets.

So I just want to end there. There are many opportunities, I think, for collaboration between people in this room and people who are working on these sort of empirical economic problems, and in particular I want to point people towards thinking about sort of the extensive margin of how demand is going to evolve in the future, how income is going to affect energy demand, and how the distribution of potential earnings based on climatic changes is going to really affect how populations are distributed across the state, and that in turn is going to have first order effect on the demand structure. Thanks a lot.

CHAIRMAN WEISENMILLER: Thanks. I was going to ask you one question. I was at a SEEP Conference last week and someone pointed out obviously greenhouse gas emissions is a global issue, you know, and to the extent we have a Cap-and-Trade, that there can be effects if different sectors have different degrees of compliance with Cap-and-Trade. And I pointed out that the utilities sector in the last ARB results was 20 percent below 1990 levels, which means that the other sectors have less of an impact, they all gave PG&E and SDG&E a round of applause for taking more of the burden, but so one of the questions is thinking about some of the -- you know, I think we expect the utility sector to lead, but it is probably worth thinking of in terms of economic impacts what if any impacts are from that disproportionate leadership role. Another question I just wanted to ask is one of the things that we always worry about is what are we missing in our forecasts? We do include climate change, but having said that, looking longer term the types of errors people have made, one is technology, if you go back to what we adopted in the '80s, there was no such thing as computers, or the sort of panoply of devices that are in people's houses now. Certainly if you look back from the '50s, there were forecasted sort of the suburbanization of America and women joining the workforce, both which no one was expecting it at that point. So the question in part, particularly for these longer term scenarios is what are those non-energy per se things that are going to have big effects on what the scenarios should look like?

MR. HSIANG: For sure. That's, I think, part of what I've been pointing out are some of the weaknesses in the studies that I was looking through, but as I pointed out in the beginning, innovations that are things we can't even imagine today, like the Internet if we go back in time, are very hard and inherently difficult to predict. I think if someone could go and think about what the rates are of innovation and what are the rates of unanticipated efficiency gains, for example, in different sectors, and can use that to go forward in time, to think about what the gains might look like. But of course, like I said in the beginning, that's sort of one of the inherent difficulties of trying to project anything going forward. And so the exercise where we were thinking a lot about uncertainty becomes important because there's also innovation uncertainty, as you correctly point out, for sure.

CHAIRMAN WEISENMILLER: Well, again, thanks for being here. Interesting conversation. Let's go on to the last but not least, Guido.

MR. FRANCO: Good afternoon. So I'm going to talk about the developing of the next generation of energy scenarios for California. Before I do that, I want to provide some background information.

And the first thing I want to point out is that we have been working on climate change impacts to the energy system for the last 12 plus years and I think we have made a lot of progress.

I think we're one of the leaders on the national level with respect to this aspect of the research. But what we have done so far is to look at the energy system of today and superimpose the climate of the future, to try to understand what will be the effects. For example, if we experience the temperatures of the end of the Century and today, we'd have a decreased efficiency of thermal power plants, we'll have increase in demand for electricity due to the peak days, we'll have decreased in efficiency on transformers, even PVs, Photovoltaics will see a reduction on the order of about two or three percent of efficiency.

So you add all of that, it means during a peak day we'll need to increase capacity on the order of 30 to 40 percent. So that gives you an order of magnitude of what will be the impacts. Again, but if we assume that the climate of the future is superimposed to the system of today.

As the Chairman indicated, the 2013 IEPR Report, you look at the next 10 years, and estimated that it will be an increased capacity on the order of 1.6 gigawatts. That's not a lot, but it's two large power plants and I think it's important, and it’s the next 10 years, the issue with climate change study, the increasing temperatures are not going to be linear, they’re going to accelerate with time.

At the same time, we have been talking today about the rapid transformation of the energy system, what we need to do to reduce greenhouse gas emissions by 80 percent. One of the problems has been that we are not really considering climate change and this is an important issue because climate change by itself will create significant impacts and if we don’t consider those impacts, we may be making mistakes with respect to the projections of future energy scenarios.

The figure on the right bottom is estimated costs and there is a wide variation of cost, for example, in 2050 the upper and the arrow bar, it’s not an arrow bar, but it’s an estimation of uncertainty. The cost goes up if you assume, for example, extensive amounts, if you assume for example, in this scheme it was a very simple exercise, hydro by 50 percent. It’s an unrealistic assumption, but it gives you an indication of the importance of hydro, even by

2050.

But at the same time, it doesn't make sense. A 50 percent reduction for the Western United States, it doesn't make sense. For example, climate projections suggest that there will be more rain in the Pacific Northwest, more precipitation, and more rain in the west part of Canada. At the same time, heating degree days will go down, so there are some papers suggesting there will be excess capacity in the winter time. So those types of things, I think, we need to start considering.

Okay, so this is the way we do analysis or economists do analysis, let's say here the power costs, the average power costs for the Western United States in different years, the red line shows the business as usual, let's see the RCPA.5, so the costs are much lower than if we have to reduce emissions by let's say 80 percent by 2050, that's the RCP4.5, you know, the costs are much higher. But one problem with this is that it doesn't take climate change into account. So what will happen with the cause of the green scenario, the RCP4.5? Of course, it will go up because we have higher temperatures, we need more capacity. The amount will go up. But what will happen with the red line if we start taking climate change into account? Remember the temperatures for RCPA.5 will be much higher than the temperatures for RCP4.5.

So one study that I just found, it was released I think a week or two, suggest that the overall cost will be compatible for both the RCP.5 and RCP8.5. So it’s a paper that was supported by the U.S. EPA, MIT, Pacific Northwest National Laboratory, and ICF did the study, and while we take lessons is also that you can different results depending on the electricity model that you use. So it’s not surprising, but I think it’s important to take that into account.

So a piece of background information. So we’re going to start the next California Climate Change Assessment that is being led by the California Natural Resources Agency, there are about 20 agency studies involved in the study, there will be like let’s say 60-80 scientific papers that will come after that. A report to the Governor summarizing the results will be issued in 2018. The Energy Commission is a very active participant of this study. We are commissioned the energy-related studies for the fourth assessment. The Natural Resources Agency's commissioned the non-energy-related studies, but all these studies will use a common set of both climate scenarios. By the way, it will be quasi-probabilistic climate scenarios, quasi-probabilistic (indiscernible) scenarios, and also we try to use compensation of socioeconomic scenarios. And that is very important because we wanted to inter-compare, we have to integrate all these studies and overall view of California.

This graph on the bottom is new results from a new downscaling technique that has been shown to be superior to prior downscale techniques for California, showing on the left, at least my left, for you left, too, that the minimum temperature will go up at a faster rate than the maximum temperatures on the right. That is in agreement with what we have in California and a lot of places in the world.

So let me talk now about the new research project that the Energy Commission just started. It will involve E3, LBNL, and Berkeley as a team, and U.C. Irvine. So for the first time, there are two things that will happen for the first time, first we will integrate mitigation and adaptation. The 2013 IEPR mandates, at least that's my interpretation, to start looking on the revolution of the energy system not only to reduce greenhouse gas emissions, but also to make it less vulnerable to climate impacts.

In addition, well, and we will do that basically having a common view of mitigation and adaptation. It's also mandated from the Climate Action Team Research Plan, we will generate in that research plan, we have a chapter on mitigation, a chapter on adaptation, and we were told by the Governor's Office no, you have to put one chapter of mitigation and adaptation. We complained, but they didn't listen to us, I'm glad they didn't listen to us, so now we have a very robust chapter on both mitigation and adaptation and how they need to be combined and considered as a whole, as one thing.

And there are multiple options towards that, toward a changing climate, one option is called a win-win strategy and we're also searching for this no regrets type of -- not only no regrets, but also win-win strategies. For example, microgrids that get the energy from renewable sources, so here is the Borrego Springs in June, just last month, so San Diego Gas & Electric has to make repairs in I think the transmission line that will have required to cut the power flows to Borrego Springs for 10 hours because they had a Microgrid, you know, they were able to continue operations. And I think this project was also funded by the Energy Commission. So we're looking for these win-win situations where mitigation and adaptation contributes to the solutions.

Okay, so the potential features of the study, we're looking for input from this audience, from the Chairman, from our sister agencies about the design of the study. But one thing is that we would like to use a common set of reference scenarios, so the three groups will use the same type of assumptions about also technology cost, vulnerability, at least for the reference scenario. We will be compatible with the next California Fourth Assessment using these common set, the same climate scenarios and (indiscernible). We will start taking into account the impact of climate change to the energy system, so for example how PVs will be affected by high temperatures. The research project is funded by the CPUC, with LBNL on Demand Response, it's like a supply curve for demand response, that's my incorrect perhaps understanding, but it will be done by March 2016, so we will try to use that information to improve the representation of the Demand Response in the study.

There will be three electricity models, one will be the Pathways, the other one is the High Grid Model that U.C. Irvine has developed, and then the Switch Model from U.C. Berkeley, and there will also be some stochastic modeling done for this project. So, I mean, we will also be asking for what are the policy type of questions that we'll need to address in the study, so for example the issue that was referenced before about the movements of goods, I mean, how important or how we should model that and what are the implications, different policies on overall demand of energy, but also making the energy system less vulnerable to climate impacts.

So we also will be starting to, I mean, one of the things that we tried to do is to do more in-depth distribution scenarios, a representation of the distribution system in the modeling work. And also I think at one point we would like to start also using this modeling system to inform what energy technologies are critical, like for example heat pumps may be critical ones, but there may not be enough work doing that. In addition, heat pumps, also used refrigerants and according to the ARB refrigerants, if we don’t reduce the amount of emissions from refrigerants, we will not be able to achieve the 80 percent reductions by 2050. So it’s both an energy and emissions scenarios type of issue.

I also would like to start incorporating the information we’re gaining from our research projects on technologies, you know, how to better represent those energy technologies in the overall work for this study. With that, thank you very much.

CHAIRMAN WEISENMILLER: Thank you. I was just going to make a couple brief comments, one was I was going to encourage Scott to talk to Picker as, you know, at this point people are starting the detailed engineering on the distribution system and I guess part of the question is are there scenarios we could be developing here that can illustrate some of the potential possibilities there, and also technologies. Again, you hear a lot of people coming through the PUC talking about technologies and, again, talking to Michael Moore about the more than Smart effort, he's really trying to get people to look more at packages and less, you know, "Here's my specific silo, give me everything." But to the extent we can actually come up with pretty reasonable areas there.

I think the other observation I was going to make, you know, when we were doing the Governor's State of the State, we were struggling between goals and pillars, and two of the areas which ended up as pillars but not goals, one of them was the short-term climate pollutants and, you know, as you go through the Pathways study, sometimes it's number 3 and sometimes it's 3 and sometimes there's 4. And what we're struggling with was that we didn't have much understanding of the inventories, we didn't have much understanding of what we could do there yet, at least when the study was done. So trying to get better there. And I guess the fifth pathway was sort of Ag and Forestry. And again, at this point given the wildflowers the big question is, is our forestry a source or a sink for CO_2, particularly now and going forward? And I think just to allude on the bioenergy part for a while, if you look at pathways, we've struggled with again whether to use it for transportation or electrification, but the other issue was, what's the amount? We found a fairly optimistic industry study that had a lot of biomass nationwide, and we somehow made an assumption that a lot of that, a disproportionate amount was going to end up from nationwide into California, and again what was the infrastructure? If you look at a lot of the biomass powered projects in California that have died, basically you could not move the biomass more than 50 miles. So, I mean, we're talking about moving lots of dirt from around the country, so again that's an area which I'm just not sure, but the results made sense there. Anyone else? But again, certainly I guess we should ask Heather to remind people when written comments are due.

MS. RAITT: They're due August 7th. And

then also, if anybody wants to make public comments, if you could fill out a blue card.

COMMISSIONER MCALLISTER: I'm good, thanks, Guido, I appreciate it.

CHAIRMAN WEISENMILLER: So on to public comments. We have some blue cards in the room. So let's start with Dr. Alexander Cannara. Excuse me if I botched your name.

DR. CANNARA: If you're Italian, it's 'Can*na*ra.'

CHAIRMAN WEISENMILLER: Okay.

DR. CANNARA: But you're not, right.

CHAIRMAN WEISENMILLER: My grandfather was, so.

DR. CANNARA: Oh good, yeah. Okay, some comments based upon being at this event and previous events at the CEC and Water Resources Control Board, BCDC, and so forth. And what it has come to remind me of today, in total, not just this hearing, is the old Laurel and Hardy movie called "Another Fine Mess." And it seems that that's the way California has been operating in recent years because we've not really put the attention to science and engineering that we should. We have a lot of people with a lot of axes to grind, and irons in the energy fire, for instance, the water fire, we know all these crazy things that go on here. So what I'd like to say is that the solution to the California Energy problem is really quite straightforward, and I don't know if anyone here has read the President's report to JFK in 1962 on how to deal with U.S. Energy needs into the future, but I have a copy here if anyone wants one, and I'll leave one for the Commission.

CHAIRMAN WEISENMILLER: Yeah, if you would put it on the record, that would be good.

DR. CANNARA: Yeah. Basically the solution is very simple. Nuclear power. California seems to have a very odd view of itself as a highly techy country of its own, eight percent of the world's GDP, perhaps, and two or three percent of the world's emissions. But that is in fact the basic solution, and the NREL presentation here demonstrated that. We had this nice graph with all these different variable sources, and beneath was a nice constant bar of nuclear power to be relied upon for years, and with the best safety record of any power source ever deployed by mankind. So that is something that we need to correct, and there are a bunch of us trying to get that corrected in California policy.

I'd also like to mention that currently there seems to be this gas orientation in California, which is really quite strange because now, as we have studied and scientists have studied, gas as a greenhouse aggravator is about as bad as coal because gas when released, by exploration, processing, extraction, transportation, and so forth, is 100 times as bad as CO_2, so we know that's science, we know it's the leakage to be measured, NASA has measured it across the country, in particular.

CHAIRMAN WEISENMILLER: Okay, thank you. Your time is up.

DR. CANNARA: I just have one --

CHAIRMAN WEISENMILLER: Your time is up. Please, let's go to the next one.

DR. CANNARA: My time is up.

CHAIRMAN WEISENMILLER: You can submit written comments.

DR. CANNARA: Well, I just had one thing that everybody should know, is that when you deploy to remove 80 percent of power from combustion, and you deploy --

CHAIRMAN WEISENMILLER: That's fine, your time is up. Send written comments. The next person is Bob Greene, please.

DR. CANNARA: Eighty percent of renewables means you would deploy 200 percent.

CHAIRMAN WEISENMILLER: Bob Greene, please.

MR. GREENE: I'm Bob Greene. My PhD. is in Physics and I'm from Mountain View, California. I want to mirror some of the things that Alex said. When I came here, I thought this was a workshop on the state of science on scenarios of deeply reducing greenhouse gases, but I never heard a word about methane which is a big issue, particularly with gas extraction. And if the real goal is to reduce greenhouse gases, we have to eliminate all CO_2 that we can, and the way to do that, I believe, is with nuclear. Your baseload up, your duck curve gets compressed, so you would solve a lot of the problems that you had otherwise.

I will be submitting comments on the record, but I'd like to go into some other broad comments, which I can't necessarily verify, but I suspect that nobody in this room can call me wrong on, either.

I think we're missing a sense of urgency. I think that things are moving a lot more rapidly than we realize. We've seen this particularly with the poles, how they are melting at much greater rates than anyone predicted, or any of the models predicted. And there's a reason for that, and that's because Scientists are naturally prone to take conservative points of view not to create panic or to look stupid. But they do look stupid because they don't get the measure of the problem.

I think we're missing quantity about how much energy we really need and, you know, some of the models have some elements of climate change, but they're missing some big ones. Okay, a big one is ocean acidification. Okay, we have done some work on what it would take to mitigate ocean acidification and it is massive amounts of energy, none of which are planned in these models whatsoever. I don't see anything in there for sea rise, sea level rise. I'm not sure we have the full measure of what it means to have an Electric Vehicle economy. We don't necessarily include desalination efforts, as well. So I think we're missing both in quantity, quality, urgency, and I think that we need to get much more active in this. So I say we need all the nuclear that we can have, as fast as we can get it. Stick with traditional nuclear, you know, like Diablo Canyon and San Onofre, but also new nuclear in terms of Molten Salt Reactors, which could be a major industry for the state if we got on it.

CHAIRMAN WEISENMILLER: Okay, thank you. Let's go on to Joseph, please.

MR. IVORA: My name is Joseph Ivora. I'm a retired Civil Engineer from the State of California and from PG&E. And I'm a Gabel supporter and nuclear energy supporter. I don't know, I think most people realize that 63 percent of our country's clean energy, no pollutions, is from nuclear power, yet we never talk about nuclear. Today there's very little talk about nuclear power. Anyway, I left this morning and I left my notes at home, so I'll have to cut this short, unfortunately, and I still have two minutes. Let's see, Diablo Canyon has a --

CHAIRMAN WEISENMILLER: You could

certainly file written comments and you can – normally, I only allow one person from an organization to speak, but since both of you have been here for a while --

MR. IVORA: Okay.

CHAIRMAN WEISENMILLER: -- I was flexible. But I'm just saying --

MR. IVORA: I'll send in something. Anyway, I just want to say the capacity factors in solar is 15 to 20 percent, and wind is 35 percent, and Diablo Canyon is 90 percent. Thank you.

CHAIRMAN WEISENMILLER: Okay, thank you. So Gene Nelson.

DR. NELSON: Good afternoon. My name is Dr. Gene Nelson. I have a PhD in Radiation Biophysics and teach on the faculty at Cuesta College in San Luis Obispo, California. I suggest a focus on the most efficient use of resources to achieve greenhouse gas and emissions reductions. We look at the Dutch and German experience where consumers are indeed requesting 100 percent nuclear power. California should offer this option in the PG&E service territory using Diablo Canyon power, and also import more nuclear power from out of state into California for other service territories. As Electric Vehicle Charging Stations expand, Diablo Canyon should power these stations so, indeed, we really have Zero Emissions Vehicles as opposed to having vehicles that are really powered indirectly and inefficiently by natural gas.

Right now, we have a unique pairing between Diablo Canyon and Helms Pump Storage and they're already used to provide more emissions-free power in California with Diablo Canyon recharging Helms at night. To make both wind and solar more grid friendly, we've had all kinds of conversations today, all kinds of like dancing around the head of a pin, but really what should be required is gradually increasing amounts of energy storage to both shave the peaks and fill in the valleys. And that should be required – required to minimize over-generation events because over-generation events cost money. The German experience is very clear on that, and basically what you're also getting by putting in energy storage is an increase in capacity factor, which again makes those variable random forms of energy gathering much much more efficient. So thank you very much.

CHAIRMAN WEISENMILLER: Thank you. Anyone else in the room? Let’s check on the line.

MS. RAITT: Nobody on WebEx. Let’s open the lines briefly. So if you’re on the phone, please mute your line unless you want to make a comment. I don’t think we have any comments.

COMMISSIONER MCALLISTER: Great. So I think I’ve learned a lot and it’s been a very stimulating discussion, you know, some of which I was aware of, and a little bit that I was not, and so it’s great and I really appreciate everybody sticking it out, we’re a little bit overtime, which I apologize for, but I think it’s been worth it, and it’s really great to share the Dais with our sister agencies and certainly appreciate all your expertise and insight, and looking forward to continuing the dialogue both across agencies and reading everybody’s written comments that they submit by August 7th, right?

MS. RAITT: Yes, the 7th, yes.

CHAIRMAN WEISENMILLER: Yeah. That’s good. I want to thank everyone. I would note, yeah, someone after the renewables thing, it was like, "God, this is the only principals (ph) I've ever been to." It's like, "Well, God, you can just come here on a Friday afternoon for an IEPR Workshop," you know? So anyway, thanks everyone for being here, looking forward to your written comments, and have a good weekend.

(Whereupon, at 2:20 p.m., the workshop was adjourned.)

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