BEFORE THE
CALIFORNIA ENERGY COMMISSION

In the matter of) Docket No. 12-IEP-1C
Preparation of the)
2012 Integrated Energy Policy Report)
Update (2012 IEPR Update))

CALIFORNIA ENERGY COMMISSION
HEARING ROOM A
1516 NINTH STREET
SACRAMENTO, CALIFORNIA

MONDAY, APRIL 30, 2012
9:30 A.M.

Reported by:
Peter Petty

APPEARANCES

Commissioners (and their Advisors) Present:

Robert B. Weisenmiller, PhD, Chair and
Lead Commissioner, RD&D

Carl Peterman, Lead Commissioner, 2012 IEPR
Saul Acosta Gomez, Her Advisor

Karen Douglas

Staff Present:

Laurie ten Hope
Guido Franco
Chris Kavalec

Also Present: (* Via WebEx)

At Dias:

Catherine Sandoval, Commissioner, CPUC
Colette Kersten, Her Advisor

Other State Government Representatives:

John Laird, Secretary, Natural Resources Agency (NRA)
Wade Crowfoot, Governor's Office

Presenters:

Daniel R. Cayan, Scripps
Maximilian Auffhammer, U.C. Berkeley
Joshua Viers, UC Davis
Larry Dale, Lawrence Berkeley National Laboratories (LBNL)
Lee Hannah, UC Santa Barbara (UCSB)
Michael McCormick, Office of Planning and Research (OPR)
Julia Levin, NRA
David Pierce, Scripps
Kosta Georgakakos, HRC/Scripps
Paul Bunje, UCLA
Daniel Kammen, UC Berkeley

APPEARANCES (Continued)

Panelists:

Susanne Moser, Consultant for Stanford University
Valerie Winn, Pacific Gas and Electric (PG&E)
Manuel Alvarez, Southern California Edison (SCE)
Bud Beebe, Sacramento County Municipal District (SMUD)
Dennis Peters, California ISO (CAISO)
Steven Kelly, Independent Energy Producers Association (IEPA)
Randy Howard, Los Angeles Department of Water and Power (LADWP)
Michael Hanemann, UC Berkeley

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Douglas Mahone, Heschong Mahone Group
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INDEX

INDEX

INDEX

P R O C E E D I N G S

APRIL 30, 2012 9:34 A.M.

MS. KOROSEC: I'm Suzanne Korosec. I manage the Energy Commission's Integrated Energy Policy Report Unit. Welcome to today's IEPR Workshop on Climate Change and the California Energy System.

Just a few quick housekeeping items before we get started. Restrooms are in the atrium through the double doors and to your left, we have a snack room on the second floor at the top of the atrium stairs under the white awning, the atrium stairway is blocked due to construction, so you'll need to take the elevator to get to the second floor. If there's an emergency and we need to evacuate the building, please follow the staff out to the park that's across the street diagonal to the building and wait there until we're told that it's safe to return.

Today's workshop is being broadcast through our WebEx Conferencing System and parties do need to be aware that you are being recorded. We'll make an audio recording available in about a day or two after the workshop and a written transcript will be available in about two weeks. We plan to have two 10-minute breaks during the morning and afternoon sessions, and expect to break for a one-hour lunch around 12:15. We've also set aside time at the end of the day for more general public comment and, at that time, we'll take comments first from those of you who are here in the room, followed by those who are participating on WebEx.

At any time during today's discussions, if you're making comments or asking questions, please come up to the center podium and use the microphone so that we can make sure that the WebEx people hear you and that your comments are captured in the transcript.

WebEx participants can use either the chat or raised hand function to let our WebEx Coordinator know that you'd like to ask a question or make a comment, and we'll either relay your question or open the line at the appropriate time.

We're also accepting written comments on today's topics until close of business on May 7th, and the Notice for today's workshop, which is available on the table in the foyer, and also on our website, explains the process for submitting comments to the IEPR Docket. So with that, I will turn to the dais for opening remarks.

COMMISSIONER PETERMAN: Good morning, everyone. Welcome to everyone in the room and on WebEx. Pleasure to have you here today. This is Commissioner Carla Peterman. It's my pleasure to welcome you as Lead Commissioner on the 2012 IEPR to today's workshop on

Climate Change and its impacts on the California Energy System.

For those of you who have been following our IEPR process this year and last, you'll note that we've spent a lot of time, a number of workshops, focused on the energy system, in particular, and how to make a system that is cleaner, smarter, and more reliable. And one of our main drivers for doing this is the impact that electricity has on climate change. As we move forward, however, and as we work to make a cleaner system, that's a process that will take a number of years, that all of us will be engaged in. In the mean time, climate change is continuing and it's continuing to impact our electricity grid.

Today's workshop focus is to look at some of those impacts and think about how can we mitigate some of them, and what are adaptation strategies as we move forward. This is a nice follow-up to a conference that the Governor had on climate change, and we're excited to be a continued part of that effort to address these issues.

We have a number of exciting panelists here today, as well as representatives from various agencies and the Administration, I'm glad you could join us. I'm going to turn now to Chairman Weisenmiller for his introductory remarks, and then we'll introduce everyone on the dais. Thank you.

CHAIRMAN WEISENMILLER: Good morning. I'd like to thank everyone for their participation today and also to thank the staff for helping organize this event. As you know, I’m not only the Chair, but also scientist on the Commission, and so one of the areas that is very near to my interest is the science of climate change effects. But I'm also the Lead Commissioner on R&D, so, again, looking forward to today's conversation. I think all of us understand that there's a real nexus between energy and the environment, just about every way that we have that produces energy has some effects on the environment and, at the same time, one of the most fundamental of those effects is climate change. It really affects the well being of the globe. And so we've had a lot of focus in our PIER research on climate change issues, and it's an opportunity today to bring some of that to the fore.

We've also, in most of our conversations, we've looked at the effects of climate change in terms of what we're doing with energy production that results in potential climate change, both in terms of greenhouse gas emissions, both CO_2 and methane.

But today we're going to look more at what the effects of climate change are on the energy systems, and obviously one of the scarier aspects could be if we have feedback loops between climate change affecting energy and accelerating some of our energy use, and then having greater climate change from that. But, again, I think all of us are looking forward to a very interesting day and, again, thanks for your participation.

COMMISSIONER PETERMAN: Thank you. So, joined on the dais here on my left, my Advisor, Saul Gomez, and to my right we have Commissioner Catherine Sandoval's Advisor from the Public Utilities Commission, Colette Kersten joining us, glad to see our sister agency here on the dais. And coming forward we have Commissioner Karen Douglas. So obviously we have the three Commissioners that are currently sitting on the Commission present at this workshop, that's a rarity, but it just highlights the absolute importance of this topic for the Energy Commission, and how it crosses the various areas over which we respectively lead. So with that, we'll turn to our next invited speaker, Secretary John Laird, Secretary of the California Natural Resources Agency. Thank you for being with us, Secretary.

SECRETARY LAIRD: Thank you very much. And thank you for having this workshop, and thank you all for participating. I know a number of you are on panels and people are here to learn and figure out how to act.

And I thought, in giving some introductory and welcome comments, I would sort of from my perspective frame this issue of what the backdrop is that leads for this in many ways, and I come at it from a number of different directions, and one is, in my checkered past, I spent nine years in elected office at the local level as a Mayor and City Council member. It was virtually the entire 1980's. And when that happened, we had the misfortune in the Santa Cruz area to, in that period of time, have six federally declared disasters. And every one of them raised the issue of energy provision in ways that I wouldn't have thought of. Within six weeks of being on the City Council, we had the 100-year storm. In 36 hours, it rained 16 inches in the Santa Cruz Mountains above the City. Our main transmission line into the County through Waterman Gap fell victim to landslides that brought the transmission lines down in ways that I wouldn't have thought about it. And as the river came close to flooding in downtown Santa Cruz, 75-foot Redwood trees battered down some of our bridges that carried transmission lines and water lines across, and knocked out service in different ways.

And then, as we went through the fire that burned through the Santa Cruz Mountains, that affected transmission, when we had the storms that led to such incredible erosion along the coastline, that was a disaster, that raised questions that are now mirrored by the work that underlies this very conference.

In addition to being Secretary of Resources, which is charged with adaptation, the Environmental Protection Agency is charged with reducing emissions, and that half of climate change. But the Resources Agency deals with adaptation. And I chair the Ocean Protection Council, and as I mentioned, at the Governor's Conference in December that you referenced, our scientists with the Ocean Science Trust Affiliated did long work to identify what the impacts and what we could expect from sea level rise along the California Coast. And it was great because, for the first time, it was science. And they looked at what the medians would be for sea level rise based on everything, and by 2050, they're estimating that it would be 14 inches along the California Coast and Bays. And by 2100, it would be 55 inches, five and a half feet. And those are the medians. And the reason they're medians is that, if we're successful in lowering emissions as per AB 32, maybe that's high. And if we're not successful worldwide, maybe that's low.

And so it balances the question because the Governor got this question in the opening panel from a *New York Times* reporter that I thought at the time was a little strange. Well, what's your priority? Adaptation or reducing emissions? As if it was a choice. And it was not a choice. And today you're looking at it going both ways, which is how is energy key to lowering emissions and lowering the need to adapt because you have less emissions, but very much we're going to have to adapt any way you look at it, the question is how much and how do you deal with energy systems that have to adapt to that change?

And in the Resources Agency, we're dealing with all these questions that are profound. Fish & Game is dealing with the fact that certain habitats will change elevations due to climate change, and how do you deal with wildlife paths? How do you deal with them being able to survive in certain habitats. We have water and, if the Sierra snowpack is, in fact, going to be 48 percent of what it is now in 2100, how does that change our entire water collection system? And we have fire. So if forest fires are changing and are more severe, how does that affect how we fight fires and try to prevent them?

And all these things affect energy, both in what are cited and how you deal with it, and as somebody that was Mayor of a Coastal Government, trying to contemplate a 5.5-foot sea level rise when we had all these sea level treatment plants and outflows and gravity flow to them, gravity-flowed water systems that are done the same way, trying to think of how you change and how over time you do it, the real problem is, Al Gore did a great job of convincing people that we have an issue on emissions and that we have to change our habits, but we have yet to have the same job on the adaptation side where people understand exactly what it means and start to think, and start to adapt in ways that really have to start to be made in decisions. If you're siting things that have a 50 or 75-year life, what's the world going to be like near the end of that life?

And I know, one of the interesting things for me is the very charge of the Energy Commission in siting alternative and renewable energy projects. And when I was, I think, in my third week of Secretary of stepping out to my first thing, I was keynoting the Planning and Conservation League Annual Symposium, and there was a huge line of people afterwards and there was this guy near the end of the line that walked up to me and said, "I work on the siting of renewables and I work on the environmental side," and I had to say to him, "Well, which side is that?" And it turned out that what he meant was that he works on the side that fights for habitat protection and didn't consider renewable energy to be the environmental side of the equation. And so it just shows the challenges that we face. And I know, since I have all sides, I have the people that want to protect habitat, and the people that want to site energy, and then the responsibility for adaptation, I know that we have to work that out, that we have to have it happen.

And so I just wanted to lead off today with sort of setting that tone because, a lot of times when I attend conferences like this, people are so good about their area of expertise, but you always have to remember why we're doing this and why it's important and why we don't have the option to ignore these issues and run away from them. We have to look into them directly and resolve them.

So, I apologize for not being able to stay for the day, I would actually love to, because I have to rush off to a number of conflicts that require my attention, but I would prefer to be here. And I want to thank you for showing the leadership to do this and wish everybody luck in their deliberations today.

COMMISSIONER PETERMAN: Thank you, Secretary. [Applause] Your comments reminded me of the workshop that we just had a couple weeks ago on net benefits of renewables, where we talked about some of the benefit of certain renewables being able to reduce water usage and fire hazard, and so, indeed, you're right, they're all interconnected. Good luck with the rest of your day.

Next will be joined for opening comments by Wade Crowfoot, who is with the Office of the Governor.

MR. CROWFOOT: Thanks so much, Commissioner Peterman, Chairman Weisenmiller, and Commissioner Douglas. I'll be fairly brief because I know those who are attending today want to get into the meat of the conversation here. But first I just wanted to thank you on behalf of the Governor for holding this conversation. We view this as an outgrowth of a conversation that started back in December, and from our perspective, after that December conference, it was really important for the Governor's Office that relevant agencies started to unpackage the many issues and questions that were raised in that conference.

And I want to talk about that conference a little bit, but just to give you a little bit of context for the Governor's interest in this issue, clearly energy and climate change are two primary priorities for Governor Brown. He's moved aggressively on energy policy largely through the work of the CEC and the CPUC, implementing an RPS on the verge of establishing some, once again, landmark energy standards, the Governor's 12,000 megawatt goal for small scale or distributed generation, clearly we have a very broad and aggressive agenda for transitioning the energy system to a highly efficient renewables-based system, and electrifying transportation. And that's really the long term vision, is to transition our energy system in a way that not only benefits the economy and consumers, but one that in a way allows us to be international leaders reducing greenhouse gas emissions. And I think that leadership is fairly well known.

In 2011, the Governor really opened up a new conversation on climate change, or at least an extended one that had been occurring, probably getting less attention than greenhouse gas mitigation, or the effort to reduce greenhouse gas pollution, and that is really preparing California for the impacts of climate change and protecting our economy and communities from those impacts.

To date, our perspective from the Governor's Office was that climate change was an important issue for people, but one that really was hard to have a grounded conversation about. In other words, it was a global issue, it was an international issue, but what does climate change mean to California? And the Governor had a conversation with Rajendra Pachauri, who is the head of the Intergovernmental Panel on Climate Change at the

United Nations, earlier last summer and they got to talking about the need while we're taking action to reduce greenhouse gas pollution, to actually prepare the world for impacts that are already here. And Governor Brown actually himself came up with the idea of having a high profile conference to really start this conversation, a better understanding of how climate change will actually impact California, and what we should be doing about it.

So the December conference did just that. We're blessed in California to have some of the world's best scientists and researchers, some of them you'll hear from today, who have actually sought to understand how this international and global phenomenon of global warming and climate change impacts California's environment. And the first part of the December conference really delved into what the science is telling us. And one of the key takeaways I call the Big Four Impacts in California in terms of the physical impacts, are 1) reduced reliability of water supplies, obviously of major importance to the economy and communities, 2) heighted or increased or lengthened wildfire season, which has great impacts and threats all over the state, and 3) is the increased vulnerability to large storms or storm surges, particularly on a coast with increased sea level rise, and then the fourth impact, at least that I remembered and was really impressed by, was increased heat in California. And that heat, as you'll hear from Dr. Auffhammer, not only has an impact on public health, but also the energy system. And so these four impacts, and many more that we heard about, actually have a number of very specific implications on the energy system, and that was one of our key takeaways that morning, was there needs to be very proactive visionary strategic planning to anticipate these impacts on the energy system.

And then the second part of that conference in December focused on what local governments and what state governments should be doing about this. Again, climate change as an issue at large is fairly daunting to try to understand what a local community or a state government can do to protect citizens and communities against climate change. But the December conference started to delve into what are common sense actions that make economic sense that can occur across the state to really prepare and protect California.

Coming out of the December conference, we've had several complementary events, most recently in Los Angeles with local governments from throughout the state, to really delve into that question of what can local governments be doing in this economy, recognizing resource limitations, that are smart investments in not only preparedness and protection of their communities against these impacts, but also that have co-benefits, whether it's the creation of a park, or the planting of street trees. And so we've come away from that conference two weeks ago very optimistic.

Undersecretary Laird's and Secretary Rodriguez's leadership, the Resources Agency and CalEPA are being very proactive on this question of climate adaptation or preparedness. Later today you'll hear from Julia Levin at the Resources Agency talking about an update, I think, that the agency is leading regarding adaptation planning in the state. And then you'll hear from a colleague of mine at the Governor's Office of Planning and Research named Michael McCormick, talking about these very impressive regional efforts that are occurring in San Diego, Los Angeles, the Bay Area, and Sacramento, that are bringing local governments together to try to engage in some team work around taking action on climate adaptation.

So as I said, we're very excited with the progress that's happening. This is a clear priority of Governor Brown, and so I just want to thank you and let you know that the work you're doing here today and the comments from both agency staff and members of the public will be quite important to our sort of policy making in the coming months and years. So, thank you.

COMMISSIONER PETERMAN: Wade, thank you very much, and thank you to the Governor for his leadership in this area. [Applause]

So I believe with that, we'll turn it over and let the content begin.

MS. KOROSEC: All right, we'll start with our morning discussion which is on Direct Impacts of Climate Change on the California Energy System. Our first speaker is Laurie ten Hope, the Director of our R&D Division here at the Energy Commission.

MS. TEN HOPE: Good morning. This is going to be an exciting day, I'm really looking forward to it. I'm Laurie ten Hope, Deputy Director for Research at the Energy Commission and I'm going to kick off this first panel on what our research strategy is on impacts and adaptation options for the energy sector.

I'm going to briefly provide some historical context for our research portfolio, the highlights of direct and indirect impacts of climate on our energy infrastructure, and how we might think about the evolution of our energy system, given a lot of uncertainty, but a need to think and plan early for changes we can anticipate.

So first, a little bit of historical context. PIER has been engaged in climate change research since 2001 and, at that time, started in really looking at the whole process of energy production, transport and use, the emissions from the energy sector that have an impact on GHG emissions and then, conversely, how climate change could be affecting our energy infrastructure going forward.

In 2003, we created a virtual organization known as the California Climate Change Center and it was the first State sponsored climate change research program in the nation. Our strategy really has been to complement research that's been done at the Federal level and one of the key cornerstones was to take worldwide models and pull those models down to more of a state and regional level where potential climate change impacts could be really analyzed on a local level so that planning and mitigation strategies really could be utilized.

We've created several scenarios with the researchers here that are in the room, that provide us insights into climate and sea level scenarios for research and long term planning. You see some of the products that are highlighted here on the slide and many more products that have both informed policy, like the changing climate that was helpful in the thinking and analysis that went into AB 32, to Cal-Adapt which is taking some of the research results and putting them into a visual tool that helps local governments both visualize local impacts and start planning for potential long term strategies that will mitigate the impact of climate change, other products that are providing some insights into our potential changing snowpack and hydro resources, these are just a few of the products that have been developed to inform policy and our energy infrastructure planning.

These are a little bit of -- perhaps tooting our own horn -- but these are quotes on the value of the research, both starting at the top at the development of AB 32, and how some of the research was important to CalEPA in the foundational analysis that was done for AB 32. And then, the last quote I'd point out is from the San Francisco Bay Conservation Delta Commission on how useful the research is in localized planning.

So I just want to provide brief context for sort of the historic focus of our climate research here at the Commission, and how the research has evolved over the course of the last year. So, historically, starting in 2001, we had four research focus areas, Climate Analysis and Modeling, GHG Inventory Methods, Options to Reduce GHG Emissions, and Impacts and Adaptation Studies.

Over the course of the last year, based on input from stakeholders in our PIER Policy Advisory Board, our Commissioners, and efforts by other agencies to start doing more research in adaptation and mitigation, we've really focused now on -- we're continuing the climate analysis and modeling, it's critical to understanding how climate can potentially change in California impacts, all sectors, not just energy, but it's critical for understanding energy.

In the GHG Inventory Methods, we are not doing any new work in that area, the Air Board is doing quite a bit of work in that area, and we've narrowed the options to reduce GHG emissions and our adaptation studies, specifically to the energy sector.

A look ahead -- our colleagues at the Public Utilities Commission are in the middle of a proceeding for EPIC, the Electric Program Investment Charge. We're optimistic that this will provide funding for the broader clean energy research and development in the areas of efficiency, renewables, and perhaps climate. The guiding principle is really that the benefits of the program need to return to the electricity ratepayers. And the Proposed Decision that was issued last week includes these guiding principles for the research that's funded and it includes bullet 2, GHG Emission Mitigation and

Adaptation that we're talking about today.

My understanding is comments and reply comments will occur this next month with an expected decision acted on in the end of May, so we look forward to that.

So let's talk a little bit about the Impacts of Climate Change to the Energy System, the focus of our workshop today. I think, as most of us here know, climate change is projected to have significant impacts on our energy infrastructure, from impacts on energy demand, both in terms of increased energy use for cooling, hot, dryer climates, and also an impact on peak demand, and peak demand is our most expensive energy cost, so it has a potential cost impact for all of us.

With the hotter temperatures, we would anticipate decreased power plant efficiency. And, again, on those hotter days when power is the most scarce and the most expensive, we would anticipate a reduction in thermal power plant efficiency. We could anticipate a decrease in heating load, which in one way is a good thing, and from a cost perspective to consumers, but something we need to think about in terms of the long term efficiency measures that we support through either building standards or incentive programs in terms of putting emphasis on the measures that will be the most cost-effective in the long run. It may change the availability of hydro power and potential risk of flooding to coastal power plants. You will be hearing both this morning and this afternoon on research in all of these areas and we'll provide a lot more insight into what some of the direct impacts are potentially that we face, and perhaps more importantly, how can we start planning to reduce that impact.

In addition to the direct impacts, we are concerned about potential indirect impacts, and a couple of examples are wildfires and the risk that provides to transmission lines and, as the Secretary spoke, the potential ecological impacts on the siting of energy facilities. So this is already a consideration in the Energy Commission's siting of power plants, particularly the larger renewable power plants, and insights that will provide a smarter mitigation strategy, so that, as ecological research matures and we have an idea of potential migration patterns, we think about that in the lands that are set aside and the sites for our future power plants, so that we can have both, we can have our renewable resources and mitigate the impact.

Finally, we have some exciting research on looking at how the energy system may change looking out to 2030, 2040, 2050, and what our resource mix might be, what our energy balances might be in terms of our total fuel input/output, what our long term energy efficiency potential could be, what our renewable and fossil mix might look like, and then what are the environmental implications of these various scenarios. There's obviously a lot of uncertainty in terms of climate projections, what our fuel mix will be, where those will be sited, but research is providing us some insights that facilitate long term planning.

And with that, I'm going to turn it over to the Research Panel and look forward to their presentations. Thank you.

MS. KOROSEC: Thank you, Laurie. Our first speaker is Dan Dayan from Scripps to talk about Historical and Projected Climate in California.

DR. CAYAN: Well, good morning. It's a pleasure. I was told I'm not close enough. Is that good? Can you hear me? A pleasure to be here. I'm going to try to set the stage for colleagues who are going to be talking about applications of climate change. And I think what I want to emphasize is this transition phase that we're in right now towards a climate that our historical intuition will no longer serve us as it has in the past.

This is a -- this picture shows the underlying largest constituent of greenhouse gas emissions, carbon dioxide, the emissions under various scenarios are shown here at the bottom as we move into the 21st Century. Today we are at a level of emissions of somewhere between 9 and 10 gigatons of carbon and, depending on the scenario, we will either increase steadily through the century, or perhaps, of course, if policies are successful, and perhaps technology will be able to level and then decline. The result of those emissions, because greenhouse gases such as CO_2 have a long atmospheric lifetime, shown here at the top, so perhaps if lucky we'll only double the pre-industrial level of CO_2 by the end of the century, if we're unlucky, we will triple that concentration. So there's critical sort of decisions and impacts of those decisions as we go forward.

This is a time slice of temperature drawn for Sacramento. Laurie mentioned the downscaling activity that the science community has been doing, so here's an example. Models are run both retrospectively, as well as prospectively. We're showing here the projected period as these colored areas. This is from the previous generation of global climate models, the fourth IPCC assessment, and there's two different emissions scenarios shown here, the lesser one is blue and the greater one is green. Important on this figure is the envelope of natural variability, which is represented by the ensemble of these 14 models that are presented here in this chart, so you can get an idea of the natural level of fluctuation of our climate here in California.

What's interesting is, as we move forward, as seen by, in this case again, 14 models, the median model projection essentially crosses the level, the upper level of the envelope of variability, by about 2030. So, in some sense, you could say by 2030, the average climate is moving outside of the top of the envelope of what we've experienced. So that's really not that far ahead and, of course, one of the discussions and actually one of the intentions we've had in talking with users such as the utility community is that they're not so concerned with 2100 because a lot of the decisions that are facing them are in this shorter period. But, in fact, in that shorter period, we're actually seeing in the model substantial evidence for change.

Now, this is the same models, but these models now are their rendition in the fifth IPCC assessment, which, of course, is an ongoing exercise, which will be released in a couple of years. But essentially what we see is not too dissimilar results from the previous assessment, which in I guess some sense is good news, in that we've based a lot of our efforts on looking at the previous assessment.

Another point to be making here is that, because of the inertia in the system, the results of policies, that is, the differences between emission scenarios, lower, medium, higher, really doesn't become evident, does not become distinguished, until about the middle, perhaps early middle part of the 21st Century. That's, of course, one of the wicked parts of this problem, and that's one reason why we have such a public debate, is that we can't really see the results of policy actions immediately. We really have to rely on science to tell us what's coming forward. But, indeed, you can see the enormous consequences of the higher emissions trajectory as we go forward.

This is a step back now to look at observations, and this is a measure of heatwaves at a set of districts across California, by colleagues of mine, Alexander Gershunov and Kristin Guirguis, who have looked at heatwaves which are primarily accentuated in their daytime heat expression, and those which have been characterized by having a strong nighttime characteristic. What they have found is that the daytime heatwaves have essentially oscillated about a natural variability level with some low frequency variation, but the night time heatwaves actually have really become much more prominent in the last couple of decades. So this obviously has some implications on users and heat demand

and comfort levels, and probably human health. This is a thing that we'll need to be looking at as time goes in the future.

You can look at the Cal-Adapt site, which Laurie mentioned in her remarks, to get various scenarios of heatwaves. And, of course, one of the important things to remember is that not only is mean climate changing, but as the mean changes, also goes changes in distributions of the extremes. And the extremes in a sense become, a) more frequent, b) more intense, and c) more durable, longer lasting. All those factors, of course, have great impacts on energy and energy consumption. So a couple of different scenarios there.

A couple of other features to take note of from the models is that, when we look at summertime heating over the North American Continent, in fact, any middle latitude Continent, we see more warming in the interior than we see along the coastline and, interestingly, we see more warming in the summer period than we do in the winter, that's this little inset that is shown here at the bottom. Both of those factors, of course, again play into energy demand consumption if you think about the moving population and development in California, the coastal area is pretty much subscribed, development going on in interior valleys, this plays a strong role.

When we look at different models, of course, and look at the incidents of hot days, there is quite variability from model to model, as well as scenario to scenario. So that's something that has to be accounted for. There's a lot of uncertainty. This is not a precise predictive science that we have at this point; we're looking at scenarios for a reason.

This is precipitation and this is the summary, again, of the same 14 models, and I haven’t shown you the spaghetti because it is so noisy, so I've only shown you the smooth median and the median from the two sets of model runs, one a lower scenario, one the higher scenario. The message here is that, well, we can expect quite likely to have great variability in the future in California's precipitation regime as we've had in the historical past, there's not too much evidence that there's going to be strong changes in Central California. When we look, however, as things unfold over the early, middle, and latter part of the 21st Century mapped out here over the West, in fact, the whole U.S., what you notice is that the southern part of the state, in particular, shows some tendency to become drier.

The other thing that should be mentioned is that there is some interesting seasonal texture to these changes, and I believe David Pierce, who is going to talk this afternoon, might mention that in his results. There is important implications for the hydrology in California, the Resources Secretary Laird mentioned this in his remarks, and we've already seen over the western part of the country a strong signature of warming to the tune of about 10 percent decline in April for snow water equivalent, that's the red. Red changes mean lower, blue higher, higher in the higher Sierra for reasons that I won't bother to get into today, but it's certainly explainable. We've seen the early signs of warming over a wide footprint across the Western U.S., including California, here in our snowpack which, of course, we rely on.

Interestingly, as snowpack goes from today's situation to a warmer climate, snow lines being higher, water is essentially going to become less manageable, early runoff more volatile and, of course, that has implications not only on ecosystems and so forth, but also on water management and probably hydropower.

This is a look at the California snowpack played out over many simulations, actually 32 of them here, as we go on into the future. And what you notice here is that in the future, each dot being an April 1st of a given year from a given model, there are still years when there's relatively ample snow, but on the whole there is a climb and, as you look at this in sort of a probabilistic sense, what was the odds of median or greater snowpack being, of course, at 50 percent, historically, declines to about 10 percent by the end of the century. And, of course, we're really in that decline as we speak, in a very volatile system.

Sea level rise was mentioned by the Secretary and, of course, sea level rise by itself is not always such an insurmountable problem, but the fact is that we have winter storms on this coast that generate large waves and, when sea level rise, high tides, and big storms coincide, we have a prescription for a lot of problems.

Along our coast, by and large, we've seen sea level rise -- this is the San Francisco record, which is the longest record along the West Coast, for a tide gauge, matches pretty well what is made to be the global rate of sea level rise, so we can probably expect California to go along with global rates of sea level rise.

This is an envelope of projected sea levels in San Francisco under that assumption from a set of model simulations. This is the historical rate, this is the projected future rate. I have to note that the Secretary didn't quite get it right when he said that 55 inches was the median that was projected, actually, 55 inches of mean sea level rise is at the high end. We would expect something like 36 inches to be sort of in the middle of this envelope. There's an NRC report that will be emerging within the next few months that will inform that in more detail.

One thing to note is that, as mean sea level rises, the incidence of extremes, similar to the incidence of temperature extremes, will increase, and actually increase quite markedly. This is mean sea level here and this is the hourly extremes above the level that would occur historically, less than once a year, which goes from less than once a year to many many times a year under a scenario here that actually is on the higher end of -- well, actually about the middle range of what I showed you earlier.

So to summarize, we're already seeing the signs of warming. Projections are indicating not only long range, but shorter range issues. There's many impacts you're going to hear more about, things like wildfire, in the remarks to come. There's continued need for regionalizing what we're seeing from these global models and I think there's a lot of room for interactions across disciplines and with the applications community to take this discussion further. Thank you.

CHAIRMAN WEISENMILLER: Thank you. [Applause] I have one question. Secretary Laird indicated one of the things we do is siting and that tends to have, say, a 30 to 50-year time scale. The other thing we do is planning, and our planning exercises tend to be more centered around 10 years, although we look at five and we look at 20. And in the 10-year context, just trying to tease out the implications of what this means for our planning activities, and obviously one of the things that is pretty clear is you see a lot more volatility. And so, in our 10-year planning exercises, we tend to look in expected case -- one and two, but also a one and 10 case -- and so part of it is trying to understand as we look at, say, the demand forecast, or hydro, or other things, you know, how much will we be seeing the impacts in the next 10 years, and how much will we be incorporating that better into our planning models?

DR. CAYAN: I think in the next -- in the 10-year horizon, you certainly have to pay attention to the historical record as a strong guide to what could happen within that interval. Within 10 years, because natural variability in California is quite large, particularly if we're talking about something that's hydrologically flavored, there is going to be a strong uncertainty because of inter annual to decadal variability. The same thing goes with temperature. Temperature is not quite as volatile as precipitation, but there are methods, of course, to understand at least the context of that variability and the statistical nature. But as far as a precise in-phase prediction along that 10-year trajectory, that's really beyond the state-of-the-art at this point.

CHAIRMAN WEISENMILLER: Thank you.

MS. KOROSEC: All right, our next speaker is Max Auffhammer from U.C. Berkeley, who will be discussing Electricity Demand in a Warming World.

DR. AUFFHAMMER: Thank you very much for inviting me. This seems to be the all climate all the time period of my life. The IPCC Report for Working Group 2, the first of our drafts are coming out in two weeks, or are due in two weeks, so we've been locked away in Holland with dial-up connections, so I apologize, the title of my slides was wrong, which we're fixing. So what I'm going to do and talk a little bit about is talking about -- thank you -- one of the aspects of the energy system which is projected to be significantly impacted by climate change going forward is the electricity demand side. It's the only side that you often see the Press and public talking about, but I just want to make clear, this is not the only aspect. Of course, everybody in this room knows this, but you can't say it often enough. So it gets warmer, we cool more, it gets warmer in the winter, we heat less. That often affects different fuels since we tend to cool with electricity, and heat with other fuels in most households. But there's other things that happen. Larry Dale is going to give you a very thrilling presentation this afternoon about the last four bullet points here, which are the impacts of the energy system that will be impacted, or anticipated to be impacted by climate change, which have to do with transmission efficiency if the Grid -- the efficiency of power plants during hot periods, wildfire risk, which is going to, or is expected to affect transmission lines, either directly or indirectly, and also sea level rise associated with power plants, or substations, that are located near water.

I am only going to talk about the first two bullets here, which is cooling demand and heating demand. This is, of course, a very sort of summary presentation, we could talk about this for days on end, and I only get 14 minutes, so let me get right to it.

One of the big pictures that we should keep in mind here is, when we talk about climate change, we always think about end of century. As somebody who is involved in the IPCC Working Group 2, Detection and

Attribution Chapter, I've been spending a lot of time, instead of looking forward, looking the other way and looking at existing data and seeing whether one can tease out impacts of climate change on existing electricity demand.

So here's a picture that would lead us to believe that, if it gets warmer, we would see impacts. This is this famous, or at least in my household, famous picture now of u-shaped electricity load, this is for the California ISO, and temperature. So what you see here is that, at low temperatures, if it gets warmer, this u-shape drops meaning there's less electricity demand. This is the fuel all-electric households, and also natural gas heated homes where fans are operated less frequently, so you consume less electricity. But as soon as it gets warmer, and this is population-weighted temperature here for the State of California, or for the ISO territory, you see this rather steep increase in electricity load during hotter days. This gray histogram you see there is the distribution of temperatures in that data set. And this is a figure that is not published yet, but it's my own calculations and hopefully this will be published at some point.

But it's key to note that the impacts here at the higher end of the temperature distribution are quite significant. The blue dashed line indicates a 25 percent increase over what the load would be, temperature corrected, for the 60 degree temperature. So these are big impacts. This is observed data, this is not modeling towards the end of the century, and this is what we're seeing currently.

Now, what you see in the current literature, and much of it is still in working paper form in varying stages, but there are several peer reviewed papers out now and some working papers and some reports which have looked at this issue going forward -- what is going to happen to electricity demand by end of century, or in the near and medium term, 2020, under climate change? So the first paper that looks at data and tries to establish a statistical relationship between these two that I could find is a paper by Guido Franco and Alan Sanstad that in 2008 in climatic change, which also looks at this ISO load data, and finds that electricity consumption overall -- this is all sectors consuming electricity -- increases by 4.8 to 17.8 percent by end of century. Now, this is consumption, this is annual consumption added over all months of the year.

The point that we should all keep in mind throughout is that these impacts are going to be bigger in the summer than they're going to be in the winter.

This large band of impacts here, the source of uncertainty or range of uncertainty here, doesn't really come from the relationship between electricity demand and weather, the statistically estimated impact here, but it comes from the range of predictions from these climate models that Dan talked about. There are some that predict more warming and some that predict less warming.

The more important thing, our most expensive electricity happens during peak, we see by the end of century a 5.7 to 19.8 percent impact on peak, which is a significant increase on peak; 20 percent, I don't need to tell you, is a large number.

Greenstone & Deschenes looked at a national exercise where they used State level consumption data, this is annual energy consumption data by end of century, and they correlate this with days counted in different bins of temperature, and they find an impact of 11 percent nationally, again, by end of century. For the Pacific region, that impact is 8.9 percent. It mixes, of course, the entire Pacific Census Division into one bucket, which isn't that interesting for California because there's a lot of heterogeneity across states here.

In an updated report that fixes some issues with earlier work I did with a graduate student, we now have a new CEC report which I don't know is on the website yet, which looks at residential electricity consumption for California, again, annual consumption, and we find counting in a measure of adaptation that impacts by end of century are somewhere between five and 12 percent. Now, this matches pretty closely what Guido and Alan Sanstad found in their work and I'm going to talk about that paper a little bit more in a minute.

What's maybe most exciting here is that the CEC has gone forward and, in their 2011 IEPR Report, incorporate detailed projections of climate change impacts for, from what I can tell, the first time. This is something the EIA is not doing, but the CEC is doing, so let's take a closer look here at what they did. The Scripps Institute provided eight temperature scenarios, which are these climate forecasts for California, the forecasting staff here chose a mid and high temperature increase for the mid and high electricity demand forecast scenarios, to come up with a prediction of what happens to peak demand in the California forecast model here.

The low electricity demand forecast scenario did not include any climate change adjustment. So if you look in Appendix A of this report, a lot of the nitty gritty detail is in there, but essentially what they did is they figured out what the peak average temperature was going to be over the forecast horizon here, and predict that increase in peak temperature, and look at what the impact on peak is.

Now, here are some small numbers with big effects, all right? If I may point -- I can't walk away from the microphone -- I'm going to point to the bottom right here -- these are pointers, high tech -- so this number right here is 12 pt. font, but what this says is, by 2020, there's a three-quarter gigawatt increase in peak if we take the mid demand scenario; and if we go out to 2022, this is 10 years out, for the high scenario, this is a 1.3 gigawatt peak increase due to climate change, that's a big number. Ten years out is significantly sooner than 90 years out, I don't need to tell you that. So, I again commend the CEC for doing this work because I think it gives us some important estimates of what's going to happen to peak in a model that we understand very well.

So I have a few more minutes. A couple of points I'd like to make here, again, here are some bigger numbers. We're talking about impact of climate change and what we've got here are these impacts on residential consumption that I did with a former graduate student here, and what you're talking about, again, are these sort of four to 11.5 percent increases in consumption by end of century. If we compare this to the impact of population growth, the impacts of population growth are clearly bigger than the impacts of climate change, alone. The important thing to remember, however, is that if we look at a lot of the official projections of energy demand here, much of the planning, even at the national level, leaves out this climate change penalty, and this climate change penalty is a big one, and this is consistent across all of these models. So, no matter what scenario you're looking at, there's always this energy climate change penalty on top of that. Because climate change is going to happen in varying degrees here, this baseline going forward over the next 30, 40 years, climate change is in the baseline now, it's not something that we can choose to have or not to have, the question is how much of it are we going to have, and how are we going to adapt to it.

Talking about adaptation here, the black line here is an estimated relationship between temperature at the bottom, X axis, and at the Y axis here, you have the percent increase in residential household electricity consumption due to having one more day in one of these temperature bins here. The black line is a response without taking into account adaptation; the red line takes into account some adaptation. That means, if all of a sudden the area you live in -- I live in Walnut Creek -- if it gets even warmer there during the summer, I may actually install air-conditioning, or functioning air-conditioning in my house. So, if we just assume that people operate their existing equipment more frequently, we would expect around the black line; if we think that people adapt by installing additional equipment and operating that on top, we're on the red line here. So what we're getting here is, in the data, some evidence that that adaptation, which economists call "extensive margin adaptation," may be significant here.

Finally, if we are trying to break this out spatially here, is this extensive margin adaptation a big deal? What you're seeing here is a map of California and a map of California, both of which look red, this one looks a little bit redder, and what we're seeing here is -- unfortunately, this doesn't come out in the Powerpoint as nicely as it should -- but the right map takes into account this notion of people installing more air-conditioners as time goes on, and it shifts the impacts up quite a bit. And what we can do with the data that we have is actually look at the areas that have more of this adaptation, or expect it to have more of this adaptation in areas that have less of it.

Now, economists have always been accused of just worrying about efficiency, meaning worrying about the size of the pie, or how much the size of your pie shrinks, but not worrying about equity as much, meaning who gets what share of this pie, or who gets what size of sliced pie right here.

So what we did here, and I just want to make clear that these results are not causal by any means, but what we did is we calculated predicted impacts of climate change, taking this adaptation into account, and we correlated it with shares of certain groups across Zip Codes. The reason this may be a significant exercise is that people do not sort randomly across Zip Codes. When you arrive in California, you don't randomly just chose a Zip Code, you sort into a Zip Code according to, you know, many different characteristics. There's a large literature on Public Goods Provision in Economics, for example. So wealthier people tend to live in coastal areas, maybe, as we go to the interior, per capita incomes drop a little bit, and what we do here is just show you some scatter plots between characteristics of the population and climate change impact. So what you have on the Y axis in these next couple of pictures I'm showing you are predicted increases in residential electricity consumption at the Zip Code level, what you have on the X axis is different properties or characteristics of the population at the Zip Code level. So the first picture here is household income vs. percent increase, what you see here is the negative sloped line right here, meaning that wealthier households are expected to see smaller increases in residential electricity consumption. And just again to be clear, this is purely due to location. If people resort in response to climate change, then these pictures are no longer valid. If we have share of Caucasian population against percent increase, again, you see a slightly negative line right here. If we go share African American, that line is slightly negative, but not statistically significant. What you see here is share Latino population, that line is positive and statistically different from zero here, meaning that areas with a large Latino population are areas that are expected to have a bigger increase in residential electricity consumption due to warming.

Now, I've probably already gone over because I forgot to set my timer here, but the point I want to send you home with is that I think there's a nice combination of literatures starting to emerge here, combining both sort of short and medium run impacts, this is due to the excellent work done here at the CEC, that shows that -- for now just for peak -- even in the short to medium run, we're expecting a big impact. The other work, much of which has been sponsored by the PIER Program, and I want to thank them for doing this over so many years, shows that, in the longer run, this is going to continue both for consumption and peak.

One thing we're starting to work on now, which I think is important, that the impacts don't affect everyone equally, but there are different people affected differentially, and trying to at least bound how big that difference is, I think, is an important exercise. Also, I think the point that can't be made often enough here is this energy penalty point, right? As we go forward and plan, this change in energy consumption due to climate change is always on top of these different scenarios. So I'm going to stop right here and wait for questions. If you want to ask me more questions, my email address is at the bottom here. [Applause]

COMMISSIONER PETERMAN: Dr. Auffhammer, a few questions. You primarily touched on this, actually, in your latter slides talking about extensive margin, but in the literature you cited and the work you've done, what were your assumptions about the implementation of the Energy Efficiency Standards for the State, the success of current policies, or just the adoption of more energy efficient appliances?

DR. AUFFHAMMER: So what we have essentially here in the work I've done, and most of the work I've seen, except for the CEC work, you have a fixed effects design where you control for things that don't vary across time at the household and at the state level, and then everybody has these time fixed effects where you control for things that affect everybody at the same time. So, in some sense what you're doing here is you're really getting at the pure causal effect of temperature on consumption. What you would have to do in order to add things like additional policies on top of that, in that particular design, you would have to worry about what goes on in that trend that is separated out through these time fixed effects. So, again, this is a very important point you're making is what these models do not do, they don't add on top the sort of offsetting effects due to policies, and those should be taken into account, of course. But we're trying to separate out the policy from just the causal effect of temperature.

COMMISSIONER PETERMAN: Thank you. That's much appreciated and I think, similarly, the rates are considered as normal, etc., so it just gives us an example of what policy can influence. And I also wanted to note, I appreciate your discussion of the impact of consumption as being heterogeneous and it's something I hope we'll delve into at some of the further panels.

CHAIRMAN WEISENMILLER: Yeah. I think the question I wanted to follow-up on is, again, when we do our planning even 10 years out, we look at both an expected case and then a one in 10 case, so it looks like this has done a pretty good job on the expected one, you know, the expected case for peak. But then the other question is starting to think about what could be the peak one in 10 effect, particularly given the greater volatility of climate change?

DR. AUFFHAMMER: So I don't want to speak for Chris, I don't know if he wants to come up and speak, but I would say that, as well, I think this is a key important component of planning is worrying not just about what the mean does, but worrying about what the 95th percentile and the 99th percentile event is going to see. If we look at the -- I'm a little bit dyslexic when it comes to time -- 2006 heatwave, I think it was, when we look at that, right, that's something that we expect to occur much more frequently, and looking at what the impacts are, if those heatwaves under climate change are maybe more broad geographically. So, taking into account not just what we've experienced so far in terms of heatwaves, but really coming up with some scenarios that look at the 95th or 99th percentile event combined with what's going on in neighboring states that we often buy more resources from during these peak times. I think looking at that in a more detailed fashion is very very important.

CHAIRMAN WEISENMILLER: Chris, do you want to comment?

DR. KAVALEC: Chris Kavalec, Energy Commission. I just wanted to add that what we've done so far is a relatively simple modeling of peak impacts using a fairly simple econometric model, and what we want to start looking at in the future is more sophisticated peak models that get at the distribution of the peak, including generalized extreme values. And so I just want to say we're thinking about this and we're sort of really at a starting point where we are now.

CHAIRMAN WEISENMILLER: Okay, thanks.

DR. AUFFHAMMER: But as is always the case with California, they're the first ones, as far as I can tell, from a policy modeling perspective that has issued official forecasts that take this into account. The EIA is not doing that.

CHAIRMAN WEISENMILLER: I think the other question, just following up on Commissioner Peterman's question, it seems like as you look at the distribution across their demographics, that if we do some of the policy overlays, unfortunately the lower income is less likely to be in a new housing, or to have the more efficient appliances, so, again, that could show greater impacts among the lower income than the more affluent areas going forward.

DR. AUFFHAMMER: I'm going to follow-up Chris' notion here, this is again just a first step. We have to do much more careful thinking about, you know, what's jointly going on here between the areas that are affected here differentially, and what are the properties of these areas? Right now, I'm just rolling everything into these pure correlations, but one should really break this down into several characteristics, conditioning on the other ones at the same time. So, again, this is just a first step here, but I think this equity point of view is an important one to consider because it also allows for us to think more specifically about targeting of these policies to different climate regions, for example.

CHAIRMAN WEISENMILLER: Or looking at trying to think very explicitly about developing policies to help mitigate the impacts on a more equitable basis in our society.

COMMISSIONER DOUGLAS: I just have a question for clarification. Earlier in the presentation, I think maybe around slide 8, or so, or 7, you were using words "climate change penalty" in the context of talking about population energy growth, and I just didn't -- I could use some explanation of what you meant.

DR. AUFFHAMMER: Well, the way -- people use this notion differently, but the way I think about it is, we think about the world going forward in terms of a baseline that often doesn't involve planning for climate change, so when we come up with baseline scenarios of, you know, what's the baseline we have to reduce the emissions from, or calculate impacts relative to, that often leaves out this particular notion. The fact is that the baseline, because of what's going to happen already absent of any addition policies right here, is higher due to this climate change impact, there's this what I call a penalty on top of that, but maybe penalty isn't a good word here. So, thinking about existing climate change that's already in the baseline, I think, is an important component.

COMMISSIONER DOUGLAS: Okay, so I guess just because it's Monday, or I'll write it off it's just because it's Monday, but the baseline of what is higher because we're not looking at climate change?

DR. AUFFHAMMER: So the baseline, think of energy consumption, think of, you know, any variable -- agricultural yields, and so on -- so if we ignore the fact that there is already existing stock of CO_2 emissions and durable capital in place that will continue producing these emissions no matter what we do for the next 10 to 15 years, there's already this climate change that's built into the baseline that many projections of baselines do not take into account.

COMMISSIONER DOUGLAS: And the relation to the impacts of projected population growth --

DR. AUFFHAMMER: So the point I was trying to make there is, if we keep population constant and we just roll out additional climate change, the impacts are five to 15 percent, or something like that, if we take the median projections that PPIC has issued, that we've worked with, and we roll those projections into projections of electricity consumption, the median projections of population growth will have a much larger impact on overall electricity consumption than will climate change. So if you ask, you know, what's the bigger impact here? Climate change or population? It's population because each additional person consumes a certain fraction of what existing people do.

COMMISSIONER DOUGLAS: Okay, now I'm completely clear. Thank you for that.

COMMISSIONER PETERMAN: And I was just really kind of following up on that, it was nice to see the scale with population and climate change, is there something else, though, that people are talking about as a significant driver, which actually for the consumption was just less than this climate change impact? You know, are we over-emphasizing something else?

DR. AUFFHAMMER: So I always look, you know, we look in the traditional breakdown -- incomes, population, technology, and now it is temperature is the missing one here. It's very hard to empirically quantify the impacts of technology, so I think one thing that has received a lot of attention lately is policy-induced technology changes, and I have some other work that was sponsored by PIER that looked at the impact of Building Codes at the national level, and looking at it for states that are more serious about it, like California, rather than other states that will remain unnamed here. And there is a significant offset in energy consumption due to these existing policies that in many cases are well enforced here in looking at, you know, the importance of enforcement vs. just standards here. So if you have good enforcement and good standards, you can get in some cases pretty close in some of these sectors, over longer periods of time here, to what climate change would do here. So, really thinking about what the order of magnitude of these impacts is in the existing data, I think, is an important thing to do, but it's also a very tricky thing to do because the data, as we all know, are scare and often not as clean as we wish they were.

COMMISSIONER PETERMAN: Thank you very much.

DR. AUFFHAMMER: Thank you.

MS. KOROSEC: All right. Our next speaker is Joshua Viers from U.C. Davis, talking about Climate Change Impacts on Hydropower Generation.

DR. VIERS: Good morning. My name is Joshua Viers, Associate Director of the Center for Watershed Sciences at U.C. Davis. Thank you for having me to share some of our own research and review some of the research of others. And I'll go over that fairly quickly and reserve some time at the end to talk about some of the policy implications as it relates to the impact of Climate Change on Hydropower Generation and with a policy focus on relicensing of hydropower units in the State of California.

As most of us --

COMMISSIONER PETERMAN: Doctor Viers, would you mind putting your mic up just a little bit?

DR. VIERS: Is that better?

COMMISSIONER PETERMAN: For me it is, yes, thanks. Everyone else? How are we doing? Okay, yeah, we're good.

DR. VIERS: As most of us are aware, California is blessed with both the topography and the climate to create what's known as potential energy so that stores of water, most typically it's snowpack at high elevation, that can be transformed into kinetic energy, which is the basis for hydropower generation. However, there are a number of contingencies in the use of that potential energy as that water courses through the mountains and through penstocks, generating electricity, and it's also stored for water supply, and it's also held back in times of flood, and it's used for other environmental purposes. So there are a number of contingencies with respect to infrastructure and also policies with the use of that water that constrain much of what we can think about with respect to climate adaptation.

So as we go forward and thinking about the 15 percent of the energy supply that's potentially at risk, it's important to put it in that context. The geographic context of this resource is that about two-thirds of all the runoff in the State of California occurs on only 20 percent of the land surface. In fact, if we were to look at the entire site of runoff, 90 percent of it occurs on only 40 percent of the land surface, half of that is in the Sierra Nevada and, as most of you are aware, we capture, store, and reroute most of the water that falls in the Sierra Nevada and use it for a number of purposes, including hydroelectricity generation, which is shown in the blue dots on the map to the right.

Change is taking place presently and is expected to change even more in the future, and we heard from a number of speakers already about the extent of future change. But I think it's important to consider some of the things that are ongoing. In addition to regional increase in annual air temperature that is mediated in part by proximity to the coastal areas and by elevation, perhaps with some seasonal change, is that our climate is dominated by intra and inter annual variability in precipitation, and that is the Mediterranean climate. In effect, every summer we go through a drought that happens to be remediated during the winter when precipitation falls. So there's quite a bit of variability already, that variability might be increasing.

Two of the things that have been documented as happening in the near past that do have an effect on hydropower generation, is a progressive negative shift in the onset of the spring snowmelt pulse, which means that that snowpack that we've been relying on as potential energy is changing in its timing. Similarly, the total amount of water passing through the system, one-half of that is the center of mass, and that's happening much sooner, which means that our operations have to respond accordingly. So this idea that our water management is based on climate stationarity, or the idea that the future will likely look like the past, is now under constraint, and we're having to rethink many of our previous assumptions.

One of those assumptions is what we call the "Water Year Type," and so many of you have heard "this year is going to be a dry year" or "this year is above normal," it's a wet year. It led me to ask the question, well, in California, when is it ever really normal, as we know that it's often wet or dry. And as it turns out, there is no actual normal year. The Department of Water Resources has five different water year types that they use and a couple of different indices, and one of those is the San Joaquin Valley Index, which takes four rivers from the San Joaquin Valley, and composites them with the amount of runoff. And they distribute those over five different water year types -- wet, above normal, below normal, dry, and critically dry. And typically there was what is known as a uniform distribution, or about a one in five chance of being any one of those years. So we took six different TCM models with two different emission scenarios, run through the variable infiltration capacity hydrologic models, or rainfall runoff model, and looked at how the change in distribution of years would look in the near term from 2000 to 2050, and then the later term. And as you can see, in the near term we actually get a bimodal distribution, which is either wet, as you can see here, and this is a model consensus, or critically dry increasing quite a bit, as you can see there, and then by the end of the century, of course, the critically dry years are very pronounced. I would also say that the Sacramento Valley Index shows a similar response, though not nearly as pronounced.

So water year typing is one of the fundamental ways in which we distribute water and it has a lot of important contingencies for downstream, particularly for senior water rights holders and other beneficial users.

In order to better understand the impact of hydro climatic alteration on hydropower resources, a number of different studies have been conducted and most, if not all of those, focusing on the Sierra Nevada. And these have been conducted over a variety of scales, some of those are what we might consider a macro in scale, this is looking at all the facilities across the Sierra Nevada using fairly coarse assumptions about operations, and summarizing those to the annual time step. Other studies have been quite narrowly focused, maybe looking at a single facility, but with very fine-tuned operations and looking at either hourly or daily fluctuations, or even seasonal changes with climate warming.

Most recent work, including some of the results that I'll show next, are what we might consider the intermediate scale, and so these are a number of facilities that are modeled in conjunction with each other in part because we know that water released from one facility is often captured and reused by another. These are using fairly refined operation models, though with some assumptions and looking at seasonal changes.

There are three primary findings from the body of this work, and I'm going to articulate those now. One is that total energy produced is mostly linear in response to total resource availability, in other words, this means that with less water, there's less energy. And that might sound simplistic in summary, but it's important to consider in part because a linear response means that it can be modeled much more simply. And these are fairly complex systems, anyway, and so we if want to be able to incorporate climate change, we can make some simplifying assumptions and do fairly well.

The timing is perhaps most critical, though obviously the amount of the resource is also critical, for considering changes in operations and how infrastructure may be able to capture and reuse the energy store. And then, lastly, most of these studies have concluded that adaptation is possible, particularly with how we operate our dams and reservoirs, but it's incredibly important to think about the downstream contingencies associated with that, in part, either the physical constraints with infrastructure and/or the policy constraints with how that water is used, who benefits from that, and when.

One example of a statewide analysis was just using the total amount of hydropower generated for the 15 major basins on the west slope of the Sierra Nevada, which have these codes here, such as the Kings, KNG, or the Feather River in FEA. And those are plotted in terms of their total hydropower capacity, and then a shift in the number of weeks, and so, as we move to the right, that's actually sooner in the year when one-half of all the water is passed through the system. These black lines indicate the median, so half of all the basins are above this line, and then the median for the amount of change, half of all the basins are to the right of this line. So if you're in this quadrant here, you both have a lot of capacity and a lot of change. And this is with uniform increases to air temperature of 2, 4 and 6 degrees Celsius, which is equivalent to near, mid and long term planning scenarios. And as you can see, there's a non-uniform response in terms of how these basins respond, whereas you have the Kings and the Feather being fairly close, under 2 degrees warming by 4 and 6 degrees warming, and you can see that there's quite a bit there. And I apologize for the black outline there because it was blue in my presentation and highlighted, so I'll have to fill in some of the blanks in the coming slides. One of those blanks is looking at statewide generation for over 100 different facilities, but looking at each facility independently under a base case scenario, and three different climate change scenarios. Madonnie & Long (indiscernible) would be able to show that, under the wet scenario, it actually generated more power, and I believe that number was about two percent -- let me give you the actual number -- that was actually a six percent increase -- or four percent increase under the wet, but under the dry scenario, here, that was a 20 percent decrease in power generation.

Looking at the American River and the Big Creek complex in the Kings River system, in the San Joaquin System, is that Sebastian Vicuna by mid-Century noted about an eight percent decrease in both of those systems and, again, this was modeling fewer facilities, but in conjunction with one another.

The most recent work that's been conducted and funded by PIER was to look at a number of different facilities modeled together, and so this is 15 different basins, again, from the Feather down to the Kern, with 415 co-managed entities within that model, so 56 different reservoirs and over 100 different hydropower plants. We did not include the Rim Dams in this study, so the large facilities such as Folsom, or New Melones, Don Pedro, etc., are not included in this analysis in part because they're often used for multi-year water resource needs and flood control, and they're a little bit more difficult to model within this context. We did this over a 20-year horizon using historical precipitation from 1981 to 2000, that includes the wettest year record in 1983, the flood year record in 1997, and the five-year drought. So it does show some variability. And then we increased the air temperatures by 2, 4, and 6 degrees, again, to look at the sensitivity of the system and how it may respond to warming.

In this graph here, we show the total energy produced under the yellow being the zero degree base case scenario, and then warming of 2, 4, and 6 degrees Celsius and, again, that's near, mid and long term supply, and then we have the absolute change in gigawatt hours, and then the percent change. And I'll just focus on the percent change because I think it's most telling. And you can see that, under the six degree warming scenario, there's actually an increase in generation, but that happens to take place over the winter and spring months, and that there's a concomitant decrease in generation during the summer months because of the resource availability. So one of the big questions, then, is do those two things balance each other out?

These bar graphs show the same energy, total energy, change in energy, and percent change in energy, but this is across seasons, so October, November, December on the left, and July, August, September on the right, and then annual summaries. And, again, you can see that the total net change annually across the west slope of the Sierra Nevada is a negative. And in terms of percent down here in the lower right-hand corner, that's a nine percent change overall, again, using these assumptions. And it's important to point out that this study and the other ones that I mentioned often do not include changing resource demand in terms of consumer demand, nor changing price conditions, and those are both important factors that will need to be considered in future research.

So the policy implication of this is that, from a planning standpoint, the one instrument that is most often used is the Federal Energy Regulatory Commission's

Relicensing of Hydropower facilities. These are non-Federal facilities that often get a 30 to 50-year license, that spell out the operating rules for power generation and how different aspects, whether those are threatening endangered species, or even visual effects, and how those will be managed going forward. Nearly two-thirds of those licenses remain up for renewal within the next 40 years, and so it's an opportunity, then, to look at how relicensing goes forward and if, in fact, climate change can be incorporated into that planning process. As it turns out, however, a group of stakeholders in the Yuba-Bear Drum-Spaulding area, which is not far from Sacramento, petitioned the Federal Energy Regulatory Commission to actually include climate change as a study plan for this re-licensing, that request was rejected on the basis that, even though FERC concluded that there was consensus that climate change was occurring, they're not aware of any climate change models that are known to have the accuracy that would be needed to predict the degree of specific resource impacts and serve as the basis for informing license conditions. That being said, I think we can all take a moment to think that, going forward, we're probably at the point now, based on some of the research that you've seen, and the work of others, that we can begin to incorporate climate change scenarios as part of this planning process. One such way of doing this is to provide what's known as climate change alternative, if you will, under the National Environmental Policy Act, or NEPA, which considers a number of alternatives for planning purposes. We're now focusing on the greater Yuba Watershed in part because it has a number of facilities up for relicensing and it is perhaps the most complex of all the waterworks we have in the Sierra Nevada, so we take water out of the Middle Fork Yuba, move it over to Canyon Creek and Bowman Lake, and then from there over to Lake Spaulding on the South Fork Yuba, some of that water ends up in the South Fork Yuba, but a lot of it actually goes into the Bear River, generates hydropower going downstream. So it's a highly complex system with a number of licenses that are now up for renewal, and could benefit from thinking about climate change going forward.

I would note the one area that few people have looked at that would be important is the fact that, as air temperatures rise, as do stream temperatures, and if stream temperatures as inflows and reservoirs are much warmer, it could be considered that the actual lake or reservoir itself will fail to stratify thermally, which means that the cold water pool at the bottom of these reservoirs may be much warmer and so their ability to meet downstream targets for water temperature that are very important for native fishes such as Salmon, may be compromised. And so that's an area of work that we're presently engaging in.

So, to think about FERC remedies, it isn't just incorporating climate change as part of a modeling perspective, but climate adaptation requires that we embrace uncertainty, that we enable flexibility, and we employ policy feedbacks. In order to do that, I've highlighted three areas that I feel would be of some utility: the Aggregation of Licenses, Escrow Accounts, and Regionalization. The Aggregation of Licenses is that we go about this in a very piecemeal fashion; each project is licensed independent of all the others, very rarely are they licensed together. Presently, we do not include Federal dams in any of this, and so they're modeled and operated in isolation of others, and as we can imagine this idea of the watershed context is that, in order to be proactive in managing our resources, we need to do that cumulatively. This would also have the benefit of minimizing direct liability for any one Licensee. Presently, a lot of the relicensing studies that are done are conducted by consultants, paid for by the Licensees, as it's very expensive, and a lot of the stakeholders actually question the partiality of those consultants. And so the studies themselves perhaps get contested and that draws out the amount of time that we have to be proactive and coming up with solutions. This would also improve the standardization of study plans going forward so that we're all using the same models and same assumptions and we have some basis for comparability.

The last point is Regionalization. And that is that our working rivers are asked to do a lot of things, some of them produce hydropower, some of them store water, some of them do flood control, and some of them support Salmon, and often we ask them to do all of those things simultaneously. In an era of climate change, it may become untenable to ask our rivers to do all of those things, and so we need to start thinking about what we call Regionalization, or Specialization, is that we're asking specific basins to do specific things. And I recognize all of the problems associated with that.

So lastly, we will adapt, you can imagine that the power generation -- that they want to maintain generation, they want to maintain revenues, and that there will be some change in operational behavior. What was highlighted under here is will they adapt with difficulty or with ease, and because, at least with humans, the future is likely to look like the past, what

I would say is what is likely is a reactive adaptation with local single actor solutions, that are made on short run decisions, and that those solutions are held in a private domain. What I would contend, however, is that what is needed is anticipatory adaptation with regional and multiple actors, with middle to long run decisions, and those solutions that is held in the public domain. And the reason is that there are really only two remedies presently for looking at FERC relicensing within the existing framework, one is the idea of a reopener, which is that, once the license conditions are set, you could actually go back and renegotiate those, those are incredibly rare, if ever enacted; and then, secondly, this idea that we can do adaptive management. Well, as it turns out, no one really knows what that means, and so it's the lack of surety in incorporating adaptive management as a formal term in these licenses that prevents a lot of stakeholders from engaging in that. And so, with that, I'd like to say thank you to you for having me and presenting this, and also to my colleagues that helped produce a lot of this work. Thank you.

[Applause]

COMMISSIONER PETERMAN: Thank you much. Thank you very much. I found it very interesting. I just wanted to clarify -- I was a little bit confused by the slide -- does FERC consider climate change in its hydropower relicensing?

DR. VIERS: Not as a formal component.

COMMISSIONER PETERMAN: Okay.

DR. VIERS: With the idea being, is that if something -- if the hydrologic regime were to change, it's contingent upon the Licensee to actually still meet the terms of the license condition, and so if they're unable to meet that, then they would have to go through a formal process of compensating for it -- either changing the operations and getting a change in the license, itself.

COMMISSIONER PETERMAN: Thank you. And I think you've highlighted a couple opportunities we have in the relicensing forums to come up, which I appreciate, and the most recent California RPS legislation allows more opportunity for hydropower in different forums, as well, and so this is an area that is current and live and we're looking at new projects, and so I appreciate your feedback.

CHAIRMAN WEISENMILLER: I guess, obviously, we look a lot at the hydro system in California, we also integrate it with hydro systems in the Northwest, so I was trying to get a sense of how similar or different the impacts will be in the Pacific Northwest compared to

California.

DR. VIERS: That's a very good question and I may not be able to answer that in a thoughtful way in the sense that our studies have focused almost entirely on the Sierra Nevada. That being said, a lot of the climate change work has focused on the Pacific Northwest, and certainly they've been able to anticipate the hydrologic change there. Currently, there are a number of facilities in the Pacific Northwest that do undergo FERC relicensing, and our research has been the basis for some changes in how they do relicensing, but it's also important to point out that quite a bit of that energy that's produced by hydro power through the Bonneville Power Administration and the Columbia River, and that would not be part of the FERC process.

MS. KERSTEN: One more time. You mentioned there's no normal year and that we don't look at history to describe the future, there's need for more refined operations models, we need to look at flexibility, uncertainty, feedback flows for policy, do we have the computing power, you know, to deal with these changing scenarios? Do you have any comments about the limitations of hardware/software in order to do this? I mean, all of these ideas are great, we look at all these potential impacts, but what are your personal thoughts about the ability to actually project based on the tool, itself, and its impact on influencing what you come up with?

DR. VIERS: I think that's an excellent question. Thank you for asking it. As Professor Jay Lund likes to say, and I’m sure others have said this, too, is that all models are wrong, some are useful. And I think we've been able to show that there's some utility in what we've done, not that it can't be improved. I would say that the limitation isn't in the hardware itself, I mean, the actual computations that are being done compared to some other forms of computing don't strain systems. The real limitations are lack of information. Oftentimes, these models do what we might -- we've kind of -- we back into them, we don't actually have the specific operation decisions, but we know how the system behaves based on the flows that come out of them, and so that we can reverse engineer what's going on. But these are definitely coarse approximations and, to the extent possible, we use hard written-in legal instruments, say, an environmental flow requirement can never -- you know, flows can never drop below this level, and so we can build that into a model, but if it's a warm day, or we get a pineapple express and they end up dumping half their water in anticipation of the shock to the system, that's a very difficult thing to model. And so going forward, there's always going to be approximations, and we use the ensembles of GCMs to kind of help guide this and we can put bounds on that. So I think it's more of this consensus modeling, is that if we have a bunch of different researchers that use a bunch of different methods, and a bunch of different assumptions, and they're all kind of coming to the same general conclusion, then that gives us a little bit more confidence going forward. But I would say having data that were available to the research community about actual operations would be very helpful.

MS. KOROSEC: All right. We're scheduled to take a break now. We're running a few minutes behind, so I'll ask if people can be really good about being back at 11:30, and we'll reconvene then. Thank you.

(Break at 11:18 a.m.)

(Reconvene at 11:33 a.m.)

MS. KOROSEC: All right. Welcome back, everyone. Thank you. Next we'll be hearing from Larry Dale from Lawrence Berkeley National Lab on Potential Impacts of Wildfire, High Temperatures, and Sea Level Rise to Transmission Lines, Performance of Thermal Plants, and Electricity Reliability. Larry.

COMMISSIONER PETERMAN: And before we get started with the next speaker, I'm just going to take a second to introduce Commissioner Cathy Sandoval with the California Public Utilities Commission, who has joined us. Thank you very much for taking time out of your busy schedule to join us for this workshop.

COMMISSIONER SANDOVAL: Well, thank you for the opportunity, so very excited to hear about this very important issue.

COMMISSIONER PETERMAN: Thank you.

DR. DALE: Okay. I'm Larry Dale. I work at Lawrence Berkeley Lab and I'm happy to be here to tell you about what one of the earlier speakers said would be a thrilling description of impacts to the energy infrastructure of California. But before I get to the thrilling impacts, let me first mention that the work that I'm talking about is building on the works, the work of many people who are in the audience, as well as many people who worked on this project. You can see several names there, many of us at Lawrence Berkeley Lab, some people at U.C. Berkeley, one person in Brazil, and I should also mention several other people on campus at U.C. Berkeley have contributed to some of the findings of this study.

The idea is to estimate the impacts of climate change to the energy infrastructure, in general, but with some focus on power plants and transmission lines to warming temperatures, wildfires, and sea level rise. And I think, you know, the idea behind this notion of a thrilling talk is that -- is the idea that these things could happen in conjunction, that you could get a wildfire at the same time, in the same year, following massive floods along the coast, and when energy demands are peaking and the system -- it is the idea that this could crash. So I will confess that those of us working on this kind of had a double mandate, one was to be very careful with our analysis, stick to the facts, we worked with a group of people from electricity utilities who were very careful to have us stick to the facts, and the facts are limited, particularly if you're talking about data.

But at the same time, we did want to get at this notion of how the combined impacts could be much worse than the separate sum of the impacts. And so we made a few small steps in that direction.

This slide gives you a sense of how we approached the problem. On the lower left-hand corner, you can see a chart showing GIS data for changes in temperature for different parts of California, and in the upper right-hand corner, you can see the electricity infrastructure of California laid out in a sort of simplistic fashion.

Some of the dots are power plants, and the lines are transmission lines, and that's the system that we were largely focused on in this study. So, in the first part of the study, we wanted to look at how are these rising temperatures and, in addition, rising sea level, going to affect that infrastructure? So the method that we used was actually pretty dead simple, we downscaled all of the temperature data that we could get, particularly temperature data focused on those peak periods when the infrastructure is at its most vulnerable, to different parts of the state. And that map at the bottom shows you both current -- 1999 -- temperature, the 2050 temperatures, and the change between 1999 and 2050 and 2099.

So the procedure was, using GIS, we would look at the energy infrastructure, there was a lot of data provided to us by the Energy Commission, overlaid the temperatures on that infrastructure, and then looked at the impacts. Now, here are the same GIS maps, but this is showing changes in impacts to the generation capacity of the natural gas plants of California at peak temperature periods during August, looking ahead between a current period, and the end of the Century period, and then the change.

The reason we did this is that it turns out that natural gas and most thermal generating plants lose efficiency. It seems like a small thing, but the changes in temperatures between now and the end of Century could cause something like a six percent drop in the efficiency of thermal power plants. It's important to note, power plants at the end of the Century are going to be operating at about 75 percent of nameplate capacity, whereas now they're more like 81 percent on average during a hot August day.

So what this means is that any changes to the electricity system in that period, this penalty that Max talked about earlier, this climate penalty on the energy infrastructure, is going to have a redoubled effect. You can't just replace -- if we have an increase in demand, which we will have, you don't just meet it with one more power plant, you have to meet it with a power plant that's a little bit less efficient so that the penalties interact. You have an increase in demand, you have to increase the power plants to meet that demand by about 1.3 times the number you would today.

And here is a slide that is, as everybody tells me, far too busy, but I have limited time. Here, I'm showing you again a map on the right side showing you the energy infrastructure, but I'm summarizing impacts to that infrastructure in terms of decreased generation efficiency, transmission capacity, and then a summary of end of Century, mid-Century impacts. Currently, we have about 44.1 gigawatts of natural gas capacity. Because each of those plants is less efficient, this is going to mean we need about eight percent more capacity just to hold per capita demand the same by the end of the Century. Peak period demands, we did our own study of peak period demands and how they will change with peak period temperatures, trying to look at the one in 10 impacts, or trying to look at the particularly hot August days at the end of the Century, and we found about a 21 percent increase in peak period demands end of Century. For that, we would need another 12.1 gigawatts of natural gas capacity. At the same time, the system, the substations are working less efficiently, the transmission lines also very slightly less efficiently. That has another need for about 1.6 gigawatts. You sum all those thing up and you need about 40 percent more generation capacity just to satisfy the demands we would expect if we had today's system.

Transmission is also slightly less efficient. You're going to have some extra energy losses, but they're very slight, surprisingly small. But the capacity of the transmission lines may be a constraining factor. Transmission line capacity drops about seven percent by end of the century. Coupled with the higher peak loads that we're expecting, this would mean about a 31 percent additional transmission capacity need for the end of the century. So this gives you a sense of how you start combining the penalties of climate change, how you can get a fairly large impact.

I should say I've been working now for -- since before my hair went gray -- on climate change impacts and this may seem fairly small, but it's the largest economic impact I've seen of any study for California, by a large degree, in fact. There's many billions of dollars of cost involved in that. So then you might ask, well, what's going to happen from some of these other impacts? Well, one of them, one of the dramatic ones, would be wildfires. Here, we're building on the work of Tony Westerling who put together the most widely used fire model for the state, and he finds, as you would expect, as things get hotter, the mountains are going to be drier, vegetation will be drier, and coupled with dry years, which may happen with some more frequency in parts of the state, you're going to have a much higher fire risk. The fire risk using that model can be downscaled to each separate pixel of the state, about a 4 kilometer pixel. We did that for the state, we overlaid it with transmission data from the Energy Commission, and the result are these maps that you're seeing here for each of the climate scenarios and emission scenarios that we looked at. And then one more step was we then summed the changes and probability of a fire along the entire length of the transmission lines that we were concerned about. And here you see a chart showing the changes in fire risk caused by climate change, end of Century, to the transmission system. And the red is a much higher fire risk, that's about a 35-45 percent higher risk. The green is a smaller risk, between zero and 15 percent. And the blue is actually showing you lower fire risk. The reason you can get lower fire risk is that, in the model, once you have a fire, the vegetation is gone and your fire risk disappears. So, by end of Century, you've got a lot of areas where they've had enough fires so you don't have to worry about them, about the fire risk anymore.

But some things do stand out, in particular I'll focus your attention on the red transmission line up here at the top, which I think is called Path 66, which is California's major transmission corridor going north to all the hydropower that we now get from the Columbia River. There's also a lot of higher fire risk around Los Angeles, at least for some of these A2 scenarios. And those are you can think of the Santana wind fires that we often get down there that's representing that increased risk. So think of about a 40 percent higher risk of wildfires.

And then finally, here is the sea level rise problem that we dealt with. This was again a very simple analysis in which we overlay a 1.4 meter increase in the sea level rise end of Century, coupled with a storm surge, onto a map of California that includes the locations of all the power plants and the elevations of all those power plants. And wherever there was an encroachment of the higher sea level plus storm surge upon the power plants, or also we were looking at substations, we considered there to be a plant at risk. And based upon that analysis, we found 25 power plants and about 90 substations that are vulnerable to this kind of risk.

The map shows you both the number -- it gives you a sense of the numbers of the power plants and plus it does clue you into the fact that a lot of the power plants we do have, particularly natural gas plants, are along the coast where water supplies are plentiful and it's easy to build these plants, or easier to build these plants. But I should say, and it's a kind of common theme in this study, the data is not very good, it's surprisingly poor. We went out and visited a couple of these plants, maybe about five of the plants, and we found two things. The elevation maps we're using are astonishingly poor, you can't tell within a few feet what the elevation is off and along any stretch of California. You would think in the days of satellites, this would be not a problem, but it is still a problem. And also, even thought the Energy Commission has the best available data for the location of plants, the best available public data that we could use for this, the location of power plants is itself not very accurately portrayed. So, when we visit the plants, we'd find they not only had the wrong elevation, but they also had the wrong location.

Offsetting this, I should say there's -- it's quite easy to adapt to changes in sea level rise by building dikes, and many of the plants actually have dikes that aren't portrayed in the data.

So those are the results of the study, but I guess I want to mention something that I was thinking about as I drove down here today. A lot of people in the Bay Area probably still have in the back of their minds this sailing disaster that took place a couple weeks ago, in which five people were killed in a race going around the Farallon Islands. I sail some and have raced a little bit and have gone around those islands. And one of the people that died was actually in the building where I work, so this was quite fresh. What happened was a number of very experienced sailors on a not particularly rough day, not particularly competitive because they were far behind everybody else, they didn't really think they'd win, they did three things that caused a disaster -- they took an inside tack close to the islands, they met with a wave that was unbelievably large for that day, and some of them were not tethered, which is very common, I must say, for sailors. And those three things led to a disaster. Now, here I'm looking at three things, I'm looking at infrastructure, power plants, sea level rise, fires, but we don't have close to enough data to talk about what the odds of all those things happening at once are. And those are -- I guess what I would say is I don't foresee a time when we're going to have the data to do that kind of analysis, it will come, but it's going to take time. So my sort of final words about this subject would be, you're going to have to keep your own sense of judgment about what these impacts are, what the risks of these kinds of impacts are to the energy infrastructure, or to any other part of the economy of California. The impacts we estimate are fairly modest, actually, these are of course billions of dollars, but everything could be managed by electric utilities. They can build extra supply, they've dealt with changes in demand that are much larger than those I'm projecting. So there need not be a disaster just within the terms of this study. But if you start linking risks across possible categories, it gets to be very hard to know what's going to happen.

So I'll just leave it at that and take any questions that people have.

COMMISSIONER PETERMAN: Thank you. A couple questions, most are centering or pertaining to slide 5 where you did the results summary. So just remind me again, is this a snapshot of 2100, is this current based on projected temperatures?

DR. DALE: Yeah, thank you. This is the current infrastructure, the current population, focused in the end of the Century climate impacts.

COMMISSIONER PETERMAN: Okay.

DR. DALE: If you want to think about mid-Century, there may be 40 percent of these impacts if you look at temperature data.

COMMISSIONER PETERMAN: And I find this slide valuable both to think about what we could be doing policy-wise to change this, and also some other things that are coming on the horizon, and one thing with -- this identifies an increase in transmission capacity needed. I think that's one of the reasons why the

Administration is focused on a goal for distributed generation, to think about how we can reduce our transmission needs, and so one would expect that, if we do see the increase in DG as is being planned for, then there will be less need for increased transmission capacity, but acknowledging that, just with our transmission lines, alone, we would see significant impact from fires.

DR. DALE: Yes, that's right.

COMMISSIONER PETERMAN: We had a workshop, I mentioned, on net benefits of renewables and we had significant participation by CalFire and the U.S. Forestry Service, and they're looking at opportunities for clearing biomass for fuel in order to reduce fire risk. I think the challenge, though, you've pointed out some of the most sensitive transmission lines are not located in the areas where we're able to do some of that forest clearing, particularly in the southern part of the state, so there's a bit of misalignment there. There is a question, though, here it is -- obviously, the state is relying on, or expecting to rely on, natural gas plants as a resource to both help firm and shape renewables in addition to Demand Response and storage, and you've highlighted a couple of impacts to natural gas plants in your study. I was wondering if you're aware of any other impacts the increase in temperature might have on support for natural gas plants, like particularly the pipelines and the ability of the pipelines to deliver the gas, as well as the ability to ramp or anything like that, are there other operating characteristics that might be affected?

DR. DALE: We did look at where flooding could affect some pipelines, mostly in the Delta. But we didn't look at the natural gas pipelines going in and out of the state, we didn't cover that part of it in this study.

COMMISSIONER PETERMAN: Okay. You've also identified a number of plants on the coast that are vulnerable, and I think this is topical -- timely and topical -- because of currently plans to replace facilities through once-through cooling regulations. And considering we are repowering facilities in the same location, and if so are they going to be vulnerable to the sea level rise impacts, as well, you did not call out specifically San Onofre or Diablo Canyon, and I was just wondering if you wanted to comment on any possible impacts to some of the nuclear facilities.

DR. DALE: My understanding is that they do have the same efficiency impacts, maybe even larger than natural gas plants. I think that's true for coal, as well, but we didn't focus on those, in particular, we looked mostly at the natural gas plants as representative of thermal power plants.

COMMISSIONER PETERMAN: Thank you. We noticed that Humboldt is up there as one of your plants, that scenario where some of the spent nuclear fuel is stored, and so that brings concern, as well.

DR. DALE: I actually visited that plant, actually ex-plant, or soon to be ex-plant, and it's pretty astonishing what they have to do. There's a guard there all the time, there's fences around that spent fuel, it's located about, I don’t know, 50-feet above, maybe 75-feet above sea level. If you had a big enough tidal wave, it could be a problem.

CHAIRMAN WEISENMILLER: A couple questions. Obviously, I tend to distinguish between siting which gets you the 40 or 50-year issues and the planning which gets you more in the 10 or 20-year issues.

DR. DALE: Right.

CHAIRMAN WEISENMILLER: So in terms of, you're obviously looking at 2050, or, you know, 2100, so in terms of looking at that 2020 to 2030, what can you say from your study about that period?

DR. DALE: I think --

CHAIRMAN WEISENMILLER: If anything.

DR. DALE: -- yeah. Well, I can give you an idea of the impacts mid-Century. And a number of the natural gas plants, or similar kinds of plants that might be put in place now are going to be around long enough to see some of the bigger impacts that we're talking about, so you have to keep in mind, I think, the long range impacts in order to plan well, even for short run impacts. But I don't -- we didn't specifically do a short-run planning study like that, and I think, you know, one piece of advice would be that there are different kinds of energy generation that seem to be less vulnerable to the impacts of climate change, and those could include both wind and solar, distributed generation, all of those are -- because of this study, I think in my own mind -- somewhat more valuable than we would have otherwise thought. But those are the kinds of lessons I guess I would suggest for the near term.

CHAIRMAN WEISENMILLER: The other thing, which we've experienced in terms of impacts on the infrastructure in Southern California, have been sort of windstorms knocking out, and part of the question is, is there any likelihood that extreme windstorms are connected to climate change?

DR. DALE: I think there is and we spent a good while trying to figure out how we could try to incorporate the information that's now available into the study. It's difficult and the climate models are, I think, not -- they're not unanimous about what is suggested for winds. Some of the studies are showing that Santa winds might become less severe in the future, at least that's one of the things I heard. And Dan Cayan probably can -- is in the room, I think, or was a little while ago -- might be able to tell you more about the degree to which those kinds of studies are becoming feasible with the better data that we're now getting from the climate scientists. But I think it was not quite feasible -- we just decided it wasn't quite feasible at this stage to do that analysis.

CHAIRMAN WEISENMILLER: Yeah, and the other one, if you go back to the slide on transmission line vulnerability for a second, that it was surprising to me, at least, there's been a lot of public attention in terms of the wildfire impacts down in San Diego.

DR. DALE: Yeah.

CHAIRMAN WEISENMILLER: And so at least looking at what seemed to be the SWPL and Sunrise corridors, it's not obvious that there's much of a concern there.

DR. DALE: Down here?

CHAIRMAN WEISENMILLER: Yeah.

DR. DALE: Yeah, I think -- well, one of the problems is that we're looking at impacts only to the larger transmission lines and we aren't looking at the smaller transmission lines around the distribution transmission lines that are closer to the urban areas. And I think that's where the fire impacts are in San Diego, they're in the hills surrounding the city where there's a lot of development and a lot of smaller transmission lines. So, you know, that's a big caveat to this study, we were only looking at impacts to the larger transmission lines of California's electricity grid.

CHAIRMAN WEISENMILLER: My final question is just, as we look at -- right now, we're committed to a very strong roll-out of EV, and that's certainly going to put more stress on the distribution system, particularly in terms of charging at night, and so trying to understand how your climate impacts, weather impacts, on when we suddenly start having much more charging in the distribution system overnight, how those interact.

DR. DALE: Yeah, we didn't look at that, that time period. But we did look at substation risk and a lot of the transformers in substations, you know, when a substation stepped down the electricity from the larger transmission lines down to an electricity voltage wattage that can be used in homes, and substations are vulnerable not only to peak temperature impacts during the day, but also to a sort of -- a long run temperature impact, including temperatures at night. They need to cool down. And they're not going to be cooling down as much. I think one of the things we heard earlier is that nighttime temperatures, in fact, are going to be going up more than daytime temperatures during some peak heat storms. So there is a risk, yet another risk we haven't really focused on in this study, there's a lot of stuff that you would like to look at if you're really going to try to pin down the various facets of the risks that are facing the infrastructure.

COMMISSIONER SANDOVAL: Thank you very much. I was wondering if you could just explain a little bit for the record, a little bit about the technical aspects of why increased temperatures make gas plants less effective? You said that it was eight percent less effective. Could you just give us a little bit more information about technically why that happens?

DR. DALE: I'm really the wrong person to answer this question, but I can take a stab at it. There's surprisingly little literature about this, but we did find a couple of studies that showed how -- showed the impact of temperature on plant efficiency, and generally nameplate capacity for these plants is estimated at a temperature of around 59 degrees, so capacity is actually a little bit larger, below that temperature, and it tends to be about one percent lower for every degree you go higher than that temperature. So a current peak period capacity for a natural gas plant, a typical natural gas plant, is going to be around 20-25 percent. Now, I'm averaging across the two main types of plants that we have. We have combined cycle plants, which are a little bit less vulnerable to temperature rises, and simply cycle plants, which you have about 40 percent of the total in the state, and they're more vulnerable. We tend to be moving more towards the combined cycle plants. We have some plants that have chillers that would be even less vulnerable to rising temperatures than those shown in the slide.

COMMISSIONER SANDOVAL: Okay, great. And then the same for transmission lines, I know that also with transmission lines that certainly as they are required to carry more capacity, some of them actually will also sag, so that's something that we're looking for, as well, in preparation for this summer. But, again, could you explain a little bit for the record about why transmission lines are also affected as not only you have increased demand, but also as it gets hotter?

DR. DALE: Yeah, well, during the same periods that you have increased demand and a high fire risk, you're going to have -- the lines are going to be hotter, there's more electricity going through them. And they're made of metal, and metal expands when it's hot, and so they tend to sag everywhere. Some of the lines are less vulnerable to that than others. And one of the problems is we really had no detailed information about the transmission lines, and that's not something that's readily available, so it's hard to make a detailed estimate about that kind of a risk, but it certainly is there.

COMMISSIONER SANDOVAL: So it sounds like it's a combination of the demand side, as well as just simply heat would expand the metal, and then you add more demand to it, so both of those factors might expand. And then, what you were saying, that substations need to cool down at night, I know that transformers also need to cool down at night, so that's something that would affect us at the distribution level, as well. So did your study also encompass the impact on transformers?

DR. DALE: Yeah, and we didn't really -- in the summer I presented, I didn't talk about the increased risk of the transformers blowing up, they are part of the substations I'm talking about, though. Overall, efficiency was dropping and we did include that in the summary estimates, but there is also increased risk of failure. In general, the utilities have a pretty good sense of what the failure rates are for different temperatures, and so if they're on top of it, if they get the rate increases they would need to cover all these costs, and if they are planning far enough ahead, then they can replace the transformers frequently enough in order to avoid that kind of failure.

And I should just mention one other thing, you know, this notion that there's all these different ways that are hard to anticipate, one of the things we did look at was the possibility of transmission line failure in the event of extended dead air spells, and the transmission lines need to be kept, you know, they can suffer both capacity loss and the sag problem that you're mentioning, as well as some efficiency losses. All of those problems can get significantly worse as the lines get hotter, and right now they generally assume a tiny bit of wind, at least two miles per hour wind around the lines, but if climate change also brings higher frequency of dead air spells, something that we haven't looked at -- I don't know if anybody has -- those lines could be at significantly more risk than they are now.

COMMISSIONER SANDOVAL: Thank you.

COMMISSIONER PETERMAN: This is Commissioner Peterman. I'll also just note that some of our renewable facilities will be affected by the higher temperatures, as well, such as solar PV, the efficiency of those facilities is decreased with higher temperatures, and so, going forward, as we're building out more renewables it's still an important issue to look at, and I was wondering if your study touched upon that.

DR. DALE: We didn't cover wind or solar, we of course recommend that be done. I think it's the thermal solar that's most at risk, that would be the biggest technical problem for that, the efficiencies of that would be dropping. PV, I'm not -- it's a little bit less efficient, I don't know that it's significantly less efficient, that would be more vulnerable to higher cloudiness problems.

COMMISSIONER PETERMAN: I think, considering the scale at which we're increasing our investment, in solar PV, in particular, that's an area I'd like to get some more information about. It sounds like there's a lot of possible follow-up to your study, as well, which is great.

DR. DALE: Thank you.

COMMISSIONER PETERMAN: I think we're about to transition to the next speaker and we are running behind schedule, as is the case, and so I would say to Guido, since he is one of our own, if you can go quicker, that's all the better, but it's all good information, so we appreciate you all being here and bearing with us on time. Thank you.

DR. FRANCO: Will do. Okay, so far -- well, so I'm going to talk about the potential impacts of climate change on renewable sources of energy. I'm going to talk about hydro because there was already a very good talk about hydro, so I'm going to talk about the impacts to PV systems and other systems.

Okay, so first I would like to acknowledge two people that really helped me a lot. Whenever I have to read a very difficult journal, paper for the scientific literature, they are there to help me, and they are there. They are Max and Olive. I don't know if you have heard about the CAT team, well, now you see them.

Okay, so also going to talk about bioenergy and I'll touch a little bit about the issue of water operability and the electricity system. And then I will conclude.

So wind resources, first of all, you may have heard that wind speeds are slowing down in the United States, there are some issues about this, but I will now talk about them. But if you look at the southwest, at least for this -- and this is one of the major papers to come out from the literature recently -- showing for the southwest, wind velocities are not slowing down. That includes, of course, California. And not only that, also the high wind speeds are not slowing down. So, at least for an historical context, it seems that wind resources are still viable. Well, some research has done a lot of regional climate models using dynamic models, these are models that simulate the physics involved in weather, and here are some of the outputs of their model for the historical period.

Plot A is supposed to be the historic conditions and the other ones are realizations from the different models, making combinations of output from the global climate models with downscaling use in regional dynamic climate models. And I don't want to get into details, the only thing that I think is worth noting is that the modeling outputs are not very close to the historical realizations, so -- and also, the one thing that they did, I mean, that's one thing to say here is that, I mean, so be careful when your research is showing you potential impacts to climate change on wind resources; if the historical simulations are not good, I will at least doubt the accuracy of any projections. But they did involve some -- I mean, perform some projections for the future and the end result is with their models they see that changes are not outside of the natural climate variability in the historical record. So the bottom line is that it seems that, at least for the next 50 years, wind resources will be a viable source of energy in the United States.

There are other ones that have tried to simulate conditions here in California, here is Altamont, San Gorgonio, and Tehachapi, the black line is the observations, the other ones are the simulations, the same message, since I'm going to go fast, basically, I mean, be careful when somebody tells you that wind velocities are going down.

But we asked Dan Cayan from Scripps to develop a new statistical downscaling technique, what it does is to take the largest scale features of the global climate models and translate them into what will happen at the local regional level, in this case California, with the idea that the global climate models are not supposed to simulate very well regional features, but are supposed to simulate very well large scale features. And he did the analysis for three areas of importance for wind resources, he used three global climate models and one global climate scenario, so I'm just using the advance conclusions, distinctions between climate models prevent any definite consensus. So the bottom line is that, since we don't know, winds may not change, at least in

California.

Now let's go to photovoltaics and concentrate on solar. This is a study that came out recently in *Environmental Science and Technology*, this is a study done by researchers in Japan looking at the worldwide potentials of PVs. In this case, the map at the bottom, the focus here, is the amount of deficiency of photovoltaics without taking temperatures including account, and this is historical conditions. And over here is taking into account temperatures. So as you can see, the orange colors in the Southwest became yellow, that means there is already a 10 percent decrease in efficiency on photovoltaics. This is the conventional photovoltaics; there are other type of photovoltaic that have the effects, it is not as great as this. So the bottom line is that, like was mentioned before, you know, with increased temperature, if we continue using the same type that is commonly used right now, the efficiency of photovoltaics will go down.

With respect to solar, the main factor affecting efficiency is the amount of direct solar radiation reaching the surface of the earth, that's when it is very sunny we get direct solar radiation, we will have low clouds, and the solar radiation is diffuse, is the indirect type of solar radiation reaching the ground.

And they did analyze conditions in California, this little dot there is supposed to be California, I mean, I can go on and on about this, but the bottom line is that -- I mean, they didn't find a consistent response for California -- the bottom line is that concentrate solar power, we don't know how climate change will affect cloudiness, and therefore how it will impact concentrating solar power units.

It is not surprising because the IPCC and several scientists always tell us that one of the greatest uncertainties on climate projections is the role of clouds, and not only clouds, but how aerosols interact with clouds, and therefore how it will affect the amount of solar radiation reaching the ground. We are finding similar results for California and we have several studies going on at Scripps, LBNL, and NOAA, looking at this issue, the interaction between aerosols and clouds and regional climate.

Water and evolution in the energy system -- Dan mentioned, and Joshua also mentioned that there is this tendency towards drier conditions in California, at least for the southern part of California, and in general the Southwest. So that basically will mean less water available for everything, including power -- I mean the use of water to cool our power plants. I mean, Dan Cayan is going to talk about potential scenarios for California from the Western United States for the electricity Grid and, I mean, I think he's going to tell us that high penetration of solar renewables are feasible. So I'm sort of combining that with the result that was published late last year by the Pacific Institute, looking at the implications of using more renewables to water withdrawals for power generation. And the implication is, the bottom line is, that more renewables tend to reduce water consumption, solar PV and wind mainly, but in addition to that, that it is possible to use also hybrid type of cooling, also dry cooling, that will further reduce the amount of water that will be needed to cool our power plants. We have a study related to this that we call the development of energy scenarios for California and their potential environmental implications. It's going to be looking at these type of issues and then Dan is going to be talking about that this afternoon.

Bioenergy -- I reached -- I mean, I tried to find papers from bioenergy, I mean, I found a lot of papers about how bioenergy could reduce or penetrate into the energy mix that we have, but I didn't find papers about how climate change will affect bioenergy. I talked to a lot of experts and they said all of these studies are forthcoming. In part, it is that, I mean, in order to do a study like this, we really need to know the geographical location where the bioenergy systems will evolve. And fortunately, there are some already background studies, foundational studies, that are doing like this, for example, the study by Parker, et al. at U.C. Davis, we're also funding him now, I believe, or very soon, to do more detailed studies for California, and studies also funded by PIER looking at the potential impact of climate change to crop yields, to forest resources. Together with this type of information, plastic regional climate models will allow us to look at the potential impacts of climate change to bioenergy in California. But at the same time, I believe there are enough number of options that we could adopt in order to mitigate any negative impact of climate change on bioenergy. So the conclusions are there. I think I will stop here, so I will be glad to answer any questions that you may have. [Applause]

COMMISSIONER PETERMAN: Thank you. That was a good overview. Any questions? No. I was going to say, you are the most polite audience I've ever seen at an IEPR Workshop because I don't think I've ever been to one where people actually clap, so that shows your optimism, as well as your appreciation for the research we're having presented. So thank you.

MS. KOROSEC: All right. Our final speaker before we break for lunch, an unenviable position, I know, is Lee Hannah from U.C. Santa Barbara.

DR. HANNAH: Thank you. Thank you for inviting me. I have a cold; if you can't hear, just raise your hand and I'll try to get closer to the mic here. With lunch just around the corner, I guess it's only appropriate that I'm here to offer food for thought, and I'll try to do so in a timeframe that lets you get the actual food in a timely manner.

What I'm going to talk about at the end of the morning here is the impact of climate change on species and ecosystems and the possible implications of that for siting energy facilities and transmission specifically within California. But I'll be talking in general about the problem, trying to frame the problem, describe some of the tools we have to address the issue, and then make a few recommendations about how we might proceed.

And in contrast to our previous talks, some of which have shown the results of some excellent research, much of it which wouldn't exist without support from the PIER Program, this is really looking ahead to an issue that we're just beginning to come to grips with, and it's a very complex issue which is really the intersection of two complex issues, one of which is energy siting, and the other of which is climate change impacts on species. So this first slide is just to illustrate the impact of climate change on species is something that's an immediate research interest, and it's receiving a lot of attention, but is also quite complicated and is being dealt with in book leaf treatments such as this recent work that I and a number of co-authors produced with *Island Press*.

The other complex problem that's coming together in this intersection is that of energy siting. And -- if this is my laser pointer -- the background to the graph here simply indicates the area needs of different types of research technologies, and some of the lower -- if we were in a nuclear future, we might have very low energy land use needs, but we're much more likely to be in a renewable energy future where we're going to have land use needs that may be larger than we've had for energy and for structure in the past, and one to note here is biofuels, which is just this very area intensive renewable technology, and the noteworthy thing is it's on a completely different scale from these other renewable sources. So the other renewable sources are scaled here. Biofuels has its own scale here, which is about 10 times greater than these other renewable sources. So, if I was to show biofuels on the same scale as other -- as the area demands of other renewable energy resources, I'd have to go all Al Gore on you here and it would go up through the roof somewhere.

But these even intermediate renewable energy technologies have significant area demands, and those area demands, as people in this room are well aware, requires significant planning exercises for siting. And one of the elements of those planning exercises are considerations of species and ecosystems, both for regulatory reasons, but also because species and ecosystems are part of what we value about living in California, and we want to see those values represented and considered in our energy siting processes.

So what do we know about what climate change does to species and ecosystems? Well, what we know more than anything else is that, when climate changes, species move. And these charts illustrate that for North America one of the biggest climate changes in recent sort of geologic history is the retreat of the ice sheets, 20,000 to 10,000 years ago, and when that happened, oaks had -- when the ice sheets were in full bore, oaks had a distribution that was centered in the Central South of the U.S., and by the time the ice age was over, oaks had a central distribution more in the Northeast. And that is true of a number of tree species and all sorts of other species, and we see it all over the world. One of the things that means, though, as well, and that's illustrated in these panels on the right about biomes, is that different species move at different rates in response to climate change. So, what we may think of as vegetation communities now, different sets of plants that are found together right now, may not be found together in the future, and may not have been found together in the past. So a particular set of climatic conditions leads to a certain type of plant community and, then, as climate changes, species move individualistically, and plant communities are sort of literally torn apart, if you want to be dramatic about it, and then reassembled in what are often referred to as "novel assemblages." So we may wind up in the future with some of the sort of plant communities that we're used to now, but we may wind up with quite different ones.

And while the climate change is human induced, that process of species rearranging themselves is entirely natural. And part of our challenge is to figure out how to accommodate that natural process or rearrangement as we plan for the future. My specialty is planning conservation strategies for the future, but in this case we're talking about how can we plan our energy infrastructure for the future and those sorts of species movements.

Okay, that was data from the past. Just to illustrate quickly that we're already seeing changes in species ranges, we're seeing species move due to climate change already due to human induced climate change, up here in the upper right we have a set of slides from England, the blue areas are the traditional areas, ranges of species, and then the yellow and red dots represent where species have been found over the last couple of decades as climate is warmed and these species have expanded their ranges.

The Antarctic example is a little more complex and, in the interest of getting us all to lunch, I may gloss over it, but the short story here is that some penguin populations in Antarctica are increasing and some are decreasing. And that may seem anomalous in a generally warming world, but in fact Antarctica is insulated from much of the warming that's taking place in the rest of the planet by circum-Antarctic winds. And in the Antarctic Peninsula that juts out from those circum-polar winds, warming is taking place and penguin populations are suffering because, simply put, penguins like cold, whereas, in other places the intensification of those circum-polar winds is resulting in increased sea ice and growing penguin populations because penguins like sea ice, they actually feed on things that grow under sea ice. And I included that example just to illustrate that it's not always warming that we're worried about. The climate change is a complex set of conditions which is one of the reasons the term is now "climate change" rather than "global warming," in general, although you can debate the political side of that, the changes that we're seeing are definitely complex and we have to worry about complex changes in species.

And then if we want to look a little bit closer to home and think about how widespread these changes might be, we don't have to go any farther than looking at Lodgepole Pines and Bark Beetles. Climate change warming has driven huge outbreaks of bark beetles across the Western U.S. and Western North America into Canada, it's allowing bark beetles to jump over the Continental Divide and gaps in forests that formerly kept them out of eastern forests, and so we may have western species moving into eastern forests and causing widespread destruction, which impacts tourism, it impacts timber, it impacts wildfire probabilities, it has a large number of impacts. So that's just one example of the very real sense in which we're already living in a world in which climate change is affecting species and ecosystems. And we need to be planning for that.

So as we do energy siting, what are the sort of tools we have to deal with this problem? One of the tools we have are known as Species Distribution Models, and as their name implies, they tell us about where species are in response to climate, and this graphic simply illustrates that a Species Distribution Model considers multiple sorts of climate and soil variables, and then uses a species' existing distribution to predict where you might find that species, and that's important in some senses in the conservation realm because we don't always know every place a species exists, and we might like to if we're trying to site a park, or decide whether an energy infrastructure has an impact on a species, we may not have observed that species there, but we'd like to know where they are.

But the other utility of Species Distribution Models are that we can take information from Global Climate Models and put future climate conditions into the model and have it project where the species would be in the future. And in order to properly site something in a changing climate, we need to think about both where the species is now and where the species is in the future. So if that means that we're taking something that's already a politically fraught conversation, a very complex negotiation, and then we're saying the target is moving, yes, unfortunately that's exactly what we're saying, and that's what we have to be able to plan for, and that's really the challenge.

You can take those Species Distribution Models, then, and put them into a geographic space, and look at where a species is now and where it might be in the future, and I just happened to grab this Pigmy Spotted Skunk from Mexico as an example, but the colors here represent simply where that species is found in different decades from 2010 up until 2050, and with information like this, you can then begin to look at areas that are very important for this species, these purplish areas where it's found in all time slices are then places where that species is likely to persist, and those might be good areas to avoid, they would be good areas to put a conservation area, they would be areas you might like to avoid as you're siting an energy project.

And then the problem gets slightly more complicated because we won't be able to always find those areas where a species is going to exist for decades until 2050, or until the end of the Century, we're going to have to recognize that some species are going to move as we're experiencing climate change, and that we have to take into account those movements. And one method for doing that is a Network Flow Analysis, and this is based on an algorithm that United Airlines or UPS uses to route packages or passengers or jets around the country, and we simply apply it using Species Distribution Models to the problem of climate change. And what we do is we construct one of those Species Distribution Models that I just showed an example of for a large number of species, and then we ask, well, what are the most efficient ways for that species to be represented in every time step from the present to a future target, in this case 2050? And sometimes those species can stay in one place, those are the easy ones, and sometimes they're going to have to move a little bit. And this part of the diagram illustrates trying to find habitat that's suitable and link it together all the way to suitable habitat in 2050. So even when your suitable habitat in the present isn't in the same place as it is in 2050, by linking suitable habitat together, you can form a chain of suitable habitat that gets a species from where it is now to where it would be in the future. And then you can ask where those chains are and where they should be if we were planning for conservation or energy design. And this is just an example using multiple plant species from California, the green colors indicate public lands, or lands that are already in conservation uses. The yellow areas indicate private lands that hold areas particularly important for a large number of species to move as they respond to climate change. And that doesn't mean you need all those yellow areas, but that means that those yellow areas might be good places to think about avoiding as you're siting infrastructure, or would be good places to think about placing conservation.

Another possible technology is an analogy really from the physical realm and it's the Circuit Scape Technology that has been developed at U.C.S.B. and the National Center for Ecological Analysis and Synthesis, University of Washington, and it simply uses an electrical circuit analogy for movement of species, and in this particular case we're showing for the desert, populations of Bighorn Sheep, which are in the white areas, and then you estimate the habitat quality throughout the entire area, and then a computer algorithm that simulates electrical circuit asks where flow would be, where population movements would be between these established populations. And the higher the lighter colors, the warmer colors here, illustrating areas that might be particularly important, in this case for Bighorn Sheep movement in the desert. This happens to be a model of their potential movements in the present, but you can also do a model for potential movements in the future, and ask what areas they're shifting, and which areas are constant, and where you might want to conserve or avoid siting in order to not break connectivity in these population movements.

So, in this case, the populations are unlikely to move, they might disappear as conditions warm because these are mountaintop populations, and those cool mountaintops might become too warm for Bighorn. But, in general, what you would be concerned about is their ability to move between these relatively isolated populations, which is very important because these are small populations, and to have a successful genetic pool for survival, there needs to be movement between these populations. So both for plants, but also for more mobile mammals, we have some tools that we can apply to this problem.

And so looking at the intersection between these two problems, what are some recommendations we can make for the future? Well, in terms of energy siting, unfortunately for impacts on climate change on species, the attributes we might like to see would be relatively short lifetimes of infrastructure, so that we'd have a very adaptable system. We'd like to see it going in very gradually so that things would mature at different times and we could adapt as they mature, and we'd also like to see a situation in which we probably don't have a lot of linear disruptions in the landscape because things are moving and linear features will be detrimental. Unfortunately, those are probably exactly the reverse of the attributes we'll actually have. We have very long lived infrastructure, we have a situation in which we're probably going to put in a lot of renewable energy all at once, and it's going to mature all at once at some point in the future as that infrastructure gets older. And then, finally, we have transmission corridors which are a very important part of guiding where infrastructure, where energy facilities are going to go, which are generally linear features, are going to tend to configure disruptions in the landscape in linear ways. So that just means that we've got a very thorny problem with a lot of the attributes that we wouldn't like to have, we can't really change that, but what we can do is recognize that it's a difficult problem, try to fold consideration for species in in the best ways that we can. The best practice for doing that is really through a participatory vulnerability assessment. When we try to assess the impacts of climate change on communities or species, we generally try to get the best scientists, the best biologists together with the best climate change people, and let them talk it through because there's no set recipe; although we have these tools for addressing it, there's uncertainty in climate models, there's uncertainty in these biological models, there's a lot of value in expert opinion, and so a great way to do that is to bring together experts in an interactive form with policy makers and try to work through some of these thorny issues.

A second thought is that transmission corridors are of particular concern because it's a long complicated permitting process, and once those transmission corridors go in, they're going to tend to attract energy development along those corridors, so we need to pay particular attention to that problem, but I must say, having looked at it a little bit over the last few months, it's a very complex process and it's difficult to know where the pressure points are, or how to influence that process in a long term sense.

And we need to still think about flexibility and adaptive management, even though we may have some very hard constraints on flexibility because we just will need to recognize that there's uncertainty in climate change, uncertainty in species responses, and we'll have to be adjusting on the fly, even if we have locked in a majority of our infrastructure in a short period of time.

And finally, again, tools -- the sorts of tools we've described are really valuable, it's really important to use the tools we have, and to do them well, but the tools themselves are not enough. What tends to happen sometimes in siting exercises is that studies are done, that's laid out as facts, and then the process is all in determining a balance between stakeholder concerns. In this particular setting, there's quite a bit of uncertainty in the science that needs to be discussed and understood to reach a reasonable decision, so we need to have the experts involved not just in producing reports, but in actually interacting with policy makers and managers to try and determine the best viable solutions.

So that's a snapshot of two very complex issues coming together. Hopefully, you know, there's optimism for the future because we recognize some of the difficulty of the problem, we know how to address it, we have some tools for addressing the problem, but there's a lot of work to be done on this one. Thank you.

[Applause]

COMMISSIONER PETERMAN: Thank you very much. And I find your recommendations sobering just for the reason you pointed out, that they are not necessarily in line with how we are proceeding ahead, but good to be aware of. I think, Chairman, do you have a question?

COMMISSIONER DOUGLAS: I have -- oh, I'm sorry, would you like --

COMMISSIONER PETERMAN: Everyone is biting at -- ladies first, please, go ahead.

COMMISSIONER DOUGLAS: Oh, thank you, Commissioner Peterman. I just wanted to make a comment more than a question, you know, first of all we have a number of the participants in the Desert Renewable Energy Conservation Plan in the room, and actually we were having a meeting upstairs and we -- I might have warned you at the beginning -- but came down for this, so we've got Lorelei Oviatt in the audience, the Community Development Director from Kern County, and David Harlow, the DRECP Director, and a couple of other people, and obviously we are actually making an effort to do landscape conservation planning and renewable energy siting, and this is the only example in the country where this is being done at any sort of scale, or at all, and it's begun at a pretty large scale. You know, I guess I'll just ask you, as you went through your presentation it was almost painfully familiar as you walked through the different steps and the different considerations, and in fact the reality that we are doing the best planning we can in a context where we know that the world is going to be substantially different for many of the same creatures that we're planning for. You know, what are your thoughts in terms of the degree to which we can take climate change into account and the effectiveness of current tools to do that?

DR. HANNAH: Well, I think speaking in general I'm quite optimistic because the tools we have are evolving very rapidly and we actually have a very good understanding of climate change impacts on species and ecosystems from paleoecology, some of those past exercises. So there are different realms that we can draw expertise from, but we're racing to keep up with planning and you know from working in the desert that it's kind of ironic that we're working as fast as we can to try and solve this problem, and it's creating a set of problems that we're having to deal with, and we really need to anticipate if we're to avoid really serious sort of conflicts and consequences in the future. And definitely, you know, I think the planning process that's going on here for the desert is leading the country, if not the world, in these sorts of processes, but it's difficult and needs all the support that everybody can offer to it.

CHAIRMAN WEISENMILLER: Okay, I have an observation and a question, and the observation, last year we had an IEPR session on what happened to Japan and the consequences, and one of the nuclear engineers started out by saying, well, if you really look at the land use implications of nuclear vs. renewable, blah, blah, blah, so I marched him through the calculations of comparing the land use implications in Japan on the evacuation zones and the contamination zones, and obviously, you know, for an unusual event, but they were much larger in renewables and actually were of a much different consequence, so it would just discourage that part of the mythology.

I guess one of the more interesting questions that we're really struggling with, particularly in the wind context, is with wind reduction in the Condors, you know, their areas are really expanding dramatically and, at the same time, just trying to figure out that expansion overlaid with climate, what that means for us as we try to think through the wind siting.

DR. HANNAH: Right, and I think that's just a great example of the sorts of things we have to be looking at, and there are two sorts of species here, one of which are already in trouble and we need to be worried about those and the impacts to climate change on those species in the future. We've tended to assume that -- and this is sort of pre the planning process that we're undergoing now, but 15 years ago we would have assumed that we had threatened species, that if we sort of stayed away from the places that were good for them, and then if we did have to impact a place that was good for them, we did mitigation and created someplace that took care of them, that once we did that, those species would stay in those same places, and we were good. But now we see that that's not necessarily the case. Those threatened species may themselves start to move around in places that were good for mitigation now, might turn out in the future not to be, hopefully they would be, but we need to look at that. But the other category of species are species that aren't in trouble now, and those species may get in trouble in the future due to climate change, and while, as I say, there's uncertainty involved in that, we need to try and anticipate that because, to the degree to which we can fold that into our planning now, we'll just save us untold headaches, I think, in the future, or if we don't consider it at all in the future, then we'll wind up with a number of extinctions, which I think, you know, legally and morally we want to avoid.

COMMISSIONER SANDOVAL: It certainly sound like with migration that these are things that we need to model out as we look at things like transmission lines, you know. I know that there already are issues where sometimes you do the best work you can and then unexpected things are happening, but it also sounds like we have to be prepared for species moving. So how much is the science really available to do that kind of modeling as we plan for the expansion of transmission? And we heard that we're going to need more of it because of climate change.

DR. HANNAH: Yeah, the tools are there and much of the science that's needed is there. We don't always have the scientists that know the species best doing the climate change modeling yet, but it's getting there. The Desert Tortoise people are getting there, and I think scientists who care about the species they study, which is most of them, recognize that climate change has serious implications for the long term survival of species, and those scientists are scrambling to come up to speed on these tools. But there's still a challenge of putting the science together with the tools and the biologists together with the climatologists because you can't just assume that a GCM captures everything you want to know about a system, and you need to talk to the climate people to understand how biology and climate work together. So we can do a lot of good work with the tools, but it's not just mechanical cranking it out, you really need to be interacting with climatologists. We saw earlier how, you know, the GCMs don't always represent wind fields, or some things that affect fire conditions and other things very well yet, and those things can be critically important to species, either directly or indirectly, by fire opening new habitat and allowing species to colonize new areas. So we really have to be talking between disciplines in the sciences to get this right, and then to apply all the tools we have to do it. And I think there are good chances to do that, then, if we have policy makers and managers who are listening, and which you are. Thank you.

COMMISSIONER PETERMAN: Great. Thank you very much. So with that, we'll be breaking for lunch and we will return at --

MS. KOROSEC: It's up to you. We can take a full hour and do 1:45, or we can try to catch some time and have everybody back at 1:30, but that does shorten the --

COMMISSIONER PETERMAN: I'm just going to say let's go for the full hour. 1:45.

MS. KOROSEC: Okay, 1:45, we'll return. Thank you.

COMMISSIONER PETERMAN: Thank you.

(Recess at 12:44 p.m.)

(Reconvene at 1:50 p.m.)

MS. KOROSEC: All right, our first speaker is Michael McCormick from the Governor's Office of Planning and Research.

MR. MCCORMICK: Thank you very much. It's a pleasure to be here today. I think there's probably half the people in the room were actually at the workshop we hosted on April 9th. How many of you worked with OPR in the recent past, say in the last year or so? Raise your hands. Okay, well, we've got about a quarter of the room that's worked with us. How many people have worked directly with local governments or done research specific to local government policy? That's a better show of hands. So you should be talking to OPR, actually.

BUD BEEBE: We talked to OPR a decade ago.

MR. MCCORMICK: Okay, well, a decade ago. Well, we -- OPR has recently been reconstituted, last year when Governor Brown came in to office, and we've been working on a number of priority items around energy, climate, and inter and intradepartmental coordination among a number of other things. One of the things that we've done recently is we hosted a conference April 9th for local governments to try to bring the tools, resources, and information that's out there right now to them so they could more proactively move forward with addressing climate change, specifically adaptation because there's been a relative lack of information specific to local governments on adaptation.

We have a video on our website if you're interested in taking a look, to get the unique local government context of how they're dealing with the adaptation and how they're using the state's data, which is really what I want to focus on right now, particularly the CEC PIER data, which has become really helpful in how local governments move forward with their planning for climate change and energy. Local governments have General Plans, we've got the California Environmental Quality Act, local Coastal Plans, Hazard Management Plans, and now Energy Assurance Plans, Energy Management Plans, and all of these rely a certain amount on State data.

What's interesting about the data that PIER has pulled together is that a lot of local governments and regional efforts are using the data that was never meant for them to support their policy development efforts. And one of the things we've found, coming out of the conference April 9th, was that there's a lot of local governments that, lacking other forms of data, have moved forward with data that was specific for the state. And we look at the California Adaptation Strategy in its 2009 version, which was primarily focused on State operations, but local governments use that to serve as the basis for their Climate Action Plans, and discussions around climate change in their General Plans, and even in their CEQA documents.

So the biggest thing, I think, coming out of that conference for me was that all the work that we're doing at the State level, we really need to take a look at what local governments are doing, and make sure that we provide them context for the materials that we're developing. A lot of the research that we're doing, even though it may be specific to the statewide context, or the state operations context, is also applicable at the local and regional level. And we see this to a certain extent with Cal-Adapt, which was originally created to produce a visual interface with some of the science that's out there, most of which was funded through the CEC PIER Program. But Cal-Adapt has now been actively used by local and regional efforts to help inform their planning decisions as they move forward.

The Adaptation Policy Guide, which is another resource being developed by Cal EMA and the Resources Agency is another resource that we're really excited to see out there, the local governments are really eager to interface with, and Cal LEAP, the California Local Energy Assurance Planning tool which, Dave Michelle, if you're interested, is out here in the audience. And so, as OPR, we serve as the Conference of Planning entity for the

State, so we're the unique liaison between local governments, regional efforts, and the State, and we help to inform how local governments move forward in planning. So, you know, I'd like to reinforce that, as folks move forward out there, I know I'm speaking to the choir, but if you think about the local government context as you move forward and the regional context, that's where really the rubber hits the road on these planning and implementation efforts. And I think Paul Bunje is going to talk a little bit about this a little bit later, but local governments and regional efforts are really our partners in succeeding in our own goals and our own priorities. If you have any questions about how to interface with local governments, to reach out to them, OPR manages a very current email list of people that are working on the issue. If you ever want feedback, support on anything, let us know, we're happy to engage with you and help distribute information and resources. Thanks again, and I'll pass it off to the next speaker. Have a great afternoon. [Applause]

COMMISSIONER PETERMAN: Thank you, Michael. We also heard from Wade Crowfoot this morning, as well, and appreciate both your interest in this area, as well as the opportunity to work with the local governments.

MS. KOROSEC: All right. Next, we will hear from

Julia Levin from the Natural Resources Agency.

MS. LEVIN: Good afternoon, everyone, and thank you for returning after lunch on such a beautiful day. I wanted to start by thanking the Energy Commission, Commissioner Peterman and Chairman Weisenmiller, and all of the staff, for organization and holding this workshop. I think it's an extremely important issue, an extremely timely issue, and I'm sorry I wasn't able to be here this morning, I had a conflict, but from what I understand from a number of you, the presentations were very valuable, which actually brings me to a second thank you and plea, basically. I think that the research that was presented this morning, the research that was presented at the Governor's Conference in December, both the one in San Francisco and the one at Scripps, really highlight how valuable the PIER Program, in particular, has been. And Guido Franco, who has led the Climate Change part of the PIER Program is here, modestly in the back, Guido, wave your hand in case there's anyone in the room who doesn't know you. It has been incredibly important, the PIER Program, and the Energy Commission's work, more generally, in continuing our understanding and furthering our understanding of climate change impacts and solutions. It's really important to remember that the solutions are not going to be simple, they need to be multi-disciplinary, they need to be cross-sector, there are going to be trade-offs, and understanding all of the interactions of not just the climate, but the solutions and all the other changes in society requires a very thoughtful approach to research. And I think that the Energy Commission has provided that for years, and it is very important that we find a way to continue it. And so I hope that all of you will help us figure out where and how to find the funding, whether it continues to be State funding, or private foundations, companies, the Federal Government and partners, this research is absolutely critical to continue, and to continue in the multi-disciplinary thoughtful way that the Energy Commission has led it over the past couple of decades.

So as you heard this morning, the impacts of climate change are here, and they're now, and they're very serious. We're already facing many of the impacts of decreasing snowpack in the Sierras, for instance, and its impact on hydropower supplies, or on increased forest fires, which are directly linked to how much snow there is and when it melts. We're also facing increased energy demand because of increased heatwaves and higher temperatures, more generally. And there are a number of other impacts of climate changes that we're already experiencing in California, and we know those impacts are only going to become more frequent and more severe over time. That's the bad news. Hopefully we got most of that out of the way this morning.

The good news is that everything we need to do about climate change, including in the energy sector, but more broadly, are things we should be doing anyway, they make sense, they have a lot of other benefits. So focusing on the energy sector, in particular, we know that there are already impacts, there will be more impacts to energy supply, as I mentioned, hydropower, impacts of fire on transmission lines, impacts of sea level rise and flooding on energy facilities, on power plants, transmission lines, pipelines, as well. All these impacts, there are solutions to these, same with impacts on demand. We know that, with higher temperatures and other extreme events, there will be more demand, in general, and more disruption to both demand and supply. But the things that we need to do about this are all things that make sense anyway, they're things that make our economy stronger, they make us more efficient, they give us energy and water and food security, they make us more economically competitive, they create jobs. So many of the new jobs and businesses in California are in the Smart Grid development, or energy storage, or making power plants more efficient so they can withstand heatwaves without a significant loss of production. So these are all things that will benefit California and they make sense to do. You're going to hear more about them this afternoon, but I wanted to highlight just a few because I think, while there is a lot of very bad news that you heard this morning on climate change, I think it's important to remember there are a lot of exciting developments, as well, and a lot of opportunities in climate change, and if we really focus on those and how to further the Smart Grid, the energy storage, the Distributed Generation, power plant siting in safer locations, those will have so many benefits to California that I think we can get excited about rolling up our sleeves and moving forward on the solution side, which is what the afternoon will focus on today.

So just a couple that I'll throw out there and, again, you'll hear more about several of these this afternoon. But in terms of protecting supply in California, the Governor has set a very ambitious goal for 12,000 megawatts of Distributed Generation. The State also has a 33 percent renewable portfolio standard. How do these help? They help by diversifying supply so that we won't have a single nuclear power plant that, when it shuts down, jeopardizes the entire Southern California Grid, or so that, when we have an extreme event in one location, we have diverse energy supplies in other locations that can help offset disruption to the power system. So Distributed Generation, in general, and renewables, in particular, are going to be very important to help us adapt to climate change, and I think you all know all the other reasons to do them.

In addition, we can make our existing facilities more efficient. There are technologies now, and the PIER Program has helped to fund research on new technologies, that keep the output of existing natural gas plants steady, even during heatwaves and other extreme events. The Energy Commission has also been a leader in promoting the Smart Grid, and we're seeing the adoption and implementation of technologies now that will allow us to respond to extreme events and to climate changes much more efficiently and protect the Grid, which is going to be essential not just for energy supplies, but for emergency response, and things like that. We need to know that our energy infrastructure will keep working in climate change, especially around extreme events.

In terms of new infrastructure, I think that the Intergovernmental Panel on Climate Change said it best when they said that the most important thing we can do going forward is stop putting new development in areas that are at high risk of climate changes, whether that's high risk of fire, catastrophic fire, whether it's at high risk of flooding, or of sea level rise, we need to be very smart now about we develop in the future and avoid, as much as possible, putting in new infrastructure and, for all of you, we're talking about energy infrastructure, in harm's way. We're going to face enough impacts of climate change to existing infrastructure and we certainly don't want to put more things in harm's way when we're going to have fewer resources to protect them.

One of the other things that we need to do, which has multiple benefits to the energy sector, is develop community-scale biomass in high fire risk areas of the state. We know that many of the forested areas of California have an abnormally high level of fuel load in the forests; one of the ways to treat the forests and address that fuel load is with small scale environmentally sustainable biomass facilities. And that’s something that we're working on in a number of areas now.

And finally on the demand side, one of the most important things that we can do is reduce demand, continue to push demand response measures, green our buildings and our communities, everything from making our buildings and our appliances and our plug load more efficient, to literally greening -- trees and cool roofs and cool pavements, cool vehicle services, even, all of these bring down energy costs, they also help protect health and safety during a heatwave.

And finally, we need to protect and restore natural ecosystems because they provide our first line of defense, whether it's against floods, or whether it's against droughts, natural ecosystems, be it wetlands, or riparian corridors, or wet meadows in the Sierras, they are really at the core of our water supply, our air quality, our ability to manage heatwaves and more. And so protecting our natural environment is going to be critical to protecting California against extreme events in climate change.

Finally, as I said at the beginning, I just want to underscore, much as there's a lot of doom and gloom around climate change, there are a lot of benefits of taking these steps, and I think the more we can focus on creating jobs, making California more economically competitive, building the businesses of the future, the better off we'll all be. Thank you very much.

COMMISSIONER PETERMAN: Thank you. [Applause] Thanks to the Resources Agency and Julia, in particular, for her personal commitment and the attention she has afforded to this topic, and continuing to remind us about the importance of thinking about adaptation, as well as the impact of climate change on the Grid. And thank you also for your comments about the value of the PIER research that we're seeing today and that has increased our understanding of these issues. I was reminded during the break that, even getting legislation such as AB 32 passed depended on having a good scientific basis and understanding of the issues, much of which has come from the researchers in this audience over the last few decades, and so thank you for that. And we've already identified today future issues, pressing issues that need research and, so, we look forward to continuing to have opportunities to fund that type of work.

MS. KOROSEC: All right. Before we get started on this afternoon's presentations, I just wanted to ask the subsequent presenters if you can try to focus on the main points of your presentation, try to keep it to 10 minutes so we can catch up on our time, I hate to jam anybody up, but we want to make sure we leave enough time for this afternoon's roundtable discussion, so 10 minutes for speaking, five minutes for Q&A.

COMMISSIONER PTERMAN: And another housekeeping matter, I'm going to suggest we skip the afternoon break and people can feel free to get up in the middle of any presentation and no one will be offended if they need to step out.

MS. KOROSEC: Great. That's a good idea, too. Okay. Thank you. So with that, I will introduce our next speaker. We have David Pierce from Scripps to talk about adaptation.

DR. PIERCE: Thank you very much. I'm going to talk about using seasonal to midterm climate forecasts. And in this context, I'm talking about a few months to a few decades. And we just heard how a lot of this research has additional benefits besides climate change, and I think using climate forecasts to run a more efficient operation is an example of that.

So one of the main climate fluctuations that affects us in California is El Niño. I'm not going to spend much time on this since you probably know about it, but the left panel here shows what El Niño looks like, it's characterized by warm temperatures in the tropical Pacific; on the other hand, its brethren, La Niña, is characterized by cool temperatures in the tropical Pacific. And the reason that this is important to California and the energy industry is because El Niño affects how much precipitation we get in California. And besides the direct effect on water supplies, you probably know that moving water around is a huge energy use in our state. So because this is fairly familiar, I'm not going to talk much about it, I'm just going to point out that we already do an operational El Niño forecast at Scripps, it's issued every month, this shows the scale of the forecast, this is the tropical Pacific, and we get a correlation between what we predict and what's actually observed at a one-year time forecast of about .6. So that has use for all sorts of different industries. I get email from everything from professional divers to mango groves, asking about the El Niño forecast. And if you look at it at nine months ahead, it's about .7, so this is one of my themes, that the climate forecasts have this statistical approach, you know, you're not guaranteed exactly what's going to happen, but you know the changing probabilities of events.

Now, more relevant to energy is something called the Pacific Decadal Oscillation; you may or may not have heard of this, but it looks like this, when we have the high phase of the PDO, we have warm temperatures in the ocean off California, cold in the center of the North Pacific, and in the low phase of the PDO, we have cold ocean temperatures off our coast, and warm temperatures in the Central Pacific. Now, I've plotted the time series of the PDO here on the bottom and you can see that it changes rather slowly and gradually as compared to El Niño here, see how that changes? About every two to five years we get an El Niño. On the other hand, we get changes in the PDO at maybe every five to 10 years. So that gives you a little bit of predictability just because the thing is persistent, it tends to hang out once it's gotten established.

Now it turns out that PDO affects all sorts of things in California, but one of them is heating degree days. So what I'm showing here is the relationship between the Pacific Decadal Oscillation, the PDO, and when you have a positive PDO, that means it is warm temperatures along the coast, these blue symbols indicate you have less heating degree days, which is it is warmer. So there's a strong correlation between the phase of that PDO and what the energy use for heating is in winter. Conversely, when there's a negative PDO, that means there's cold water along our coast, you have positive heating degree days. And this makes a fair bit of difference, these are about 100 to 150 heating degree days and about 70 when you've got a negative PDO, so that makes a fair bit of difference. And that's predictable to some extent just because of the persistence of the PDO.

But since we're mostly talking here about electricity, I actually want to talk about peak electrical load, so this was a winter event I was showing on this slide, because it's heating degree days, but now I'm going to look at summer events and the peak electrical load. What I'm showing here is the additional load of the peak days of the year. So let's just look at the first one, so for example, in 1998, the one peak day of the year for the electrical system, consumed about 39 percent more electricity than the average summer day. So that year was incredibly peaky, and that's very hard for the energy system to accommodate itself to one day which has 39 percent more demand than the average day, so that's quite difficult. On the other hand, here at the bottom is 1989, and you can see the peak day there was only 18 percent more than the average day, so that was easier to accommodate to. And there is quite a divergence of years, you can see there's this whole zoo here from very bad to normal to pretty good. So what we'd like to do is try to understand what is driving that diversity amongst the peak days of the year. So what I'm going to do is just look at the one top peak day of the year, you know, we could look at peak 10 days, or peak 20 days, but I'm going to be extreme here, just look at the peak day of the year. So for each year, we've got a peak associated with it, so that's basically a time series because, for every year you have a value, which is how much more energy the peak day used. So that's the peak day time series plotted. Now I can just relate that to ocean temperatures, and what you see is that this is the PDO again. So the correlation between this peak day usage, the one peak day of the year, and the previous winter's ocean temperatures really brings out the Pacific Decadal Oscillation. So that Pacific Decadal Oscillation is affecting not only heating degree days in the winter, but also the single peak days in the summer.

Now, you can use this information to make real forecasts, and the reason I'm going to show this forecast is to give you a sense for how these work in practice. So this was worked on by some colleagues of mine at Scripps using the spring time Pacific Decadal Oscillation to predict summer temperatures, so this is like three or four months ahead. And what they found was that the best predicting signal in the ocean, here on the top right, this is hopefully a somewhat familiar pattern by now, that's the Pacific Decadal Oscillation pattern, I mean, they didn't put that in, they found it from the analysis that it drops right out. And here's how much relationship there is between that predictive pattern of temperatures in summer in California. Now, you see a fringe of reds here along the coast, which means there are good relationships between the PDO and electricity use along the coast, which there's not as much in the interior, but somewhat unfortunately, most of the people in California live along the coast, so that's useful, we can make use of this relationship. Let me show you an example of how you would make use of it. And, again, the reason I want to show this is to illustrate the kind of information that these climate forecasts give, because it's a little bit different sort of information than people, I think, are typically used to thinking about. And I picked it for San Jose here because people in San Jose own air-conditioners, but they only turn them on if it's really warm, so that's an area where temperatures make a big difference to energy consumption. You have other places like San Francisco they don't own as many air-conditioners, so they just sweat right now if it's hot. On the other hand, in Sacramento, here you guys turn on your air-conditioners all the time, right? So it doesn't really make much difference there, either. So there's different areas of importance to the energy system and San Jose is pretty important. So what I'm showing here is the summer cooling degree days, that's basically how much energy you need to cool your facilities in the summer, and I've just split into three categories Below Normal, Normal, and Above Normal. So since there are three categories, if we didn't know anything about it, we would just say there's a one-third chance of being in each, 33 percent chance. On the other hand, if we look at what's happening in the PDO in springtime, that actually makes quite a bit of difference to these probabilities. So, for example, if the PDO in spring is above normal, you have a 59 percent chance of having an above normal summer cooling degree day load, as opposed to 33 percent. So it's not doubled, but a pretty noticeable shift. On the other hand, if the PDO in spring is above normal, you only have a 12 percent of having a cool summer, a 12 percent chance of a cool summer as opposed to a 33 percent chance if you just ignore this. So it's making some difference here. But the reason I wanted to show this is because all of this is probabilistic information, so it requires the joining of our climate information, our climate forecast, with business practices that can make use of this probabilistic information. And sometimes that's possible, and sometimes it's not. And the climate science obviously can't dictate that by itself, it requires working with the energy companies to make use of this probabilistic information.

Well, we had a lot of questions, actually, from the Chair earlier today about can we say something over a few years, say one to 10-year time scale. So the international climate community realizes that's a time scale of immense interest, so the whole international modeling community joined up to do these experiments, trying to dynamically predict the next 10 years, and I'm just going to show one example of that. This data is still coming out, I mean, if we look today, I did those a couple of weeks ago, but if we looked today, there would be more data, that's how recent some of this data is coming out for the next IPCC.

But what you're looking at, this is just for one of the 20-some models, a Japanese model called MIROC, and what they've done is they've run the model once for a simulation of temperatures, let's say this one is starting in 1980, and this dark green line shows what the simulation did. Then they perturbed the model a little bit because we can't exactly observe the earth, so there's always some little measurement errors. So if you put those measurement errors in and run it again over and over to say, does measurement error destroy your predictability? That gives you that green envelope. And what you find is that, in California, which is what I've plotted here, just California, it seems like those measurement errors destroy the predictability. There's no predictability, it seems, on these multi-year time scales because, you know, we can't observe the initial state well enough and our physics doesn't support it.

Now, this is preliminary. We might find that some other model does well in California, I think we're going to look at that, or it could be other places in the world do well, but I just wanted to be clear that, right now, the evidence is we can't seem to be able to say that, that's just what the physical situation is.

Well, heatwaves are a big interest in California, rightfully so. Let me show you the history of heatwaves here. What I've done is I've taken the average temperature, summertime maximum temperature on the worst day, worst three days of the year for the red curve, and weighted it by California population since we're interested in energy issues, so I've weighted it according to this graph here. What you see is we've had two events where the population weighted maximum daily temperature over three days has been over 100 degrees Fahrenheit. In 2006, $5.4 billion in damages, about, you know about that one, we also had one in 1955, there were about a thousand deaths due to that heatwave back then. So we've gotten a couple of these guys in 60 years. So the question is, now looking at longer time scales, more sort of planning and strategic purposes, how are these heat waves likely to change? So I've repeated this historic one here just for comparison, but I've shown the results from five different models of the quite new series of simulations for the upcoming IPCC Report, and that black horizontal line in each case is 100 degrees Fahrenheit, so you can see how the likelihood of getting these bad heatwaves changes over time. And it varies by model. One of our research interests is how can you identify, if you can, how can you identify which of these models is the most reliable? So that's one of our interests. But you see, you start to get an increase in these heatwaves. Certainly, by the end of the Century, they are just commonplace, you know, we're going to have those all the time by the end of the Century, but you start seeing the transition between about 2020 to 2040, you start seeing a notable increase in the frequency of those bad 100 degree population average heatwaves, about 2020 to 2040, depending on the model.

Now, this is just a medium emission scenario. As you know, we might emit more, we might emit less, too, to be fair. But this is a high emissions scenario. You probably have heard that we're actually tracking on the high emission scenario right now. Anyway, by the time you get to the end of the Century, you start getting 105 to 110 degree heat waves, as opposed to ones right now, which are 100 degrees that have all these deaths and losses. On the other hand, you don't see big separation behavior of the average to high emissions scenario until about the mid-Century. So we're not going to see a big difference for some decades yet, which I think was pointed out earlier as one of the problems with formulating policy, because you don't see the effects for some time yet.

One last thing I want to mention is you frequently heard -- well, if you're on climate, you may have often heard that, on average, we probably won't get enormous shifts in the amount of precipitation we get in the state, probably a little bit drier, but there's huge year to year variability, which tends to mask that yearly average figure. But what I've shown here in the left-hand figure is the change in precipitation over the year. And I'm showing it for Southern California Coast, but it's similar for the rest of the state, and what you see is that we get most of our precipitation in winter, then it's very dry in the summer, and then we get it back coming into winter again. And these green boxes here in winter show that we'll probably get more precipitation in winter, but the brown boxes show we'll probably get less in the shorter seasons, in spring and autumn. So these are combining so that it reduces the net annual effect. So if you just look at the annual average, you might say, "Oh, there's not that much change in California precipitation." But to some degree, it's hiding these seasonal changes. Now, that makes an important difference to you if, you know, you're a farmer and you're concerned about having water for your crops, say, in spring, in other applications like that. So the timing can change even if the overall average change is muted.

So let me just sum up. We do do an operational Niño/La Niña forecast about nine to 12 months lead time, we issue that every month. The Pacific Decadal Oscillation has quite an effect on us here in California, it's important for energy use which is why I wanted to emphasize it, it affects winter heating degree days and the maximum daily temperature in summer during the heatwaves, and we have some ability to predict that in a statistical way, these shifting probabilities. What's needed then is, you know, a business process that can ingest those probabilities and make use of them. The dynamical prediction of the PDO are planning on one to 10-year time scales is not encouraging right now, I just have to say. Damaging heatwaves, you start to see the real increase in those by about 2020 to 2040, depending on the model. The emissions scenarios start to make a difference after about 2070; if you go with the high emission scenario, those damaging heatwaves can get up to

105 to 110, which is rather unpleasant to think about. And changes in precipitation are actually rather complex because there are a combination of changes over the year and changes in intensity when the rainfall happens. So, thanks for your time. [Applause]

COMMISSIONER PETERMAN: Thank you very much. I found that very interesting. A question for you really to the connection between the PDO and the cooling degree days, or heating degree days. Something that struck me in your presentation was just the reference to the Normal vs. the Above Normal and Below Normal, and could you just speak to exactly what is Normal and over what period do you calculate that? And how you're seeing that change over time, perhaps with climate change?

DR. PIERCE: Yeah, in this work we try to follow the Energy industry, and what they do is take the last 30 years as Normal, so that's what we did, too. There's a whole sort of research effort to say, how bad is that approximation? Because we know we're actually on this upward slope and, if you start talking about planning horizons of 10 to 20 years, you know, it's not really that great an approximation to just say "take the last 30 years." So you can do better than that, but I've tried to mimic what people do.

COMMISSIONER PETERMAN: Thank you. Ready to move on to the next speaker?

MS. KOROSEC: All right. Our next speaker is Kosta Georgakakos to talk about Improving the Management of Large Hydropower Units in California.

DR. GEORGAKAKOS: Thank you very much. And I'd like to thank the Energy Commission for inviting me. It's a pleasure to be here. I come from the Hydrologic Research Center, it's a nonprofit research and technology transfer corporation, and I'm also adjunct with the Scripps Institution of Oceanography. I'll try to summarize work that several colleagues and myself have done over the last decade or so in this area.

So the focus is the reservoir management in Northern California and the climatic variability and change. A system of reservoirs modulates the climatic and weather variability in order to produce downstream benefits, and these benefits are manifest in hydroelectric power production, flood damage mitigation, water conservation for municipal, industrial and agricultural supply, ecosystem benefits, and others. Reservoir effectiveness is substantially influenced by three things, climatic variability and trends, demand variability and trends, and changing water markets. And the important target of reservoir management is to maximize water use efficiency, this is for individual uses, individual reservoirs, and is a system of reservoirs, as well.

A little bit about current reservoir management. Essentially, it is based on guide rules or operating rules that have been defined from simulation runs using historical data and statistics, and with a detailed numerical description of the system. For instance, for flood control and flood management, no precipitation forecasts are used currently, only observed precipitation is used, and in some of the reservoirs, the rule curves are not even indexed by observed precipitation, they have fixed rules. This is an example for the Oroville Rule Curve that essentially demonstrates that some of our reservoirs do have observed precipitation to index the maximum allowable storage during the flood season.

Some of the elements of current reservoir management, planning involves several stakeholders and several objectives, as well as coordination among reservoir sites. No two systems are the same and generalization is difficult in reservoir management; the devil is in the details because of the climate demands and system structure.

Climate and weather predictions must be translated to system decision variables to be useful for management. So, for instance, as this example shows down at the bottom there, drawn from the Cold Water Species Fishery Management, climate and weather prediction in terms of surface temperature, wind, and so on, has to be translated somehow to a decision variable and, in this case, water temperature.

So two issues to discuss in this presentation, 1) is the Integrated Forecast and Reservoir Management Project, it is the INFORM project for Northern California, which is a prototype demonstration project, this is not a study, studies were done from the '80s through the '90s, this is actual demonstration, on the ground, working with operational management and forecast agencies. I will also discuss the Adaptive Reservoir Management vs. current management through simulation experiments funded by the Energy Commission.

So here is the INFORM region, these are some of the large reservoirs that have been taken into consideration in our studies and the demonstration project. The vision is to improve reservoir management in Northern California, using climate, hydrologic, and decision science, and here is the challenge, these are Northern California system deliveries for years 2006, 2007, and 2008, and you can see that, while in 2006 we had about 5,810 acre feet, we almost had half of that in 2008. The sponsors and collaborators in this demonstration study sponsors, California Energy Commission, the then CalFED Bay Delta Authority, and the National Oceanic and Atmospheric Administration, and in addition to representatives from these organizations, members of the Oversight Implementation Committee involved include representatives from the California Department of Water Resources, California Nevada River Forecast Center, the Sacramento Area Flood Control Agency, the U.S. Army Corps of Engineers, the Bureau of Reclamation, the National Centers of Environmental Prediction, NOAA, in Washington, and the developers, the Hydrologic Research Center, and the Georgia Water Resources Institute of George Tech.

The INFORM goals and objectives is to implement an integrated forecast management system for the Northern California Reservoirs using real time data and operational forecast models. Aspects of the actual system to be represented were selected in collaboration with the agencies. So everybody agrees that these are some of the components that will be implemented. Once the system was implemented, then that was essentially done in Phase 1 from 2002 to about 2005. Then we had the demonstration phase which is the current phase that the project is in, and that includes the performing tests with actual data and with management input.

The objective is to demonstrate the utility of climate and hydrologic forecasts for water resources management in Northern California for several years. So in the cartoon, you can see on the left there is the actual system with operation rules, more or less fixed using observed information, with real time input and system characteristics, and on the right we have the informed regional system which is a risk-based tradeoff system, as I will describe in a minute. Both interact with the decision maker.

The components of the INFORM system, there is a forecast component, essentially, in real time taking the information that comes from the International Weather Service, the National Centers for Environmental Prediction in the form of forecasts of weather, and making adjustments to them to bring them down to the scale that's relevant for the management of the reservoir facilities, this is about a 10 kilometer resolution, and then using distributed hydrologic models that include snow and soil and channel flows to determine the inflows to the reservoir facilities. This is done in interaction with the National Weather Service, we align the INFORM models to the operational models, so we're at all times in sync in terms of what is predicted.

In addition to that forecast component, there is a management component which includes decision models which interact with reservoir managers, and after that we have, once the managers develop and decide on the policy, we have a release schedule, and then an assessment system measures the water supply, flood control, hydropower, and other benefits. You can see the lower right the reservoirs represented into this system.

These are the forecast elements, very quickly, we have three scales, the zero to 16 day, six hourly scale, the zero to 35 day, six hourly scale resolution, and the one to nine-month scale with monthly resolution, the last one being probabilistic, the first one being dynamic in terms of the downscaling down to the 10 kilometers, and the in-between scale is based on an intermediate complexity regional model developed. These generate ensemble inflow forecasts for the decision model. Important to note, the decision model has several scales; unfortunately, in management of reservoirs, that involves several objectives including energy and water conservation, you can't just isolate one scale, you have to work with all scales. And in this particular situation, we have near real time decision support, decision horizon of one day out, the resolution, mid, short, decision support, six hourly with one month decision horizon, and long range decision support, one to two years, with weekly 10-day or monthly resolution. And then we have a scenario and policy assessment. These scales are coupled and I will not say much more than that, but they do represent decision making across scales, so one scale conditions would happen to other scales in high resolutions.

This is an example of what the model does for decision managers. This is an example of the lake levels for the major reservoirs, given an ensemble forecast out to nine months. What I'd like to show is the forecast utility demonstration. We did this for the three years, 2006, 2007, and 2008, and we're continuing doing this, but at least these results have been verified. And so we had the actual system starting from a certain initial storage, and we're specifying the final storage after the season, what it ended up, and that's the light green there. The INFORM started from the same initial storage and ended up in the magenta color on the graph.

The information provided is important to managers and this is one of the indices that are important for conservation and water use. For 2006, a wet year, for 2008, a dry year, the differences were not that great. What was great was the transition year between the wet year to the dry year, and that's where this adaptive management that INFORM offers -- improves. These, again, results are on the ground, these are real time results.

Very quickly, we did do a sensitivity study, this was the feasibility of using a complex system such as the INFORM to look at the details of reservoir management, including hydroelectric power production, flood control, and other objectives. We used the NCAR, CCSM3 Climate Model output because that's the one that had very high resolution, and three-dimensional information for the atmosphere, so that we could preserve the model dynamics into smaller scales, as well as long scales. For this kind of analysis, with this kind of detail in management, you will need to do this rather than just statistical downscaling because you're destroying the waves that the model is generating. Of course, you need to do it with several more models than that.

The results for this particular model, if you look at the differences in February for the 50 years ending the 21st-Century, and the 50 years at the end of the 20th Century, as expected, you see increasing temperatures in all cases, and as we heard several speakers before, precipitation is not that clear, it's pretty much the same throughout.

We did a side-to-side comparison between the current policy and adaptive policy where the current policy is more or less deterministic, the year is classified by dry, wet, and a number of other categories. In the adaptive policy, that's not the case, we look at the entire spectrum of forecasts. And just focus on the lower part of the graph, the results indicate that, while for the current climate there are improvements that adaptation can offer, particularly in the minimum water supply, about 22 percent more -- minimum water supply under current climate could be had by this analysis. It's important to note the red bars that show that, for instance, firm energy, the minimum guaranteed energy, is going to be approximately 30 percent less for the case of the current management compared to a detailed adaptive management that I indicated. Average energy, too, has the same problem.

So the conclusion is that the integrated forecast and reservoir management demonstrates significant capability for mitigating water resources impact of climate and weather variability and uncertainty, particularly for extremes such as I mentioned, firm energy, there is also floods in this analysis.

One last thing I want to mention is institutional issues for using INFORM in Northern California. The management processes are legally institutionally vested in traditional procedures and are change resistant. We have, for instance, minimum cooperation among agencies in terms of during normal or dry hydrologic periods, there is better cooperation for flood management. Unfortunately, coordination is not accompanied by integrated adaptive tools that encompass the applicable range of time scales, sectors, and prediction uncertainty, in particular. And the unintended sequence of all this is that it discourages the use of key scientific advances, for instance, hydroclimatic forecasting, multi-reservoir optimization and certain characterization, and integrated water resources management. We suggest that, as a response, institutional and legal processes best concern themselves with establishing the framework, the broad objectives and criteria for shared water management, and not with laying down policy specifics, much like the guide rule or the operational rules that are currently specified. We think that with agency coordination, the adaptive risk-based INFORM approach may become institutional practice as a real time screening and planning tool for identifying beneficial use policies. And with that, I'll stop. Thank you. [Applause]

COMMISSIONER PETERMAN: Thank you very much. I didn't realize how much you could impact the productivity of these reservoirs with basically technological solutions, with software and forecasting, and I think that was important to get on the record, and also it would be useful, I think, for us to have a better idea of how much these systems cost if we were going to deploy them to other watersheds, as well.

DR. GEORGAKAKOS: Yeah, this particular implementation of INFORM is done for essentially the entire Northern California, the Sacramento system, and it's been funded now over a period of a decade almost as a demonstration project. The key point I want to make is this is not a gadget, this is not just a tool that you just apply somewhere, this is a designed and should be used to interact both with forecasters in real time, but also with reservoir managers. And these reservoir managers might be one, or might be a consortium, it might be several stakeholders. It provides risk-based tradeoffs so, at a give risk level, we provide tradeoffs among different uses of the water so a decision can be made to improve water use efficiency.

COMMISSIONER PETERMAN: Thank you. I would probably be easier to deploy if it was a gadget, but I do agree that it is a good tool to have, you have really highlighted the range of stakeholders that you need engaged at any point in this decision making process and that it is continual considering that I think it goes up to nine months, so there's activity you would have to engage in on a regular basis in order to effectively --

DR. GEORGAKAKOS: It is now online and with secure net, all the agencies receive this information and there is feedback.

COMMISSIONER PETERMAN: Great. Well, thank you very much. Any other questions? One more question for you.

COMMISSIONER SANDOVAL: Thank you. So I wanted to know if you have looked the impact of residential watering on watershed and tree health and how that fits into this model?

DR. GEORGAKAKOS: Yeah. So the way this study has been made is to follow the base demands that essentially the Department of Water Resource specifies for different uses, and so we haven't produced a sensitivity study with respect to that aspect. And in the climate sensitivity study, we haven't looked at that, no.

COMMISSIONER SANDOVAL: Well, let me tell you why I'm asking that question. So I've been designated as the Water Commissioner for the California Public Utilities Commission, and so, as you know, a couple of years ago Governor Schwarzenegger signed a bill which the Legislature passed to prohibit unmetered watering and encouraged the transition to metered watering across the state, including munis, and then also to target 20 percent reduction in water use, so Sacramento is one of those places that's going through the transition from unmetered to metered watering. I went to a public participation hearing in Calipatria, which is south of the Salton Sea, and so this was a place that had unmetered water, okay, in my mind, clearly, while you had unmetered water in the middle of the desert, but they had unmetered water, and these people had English-style lawns and trees which required daily watering, and so since they've had to go to metered water, the lawns are all gone and the trees are dying, which also has an effect on passive cooling of the houses, and I've also wondered about the effect of this, as well, on rain and water production. So I know certainly large scale deforestation will affect rain and water production, but when we're looking at it as a small scale, then you do think hydrologically is this something that we need to be looking at? I know the area around Joshua Tree and Barstow, which also Barstow had unmetered water, that they're giving suggestions to people about here are low water use trees that you should be using. So is it important as we look at the transition to metered water that we have to look at keeping up trees in these more, you know, urbanized areas as part of protecting our water cycle?

MR. GEORGAKAKOS: Yeah, I think it depends also on the large scale climate and its interplay between, say, infection and local processes and there are a few studies that are done, but most of the successful studies I know are for the center of the U.S. more than the coast.

COMMISSIONER SANDOVAL: Well, so I'd like to suggest, this would be a really terrific area for study, you know, as we look at the transition where we're encouraging people to use less water, what is the impact of that on our urban forests, and how it affects, you know, passive cooling energy use, etc., you know, so how can we do it in a way that ultimately protects the watershed and doesn't actually increase demand for electricity. So, thank you.

DR. GEORGAKAKOS: Thank you.

MS. KOROSEC: All right. Our next speaker is Paul Bunje from U.C.L.A. to talk about Adaptive Measures for Homes, Buildings, and Cities.

DR. BUNJE: Thank you very much. Thanks to the Energy Commission for holding this hearing and inviting me here today. I think this is very exciting and very important, and I have a lot to talk about in a sense, so for those reasons, much like others, this is going to be a bit of an overview. But there are sort of three points that I want folks to leave with recognizing, number one is in the title of this, most Californians live in homes, we all go to buildings most of our day, and the vast majority of us, well over 80 percent, live in cities, live in urban conglomerations. So when we start to talk about climate change, particularly as it relates to energy issues, this is actually hitting home specifically in our urbanized regions of the state, that's essentially just what this is, and that means built-up elements, homes in buildings of other sorts.

Secondly, and you've already heard quite a bit about the fact that, over sort of planning time frames, the next decade or so, it's very difficult to get decent predictions that will allow us to make large scale changes, so many of the adaptive measures that I'm going to be talking about are going to be the primary responses that people have, essentially on very local scales, and that brings me to my third point, which is that, really, these hyper local issues are many of the actual adaptive responses we're going to have to be dealing with in identifying a policy and planning framework within which to integrate those individual actions, as well as local government actions, into a statewide understanding for the energy system, is going to be critical and something that I feel we're not quite there yet, although we're clearly much further ahead than any other state, so that’s' incredibly encouraging.

First I want to point out that, when we talk about climate change, many of the worst impacts that we're responding to are critical impacts to cities of various sorts, including -- we've heard this many times and I'll go over it a little bit more -- issues such as heat, but also flooding, sea level rise, and storm surge issues, since so many of our residents do live near the coast, intense storms, and that includes not just flooding events, but also windstorms, decreased water resources, or flashiness of those water resources at appropriate times, and then all of the sort of secondary and tertiary impacts that come related to things like wildfire, diseased vector distribution, and heat related pollution impacts, and other sorts of public health impacts you might see, and then, of course, the ocean coastal changes that are in large respect a critical nexus between what we're doing to our coastal resources, themselves.

So I'll break this down just into homes and buildings, which obviously there is a lot of overlap there, and then talk a little bit more about cities. And really what I want to do is just offer a sense of the sort of grab back, the smorgasbord of different adaptation efforts that are underway, and one of the things you'll note throughout this is that most of these adaptation measures that happen at the sort of hyper local scale are things that we're either doing already, or already know how to do, they don't require necessarily technological innovation, although they may in many respects require different policy framework in order to do them. Oh, I'm sorry, I said I'm glad, Commissioner Sandoval, that I put up the water conservation one first per your questions just now because this really is kind of a critical issue, particularly when we want to think about ways that we can reduce water use in order to save energy associated with water treatment and conveyance, as well as some of the efforts we might be utilizing that water has to actually cool off some of our buildings, for instance. And most of the efforts you can use to actually conserve water are pretty straightforward. Again, this is not new or rocket science, but low water landscaping, moving beyond just metering to tiered water pricing, and that includes both total use tiered water pricing if you're going above a certain threshold, which many jurisdictions of course have, but also starting to implement things like dual metering technologies, so that you can discriminate between indoor and outdoor use, which is a big deal in many of our larger cities. And then some of the other classic things -- putting out a rain barrel, building out gray water systems and the like. But then it should be noted, and the CEC ha actually done some good work on this, that many of the lowest hanging fruit are continued things like replacing old leaky toilets and faucets, and the like, still have a tremendous impact, as do, of course -- and I'll get to this in a little bit later -- fixing the distribution systems in our cities where pipes can result in well over a quarter in many places of water loss.

I want to note really quickly that the current water plan goals to reduce urban water use by 20 percent by 2020 and that most folks, including Gail (indiscernible) and Linda Davis there (indiscernible) have noted that getting there will actually be able to save us -- if we're getting to rates that are something like what Australia is doing, which isn't outside of the realm of possibilities, the point in a similar climate, and then in a similar economic position, we could potentially save a million and a half acre feet or so in assumptive use by others. And then note again -- I'll put in purple a couple of these times because this, I think, is a critical place here. We often talk about the ways that you can both adapt and mitigate greenhouse gas emissions simultaneously, and there really are a lot of opportunities for doing that. The water energy nexus is probably the most obvious and most salient of all of these.

Probably the chief concern in terms of immediate impacts, largely because we have a greater grasp on exactly how heat is going to impact our state, is directly mitigating, or directly adapting to high heat, and we've already heard repeatedly that the primary way to do that is through air-conditioning, essentially people will turn on their air-conditioners when it gets hot, and we've already heard that repeatedly. Knowing full well that things like 30 percent of peak load is due to air-conditioning demand, and you've already heard -- so I don't need to repeat this -- that expected increases are very likely, especially what you start to think about the fact that our population growth is supposed to be most intense in places like the San Joaquin Valley and the Inland Empire, which have higher air-conditioning demands already.

One important element to this, and I pointed out that a lot of the responses that we're going to follow are things that we already know how to do, is really some very typically urban heat island mitigation efforts, reducing daytime temperatures or peak temperatures inside buildings can be done through mechanisms that will reduce urban heat light and island effect, both on an urban-wide, or citywide scale, but also even on individual homes and buildings, for instance.

But there's also still a lot to do and this includes improved housing design, there's increasing efforts on both materials and other methods, but also new technologies that can go beyond exactly what we're building now. I do want to point out, though, that still the most important element in reducing things like cooling demand is improved insulation weatherization, we will have more than half of our building stock generally is pre-Title 24, so there's an area for actually retrofit that can result in substantial thermal comfort issues within homes, for instance. And then, of course, there's these individual adaptive behaviors, and you're going to start to see this, and this is going to pattern out and there frankly hasn't been nearly enough work on this because this will pattern out in unique ways across the landscape based on demographics, economics, and the like. Individuals will actually respond to things like high heat by going outside, or changing their clothes, or bathing, for instance, when it gets particularly hot, and these are elements that shouldn't be overlooked, particularly if you want to not simply respond by putting in more air-conditioners.

There are other impacts that I just wanted to highlight really quickly, including wildfire and ways we might respond, the most simple of course is not to build homes in fire prone areas, and we've already seen that many of those can actually pattern right around -- in terms of transmission lines -- they're right near many of our dense urban areas. Other efforts that can be mediated are improved emergency response so that you can get cross-jurisdictional response to wildfires, and particularly if you can predict it, and then the basics, right? Clear your vegetation. I used to -- I lived up in the mountains when I was a kid, and it seems silly when you don't clear around your house, but we very often don't do this, particularly in suburban areas that are at risk of wildfire.

Health issues go beyond high heat, of course. Diseased vector prevention is a critical one. Many diseased vectors, particularly mosquitoes, may be seeing their ranges expand. We heard how various species can change in response to warming temperatures. I want to point out that things like empty swimming pools are actually a primary site of mosquito generation and, in one study by Harrigan at all the West Nile Virus, the single factor predicting the expansion of West Nile

Virus, which is up throughout Orange County now, and the rest of what's south of there, were economic factors, primarily things like foreclosed homes because they would have empty swimming pools in the back. And so there are things that you can actually do, knowing that the temperature is changing, to respond to some of those efforts, as well.

And then sea level rise, and I know everyone here, you all have been fully briefed on these issues, but outside of hardscaping and other coastal erosion prevention methods, there is very literally a role to be played for relocation, and I'll get to the critical infrastructure element, but also even homes, in particular. And I didn't put up the scary sites of homes in Malibu or Half Moon Bay getting washed away, but I think you can imagine what those start to look like.

Though things sort of continue on from there, and I wanted to spend a little bit of time talking specifically about cool roofs. And, again, this is very typical efforts. Cool roofs have been investigated for a long time, including by a former colleague, Art Rosenfeld and his entire group and others at LBNL, this is clearly also a method for adapting to higher temperatures in the future, temperatures whether it be a result of climate change, or the urban heat island effect, the adaptation response can be quite the same. Cool roofs are most effective in older buildings. Those with good insulation, as it turns out, tend to see smaller improvements in energy performance, and so when you're thinking about retrofits, there's a role for thinking about how you would retrofit a building, what steps to do, one after the other, and you wouldn't necessarily put a white roof on a brand new Leed certified building, which probably has a white roof to begin with, but you might start to look at some of those, especially pre-Title 24 buildings, as an effective way of mitigating the inside temperature and thus reducing things like energy demand for cooling.

I also wanted to point out that cool roofs aren't necessarily a way to reduce global temperatures directly, we know that the urban heat island effect can contribute a fair amount of heating, Jacobson and Ten Hoeve's recent study looked at two to four percent, although they acknowledge that those numbers themselves are very very uncertain. We do know, and you all have been briefed before on the Urban Heat Island effect, but that does have an effect on global temperatures, however, it doesn't appear that straightforward things like cool roofs or white pavements are likely to have any effect on reducing those temperatures, but because they can actually be a mitigation strategy by reducing cooling demand by getting rid of some elements of the Urban Heat Island effect, you can reduce power generated by fossil fuels and thus, sort of indirectly, get at a mitigation strategy. Numbers, again, are difficult to put on any of this, but it's critical to remember that many of the ways we're adapting, again, can be strategies to reduce our energy consumption and thus greenhouse gas emissions, as well. Just some examples for those of you who haven't seen them, most cool roofs are straightforward, high reflective, high Albedo surfaces, but of course can be combined with things like rooftop solar, or even green roofs, which have themselves an evaporative cooling phenomena, as well, and there's lots of different mechanisms you can do this.

One of the things I pointed out in an earlier slide, and one of the reasons it's hard to be proscriptive about this, is that these are highly dependent on their location, what the exact climate happens to be there, as well as the purpose, of course, of those buildings, and the building characteristics themselves. And so, as Michael McCormick pointed out, when we get down to the sort of local government scale, but even smaller to the building scale, this is where the rubber meets the road, and it's very difficult at a sort of statewide scale to say this is the best strategy to go forward, but identifying a mechanism in which you can create policies that allow buildings, for instance, to have the most efficient response to things like thermal heat stress in a unique way is going to be important, so setting up a much more flexible strategy is going to be critical moving forward.

Then there's lots of other cooling methods that we can use for buildings, as well, including directly managing things like building heat from air conditioners, at least -- and on modern buildings with some of the most advanced HVAC systems, this is pretty effective, so that you're not essentially off-gassing heat into the atmosphere nearby, which sometimes flows back into the building; optimizing building materials, again, newer buildings, this isn't nearly as big a problem, although there are still gains to be made; geothermal heat pumps, which have been used most successfully in cold weather climates where you can use the heat underground as a storage regulator, are also plausible for cooling off buildings, as well. If you go beneath about a foot deep in most parts of California, then you have temperatures that on average stay below 60 degrees Fahrenheit, you're able to actually use that as potential heat sink. Again, the performance here is highly dependent on the local climate, ground temperature, seasonal demand and, of course, getting these things actually built, especially in cities that already have all of their infrastructure there, can be a real challenge. But then there's also other building mechanisms -- passive structural cooling, including things like ventilation shafts where not only can you reduce energy savings, but often times ventilation shafts have proven to have much higher rates of occupant satisfaction, they improve building comfort, and simultaneously reduce energy consumption, and this has been demonstrated in many many climates around the world, including here in California. Passive solar cooling, and obviously the work of the Energy Commission through its Building Standards has been one of the leaders on this, of course, though I would argue that there's still some room for Building Code changes that we can advance forward, including things like expanding the thermal tolerance range, right? So building comfort issue is a problem with this, most people don't like to be too hot or too cold, but if you're able to actually expand the building standard at which occupants are allowed to stay, then you can respond, in particular to some of those variations that we'll see in temperature more effectively, and probably there are a host of buildings that will -- you can stave off for a couple of years the need to put in new air-conditioning and other results.

To your question about trees, in particular, we know in particular that trees can reduce locally experienced temperatures and the Urban Heat Island effect through both evapotranspiration and shading. Evapotranspiration does consume water, of course, but it does provide a significant local cooling effect. This, again, is highly dependent on the exact location where you are, and the tree species, and the amount of cooling that you have, so it's incredibly difficult to model with and predict what the relationship between water savings might be vs. the actual cooling effect that you have there, and whether it's effective in all cases. Certainly, there are some places that it is not. But energy consumption can be reduced in buildings by reducing air-conditioning, especially through shade, which doesn't always have to be directly through high evapotranspiration of trees, they can be through low water use trees, for instance. And if done wisely, i.e., put the tree to the west of the building so that it's cooling off the building -- so that it's shading the building during peak demand, the height of the building, local climate, type of tree, all of these sorts of things will directly affect both the energy savings you have and the cooling role that they might play.

And then buildings, in particular commercial industrial buildings, we've already seen these as a place where new water technologies can actually roll out quite rapidly, there's lots of rain water harvesting, gray water systems are very effective, especially in industrial systems, recycled water -- I put an image there that we've all seen lots of these gray buildings where you recycle the water and create both cooling ponds, as well as sort of nice aesthetic features of the area, as well. And I do point out that this could be an even more successful strategy for commercial and industrial water uses, in particular, because of the regulatory burden, in some respects you get more bang for the buck because you've got bigger buildings and such that you can control, in particular some of the recycled water systems that you're utilizing.

Real quickly, going one step up the chain to cities, cool centers are going to be a critical element of our response to adaptation in the future, in particular, in particularly high areas where you have dense agglomerations of residents in multi-family residence, and the like, it's critical to have central locations with air-conditioning that local residents can use. This is one of the first steps that any public health department will look at when thinking about climate change adaptation, especially as it relates to heat stress and the types of deaths that you might see in other heat related illnesses you might see on high heat days. They can be located in many different places, senior centers, community centers, and such, but thinking about these as cool centers, as well, provides another requirement for their reliability, as well as their actual structural requirements, and they need to be located in specific areas to vulnerable populations, so this needs to be discussed and identified with public health departments and others and, of course, need to be accompanied by things like transportation plans for at-risk individuals. So not only do we need the Energy Commission and utilities to be able to actually keep these things cool, they need to be in the right places, and they need to be accessible, and they need to be tied to things like evacuation and warning plans in these cities. So in these cities, we're starting to talk about a heavy integration of the energy system broadly with the suite of other agencies and purposes that are being run in cities.

Critical infrastructure, and I won't read through all the critical infrastructure elements, but they go far beyond just the electricity system to include things like wastewater, sewage, ports, airports, hospitals, etc. etc.

All of these are in different parts of the state, potentially at risk from things like sea level rise, where we need to start thinking about resilient infrastructure design, other things like relocation through policies that could include all the way up to things like rolling easements and other types of managed retreat, and then direct relocation of those critical infrastructure elements when feasible, not always feasible, of course, but if you're able to go to air-cooled power plants, for instance, then that may reduce their requirement on being near the coast, for instance.

Flooding is going to be a hypercritical issue in many many cities, of course, in the state, from Sacramento all the way down to San Diego. So expanding our flood zones and improving flood maps is a first step in this, these tend to be quite old and tend not to filter down to the local government scale very effectively, but that needs to be integrated with improved flood channel design and land use policies, as well, which I won't go into it here, but there are some critical elements to the energy system, as well there.

Wildfire, we've heard a lot about this, including with respect to transmission lines, but of course, as well, fire impacts in the Grid, cost of wildfire associated with our suburban communities, in particular, we need to start thinking about some of these buffer zones in the context of those buildings and homes, themselves. And then heat itself, again, I'll just refer you to the sort of Urban Heat Island literature here because, again, heat and critical infrastructure elements are a big part of that.

One piece, though, I want to pull out is transportation infrastructure since there is a lot of work in California, in particular from Caltrans, as well as some of the larger transportation planning agencies such as Metro and MTC and others, to think about how their infrastructure is going to be impacted, including things like road surface changes, to be lighter pavements, this is something that I know Caltrans has started to look at, how can you actually change some of the paving standards to address this, but they also need to be integrated with other impacts like flooding, like groundwater re-infiltration for places that are interested in that, etc. etc. etc.

Critical transportation routes need to be addressed. Just like transmission routes of electricity, we also need to be thinking about where roads are accessible. Rail tracks and overhead electric lines, these frankly are affected in the same ways that large scale distribution are affected. Substations and local transformers are affected in the same way that large scale transformers are, and we need to be thinking about how managers of those local things, utilities at those local scales, are going to be able to respond to it. And then I won't go too much into bridges, of course. Those are just a couple of pictures how heat can actually warp rail lines, for instance, extreme heat. And so one thing, looking at that is critical. The same thing can happen, of course, to overhead electrical lines associated with rail lines. And then roads and damage from floods, for instance, there.

I mentioned emergency response. Very briefly, we want to point out the one good example from a specific type of storm, the San Gabriel Valley windstorm just last December, where you saw almost half a million Edison customers, alone, affected, and more than half a million customers total were affected when you add in Pasadena Water and Power, in particular. Three hundred poles were replaced, 100 circuits repaired, this is the type of local scale within a city impact that you're likely to see with greater frequency of storms. This, of course, is just one particular wind storm in the Santa Ana event, but other types of storms including rainstorms are also likely, leading to lots and lots of damage, and power outage. Power outage here is critical not just for the fact that customers like it, but it's the central requirement for emergency response, maintaining access to power is maintaining emergency response so that crews can get in and assist affected residents, can get critical infrastructure like gas stations back online, and the like, etc. etc. This is a good example where you actually had lots of collaboration between different utilities. I know Anaheim, for instance, turned on their extra power and sent that up to Pasadena in order to maintain lights longer than they would have been, and it kept the Call Center, the 911 Call Centers open for an additional 12 hours, or something like that. So this is thinking about resiliency of the power system in order to help out the other elements that a critically -- that are going to be impacted by climate change.

And then Community Outreach Protocol, because of things like emergency response hinging on having access to power, we need to be thinking about these outreach protocols and how that interacts with our maintenance and management of the broader power system, itself, if we experience extreme heat events, flooding and storm events, or wildfires -- when, I should say, when we experience these at greater frequency.

I'll sort of gloss over this because I know I'm running a bit out of time. The Water Resources, again, within cities you're not just building transmission lines and gas stations, you're not just dealing with the energy, in other words, there's all these other issues that need to be built out as a part of the infrastructure, and of course these local governments are thinking about how to do things like reduce their reliance on Sierra Nevada water resources, or Bay Delta Water Resources, and increase things like surface storage, so that you can overcome some of these extended drought periods that we might see, or extended summer droughts that we're likely to see in the future. Of course, this is highly tied to flood management in many places, Sacramento, Southern California, and the like, flood management and water resources are tied at the hip. So there's an increasing emphasis on conjunctive use, which is extremely valuable, and I would suggest there is a critical role that, because of the water energy nexus, there's a critical role for the Energy Commission to play in thinking about conjunctive use plans for the future, as well as supporting groundwater resource utilization and, in particular, in places where there's a high -- which is most of our urban population -- most of the population in the state, of course, is dependent on imported water of some sort or another. So greater reliance on groundwater resource, including infiltration, recycled water and such, recharging with recycled water is critical.

And then I want to point out that one of the best ways to do this in an urban environment, since we're talking about homes and buildings, is land use planning. It's not necessarily entirely about transportation planning itself, or Grid and energy planning itself, but explicitly about land use planning. We've already heard about the fact that the impacts of heat are differential across the landscape, so thinking about where it is that growth happens and exactly what type of growth that is. Is it low density residential? Is it high density, but highly paved, highly absorbent materials that are occurring, etc., are critical. And as this gets built out, you know, in the context of climate change adaptation, these local governments are going to be thinking not just about the energy that's required for this, but it needs to be -- they are considering first and foremost things like public health, public safety, emergency response, and how their different communities are going to be responding to this, including those in high risk areas, in flood plains, for instance, or in urban land, and interfaces might be subject to higher rates of wildfire. So as a result, we're going to need specific land use efforts that deal with this. We've thought about this to some degree, as I said, in the context of sea level rise where you can do some managed retreat, or the thought is we can do some, but it may be that with respect to increasing risks associated with things like wildfire and interior heat events, we might want to start thinking about how to respond, what kind of policy responses might be appropriate in a land use context for mitigating those issues, as well -- where we build and what it looks like when we build them.

This, I pulled this out because it's sort of an old saw by now that you want to do adaptation things, you know, you want to adapt and mitigate at the same time, let's find the ones to do it. Very often, that's really not possible, reducing greenhouse gases, it's just reducing greenhouse gases. Very often, adaptation is just adaptation, but this is a -- I pulled this out of the Draft Climate Adaptation Policy Guide that the Department of Resources has out right now. There is a tremendous amount of overlap on this side, which is precisely where I know the Energy Commission has been thinking for quite some time, but it goes far beyond things like the water energy nexus, or simply thinking about hydroelectric resources, there's a whole suite of different efforts that are good for adaptation planning that will in theory, if we do it intelligently, and you can see them here, will result in greenhouse gas emissions reductions. And Julia Levin pointed out a number of the ways that I know that the State is already thinking about these. This is sort of the first place to start in a sense, let's get more bang for the buck.

I'll ignore this, maybe I'll leave this for the panel discussion afterwards because, as I put this together, adaptation at the local scale is highly variable, it's highly dependent on what individuals, including building owners, companies, and local government decision makers are doing, and so it's very difficult frankly to come up with proscriptive assessments of what effective adaptation strategies are for the State of California. As a result, I think it's extremely valuable to have things like the Climate Adaptation Strategy that I mentioned, but further elucidation is really warranted in really thinking about how we do this moving forward in a framework that evaluates things like GHG benefits and adaptive strategy, without knowing what's going to happen, but allows us to be respectful of evolving science and the uncertainty that is present in this, is going to be really really important, really really critical. And I put at the very bottom sort of leading to that, and Kosta sort of hinted at something like this, it's really valuable to recognize that we're going to be dealing with these changes essentially forever, and it's not enough to know what's going to happen at the end of the Century and think we can plan for some sort of identified future. You've heard repeatedly that that's not the case. So what we really do need are an integrated set of climate services of various sorts that allow us to do both real time, short time, and long term monitoring, forecasting, decision support that integrates the science with the decision makers in a structured way. California through leadership like your own is at the forefront of this, but we're still a long ways from where we need to be.

A few folks to thank for this, but I thank you all for your time.

COMMISSIONER PETERMAN: Thank you. [Applause] I mean, you covered such an array of topics, I think we could have had a whole day on that set, frankly. So I'll just -- I found it very informative and I'll just offer a comment, particularly in terms of talking about the transportation concerns, I think it's useful to bring up especially as we're transitioning to more electrified transportation sector, and particularly in the transportation space, this is an area where we are currently planning the fueling infrastructure, so the Energy Commission through the 118 program has provided millions in funding for electric charger infrastructure, hydrogen fueling stations, E85, and we have this opportunity now, since we haven't put the bulk of them in yet, to think about this consideration in advance, and it would seem like that would be a less expensive way to approach it than to have to do the adaptation after the fact, and so considering the points you've raised, thinking about the infrastructure we're investing in now, how to do it more smartly. So I appreciated that context.

DR. BUNJE: Of course. And I think, with respect to that, obviously things like population are driving, and demand are going to drive EV infrastructure, but thinking about it as you say an integrated way is going to be important.

COMMISSIONER PETERMAN: Are there any questions from the dais? Commissioner Sandoval.

COMMISSIONER SANDOVAL: Yeah, thank you. I certainly found the integration here between water and energy to be very insightful. So with regard to water use, when you're talking about, of course, various tools and the tiers, you know, traditionally the tiers have distinguished between the indoor water use and outdoor water use, and what's interesting, one of the things I found is that most of the tiers are set at assuming two people in an apartment with no outdoor water use, which in many communities is not at all reflective of the average household. And this tends to push everybody up into the higher tier. But also, it seems like it's almost an assumption that outdoor water use is bad, but yet when we talk about trees and passive cooling and heat islands, there are good uses for outdoor watering and trees, and tree house, so this is an area that I'm very interested in learning more about as we try to figure out, well, what is a wise water policy? What outdoor use should we be encouraging? And what is discouraging? So if you have any resources that you could give us on that, you know, you've done a good job of really emphasizing the nexus between water and energy, and we usually talk about that with the movement of water, but this is another example of that.

DR. BUNJE: And you highlight essentially the critical issue here, which is that we don't really know enough, frankly. And you're absolutely right, the tiered pricing is based upon this assumption that you can know based on the amount of water used whether or not it's indoor or outdoor. But that's frankly a fairly dumb approach to it, as it were, right? So we're moving to smart meters and a smart grid in the electricity sector, there's clearly a role for that to be played in the water sector, as well. And you're absolutely right that -- I like to think one of the things we forget with respect to climate changes, what we're really entering into is an era of hard choices, and we'll need to have -- a wise water policy is one that recognizes that there may be some value associated with utilizing something like water for tree growth, for instance, because it reduces the building's demand for air-conditioning. But we don't have enough data to even know where that sort of tradeoff lies yet. It's clear that we're going to have to make those hard choices at some point. At some point, one side is going to get more than the other. But we don't know yet, and I would argue that that's really one of the places that we're at. One place I'd point you to as an example of this, I put up here Stephanie Pincetl, a colleague of mine, but led by another colleague, Terri Hogue, have been doing a study in DWP territory, in Department of Water and Power territory, looking at two things, 1) they looked at urban greenness associated with water use, and find that essentially urban greenness doesn't change, so how green the entire city is hasn't changed regardless of how much water is being applied for the whole city. And so, in some respects, at a total sum, we're probably watering too much, but that doesn't mean that any individual home is, or that doesn't mean that any individual part of town, for instance, might be as well. But that's one of the first studies that I know of to actually start to look at, at least at a water utility scale, whether or not there is too much water being applied outdoors or not, sort of an open question.

COMMISSIONER SANDOVAL: Thank you. And then, also, when we talk about the Edison windstorm, one of the things that's important to note is that those were hurricane force winds, so it wasn't just your standard Santa Ana winds. I grew up in Los Angeles, and those were hurricane force winds. So one of the questions at Edison the IOUs are facing is, do we have to plan for hurricane force winds now? Was this just a one-off? You know, that’s a really hard thing to plan for and, as we look at changing winds, you know, I remember my step kids saw a tornado here in Sacramento a few years ago, they form once in a great while, you know, are you seeing anything in the models of increasing hurricane force winds or tornados in California?

DR. BUNJE: Yeah, you've heard this a number of times, but modeling wind is extremely difficult.

COMMISSIONER SANDOVAL: Yeah.

DR. BUNJE: And it's very difficult to say, as you heard, even Santa Ana's -- some models indicate that you're going to see a reduction in the frequency and intensity of Santa Ana events, but that's highly uncertain at this point. I think -- this gets to really some of the points for planning purposes, we're used to planning for something that we know, assuming that the world is somehow stationary -- if you've heard it once today, you've heard it a thousand times, we're planning for an uncertain future, and so we need to start thinking about the possibility of some of these things coming true, as opposed to knowing -- as opposed to a traditional risk infrastructure where you think you know how frequently a one and one hundred year flood event or hurricane-like event is going to happen. We can start to put better bounds on that, of course, and that's where the climate science comes in, but frankly, the policy framework and planning methodologies need to catch up with this sort of adaptive approach that a number of people have been advocating for.

COMMISSIONER SANDOVAL: Well, then looking at kind of where are the risks, we haven't fully counted for because I know I asked Edison, the day before the windstorm, there were actually good climate predictions of almost a statewide windstorm, and PG&E said -- they announced they were getting crews out, they were proactively doing tree trimming, and I asked Edison, did you proactively trim? And they said, well, they didn't, and if they had proactively trimmed, they would have gone to Fontana, which was very far away from the epicenter, they would have gone to the places that had traditionally been a wind pattern, and that was part of the reason this happened is that this area was not a traditional big wind pattern, so the cities involved hadn't really been tree trimming, the utility hadn't aggressively trimmed trees on private property, in part because we assume that the future is going to be like the past.

DR. BUNJE: Right. That's the lesson.

COMMISSIONER SANDOVAL: Great, thank you.

DR. BUNJE: Thank you. All right, thanks.

MS. KOROSEC: All right. Our final speaker before our roundtable is Dan Kammen from U.C. Berkeley to talk about Potential Evolution of California's Energy System.

DR. KAMMEN: Well, I'd like to thank you all for the chance to speak, as well, and to recognize that I am the speaker between you and the ultimate event for the day, so I will try to keep in the 10 minutes. You know, it's very interesting going last in this regard -- am I on? -- it's very interesting being last in a sense, but painful to one degree, but sobering because all the models I saw across different areas, across water, across biodiversity, across energy planning, buildings, all had an incredibly similar message in them in terms of the need to use models and to use scenarios to think about where we're going, but not to be too wedded to them because they're useful as guides, but they don't get you to the precise touch. The human element is really critical here, and I think that, if I were to characterize just a couple of the lessons, it's very true in the work we're doing, clear in the work I've heard, as well today, it's that we're going to need an increasingly information transparent way to compare results across all of these different issues, and it's really critical to have quick feedback. And it will come up in what I'm talking about, but I heard and was taking furious notes during a whole number of these sessions, so I'd like to both thank the Commission, thank the PUC, thank Laurie ten Hope, Guido Franco, and Joe Hagan for enabling the work that we're doing. And really, what my main finding, if you will, is not a specific result up here, but it's finding the forums to make sure that we learn from the results. I mean, even though I know Max Auffhammer really well, I was jotting down in detail some of the curves of his frightening climate penalty graph, if you will, because they feed in so close to what we're doing. Same thing is true for the water scarcity, same is true for those high degree days. As someone who just spent a year battling these stories in D.C., it's both a blessing and a curse that we have this many high quality assessment efforts going on, it both means that we're ahead of the curve in terms of doing these things, but it also means that the challenge to pull these pieces together so we actually utilize all these information is pretty great. And so if I were to summarize everything that we're doing in our team, in kind of one piece, it's that we're quite good at thinking about the mean -- or the medium responses, we're very bad at figuring out how we integrate in the extremes of all these features. In the energy piece, it's largely a battle that everyone gets taught in their undergraduate or graduate versions of this, and that is our costs are largely defined by meeting our peak and our extremes, and the revenues or the services in a given area are defined by the mean, and that spread is getting bigger in every single one of the cases we talked about hee3. And so, again, I'll try to illustrate these and I mainly look forward to the dialogue around this.

The main features that have proven useful in our conversation around energy planning are that I'm lucky enough to both manage a renewable energy laboratory, but also a transportation laboratory, and we look in some detail at the interactions back and forth, and I'd like to think about the ways that we can share the data from these systems much more broadly. The beginning point for my comments are that the paper I'm going to describe is a resource that's available on *The Rail*, the Renewable Energy website, it's a model called SWITCH, and there's a paper out on the counter that was published earlier this year, in fact, my team is currently on a phone call with NREL comparing our model and their model of the Western Grid System. So, again, lots and lots of details I won't be able to get into, but I'll try to highlight the big ticket items.

Probably the biggest one, and again it's obvious to everyone who is involved in the modeling efforts here, but it's hard to keep in mind in the day to day decisions around individual rate and other issues, is that the 2030 and 2050 scenarios are critically linked together and we have goals for 2020, 2030, not quite yet 2040, but 2050, and getting to one, certainly in the energy sector, requires planning and operational choices now that will impact how much we can get to one vs. the other, and I'll echo some of the comments we heard about distributed renewables, the planning around transmission and distribution, in particular. But, again, the biggest part of the story isn't the details of any scenario, it's finding ways to make our results as transparent as possible, and so my biggest test is for anyone who goes through our paper and website in detail, again, on the website is not only the paper, but a tome of a operator's manual for our model called SWITCH, all of the datasets are available there, is how to make that most useful and how to interact so that we run scenarios most useful for the other sectors. I think we have a pretty good feel for what the operational ranges are in terms of costs within the energy sector, but the linked issues around the multiple uses of water and land and how buildings can be utilized, that's actually much harder to build inside the models; it's easier to talk about in hearings, but it's hard to make operational. So I'll try to come back to that a couple times as we go through this.

I won't highlight the background story except that California has once again, in the last year and a half, been the lead in presenting a whole set of different models of how the energy sector is both the driver and is driven by land use, population and, in this case, climate change. And we'll come back to those in a number of ways as we go forward.

Our model is designed to allow us to think about how to manage costs, how to integrate renewables, how to integrate intermittent sources and, in particular, what is going to be the role of different low carbon technologies. All of this is based on the assumptions that we put in because you don't learn much from models that you don't plan into them, except that they can humble you for how unforgiving the system can be, given the targets we're after, and so looking at how to get there is really critical in the process. And, again, this 2020, 2030, 2040, 2050 set of planning decisions are linked in some ways that I think, at least I hope, will be surprising in kind of a challenging way as we go.

This is the team that I'd like to thank for the work going on here and, again, the funders and supporters at the PUC and the CEC. Again, I'm not going to talk about the details of the model, it's a mixed energy program model, we have lots of investment periods, there's lots of really critical details. I'm not skipping over it because I don't think they are critically important, it's that I think they're better in kind of the more detailed one-on-one. But what we assume in terms of prices for different technologies, in terms of availability and deliverability times, if one wants to build out large amounts of a specific solar technology, storage technologies, they critically matter and I hope that our contact information is available in here to go into detail. Any question you have, I'm happy to talk about, but there's such a mass of it when you get into the models in detail, it's really pretty critical.

What we do in this particular modeling scenario, this modeling framework, is somewhat different than what the NREL team in Colorado does. We have a least cost optimization function that we run forward in time, we're running scenarios through 2030 and 2050 as we speak. We meet demand with supply every hour, all the way to 2030 and 2050, so it's somewhat of a data nightmare in terms of the amount of information involved, but those datasets are increasingly available today.

A number of sort of features of the system that are important is that, in our modeling framework we maintain a 15 percent reserve margin for every single hour, and if you look in the paper, and the graphs will show in a second, I've shown both a peak day and an average day for each month, and so what looks like kind of a seesaw curve of results is actually showing within each month of the year that peak and that average day, just stitched together to make it geographically and sort of physically viewable. In this modeling scenario, we make investment decisions around generation assets and transmission distribution assets every four years, we run on a 10-year cycle for the 2050 cases, but I'll focus on the 2030 results for now. And that's that there is a four-year process time to make those decisions. Build-out times are much longer, and so, in particular for transmission and for nuclear, it takes quite a bit longer, there's lots of modeling details. Again, I'm going to try to just highlight -- go through the story.

We build all existing well known technologies, we do not build, of course, coal or nuclear in California today. We build not only all of the conventional renewable and thermal generation technologies with that constraint, but we do different storage technologies, we pump hydro, all of the features involved in our system are engaged in the model result. If I jump to kind of a generic result, just to highlight the features of the story, what we find in looking forward, and so what you see here is kind of a generation mix graph on the bottom, going from a carbon price adder of zero up to $100 a ton of CO_2 and, looking across the west it shouldn't be any surprise to anyone, is that as the price of carbon rises, the amount of coal in the system basically decreases linearly, and that's filled in with gas at the lower to middle price ranges, and the more of the renewables, in particular solar and wind at higher prices -- I'll highlight the nuclear story a little bit at the end -- but just to put things in kind of a numeric context, if the whole world looked like us, which sometimes they wish we thought it did more accurately than it does, but as a sort of key line in the sand, if the world operated as if we were aiming for a 450 ppm scenario, we find that the WECC region broadly, not just California, but WECC overall, would meet that in an optimal investment picture by 2030, so arguably some decades early, with a CO_2 cost of $70.00 a ton. And that number sounds very reasonable to some and it sounds like science fiction to people outside of California, but I'll come back to that in a little bit. But it's really instructive to have that kind of benchmark for how much is required to get to various targets, and that's a marginal cost of CO_2 in the sense that that's added on to the fuel prices for the thermal sources. The picture that was shown by Laurie at the very beginning highlights kind of one of our WECC-wide maps of the region. Of no surprise, lots of hydro from the Pacific Northwest, wind in the mountain states, lots of solar thermal, and some wind in the southwestern California, red being geothermal, purple being nuclear, and the transmission flows are also pretty critical in the story. And this is one of the real basic places where the planning decisions around 2030 and those for mid-Century are critically linked because which of the scenarios you envision will dramatically depend on is that capacity there to bring those supplies online. And so, at a not an apologetically busy graph is six different scenarios, all of which get one to that 450 ppm case I described. Again, 450 in 2030. But what's different about them are a couple key features. So there is a base case which is the generic current technology costs with their annual learning rates, we use the Black and Veatch data to do this work, cases with low cost nuclear as a figure of merit, that's $4.00 a watt. Our base case is $5.00 a watt. And arguably, the cost of nuclear is $6.00 or $7.00, or more, depending on your math and, again, we can't build any in California in the current scenarios, but we have low and high gas prices, and then we have cases where the cost of PV is high, and the cases where the cost of PV comes down basically in the lines with the DOE Sun Shot scenario, which is a $1.00 a watt by 2020, that's actually a case that we are now exploring in quite a bit of detail, largely because the mix of solar thermal vs. PV that one would build out based on costs, water constraints, land constraints, is an area of a great deal of interest right now.

I highlight these range of cases not for their details, but because the key feature is that we find quite a diversity of scenarios, all of which get to California's climate targets, but they envision incredibly different plans around the infrastructure. And this is not even an exhaustive list, this is not like we ran thousands of Monte Carlo scenarios and pulled out those few that got there. It's -- I don't want to say "easy" because none of this is easy -- but there's lots and lots of realistic technology scenarios that get us to our climate targets. And when I say "realistic" what I mean is realistic in terms of the amount of time to build the generation resources, amount of time even with the often slow process to build the necessary transmission to get that power to the markets, but diverse -- different scenarios get there. And just let me highlight the range of that.

It shouldn't be any surprise that a case where nuclear is low cost and is built widely in the west, but not in California, results in a scenario that meets these goals with 50 percent as much transmission as a case where we're doing a lot of solar, so from 6,000 gigawatt kilometers to 12, full factor of two in terms of amount of transmission, both scenarios get there, but it dramatically changes one vs. the other if you say we're going to have an incredibly hard time building some of the longest transmission, whether it's high efficiency AC or DC lines, etc.

What makes the story, I would say, even more interesting is that, while there is a range of carbon prices, in this case from a low of about $59.00 if one builds a lot of nuclear at low cost, which I'm -- I'll reserve personal judgment on how realistic that is -- to high costs in the high $80.00 range per ton of CO_2 in some of the cases where gas is cheap and on the cheapness trajectory that many are claiming now, meaning you've got to get to very high carbon prices to get around the fact that gas ends up blocking, as opposed to enabling, a lot of the renewables cases. But the place of power is remarkably constant, meaning these are really choices in planning and infrastructure and which of the policy tools we're going to push hardest on, not we only have a very few opportunities and avenues to get to those cases. This is really a pretty critical part of the story because it says that the diversity of modeling efforts that you've heard today highlight interactions we're going to have to make. And so as one example of the process, we utilize in our scenarios hydro resources with the water for agriculture and for reserves held constant, but we utilize the rest of the water for hydro. Sitting down in detail, and talking to Josh and some of the hydro people, that may or may not be in kind of the sweet spot of the water scenarios that we want to do for other reasons, and those were highlighted in some of the questions before. So optimizing in one of these models won't get us there, and it's got to be this dialogue, and

I know that's obvious, but making that dialogue transparent and operational is really the part where hearings like this are going to need to happen at a very regular basis to make sure that we run scenarios that are seen as most realistic by all of the players here, and that's really very difficult.

One other aspect of the story that we've spent a huge amount of time on is, in fact, the story around gas. And when we look in detail at the build rates of solar, the investment costs in solar to get there, it's not at all off the charts in terms of the ramp-up of the industry that we would need to get to, we're worried about where some of the Federal incentives are going to be after 2016, but those cases are critically dependent on building out enough new resources so that we can utilize gas to enable the low carbon technologies not to block it. And when I highlight that, I'll just show a picture here of a 2030 dispatch scenario that the colors are designed to be fairly intuitive, light blue is wind at the top, the demand curve here is the gray and, again, don't be sort of worried by the little double notches you're seeing a peak day and an average day within each month. But if we look at a picture like this, this is kind of how a typically plotting, thinking about how much of the renewables, in particular, solar you might need, but if I plot it in a way that looks more familiar to some of my friends who actually operate power plants, what they see for the gas is incredible demands in terms of ramp rates for gas plants. Those gas plants that are running more or less base load than those that are effectively running no longer in the old style form as "peakers," but really firming up renewables across the whole region.

What this means for emissions during those ramp rates is actually very significant and we'll be working on some detailed scenarios there as we go ahead, but it also means incredibly different air quality concerns as we try to, again, use gas not to block, but to enable the renewables. And if I were to highlight one with the in-sector issue, it's really that solar thermal, PV, wind, gas tradeoff, that we're going to need not only a lot of modeling efforts, but also working closely with utilities, the regulators, to figure out which of those scenarios is most realistic in terms of moving this ahead. The hearing that was chaired by the CEC on April 12th around the benefits or the co-benefits of renewables, I would add that working through the full range of economic and social benefits, I've been calling it the benefactors of the renewables, against what Max highlighted in the beginning as the climate adder in our costs. We're not going to be able to square this equation if we don't work through in real detail where we see those climate costs, and where we find the benefits, whether it's in terms of reduced transmission loads, whether it's in terms of economic opportunities for large and small businesses and homeowners, and again that gets us straight back to the PUC and some of the policy choices around moving well beyond, but including RPSs, but also looking at what are the full benefits of that metering, what are the opportunities, not only within California, but within the region to look at feed-in tariffs. Again, carbon price is in some sense a surrogate for those, but we're going to have to look at the overall set of those features in some detail to see where we're going to get to.

So if I was to conclude not with the broader set of questions, but the ones that I would expect to be sort of pushed on back within our modeling piece, it is again how we're going to deal with the price of natural gas. I returned 48 hours ago from the Clean Energy Ministerial in London, where the CEO of Duke Energy said that there's three things in life that are inevitable, death, taxes and volatility in gas prices, to which he was hissed at by a whole number of people from the gas industry. But if you look at the record, no matter how rosy the low gas prices seem to gas proponents today, the history -- and we heard people arguing about where the history puts us -- is that something is sure to come up and make that story more complex and, hence, more volatile, one of which is going to be that, if we're really going to achieve California's climate goals, and I'll say this one twice, it's so important, is that we're going to eventually have to start distinguishing based on carbon content different flavors of gas, and this is not just the Alberta tar sands oil sands story, it's lots and lots of other forms of gas coming on line. That's a level of lifecycle analysis that analysts with an industry and think tanks are working on hard, but is not generally park of the equation so far. And having not only natural gas supply curves, but natural gas carbon intensity and water intensity curves, is going to be part of our currency going forward. And, again, that's a pretty big step for a number of players in this field.

What is not only the ability to meet some of the low cost solar scenarios like the DOE's Sun Shot scenario, but also what is the ability to ramp up the production of these technologies in terms of the gigawatts that we're going to need in our region, and the demands for them elsewhere in the world? And that’s really, can we deploy some of the low carbon technologies at cost in this timeframe?

Concluding on one bit of good news, though, is that for all of the analysis I've been highlighting here with these different scenarios, not only do we find that the costs of power don't vary much between them, but it's actually a relatively small price adder to meet our goals, and that's before we put in many of these co-benefits into the renewables equation. So we find these are deployable and they're workable at scale. The trick, though, is that what our model and what the NREL model agree on in detail is that, if you don't have the ability to plan around new generation and new transmission simultaneously in a co-evolved way, you don't get there with reasonable cost. And that throws the story in many ways back to regulators and the clever policy tools to set up this equation because we have to have that ability to plan around and to deploy new generation, new transmission, and a lot of the efficiency programs that make all of this equation work. So I've tried to hit on the high notes only, I'd be delighted to talk in detail about the scenarios as we go forward, both today and over time. And thanks very much for the chance to present.

COMMISSIONER PETERMAN: Thank you. [Applause] Thank you, Dr. Kammen, for that overview of the SWITCH model. I know there's a lot in that model, as well, and

I appreciate you focusing on some of the more relevant elements for today. I guess one takeaway I have from your presentation, as well as looking at your slides, is that although the model accounts for a lot, it doesn't fully account for this energy penalty, this climate change penalty, that Dr. Auffhammer brought up, and this is an area in which we can push our models because it seems like the expectation around hydro power really is the assumption that we will still have supplies that we do currently, right?

DR. KAMMEN: Yeah, that's absolutely right. And so, thinking about which metric -- so I go back to Dan Cayan's talk in the beginning in some sense -- which of the metrics we're going to apply into the energy sector for the multiple uses of water and for the availability, and for the degree to which we, for example, want to trade off investments in technological storage options vs. hydro, is one of the places where we find a real need in the model. So, as an example, in a model like this that tries to minimize costs going forward, the model almost never wants to build storage because, as it looks ahead at demand, we would almost always rather build and then under-utilize or dump renewable capacity for anticipated future costs. That's what a model will do, that's not what real life does. So we can either make our model dumber in the short term, or we can overlay it with constraints like a million solar roofs, or the five percent and then two and a half percent discussions around storage, because we anticipate we're going to need those later on, and models that are tractable can get there, and so that's one of the key features.

And one last point that you can highlight here, as well, is that when I mentioned that the prices in our model aren't that much higher than the business as usual costs, that actually assumes that the carbon price, which is non-trivial as you see here, gets reinvested in the power sector. The more we start to pull out of it for very legitimate social and political goals, is going to change those prices. And so we pay a different premium to meet these environmental targets if we use the money in very justifiable ways to meet other social and political needs. So we really do need to keep running these and looking at the results from other models to figure out what mix works for California.

COMMISSIONER PETERMAN: Thank you. I think that's a good point as we're approaching a period where we'll have cap-and-trade revenues, and these will be timely questions. So I think, with that, we're going to turn to the all anticipated panel. As everyone comes up to take a seat, I've only got one public comment card now, and so I would use my Commissioner prerogative to see if that person, Louis Blumberg, wants to make his comment now. That way, he'll make sure everyone is still here to hear it. Louis, are you here? Okay, well, if you come back the mic will be yours. Okay. So, yeah? Come to your seats if you're on this panel. If anyone else would like to make a public comment immediately now, or after the -- oh, sir, please come to the mic. We will have public comment period afterwards, and our format is you fill out a blue card which are available on the front desk, but it seems we only have one at this moment, so we'll take it.

MR. MAHONE: Okay, well, thank you very much. My name is Douglas Mahone. I'm with the Heschong Mahone group, an energy efficiency consultancy here in the Sacramento area. And I've been working for over 30 years on energy codes, efficiency programs, and most recently on the Zero Net Energy Roadmap Project. So after listening to this all day, I think we haven't really addressed the elephant in the room, which is the energy use of buildings. Most of the presenters today and most of the modeling assumed that buildings were just the load, and the whole system is there to meet the load, but buildings account for something on the order of 70 percent of the electricity use, and buildings drive the peak, and it was pointed out that population growth is going to be a big part of the problem, but that population growth is all going to translate into more use by buildings. So buildings really are a big part of the problem. They're also a big part of the solution, as Art Rosenfeld was fond of pointing out. We introduced Energy Codes in the late '70s and they have helped to flatten the load growth in California. There are a lot of energy efficiency programs in place that are being used to overcome obstacles towards making those buildings more energy efficient. The PUC and the Energy Commission have adopted a strategic plan, which is largely focused on improving buildings.

So of all the things that we've been talking about, sea level rise, and wildfires, and everything else, buildings are the one aspect that we can actually manage and change. And I know both agencies here, the Energy Commission and the PUC, are involved with trying to improve buildings, the Energy Commission through energy codes and, to a lesser extent, through their PIER Program, the PUC through all their energy efficiency programs. So collectively you're engaged in trying to transform the building industry which is the biggest industry that we have, and also unfortunately the most fragmented. But I'd like to hear a little more discussion from our assembled experts about what they think they can be doing with all this research to improve the energy use of buildings, to reduce the energy use of buildings, and I'd also be interested in hearing from the agencies. I think there's a mindset that buildings are just, you know, all those things out there that we do things to try to make them better. But in reality, both agencies are really part of the building industry, they don't act like that, they don't talk to the building industry, but I think that's a big part of the solution. Thank you.

COMMISSIONER PETERMAN: Thank you very much for your comments, and I think you're right, buildings are a space that we can do a lot of work in. I'll say one of the challenges is, you already can tell, we've got too much already for one day of workshop, and so really the focus of this one is on the impact of climate change on those factors that produce energy, but acknowledging that, especially with our loading order, the extent we can reduce energy consumption, that's going to be probably the number one adaptation strategy, and don't want to not acknowledge that, and so if the panel wishes to touch on that, please do, but also there are other forums and other workshops we'll have specifically dealing with energy efficiency that will delve more into that topic.

I just wanted to give Louis Blumberg a second to give his -- well, more than a second, technically you have three minutes -- to give your public comment while we have the benefit of the panel. Thank you.

MR. BLUMBERG: All right, thank you. Good afternoon --

COMMISSIONER PETERMAN: Welcome.

MR. BLUMBERG: -- Commissioners Peterman and Weisenmiller. And I'm Louis Blumberg, I'm the Director of the California Climate Change Program for the Nature Conservancy. I want to thank you for convening this workshop. You are asking a very important question, how will climate change affect our energy systems? Well, how do we know that climate change poses a threat? Because of the important research already completed and funded through the California Energy Commission, through the Public Interest Energy Research Program. So I have three quick points that I'm going to make today and I'm submitting written testimony, as well.

As we've heard repeatedly today, that everything is connected here, that the PIER Research Program on Climate Change and the impacts on our natural environment has provided information that is critical to the state by addressing issues that relate to the demand, the supply, the transmission, and the reliability of power, as well as cost containment and general welfare and well being for ratepayers. And so we are not supportive of the narrow focus that the research program has taken recently, nor do we think the focus right now from the Public Utilities Commission is sufficiently broad to address the scope, the actual question that you are asking -- how does climate change affect energy? Because it does affect our natural resources. And so, in my written testimony, I have many examples of how prior research has addressed this. And we heard, for example, that the research on salmon is often held up as some as ridiculed, as too far afield, but we heard already this morning how research on Salmon is connected to hydropower and the potential licensing and relicensing under FERC.

The second point is that today power plants contribute about 25 percent of the greenhouse gas emissions in California, and the energy sector as a whole produces almost 85 percent of the state's greenhouse gas emissions. So I would posit that understanding the impacts to our natural resources and communities from our energy use is a responsibility for the state, and so we've been pleased that the Energy Commission has done this in the past through PIER, and we urge that it continue. And as Deputy Secretary Levin pointed out, and others, the Governor pointed out in December, and the research is showing, that climate change will increase the frequency and severity of extreme weather events like storms, floods, wildfires, and coastal inundation. So clearly more research on the impacts of our energy use on the climate and on natural resources will be needed to provide reliable and affordable power to California ratepayers.

The third point and closing point is, yet, with this demonstrated need for more research, we are quite concerned that, with the expiration of the public goods charge, that the state's capacity to continue to conduct this research could very well be reduced. And frankly, this makes no sense at this time that California would take a major step backwards in our ability to understand the impacts of our energy use when we're trying to do more to respond to those impacts. So we've heard today that there's no option to ignore this, that we have some of the world's best science, that California has been a leader in this.

So we would urge you to do all in your power, be it through the IEPR, perhaps, or some other mechanisms, not just to retain, but to enhance the state's climate research program with a component that includes a focus on the natural environment. Thank you.

COMMISSIONER PETERMAN: Thank you. Thank you for your comments and your attention to this area, and I wish wildflowers were a side effect of climate change, but perhaps I say that now, now that I found out they're invasive species, and then, so, be careful what you wish for. So as we move forward with this panel, I'm going to recommend that we shoot for 45 minutes, although I will sit here for as long as you want to talk. But at that point, I might take a break and ask -- not take a break, but ask if anyone has anymore public comment so that we make sure to allow opportunities for that, and if you have a flight or a next engagement, our apologies for being delayed, and please leave when you need to. So, with that, I'll turn it over to the Moderator, and thank you all for being here.

MS. MOSER: Thank you so much, Commissioners, for that introduction and that overview. We have 45 minutes for a long anticipated conversation, and so let me just quickly introduce myself and then give a couple of words of overview of what we want to do here, and then get right to it. So my name is Susanne Moser, I'm an Independent Researcher for many years contributing to the PIER Program and, you know, am not an expert in energy or electricity issues, in particular, but I'm quite an expert in the relationship between science and practice

-- policy and practice. And so I'm very delighted here to have a conversation now, an opportunity to hear from the utilities, from the people who keep the lights on, to talk directly to the experts that gave us all this information this morning.

And so what I would hope that we do is that we hear a lot from you all, and then maybe get some responses, and I'll call on you. We have Michael Hanemann here, a freshly minted member of the National Academy of Sciences, I can't help saying that, Dan Cayan, the man who is behind all climate projections in the state, and then, as you just heard, from Dan Cayman, one of the best experts on renewable energies.

So, with that little introduction, what I would just say we do to start out is a round of responses from you all in the utility sector, that basically is a stocktaking of reactions you had to what you heard so far this morning. And I would just say, you know, click on the little button, introduce yourself, who you're with, and maybe just two minutes each and we'll go around, and then we'll go from there. So if I just turn to you on my right, I'll give you the first word.

MS. WINN: Hi. I'm Valerie Winn with PG&E. And I was just -- I guess one of the first things that comes to mind based on Susanne's question is, there's just a lot of research that's being undertaken across the state that can provide a lot of very meaningful information to the challenges that face us. You know, and PG&E has -- we have a pretty robust planning process and, as we go through these planning processes every few years, we're able to incorporate the most up to date science that is available, so information on what's going on as far as demand forecasts and how they're influenced by higher minimum temperatures, what we know about windstorms or heat storms, and how do we incorporate that experience into our planning process. All the research that you're doing will be very helpful to move that discussion along.

COMMISSIONER PETERMAN: And, I'm sorry, Manny, just one question that came to mind, something that the utilities could touch on at some point, is I'm aware that you do your own funding, as well, of energy research outside of the PIER Program, state funding, and if you could just speak to what extent your research is starting to address some of these climate change impacts to the electricity sector, that would be terrific.

MS. WINN: Okay, well, for PG&E right now, we do not have a separately funded energy research program. We did recently file an application with the CPUC to do a joint research project, I think, with several of the other investor-owned utilities and with Lawrence

Livermore Labs, to look at really three areas of research that we think would be really critical to planning going forward, and those areas of research were cyber security, also operations research, and then some infrastructure planning, as well. And so part of that research project, we just have so much more data available now to help us better understand our systems and the planning than we used to, but we're not really able to process all of that data. I think I was reading something that said, you know, we've got 20 million customers, and we used to have 12 data points about their energy usage a year; now we've got 20 million customers and about 30,000 data points per year, and so how can we actually manage all of that data in a way that's meaningful to inform the research process.

MR. ALVAREZ: I'll add to -- I'm sorry, Manny Alvarez, Southern California Edison -- I'll add to that question, and then I'll go on to my points. I guess, like Valerie, we don't have a separate research program per se, I mean, any kind of research we're doing is basically geared towards operational and planning activities on the transmission side and on the distribution side, that's the majority of our focus for the most part, so I think that answers your question. But I guess what I wanted to bring up today is what I heard during the course of the day was I heard a lot of terminology and phrases that I haven't heard at the Energy Commission for quite a while.

And so I guess issues such as balance was brought up quite a bit, starting the dialogue on some of these issues, long term planning, questions between planning in the 10-year cycle that the Energy Commission undertakes under the IEPR, or a longer term period, I think, was something that was touched upon. The models that we use, or should be using, or want to use, or can use, I think, was all brought up and it's something that the Commission historically had undertaken in the past, but in recent history hasn't spent the amount of time there. But that all leads me to the question of the institutional setting for the kind of decisions that you think you're going to have to make, and I wrestle with what is that institutional setting that we actually have and are confronting to make the decisions that you want to make, looking out 50, 100 years from now.

And at a practical level, that calls into question some of the basic planning parameters that we have to address. The issue came up today about do we always plan for the peak load? Is that how we plan for everything, even though it's only a limited number of hours per year. But that is one of the basic parameters we have in the electric power industry and, if those kinds of issues are brought up for discussion, I think this is the place where we could have those discussions in looking at that long term.

MR. BEEBE: Thanks, Manny. This is Bud Beebe with SMUD. I'm Bud from SMUD. And in these introductory remarks, I can't help myself with my gray beard to note that the last time I was in sort of a broad forum at the California Energy Commission on Climate Change, it was in 1999. At that point, we were considering doing some California specific research with the PIER process, and what a change that's made. So at that time, of course, at SMUD we had already been doing some Climate Change sort of interest planning for five years and we were about nine years into sort of beginning to think about that. People in this room have been doing that for that length of time, as well. So, yes, we do incorporate portions that we think we can rely on for climate change into our future scenarios; yes, our Board has taken specific actions to assure that we have goals associated both with greenhouse gas reduction, but also the supplementary very practical goals requiring us to increase renewable energy and increase energy efficiency. So we take it seriously. This will be a good interaction, there's a lot of really interesting stuff actually happening, some of which you've heard today, and some people may not know how new it is, so look forward to that interaction.

MR. PETERS: Good afternoon. Dennis Peters with the California ISO. And appreciate the Energy Commission putting on this workshop and appreciate all the presentations today, I was here for the entire day and learned quite a bit, myself personally, and thinks I can certainly take back to our shop. I guess, you know, just looking at all the presentations and hearing all the information, again, I get back to something that Manny just mentioned and Chair Weisenmiller has pointed out to a number of the presenters, you know, in the energy business we're looking at 10-year horizons and we're going to get into more detail, I'm sure, in the questions that Dr. Moser poses to us, but you know, how can we use information that's as far out as 30 years, out to the year 2100, in current planning horizons of 10 years, when it takes five to seven years to plan and build a power plant, seven to 10 years to build transmission lines, I mean, we're dealing with those kind of time horizons. I think that's the biggest gap here. I mean, certainly, we as the ISO are very supportive of the State's policy goals, AB 32, we're very involved in RPS for renewable integration, we've done quite a bit with the CEC and with the PUC, we're involved in the Desert Renewable Energy Conservation Plan, and in that case we have been looking at transmission out to the years 2040 and 2050, but not to the extent that it's actual planning and routing at this point. So I'm looking forward to the dialogue and the questions, and appreciate the opportunity to be here.

MR. KELLY: I’m Steven Kelly, I'm the Policy Director for the Independent Energy Producers Association and my members are the experts in developing the resources that the State is going to want to put in over the next, you know, 10, 20, 50 years. So we look forward to working with the State in making that happen.

I was asked a question, what kind of keeps me up at night when I think about this, and let me quickly respond by saying that, for my members, the most important thing is to know kind of the what, when, and where that people need to meet these policy goals, and know that far enough in advance that we can get the private sector dollars to the table to make the investments. As Dennis just pointed out, it takes a long time to develop projects and one -- our big concern is the need for regulatory certainty, policy certainty, it's hardly a year goes by that the state doesn't implement a new policy that's pretty significant, that changes everything and forces everybody to go back and re-think the wheel. And we're getting to the point where we think that that's not necessarily helpful. The other thing that I'll just put on the table is what I see as a tension between planning and infrastructure needs. Certainly, we want to use the best available information and technology we have available to make the decisions today that we have to in order to set the right infrastructure. I do have a concern that we're moving down a path as a state where we are what I will call over-siloing resources, where we are cutting this pie up into so many small slices that it's very very difficult to get really competitive outcomes that are going to benefit consumers. And from a consumer perspective, I suspect while they are very concerned when the temperature reaches 105˚, they are more concerned when their air-conditioner goes off when it's 105˚. So we can't lose sight of the need for the right technologies, the right spots to maintain Grid reliability while we do all this. That speaks to planning horizons, and it was interesting to hear the planning and the modeling that was talked about this morning, that goes out to the end of the Century. For me, when I think of the world, I'm thinking of one long term Power Purchase Agreement away, 10, 15 years, that's the scenario that we're kind of looking at, that can manifest itself in infrastructure.

And I think I agree with Dan Cayman when he mentioned in his speech that, you know 2030? That's pretty far out there, so it's good to have a 2050 perspective as the long term where we're going; modeling out to the end of the Century, you know, I get less excited about that, but it's probably maybe helpful to do, but I'm not sure that it has a practical implications for the commercial investment that we need here. So I look forward to the discussion.

MR. HOWARD: Randy Howard, Director of Power System Planning and Development for Los Angeles Department of Water and Power, and it's very unusual for me to sit here and say, "Steve, ditto." I could support most everything you just said, and that's quite unusual. But I think what I've heard, and we are fortunate at LADWP because we have a very robust large water system, and obviously they've actually been leading a lot of these discussions and efforts on climate change and climate impacts, and we get dragged in, obviously, because of the water resources and the need for the hydropower and how we utilize hydropower. But I did hear some very good information today in how we could incorporate some additional concepts in our resource planning. We do a 20-year IRP, we do every other year a full-blown IRP, and then the off years we do a true-up based on typically regulatory changes. So, regulatory uncertainty does drive a lot of the issues. I think key, too, is Grid reliability, it remains probably the one thing that keeps me up most at night. I mean, I have to worry about, you know, the 280,000 low income customers that, you know, when the lights are out, they can't necessarily afford to go to some motel, some other place after we've had a wind storm, and have a good night sleep. Or those that are on lifeline and rely on the power that we serve. So I think we're doing a pretty good job long term looking at the resources, some of our concerns are, as we're making these very large capital investments, are they the right investments in the mix, but are they at the right locations, as well? Are we going to see changes in wind patterns from where we have put estimates in place as to the capacity factors of new wind farms? Are those going to change? Are they going to change dramatically? Are we going to see the times that they're going to produce change and have we modeled those properly for the future? So, as we make those capital investments, we want to make sure we're doing it in the right place. But I think at the local Grid level is where we're probably the weakest as to the impacts of climate change in cities like L.A. where you have very very old aged infrastructure, it works fine under normal conditions, it really fails under extreme conditions, and it's becoming very challenging to keep up with, as we have these greater and greater anomalies such as the 2006 heat storm that just took out, you know, thousands of transformers, or in the 2011 windstorm that put trees into power lines and power lines fell, it becomes more and more challenging as these infrastructures age. And they're not driven by other mandates, necessarily, that we're seeing in replacing the resources, but we're concerned about being able to just deliver the power to the end users. So I'll stop there.

MS. MOSER: Thank you. I'm going to bring you guys in, in a little while. I want to pick up on a couple of the themes that you just all raised, and pick up on the idea that you just sort of had which is to name a few words that we hear. One of the sets of words that I heard this morning was "uncertainty," "volatility," "cross sector interactions," and then from you all, now, I just heard words that sound more like "robust," "reliable," you know, trying to basically have flexibility, but also being able to provide for the reliable delivery of energy. And so, then, a couple of you brought up the issue of, well, we have planning mechanisms, but they're very short term, they don't go out as far as some of what the scientists presented. So

I wonder if maybe you could speak a little bit to the institutional needs that you have to create the kind of environment in which you could take into account some of the longer term changes, even though, you know, the next power plant might take you 15 years, it's going to be around for another 50. So obviously you make much longer lasting decisions in many ways. So I wonder if maybe you could think a little bit, or think out loud about the institutional environment that would enable you to take account of some of the uncertain volatile long term issues that the scientists presented this morning. Just whoever has an idea, speak up, just maybe introduce yourselves again just so the people online will hear who is speaking.

MR. ALVAREZ: I guess -- this is Manny Alvarez again -- I guess when I raised that question, I kind of wonder what decisions do we have to make today, what decisions do I have to make five years from now, and what do I have -- what kinds of degrees of freedom do I have to make 10-year decisions? And do I have to make those long term decisions in this particular cycle, or this particular period? Because institutionally we work on an IEPR process and a long term procurement process, and so there's institutional settings in which we have to make those decisions, and we're driven to those processes.

And I guess what I don't hear, or what I don't see, is some kind of capability to figure out what decisions are critical to make now, and what decisions can wait sometime in the future. So that's what I'm looking for.

COMMISSIONER PETERMAN: And, Manny, this is Commissioner Peterman, I have those same questions and challenges, so I'll ditto that.

MS. WINN: Hi, Valerie Winn with PG&E. And I guess one of the things that we always look for is how much flexibility do we have in the planning process to choose between one type of resource or another type of resource, and I think Steve Kelly said it when he said we've got -- we're moving down the path of having really siloed resource planning. And whenever you start, you know, having mandates that this much must come from this, and this much from here, and this much from there, you start ending up with something that looks like the State's Budget process and, you know, we can't figure out how to get all the pieces to work together. So all those silos do is reduce our flexibility. So we, you know, really look towards what is the State's overarching goal, and which we think is really climate reduction, and then how do we develop a flexible toolkit to help achieve that in a way that ensures reliability and reduces cost to customers? But right now, we're looking at things very fragmented, and all that does is reduce flexibility and increase cost.

MR. BEEBE: Bud Beebe with SMUD. Energy infrastructure changes very slowly. You know, and you're absolutely right when you say that, if you put in a power plant you start thinking about the power plant maybe 20 years ahead of time, and maybe it happens, maybe it doesn't happen, 10 years ahead of time, people in the industry are starting to like crystallize certain specifics, and you know, eight years ahead of it, you have to have things going because, by then, you have to have siting, and there's lots of things that have to happen. So getting a new project going takes a long time, but once it's in, it's going to last for a long time. Nuclear power plants, we design those for 40 years, that was 40 years ago, incidentally, that's another note, and all of these resources they have time frames, but they're very much longer than people sort of tend to have to deal with in their normal lives. And once transmission gets involved, once you've put in the transmission in the substation, those things change as often as, say, a freeway corridor. So we know that we're dealing with things that last a long time and that's one of the reasons that the electric sector management is so very conservative and very set on trying to do the best we can near term, medium term, and long term. We really do accept input on these far reaching phenomena to the extent you can understand them, and we have to be responsive to regulatory changes that can happen frequently, unfortunately, and all of these things happen. But it's sort of a continuum, so you have long range, you've got mid range, you've got near term, and then resources that have a life span, but it's long, but it comes to an end at some time. So it's that continuum we have to deal with.

MS. MOSER: Yes.

MR. KELLY: Susanne, this is Steven Kelley with IEP, and just one observation, that it's good to do the planning and looking for some of the variables that were in the models like what's going to be the climate effect on wind variability down 50, 60 years down the road is interesting, but unless you overlay that with what's the probability a developer could actually get the land at that site, it's irrelevant. I mean, we are driven from an investment perspective about where we can actually build -- is the land owner going to provide the land to make that site available to us? How can we site it? And those are much more immediate concerns that are driving the investment. So, I have concerns that we would go down a path that would suggest that we'll be able to map this out on a long term basis, where exactly we want these resources. We know roughly where they are, we know kind of where the geothermal resources are, we know roughly where the wind is, this is not very surprising and people have been talking about those areas for a long time; we've already looked at that stuff a couple years ago. But when you get down to a more proscriptive element of directing procurement, or resource development, it gets really problematic in my view.

MS. MOSER: Uh huh. Michael, I'm going to call on you in this part of the conversation. What tools do we have that help us, you know, sort of respond to the issue that was raised about ferreting out what are the near term priorities where we need to really give direction to decisions? How do we figure that out, what we need to do first, second, and third?

DR. HANEMANN: I think we need to change the tools we use a little bit, so there's tension between the next 10 years vs. 20, 40. I think both of these need changes. With regard to the next 10 years, I think what's important is extreme events, the likelihood of extreme events, and the unusual frequency of extreme events, which would be a sign that things are changing, so sort of focusing on the mean doesn't tell us because this is a wide band. So I think, in the range of modeling that we do, that we want to focus more on predicting extreme events, and then we have a template for seeing whether they're unusually frequent. For the mid-term, the idea I have is this, I think I could imagine taking some energy scenarios, say, for 2040, what we might need and want in terms of mixes, and then working backwards and saying if that were to be realized in around 2040, sort of what investments would have to be made, and given timing or whatever, what would be a trajectory and what would have to happen when. And you're not endorsing a scenario for 2040, and you look at several ones, but you'd get some ideas of how much flexibility we have in time and when we might sort of run out of options. And so I think -- I don't think that exercise is being done by the conventional modeling. But I think it would be an exercise that could be informative.

And I want to mention one other point. You know, many mainstream economists have criticized AB 32 because it goes beyond a carbon price and has Renewable Portfolio Standards, efficiency standards, and they have argued this theoretically carbonless world, that you only need one price signal and having multiple tools is, at best, unnecessary and, at worst, counterproductive. I've responded to them and my own view is they are wrong with regard to the situation now. But I want to mention that, by 2020, or some time, you don't want -- it would be counterproductive to have described siloed regulations for carbon price, Renewable Portfolio Standard, and other proscriptive regulations, and it strikes me that it would be desirable to thin out the various regulations and rely then more on the power of carbon price. Whether that's 2020, 2018, 2022, I don't know, but the reason I'm mentioning this is it seems to me, in the next IEPR, the issue of carbon market dynamics is relevant, the issue of what happens to revenues depending upon how carbon permits are distributed, it seems to me that may be something that is desirable to get into because those things could have an effect on, for example, the fuel mix that is used, the role of the renewables. And so I think some thought of what the market might be doing in this regulatory framework, together with how it might need to evolve at some point over the decade.

MS. MOSER: Dan, I want to call on you, as well, on this one. I mean, you have put forward a number of these scenarios, mixes of fuels and how we might meet a particular policy target, so I'm wondering if you have undertaken these sorts of scenario planning with backcasting, together with the people who actually make the decisions, or have to figure that out operationally -

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MR. BEEBE: Susanne, I'm sorry, and, Dan, but I'd like to just comment on what Michael had to say about extreme events.

MS. MOSER: Sure. Go ahead.

MR. BEEBE: And extreme events often lead to, you know, specific new actions, and lots of things like that, and I fully agree with that. But just to take, for instance, you know, when a tsunami is about to occur, or is occurring, actually, the first thing you see is that the ocean starts to like go out, right, before the new stuff comes in. And so you need to watch some of these early things, as well. And I'll say that the trees have been marching uphill for a couple of decades, and birds and other fauna have been changing where they go, as well, so we should be aware that something is happening. In these long term effects, the question of are we going there, that's over, we know that we're going there and what we need to do is learn what we can do about it now, not being too over-reactive, learn more about how to deal with these things. So, yes, extreme events are going to be very pivotal, but we already know that we're on the march.

DR. HANEMANN: Let me just say, I was thinking of measuring -- the unknown is the speed of change and, I agree, we know we're changing, and so what I'm thinking is the frequency for extreme events may be a diagnostic for pinning down, or for better pinning down, the speed of change, and the speed of change is relevant because it tells us how much episode of window we have before we have to -- so that was the perspective I was thinking of.

MR. HOWARD: If I can jump in, and I apologize, I have to leave to catch a flight, but I wanted to touch a little bit on this, too. The speed of change -- and Bud is correct, typical planning cycles are quite long for utilities and new generation, planning new transmission, and they continue to be quite long. But the amount of change we've been making, none of us in this room have ever operated previously at the levels we operate today of renewables. So our reaction to the system and to some of these extreme changes, using the resource mix we have today, has never been done. So, as we go forward, I mean, what I'm really trying to capture is how do I operate the system at these extremes knowing this is a new world I've never been in, and there aren't a lot of models out there that we can compare to, there's not a lot of utilities that have these same conditions that we might have in our own mixes. So today I have -- and we just brought it on in the last three years -- 1,000 megawatts of wind -- I didn't have 1,000 megawatts of wind in 2007. But with the off peak load of 10,000 megawatts total in, say, the fall or the spring, you know, a thousand megawatts of wind is a lot of wind. But then I have an anomaly that hits and none of the wind is blowing, what does that mean to the operations of my system? And what do I need to do to integrate that? So I think from what I've heard and some of those concerns is these more frequent anomalies which are new to us, so that adds this greater risk to how we operate, and then at the same time converting and putting all these new renewables in to have these intermittency in risks that we've never experienced before, it's quite challenging. And that's where I'd like to see a lot more of the modeling effort, as we try to find the right approach to operating the system.

MS. MOSER: I think that's a really interesting addition, and I want to put it back to you, Dan, in terms of both backcasting from maybe a desirable mix in terms of the emissions, and how -- whether or not you have worked with utilities to maybe think through what would have to happen to get to any one of these, but then also taking into account the sort of multi-objectives --

COMMISSIONER PETERMAN: I want to make a comment before Randy leaves, sorry --

MS. MOSER: Okay, all right.

COMMISSIONER PETERMAN: I was going to wait, but he was on the edge and just regarding -- excuse me for interrupting -- I thought your points were spot on, Randy, and I think that ties, though, into how I think about regulatory certainty and just something to think about is that, ultimately, I mean, we could have regulatory certainty if we're around meeting our 2050 goals, by putting in some really extreme renewable targets for now, you know, 100 percent in 10 years, or something like that, but to your point, we are -- this is our first experience with scaling at this level, and so I think that's the rationale for introducing these changes over time, and with the introduction of changes, and with the experience, then you do have regulatory changes to really adapt to how these things work in real practice, what is it like to have a peak extreme event when you've got a couple thousand megawatts of wind. And for me, that is the challenge between providing regulatory certainty and flexibility, and acknowledging where we are along the experience continuum, so I just wanted to make that point while you were here. Thank you.

MS. MOSER: Well, third attempt, so I think it's still a good question to answer.

DR. KAMMEN: It's a great question, I mean, and to be honest, I think it's more of a process than an answer in the sense that there are tools that we collectively have, and actually a lot of the modeling work done at CAISO sort of began the process of thinking about how to mix the current and the near and the middle term evolution of rates with these goals, with reliability, with clarity around what's going to be the rates of return on different types of transmission and generation assets, you know, we've heard lots and lots about megawatt buildings and megawatt utilities, and all of this, are features where I think we can use the models to backcast. And I agree with Michael to a large degree on extreme events, but I also actually think that managing the process of what are our rates going to be, and what are the features we're going to build in, so that this process is sustainable environmentally and is profitable, and I want to stress profitable, not just kind of a wash, but is profitable for utilities because this has to be a process where we want to make these investments work. And that's where I think the models really become useful because we can backcast, we can do the so-called end minus 1 in reliability analyses, and the more that the modeling tools, whether it's the ISO, NREL's, our model, are available to all the players, that's actually where I think the world hasn't gotten yet, because the models right now are the tools only for the experts in very small shops, and people bring scenarios to get looked at, and then you kind of get a number and walk away. That's actually a modeling process that I think defeats what California's process is about. And it's much more about "give me a range of scenarios." I got a call earlier today from the White House OSDP and they said, "We think we're going to hit the following price numbers for storage." And I sort of -- my jaw dropped because $100 a megawatt are their really low numbers. I said, "Well, I can run a scenario on them, but you've got to tell me what is the investment at the Federal level to make these things happen." And given those kinds of inputs, we can generate cases that, again, don't specify a number, but they specify what would it take to get there. And I found that kind of modeling process the most useful. So the meeting I was just at in the UK, the Clean Energy Ministerial hosted by the U.S., is one actually where utility after utility in Australia and in Europe said the exact same things I'm hearing, and I actually think that there is a dialogue of the low carbon leaders, of which California's utilities are hugely important, and they help define these questions. So the range of scenarios that, on the energy side for our case, on the water case for the others on the biodiversity side, that we can backcast from is one of the ways to get there. But I also think we have to figure out the process to build in reasonable evolution of utility rates to make these investments the most attractive, not just minimally, you know, it's not just meeting the minimum standards, but to make these the more attractive cases. And that's, I think, the place where the modelers should be pushed the hardest. It's not, "I'll tell you a scenario that gets to 450," it's what does it take in terms of what the cost of water is going to be, what the requirement for the discharge rates in terms of temperature are going to be, what are the rates that are reasonable for commercial and residential customers, and to get to the building question we had in the open part. I would say the most exciting part of the story isn't the traditional assets, there's lots of things we can do with them, but it's how much of the building fleet in the state, both commercial and private, can we make into profitable generation and consumption facilities. That's really where the 12 gigawatt DG target becomes a new business model. And that, I think, is where we need to get pushed to really prove that there are scenarios that work, and then, whether it's cities that pilot Smart Grid opportunities, that let us build those out, and we're ready to do that.

MS. MOSER: But before you complicate it further, I want to ask Dan Cayan a little bit about the issue that Michael brought up, which is the extremes and the concern we've heard here about being able to reliably deliver energy, especially under peak demand. What is your hunch, your expert opinion on when do we get better about forecasting what those extremes, those ranges, those peaks are over, say, the next 10 years, 15 years, that are common in the planning horizons?

DR. CAYAN: Okay. It depends on what we're talking about concerning extremes. So, as you all heard, winds are, you know, if we're talking about big windstorms, those are problematic, one thing -- and other extremes, for example, extremes in temperature are kind of -- a zero order model is that the temperature distribution is a bell-shaped curve, and the bell-shaped curve is drifting, it's kind of what Bud said, things are, you know, plants are migrating and so on and so forth. You know, when I listen to the concern about -- I understand that there's a lot of operational issues that are kind of in your face and you may not have the flexibility of having a lot of say so in terms of 50 years from now, but, you know, I think our culture has been built around an environment that essentially varies about a level of natural variability, and what the science is telling us is that there are certain changes that are pretty reliable, there's no climate model that's not warming in the future, there's virtually no model that doesn't predict that sea level rise is going to increase, for example. And so I guess I would wonder, if our civilization had developed under a world which was seeing this sort of inexorable change, albeit maybe the rates are somewhat uncertain, but at least in the future I think we can count on something in the neighborhood of, you know, close to a half a degree Fahrenheit of change within the next 10 to 15 years, and that doesn't sound like a whole lot, but when you start calculating how many degree days that is, it's beginning to matter, and I was thinking about the Chairperson's question earlier today about, you know, the 10-year horizon, and all of a sudden I went, I think these incremental changes are something that actually begin to matter. And the fact that we can attribute this to anthropogenic greenhouse gases, the importance of that statement and that fact is that it's not going to reverse. So, you know, if you're running a system where you know that there's going to be a fairly small amount of change, I guess, in the next 10 years, but then you can expect another fairly small amount of change in the subsequent 10 years, and subsequent and subsequent and subsequent, so that the accumulation of this is going to be, you know, essentially overwhelming, I sort of thing you have a different philosophy in planning. Now, that's me talking without knowing the sort of details that you guys face, and so forth, so forgive that, but I think the fact that there are certain changes that are not reversible in our at least 100, maybe well beyond that, years, has to be factored into the way you do business. So, anyway, that's --

MS. MOSER: Yeah, so I want to take that idea, both the guaranteed more heat extremes, guaranteed changes over time, I want to take that back and put it back to you all about what do you need in the short term to help you increase your safety margin, if you will, the thing that will allow you to avoid the brown-outs, if you will, what will give you that increased margin? And is that information from the scientists? Or is that changes in the regulatory system? Or what will give you more buffer room, if you will? And what would it take for you to build that philosophy that Dan just sort of laid out into your ongoing processes? So whoever wants to take it first, and we'll go from there.

MR. BEEBE: Okay, I'm jumping in. I always do -- sorry, Bud Beebe -- we always want to know what the big picture is and, you know, half a degree here on average, and half a degree there on average really doesn't stoke the fires. This is where Michael Hanemann's message that it's going to be extreme events as viewed by people, what is an extreme event? Well, it could be a lot of things, but whatever people decide it is, you'll know it when you see it kind of a thing. And those will come, but we're all asking, you know, how will it affect me? And so at SMUD we have several things that I'd like to know about climate change, and the big old GCMs couldn't tell us the answers to those. Some of the newer are giving us a little better picture. Certainly the work that you did back in 2003, 2004, in putting together some of these downsized GCM outputs was very helpful. But for SMUD, we'd like to know what's happening with the mid-Sierra Snowpack, you know, that's quite something, and that’s' a no brainer, certainly, it's there. Some of these others are not -- may not be as interesting to other people, but they're very interesting to people in Sacramento and to SMUD, and one of them is what's going to happen to the Delta Breeze? Help us understand the Delta Breeze. And if it's a function of El Niño, or the function of the North Pacific Oscillation, or whatever, let us know, you know, to the extent that you can. At SMUD, we've got the Solano Wind Project, it's extremely dependent on the Delta Breeze. And a funny thing happened when people say "what keeps you up at night?" Well, it could be hot weather because, a couple of years ago, we had a not particularly strange summer in terms of average temperatures, but we had a couple of heat events, one of which where the Delta breeze pretty much shut down, and it left people in Sacramento with hot nights for the first time in anybody's memory. And the difference is, at my house, when we open up the windows in the summertime, what we do is we wake up to a 65˚ or a 68˚ house, and then we close them and we go to work, or we do whatever we're going to do, and he house starts its warming trend from 68˚ or 70˚ Fahrenheit. But if you have a hot night and you don't open the windows, or if you've got a poorly insulated building, then you start the day at whatever that low temperature was, and we had a couple of nights where the low temperature was around 74˚, which to people on the East Coast, they're going, "Of course," but for us, that was a big dang deal. And that summer, our peak, which we designed for 105˚ Fahrenheit, our peak was supposed to be somewhere around 2,900 megawatts, in fact, we had peaks nearing 3300 megawatts, so we had to come up with an extra 400 megawatts that we hadn't planned on. Now, it was there, I mean, we're serious when we say that we build a robust system, and we plan for a lot of contingencies, so we could cover that thing. But if the Delta breeze shuts down on a regular basis for some reason, maybe it will be variable, but tell us if it's going to happen again, that would be a big deal to us.

Another one is sea level rise, as you sit, you're not very high from sea level. Down here at the Sacramento Riverfront is sea level. Now, it's true that it goes up as we get more flow in the river, but if the flow in the river stops, that's sea level. So we're a long ways from the ocean and yet we're right at sea level, and that’s a huge thing for Sacramento -- yes, we have dikes and we have channeling, and maybe a peripheral canal, who knows what we're going to have? But it's a huge issue and, so, sea level rise needs to be understood as it specifically concerns the Delta region.

The other one is the electricity demand, you know, interesting, in Max Auffhammer's slides, his slide 9, it shows two different scenarios, one is what happens if you just take the existing stock of electricity users and you increase temperature, what is the usage, what is the demand requirement? And the other one is, if people start to react to those higher temperatures and they change the equipment that they have, and that shows you a different and higher one, we've had this discussion internally at SMUD and we can't come up with the right answer. People tell us that 105˚, everybody has got their air-conditioning on in Sacramento, and others postulate that, well, if that happened more than once or twice, people would be changing their habits, or changing their HVAC. And we'd like to have that, and that's actually more of an EE and it hits other structures besides climate change predictions. So maybe there would be some information we could get on that.

MS. MOSER: Okay. I know it's the time when you wanted to stop, so do we have another three minutes to get any other answers in?

COMMISSIONER PETERMAN: Well, I would say we have as long as you want to stay, but I would say five minutes would be respectable.

MS. MOSER: Okay, so if anybody else would like to jump in on this question of, you know, what do you need from either the science, or from maybe not scientific help, if you will, institutional help to give you a little bit more safety margin in running your operations.

DR. KAMMEN: We're taking notes

MS. MOSER: Okay --

MR. KELLY: I'll just offer up a thought. This was feeding off one of the presentations this morning about the effects of climate change on animal migration. And when I was listening to that, I was fascinated, but then I was going, "Oh, my gosh, this is going to be a mess." I mean, people siting generation, if we're going to incorporate that in planning and siting, how do you possibly deal with that right now, based on the information we have? I mean, the movement of animals, 1) will be used for litigation to stop everything that anybody wanted to do, but 2) strikes me as a the development of multitudes of scenarios in siting cases that will be very difficult to address and time consuming. So when I heard that, I thought, well, that could be happening, but, boy, what is the practical implications of trying to integrate that concern into policy in siting. And I don't have an answer here, but I would just highlight that as a warning that I had in my head.

DR. CAYMAN: Oh, sorry. The utility operators from Australia at the meeting we were just at said the exact same thing. And there's no easy solution to it, but in the same backcasting way, we could look at what are the demands on, for example, the high transmission build-out generation cases vs. the low transmission build-out cases, vs. what's the value to put certain transmission in specified corridors knowing we're paying an extra price to do it there to bring some together. We're already getting places where, I mean, Norway, which has more money in this game than we do, is undergrounding transmission at a known higher cost in areas they anticipate problems vs. just co-location, using already public access. So none of it solves it, but asking those questions and making these kind of modeling efforts available to say "here is what it would imply" is what the models can now do and, to be honest, three years ago, I mean, my model couldn't do it then, I don't know about yours, but we couldn't even give you the scenarios a couple years ago. Now we can at least interact on what it would imply. What are the extra costs if we're going to try to route specific transmission lines near the Mojave along current highway and rail line? I mean, that's the kind of thing we can now do.

COMMISSIONER PETERMAN: And also, I would just add to Steven, just thinking about the siting perspective, I mean, one of the challenges is you do have a number of Conditions of Certification that one has to implement over the years of a project's lifetime and, to your point, perhaps the accuracy of those may change over time as species migrate. And so I would want particular attention paid to some of those most vulnerable species that come up in our cases, to understand those patterns better, and to look at some of those conditions in light of potential movement, for example. But I think it's a valid point raised and could be a Pandora's Box.

MS. MOSER: Okay, Michael, last 30 seconds.

MR. HANEMANN: So a quick point. This illustrates a key point of economic and regulatory significance, which is it looks as though we will face a greater level of risk in many dimensions with climate change. And the question is, does that justify investments and does that justify a higher rate of return, does this justify investing resources? The investments that we wouldn't have made in the past because we would have felt those risks were sort of too low and it wasn't an appropriate decision. So it's not just about rate of return. The routing is an example, you know, it's really a metaphor for many of these things, money to underground cables, you know, given a chance, that (indiscernible), this is true across the board and it needs some sort of consensus about, you know, what risks are now reasonable to take on. In that context, I could imagine the scenario, you know, what utilities -- urban (indiscernible) have to do to submit a five-year plan, and one of the elements in that now is identifying a climate scenario -- a drought scenario, but a climate scenario -- and saying how they would address that scenario if it happened. Well, I could imagine something like this, where the Energy Commission, or the PUC, adopted a couple of sort of scenarios, and then said, you know, "Who would you manage in that scenario? And what investments would you need in order to make yourself robust in that scenario?" But there needs to be sort of cover for managers to make investments against risks that in the past would have been regarded as unimportant, you know, not worth considering.

MS. MOSER: Right. I think you bring up an interesting point and one that echoes what Kosta was presenting earlier with his example with the INFORM approach. So I want to respect the time constraints and close this session, but really only to hope that -- to say to hope that this is an interruption of a conversation that we just began. It seems like what this day here just showed is how much we both can learn from each other and what the interesting questions are to pursue, what you all need from the science, and you take already something home. More importantly, I think it is an opportunity to build the relationships that make it more likely that the information is actually used. And maybe one other final point to emphasis, just to reiterate what came up several times, which is this issue of cross-sectoral integration. I mean, you brought up the water sector, it was brought up earlier, it seems to me that, you know, the siloed approach to this, whether it's in the science community or in the management community, does not work, nor does the silo between science here and operation here does also not work. So the question that I want to leave us with is what institutional set-up do we try to put on the table, or try to build, that allows us to get the kind of climate service to people, that gets the conversation going, this dialogue that we need? So with that, I'll turn it back to you. Thank you.

COMMISSIONER PETERMAN: Thank you. I wanted to make a couple of quick comments now before we move into public comment because, at that point, I don't know who is going to be left. So I hope we can convene a panel like this again in the future and continue this dialogue. As someone who has been a researcher for a large chunk of my life, and now works for an agency, and has worked with utilities, I can truly attest that everyone works really hard. But there's a challenge between getting everyone to work on the right things together, and so -- and it's also really challenging to get data as a researcher. So I would encourage these discussions, as well, and have the agencies think, and utilities think, about how to make data more available for researchers to do. You know, I've waited sometimes years to get data. And if you really want to have action, you've got to make that stuff available sooner and work with the researchers, as well, about maintaining confidentiality and issues like that.

I really liked the dialogue about specifically what you need from a regional basis and I would encourage you to submit that information both to us in public comments, or just by talking to the researchers directly. Another challenge is that the procurement process is not necessarily transparent for most utilities, or for the most part it's not, and so I think one of the challenges is that, when you have a non-transparent, more opaque process, it's not clear sometimes what are the drivers for project building. And I think it is true that, is the land available is the most immediate driver. But I also do think we need to incorporate some of these long term potential climate change impacts, I mean, because frankly the reason we're investing all this money in renewables primarily is a concern about climate change. And I don't want to be in the situation in 30 years where we've realized we've not included the climate change penalty, and we've invested in projects that we shouldn't. Most of these projects do have PPAs and long term -- somewhat long term -- price certainty, and I think we've got to remember that, and then be thoughtful about how to incorporate some of those future considerations into our decisions. And then, finally, I would just make the point that, in the discussions we've had here, and we're talking about extreme events and certain outcomes, and unfortunately some of the most disadvantaged and vulnerable citizens in our society are going to be most affected by the decisions we're talking about here, particularly the elderly, communities of color, the low income. And so I do want to continue to encourage us to think about these impacts, that if they do happen, they will be significant, and they are exacerbated by some social and inequalities we already have. And those people aren't necessarily present here at this table, but they're constantly present in my mind as the public member, and I'll be encouraging you in your research to think about that and being the main reason why we're here. So those are my general set of comments. And thank you very much for the panel.

CHAIRMAN WEISENMILLER: Yeah, again, I'd like to also thank people. I think, you know, when we look at it, I mean, the things that strike me as interesting is there is an awful lot of uncertainty in the energy area, and for one who has been modeling the energy systems for 30 years, it's remarkable at times how far off you are in the models. But at the same time, what we need to strive to do is identify the risks, and certainly climate change is a major risk, and that has different elements of risk there, and then try to figure out how to start covering those risks through mitigating it. And certainly looking at the impacts, I think, I read an interesting article recently on the Titanic and saying that's sort of a metaphor for a lot of us in society since, within the Titanic itself, obviously the impacts were greatest for people in lower decks, and so, again, I think in terms of looking at the impacts of climate change on our society, the impacts are going to be quite different in terms of where they're going to occur, and so trying to come up with the right policy mix to not only deal with the risk, but to deal with the equity impacts, which are going to be significant there. That's going to be one of the challenges we have to do. But, again, I think we have to really look at risk and we have to think about what's the spectrum, and how do we do policies that can mitigate across the significant risks that we have. So again, thanks.

COMMISSIONER PETERMAN: And rates were mentioned a couple times, and so we're having a workshop on retail rate impacts and costs of renewables on May 22nd, we've got a number of workshops coming up this summer that touch upon a lot of the issues that were raised here, so I encourage you to call in, listen, or participate as you can. Questions?

MS. KOROSEC: No questions. Just wanted to give one final opportunity just for public comment in case there's anybody here who would like to say anything. All right.

COMMISSIONER PETERMAN: Any public comments? Any panelists who want to present themselves as a member of the public, you have three more minutes? No one has figured that game out yet? Well, let me take a moment, then, to say thank you very much to the staff who have worked on this workshop, particularly the IEPR staff, it's fabulous as usual, and the staff within PIER, and a special thank you to Guido, who has led the Energy Commission's work on climate change and the effects on the Energy sector and climate change adaptation for a number of years, and we greatly appreciate his effort and continued effort of the staff in the R&D Division. And I particularly look forward to hearing again from you all about what you could use from the researchers because I think we can serve as a conduit for some of that exchange, and I'm particularly interested in the developers' perspective because you are the ones who are taking that immediate risk on now, and I appreciate that. And if there's information that can be valuable to you in terms of your decisions, as well with our objectives as a state, that would be good to know. So with that, we'll adjourn. And we're done on time. Excellent, everyone.

(Adjourned at 4:57 p.m.)