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CALIFORNIA ENERGY COMMISSION
IEPR LEAD COMMISSIONER WORKSHOP

In the Matter of:	) Docket No. 18-IEPR-05
	) LEAD COMMISSIONER RESEARCH WORKSHOP
2018 Integrated Energy Policy Report Update (2018 IEPR Update)	) Re: Climate Adaptation and Resiliency

IEPR LEAD COMMISSIONER RESEARCH WORKSHOP
NEW RESEARCH ILLUMINATING ENERGY IMPACTS OF CLIMATE CHANGE IN CALIFORNIA

CALIFORNIA ENERGY COMMISSION

THE WARREN-ALQUIST STATE ENERGY BUILDING

ART ROSENFELD HEARING ROOM - FIRST FLOOR

1516 NINTH STREET

SACRAMENTO, CALIFORNIA 95814

THURSDAY, AUGUST 30, 2018

10:00 A.M.

Reported By:
Susan Palmer

APPEARANCES

COMMISSIONERS & ADVISERS:

Robert B. Weisenmiller, Chair of the California Energy Commission and Lead Commissioner for Climate Change and Research

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Fran Inman, Chair, California Transportation Commission

Keali'i Bright, Deputy Secretary for Climate and Energy California Natural Resources Agency

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Laurie ten Hope

Susan Wilhelm

RoseMary Avalos

PRESENTERS:

Julie Kalansky, Scripps Institution of Oceanography

Patrick Barnard, United States Geological Survey

Juliette Finzi Hart, United States Geological Survey (Via WebEx)

Maximilian Auffhammer, University of California, Berkeley

Benjamin Brooks, United States Geological Survey

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P R O C E E D I N G S

AUGUST 30, 2018 10:00 a.m.

MS. GUTIERREZ: Good morning. My name is Aleecia Gutierrez. I'm one of the managers in the Research Division here at the Energy Commission, and I'm just going to go over some quick housekeeping items for today.

So restrooms are out the door, into the atrium and to your left. If there's an emergency and we need to evacuate the building, we're going to head out the emergency exit and kitty-corner to Roosevelt Park across the street.

Today's workshop is being broadcast through our WebEx conferencing system, and parties should be aware that you're being recorded. We also will have a written transcript of the workshop.

Materials for this meeting are available on the website, and hard copies are on the table in the entrance to this hearing room.

The notice for this workshop says that written comments on today's workshop are due September 6. We are extending the due date for comments to September 20th.

With that, I will turn it over to Laurie ten Hope, our Deputy Director for Research.

MS. TEN HOPE: Good morning. As Aleecia said, I'm Laurie ten Hope, Deputy Director here at the Energy

Commission, and before we get into the meat of the workshop, I'm just going to provide a little bit of context.

So today we're going to be focused on illuminating the energy impacts of climate change, and this builds on an important week where we released California's Fourth Climate Assessment on Monday. It was released as part of the adaptation forum, and it's really been a culmination of several years of research. It includes 44 technical reports and 13 summary reports.

Each of those technical reports provides insights into the changing climate in California and what the implications are for various systems. Today we'll focus on energy, but the assessment itself is much broader, looking across the various sectors in California.

One of the things that was particularly, I think, helpful in the Fourth Assessment, and really shows the evolution from the first to the fourth, is that now we're really talking about solutions and adaptation, so, in the First Assessment, really understanding, you know, "Is the climate changing? Is it changing in California? Is it changing in ways that we can measure?"

This workshop, this assessment, is bringing some of the scientific learnings down to the local level, where it becomes much more actionable, and I think it was really important to have it launched as part of the Adaptation Forum.

So, you know, the scientific findings were released on Monday, and at the workshop on Tuesday and Wednesday, practitioners at the local level are talking with researchers and sharing best practices about adaptation, and also what needs to be done going forward.

I do just want to add the context before we -- a little more context about those various reports. You know, the technical reports are very illuminating, particularly for the research community, but then the nine regional reports take those findings and provide insights for various regions across California, and then there are three topical reports that focus on climate justice, tribal communities, and ocean communities, and really try to synthesize some issues that really wouldn't be captured in the nine regional reports.

You've probably followed the news and seen some of the headlines from the assessment, and they're sobering, and kind of give us pause to think about what we need to do differently going forward, but some of the findings that I wanted to share, if you haven't been reading the headlines.

The average wildfire area burned is anticipated to increase 77 percent by the end of the century if we continue business as usual. We're already experiencing, you know, things that seem really calamitous and it’s hard to imagine it being worse.

Also by end of century, if no adaptation measures are taken, two-thirds of Southern California beaches could completely erode. By midcentury, we could experience a tenfold increase in extreme health events, and what we'll hear quite a bit about today are the anticipation of more frequent extreme weather, with swings between heavy rain and drought. Sounds kind of familiar for the last few years here in California.

Last of the key findings were, we're already experiencing some subsidence, particularly in the delta area, and that, combined with a hundred-year flood, could result in levee failure and a different, you know, catastrophic event for California.

So, although these are sobering, I think what's uplifting is the conversation that we're now having with practitioners about "What does that mean, and how do we prepare?" What we're going to hear -- what we're going to focus on today are specific findings that are relevant to the energy sector.

The one finding that we really won't be focusing on today is wildfires, because we had a workshop on August 2nd that focused exclusively on wildfires. So, if you don't hear about it today, it's not because it's not important. You're welcome to check the record and the PowerPoints from that workshop.

In this workshop, we're going to hear from various scientists about their research on weather-related extreme events, including long-term climate projections, impacts of sea level rise and the impact on interconnected lifelines.

The second panel will highlight climate change impacts on energy demand, levee subsidence, and infrastructure vulnerability, and, finally, the impacts on our transportation fuel sector.

The scientists will be joined by practitioners from utilities and agencies, and will begin, you know, a dialogue on "What are some of the adaptation strategies?" and provide their reflections on the best plan forward, given the new findings.

I just want to conclude with a quote from Governor Brown this week, and he said, "In California, facts and science still matter," and that's what we're going to talk about today. And with that, I'd like to turn it over to the leadership on our dais for opening comments.

CHAIRMAN WEISENMILLER: Thank you, Laurie. That was a great summary. So I'll keep my comments very brief.

I think the, again, major takeaway is all of us know that our energy system is changing our climate, and part of what we're looking at today is how the changing climate is impacting our energy system, and I think, again, one of the highlights of the study is two things.

One is that we have gone from saying this is, on average, what's going to happen in California to a regional focus with nine areas, and, obviously, we have such a large, diverse state it's quite different in terms of what's happening, say, in San Francisco versus, you know, the desert areas or the northern coastal, northern wooded forested areas. So that's quite different.

I think the other thing is, is what Laurie indicated. You look at the national assessments; they only look at impact. That's what the 1990 legislation said, these studies, and, indeed, these take it to the next step on how you can mitigate those impacts and how you can do adaptation. So, again, you know, while the news generally is very sobering, it's more of a call for action at this point in terms of the need for adaptation now.

COMMISSIONER HOCHSCHILD: I concur with the Chair, and I just mentioned to him that sometimes it starts to feel a little bit biblical, some of the things that are happening now in our state, with the fires and the scale of things, but I do want to thank staff and all the stakeholders for being here, and look forward to the discussion today.

MS. GUBMAN: Thank you to the Energy Commission for having me here on behalf of CPUC Commission Liane Randolph. She's sorry she couldn't make it here today, and ask me to share a few words at the start on her behalf.

It's clear that climate change is already affecting Californians. As Laurie said, the projections tell us the negative impacts on utilities and their customers will only increase, and we at the Public Utilities Commission take this threat seriously, and are engaged in a number of activities to address climate adaptation.

Now, for some time, Commissioner Randolph and Chair Weisenmiller have jointly chaired an interagency working group on climate adaptation in the energy sector, and in our quarterly meetings, which include the Governor's Office of Planning and Research, the Governor's Office of Emergency Services, and the California Natural Resources Agency, we exchange information about each agency's climate adaptation initiatives, and coordinate to ensure that we are leveraging and amplifying one another's work.

We're also improving our communications about climate adaptation at the Commission by increasing outreach to disadvantaged communities and consulting with our newly formed Disadvantaged Communities Advisory Committee. We're engaging local governments via regional liaisons, and expanding into social media. Additionally, we recently initiated a rulemaking to directly consider strategies and guidance for utility climate change adaptation.

The proceeding will address a number of issues, including how to define climate adaptation for regulated utilities, climate-related data and tools necessary for utility planning and operations, a framework for addressing climate adaptation in Commission activities, and guidance to the utilities on how to incorporate climate adaptation into their planning and operations.

There is much to be done, and, of course, all of our work on adaptation is dependent on having great climate science and other research to ground our decision making. So I'm very excited to learn more today about all the latest research on energy and paths of climate change, and I also encourage all of you to please get involved in our climate adaptation at the CPUC. Thanks.

MS. INMAN: Good morning. Delighted to be here. Fran Inman, Chair of the California Transportation Commission.

Our mission is to ensure a safe, reliable, sustainable, world-class, multi-modal transportation system for the people of our state and the goods movement of our state. So, clearly, we are very cognizant of the impact of climate change and emission reduction, greenhouse gas reduction, and the work that we all need to do together. So, clearly, the fires the mudslides, we're not the first responders, but we're right behind them in terms of making sure that we have transportation, we can evacuate.

Resiliency is very, very important to us, to make sure, when we have folks in need, that we can help them move. We have one of our Caltrans district directors that I call our version of an ER doc, because it seems he's always putting a bridge or coast highway back together as fast as he can to provide access for our communities.

So, delighted to be here, love to listen and learn with you. I think what I'm particularly interested in is the study. Number one, hooray, it's a building block on the work that's been done before -- we're not starting over -- and, I think, the regional really drilling down, because folks’ kind of get it when you talk in a big picture, but "What about me?"

When we can take it home to the specific regions and say, "This is what the models are showing us," we pride ourselves and our Commission in moving around the state for our hearings and our townhall meetings, and it's very clear to us that we're a vastly different state, we're a huge state, and no one size fits all, and I think the fact that we now have these tools that can really personalize, so to speak, what we're all learning together will be fantastic.

I think, for me, really a sense of urgency. It takes us a while to get our infrastructure in place, and things don't happen as quickly as we would like sometimes, but I think, for all of us, especially when I look at the comments and the research about infrastructure that may be at risk, and as we try to migrate our power sources, and making sure that we will have the ability to thrive, it is so important. So, delighted to be here, and look forward to continuing the dialogue.

MR. BRIGHT: Yes. Thank you and good morning. My name is Keali'i Bright. I'm the Deputy Secretary for Climate and Energy at the Natural Resources Agency.

Really I just wanted to open by thanking the staff, you know, the small but scrappy staff of the Energy Commission, DWR, the CPUC, Natural Resources Agency, everyone else who actually, you know, miraculously pulled this Fourth Assessment together. As you can see from the numerous volumes of different studies, and the amazing websites and web materials that we can now move forward to use, those staff did a tremendous job of organizing all of those different pieces into a really cohesive body of work.

I also wanted to kind of go to one of the titles of one of our panelists. I think it really captures where we are now, and, you know, the adaptation blind spot is one of the presentations, and I think we're in the fortunate place now where we've really set the baseline for understanding the impacts of climate change.

We have years of experience under our belt of working with tools and information to deploy actual solutions for these impacts, and now, as we go deeper into working with the technicians and the people on the ground, and trying to integrate this information into the daily jobs of those who provide these services, we are, fortunately, in the place of exposing where these blind spots are, and, you know, I feel fairly confident, you know, looking at our success in the past that, as we identify these blind spots, we have the mechanisms now and the tools now in place to learn from each other and come up with tangible solutions.

So, from there, I just really look forward to the conversation, and thank you for the opportunity.

MS. WILHELM: Great. So, before we jump into the first panel, I'd just like to say, if anyone would like to make a public comment, please pick up one of these blue cards from the table in the entry, and you can pass it to RoseMary -- please remind me of your name -- she's sitting in the front there. Thank you, and with that, I'll pass it to David Stoms, who's moderating part one.

MR. STOMS: Thank you, Susan.

My name is David Stoms, with the Research

Division here at the Energy Commission, and I'll be moderating this first session this morning. Laurie already kind of gave an overview, so I won't do that again, but, just logistically, what we have is three speakers that were involved in three of those dozens of studies that Laurie mentioned for the Fourth Assessment, and then we have a panel of someone from an IOU, a POU, and Department of Water Resources, who will react to and respond to the presentations and how that might affect their work.

So our first speaker will be Julie Kalansky from Scripps Institution of Oceanography at UC San Diego, and her research focuses on applying regional climate science to decision making and planning.

MS. KALANSKY: Thanks, David, and thanks for having me here today. I will be talking about some of the results that have underpinned what started the meeting, and some of the impact that we talked about.

So this was part of the Fourth Assessment, and the scenarios that were developed, and the presentation is broken up into two main parts. One is talking about the long-term trends, and part of that will be comparing the two different greenhouse gas scenarios that were used, so the importance of looking at the impact of mitigation and the reduction of greenhouse gases.

Then the second part will be looking at the extremes, so the extremes that we're presenting -- or the extremes that we're expecting, and then, also, too, I won't talk about the adaptations, but these are really some of -- the extremes are really thinking about the adaptations that are needed to mitigate the impacts of these extremes.

So, before we get started, just to make sure we're all on the same page, and you know what I'm talking about when I talk about greenhouse gas scenarios, I'll be talking about two main greenhouse gas scenarios. Let's see if (indiscernible). No. Okay.

The first one is RCP 8.5, which is the "business as usual," minimal reduction or no reduction in greenhouse gases. The second one is RCP 4.5, which is the yellow line, which is a mitigated greenhouse gas scenario, and then the gray one there is one example of the greenhouse gas scenarios that align with the Paris Accords, and the black dots are the actual greenhouse gas emission scenarios, or what we've been doing.

So this is just looking at maximum yearly temperature for California, and, depending on the scenarios, the RCP 4.5, if you look at it, it's about a five-degree temperature increase, where 8.5 is between a nine- and 10-degree increase, and so this just illustrates the difference between the impacts of temperature -- or the greenhouse gas scenarios have on temperature.

The second figure here is showing results from one of the technical reports that were part of the Fourth Assessment, and it looks at how cumulative CO2 impacts temperature, and this is meaningful because this illustrates that the path we take in terms of reducing greenhouse gases is not quite as important as that total amount of CO2 that's in the atmosphere.

So what you're looking at is -- the yellow-colored dots are the cumulative CO2 today. The red dots are the cumulative CO2 under RC 8.5, that non-mitigated emission, and the blue dots are under RCP 4.5, which is the mitigated, and then the Paris Accord is somewhere -- you can see where it's pointing, so about at that 600, 750 gigatons of carbon, and temperature varies somewhat linearly with it.

So this is one thing that I actually think is somewhat hopeful in all of this, is that, if we do and how we mitigate globally, the impacts of temperature are reduced, and the other thing I will add to this is, this is just showing temperature, but other variables that are linked to temperature, like snowpack and soil moisture, you see a similar response.

Now we're going to turn to precipitation, so this is looking at percent changes in precipitation at the end of the century. The figure on the right is RCP 4.5, and the figure on the left is RCP 8.5, and what you can see is, there's not actually a very strong trend throughout California. It's about negative five to positive five percent, and that's largely because precipitation is so highly variable, but what does show up is the differences between Northern California and Southern California, so Northern California is somewhat wetter, whereas Southern California is somewhat drier.

The other thing in long-term trends is the changes in the seasonality of precipitation, and so what this figure here is showing is, on the bottom, it's the months, so starting in January, going through to December, and then the Y axis going up and down is the amount of precipitation per month. The color of the lines represent time periods throughout the century, so the first one, a blue dashed line, is currently through 2040 or 2039. The midcentury is the orange, and the red is end of century.

What's really noted is the increase in precipitation during our wet season, so December, in particular, January, and February, but then what you see throughout the shoulder seasons, especially, so spring, March, April, May, and autumn, typically October and November, is a decrease in precipitation. And so what this highlights is that our annual summer drought that is part of our climate is just going to become more severe, and longer in duration. Okay.

So now we're going to turn to long-term trends in sea level rise, and there's a couple different things to look at on this slide, and so what you're seeing is sea level rise at San Francisco. There's centimeters and then feet, depending on what you're more familiar with or what you think in, and then differences between the light blue and the dark blue is the RCP 4.5, is the blue, light blue, and the dark blue is the "business as usual" 8.5.

There's a couple of things to note, is, one, once we get to the latter part of the century, there's quite a bit of uncertainty, so the differences between them, but, in the near century, they're relatively similar, and so part of this is, a sea level rise is a slow responder. It takes a lot of inertia and a lot of energy in terms of melting ice sheets and the contribution to sea level rise. The one thing to note on this figure, too, is the difference between the light blue and the dark blue is the difference in the greenhouse gas emission scenarios. Okay.

So, this next slide, we're going to look at two different projections that were used. So the blue is what was part of the Fourth Assessment that took into account new science coming out about Antarctica and the contribution of Antarctica to sea level rise.

The red here is what the OPC guidance is, and that does not take into account the new science around Antarctica, because it is very new, and so there is some concern that it needs to be vetted and tested more in the scientific community, and so the difference here is about two feet between the two, depending on what Antarctica does. If we go back a slide, the difference between the greenhouse gases scenarios at the end of the century is about two feet. So there's a lot of unknowns, but there's still -- one of the things is, sea level rise will increase.

So this is just one culminating figure that shows a whole bunch of different scenarios, and you can see that it gets relatively complex, but one important thing, I think, to remember about all of this, but particularly for sea level rise, because it is such a slow responder, it does not stop in 2100. All right.

Sea level rise will continue to increase, and what will happen by, you know, the end of 2200 -- it's even hard to say, to think out that far, but it keeps going up. And so, you know, the most extreme is 25 feet, and, hopefully, we won't get there, but, you know, up to 10 feet. So it keeps going, and so these are things that, granted, it's very far out, but keep in the back of the mind that, just because the figures stop at 2100, it doesn't stop then.

Okay. So now I'm going to turn from these long-term trends to looking at some of the extremes that come with them. So, going back to temperature, this is looking at the number of days per year above a certain threshold, so this is really getting at the heatwave question, so just looking at Sacramento for, say, 105-degree days, because there were a couple days of that around that threshold this summer, to think about how it may change, and so, in the historical period, you know, there were a couple of days, four or five days, but, by the end of the century, under RCP 4.5, you can get up to 50 days. Again, this is on the more extreme side, but you can see how much more it will increase.

Los Angeles, you see an increase in temperature a well, but it doesn't have quite the highest temperatures, and that is in large part because of the mitigating impacts of the marine layer clouds, and they just provide a cooling blanket for some of the coastal communities.

This is looking at the intensity of heatwaves. So this is under the low emission scenario, the RCP 4.5, and this is a 10-model average, and so what you're seeing is the historical time period, and then at the end of the century, and so this is the change in temperature of the hottest day per year, and then the difference is shown at the bottom.

So that hottest day per year, throughout most of the state, will increase by about five degrees, on average, or, you know, about seven degrees in some of the more inland locations, so, if you think about those really, really hot days that are already really hot, and thinking about getting them hotter, and what are some of the adaptations we need to do to help reduce health risks with those?

Okay. And this was mentioned in the beginning, so, for looking at extremes for precipitation, this figure is just showing for San Diego, but it's the impact of droughts, and the frequency and intensity of droughts. And so what the top lines are showing is the number, the percentage of years that are below the 20th percentile, so the number of years that are less than the 20th percent in terms of precipitation, so the number of dry years.

What you see is, towards the end of the century, there are more years that are dry, and then, if you do the same thing, but looking at the five-percent driest years, so the really dry years, those also increase.

So this is what we talked about in terms of the climate whiplash, is that you're going to get more and more dry years, and so, particularly in Southern California, when you get more and more dry years, back and back together, you get longer droughts and more intense droughts, and so what the bottom figure is showing is the driest five-year period for the San Diego region, and you see a lot of ups and downs because precipitation is inherently very variable, but, over the long term, that driest five-year period is going to get even drier.

Another thing to think about in terms of drought is, we know precipitation is highly variable, and there's a lot of potential outcomes in terms of precipitation, but one thing with temperatures increasing, that affects the soil moisture, so how dry the landscape is, what this figure here is showing. So all the yellow areas are areas where soil moisture is going to decrease, and this is really part of the temperature impacts on drought. So temperature does exacerbate the droughts.

Now going to the flipside for extreme precipitation, this is looking at the really extreme events and the potential for flooding, and so what you're seeing here is the wettest day per year and how this will change.

So, on the right here, this is the historical time period of what the most precipitation per day over that time period is, on average, and then the middle is, you see, about a five -- or, sorry, about three- to four-percent increase throughout parts of the state, and then, on the high emissions, you see even about a four to five in parts of the state. So those extreme events, those big storms, are going to become that much more extreme.

A lot of these extreme events are attributed to atmospheric rivers, so this is a figure showing what an atmospheric river is. These are elongated moisture plumes that come off the Pacific, and when they hit our coastal mountains or the Sierra Nevada, they uplift and produce a lot of precipitation.

So some new precipitation research that is going on at Scripps, that actually wasn't part of the Fourth Assessment, but shows that most of these extreme events are through changes in atmospheric rivers, and so this is looking at the 99th percentile that are at the end, so the very most extreme events. Primarily, the changes are caused by atmospheric rivers. So understanding these phenomena are really important to better predicting and better forecasting some of the future floods.

Okay. So now turning to the extremes for sea level rise, as part of the Fourth Assessment, we took the sea level rise scenarios that were shown in that long-term trend and made hourly data for it, to look at extreme events and sea level rise, and so this is showing just one model, and it's the RCP 4.5, so the mitigated one, and a 50th percentile, so middle-of-the-road scenario, basically, is what this is saying.

What this is showing is just one-year periods, so the first year is 2049. The second one is 2074, and the last one is end of the century, and each of those red dots indicate a time that this model is showing above the historical maximum sea level for La Jolla.

So what you see is by -- you know, until 2050, it's still really dominated by extreme events, so by tides, king tides, storm surges, and such events. By 2070 and 2099, the increase in the sea level rise really impacts the amounts of extreme events we get, and the potential flooding. And so it comes relatively rapidly to the second part of the century, so thinking about how to adapt to it now is really important.

This next figure takes a lot of that information from eight different models and many different scenarios and puts it all onto one figure, and so it has a lot of information there in it. What the difference is between the colors are the pink shades are the RCP 8.5, and the blue shades are RCP 4.5, and the lighter ones are the 50th percentile, so about average, and the darker shades are the more extreme 95th percentile, and this is how many hours or what fraction of the year these hourly projections are projected to exceed the historical maximum.

So, for example, looking at -- let's just take midrange, so 4.5 at the 95th percentile, the dark blue -- at the end of the century, about half the year -- a little less than half the year, about 40 percent of the year -- sea level extremes will be exceeding the historical maximum that we've experienced in the San Diego area.

The inset is showing the same thing, but, if you look at the figure between 2040 and 2050, you can't see anything, and so what you're just seeing in that inset is that time period, with a slightly different scale so you can see the extremes.

One thing to point out on this is the -- you know, in 2020, you see some peaks there, and that's partially because of how the tidal cycles coincide. That's the next time period for San Diego that we're expected to have quite high tides.

So this is just a summary, and thinking about some of the scenarios that underpin a lot of these impacts, and thinking about how to adapt. So, obviously, temperature will increase, but this increase is really dependent upon the cumulative greenhouse gas, which is important in thinking about mitigation and how mitigation impacts the scenarios that we're adapting to.

Then precipitation, in terms of we will get wetter winters and drier shoulder seasons, so spring and autumn. Sea level will rise, especially quite rapidly after the middle of the century, though there is quite a bit of uncertainty on how much it will rise, and then the extremes, and so these are the ones that have some of the greatest impacts in terms of affecting the energy system and society as a whole, so the more frequent and intense heatwaves, the more frequent and intense drought.

These larger extreme precipitation events, I didn't really talk about this, but there's less snow, too, so the impacts it has on flooding, and then extreme sea level rise events, so these really big storms that coincide with high tides and ENSO events will really rapidly increase in the second half of the century as it coincides with sea level rise.

I don't know if we have time for questions, but I'm happy to answer any questions, either now or during the break, so thank you.

CHAIRMAN WEISENMILLER: Why don't we have all the presentations, then ask questions.

MR. STOMS: Thank you, Julie.

Okay. Our next speaker is Doctor Patrick Barnard from USGS. He's a coastal geologist with the Pacific Coastal and Marine Science Center in Santa Cruz since 2003, and he's the research director for the Coastal Climate Impacts Program.

DR. BARNARD: Thank you very much. I'm going to talk about the impacts of sea level rise and storm events on roads and transportation, and this was done through a model we call CoSMoS, the Coastal Storm Modeling System that we've been developing in the USGS for over a decade now, and really developed the most advanced version for the Fourth Assessment, and through funding over the years, also, from various branches of CNRA, and in close collaboration with Point Blue.

One of the points I want to make up front is that the kind of impacts we're going to show here, and that the model shows throughout the state, are in areas that we already know we have issues, where we see issues maybe every five years, every 10 years.

What's going to happen in the future is, a lot of these same areas, we're going to see these impacts much more frequently, maybe every year, maybe multiple times a year, and, obviously, we're going to see impacts in places we've never seen them before, but a lot of these areas aren't going to be surprises to what we've already seen over the years.

So, going back to some of the major events in California coastal history, the El Ninos of '82-83, '97-98, 2015-16, we've seen these areas being flooded before, like down here in Newport, and then, more recently, we know of areas from king tides that are flooded multiple times per year already, areas like -- in Sunset Beach and Seal Beach, we see flooding on every single springtide, several times per month, and what's going to happen in these areas, maybe this is going to be happening every single day, and even areas we have sunny-day flooding on occasion during some unusual wave events, like we had in Newport Beach several years ago. We have a large southern swell. There's not an obvious storm, but we have overtopping and we have significant flooding.

So these are very low-lying vulnerable areas we already know about throughout the state. We've built up our coastal infrastructure within estuaries in many, many cases, San Francisco Bay, throughout San Diego, Orange County, Los Angeles in particular, and so a lot of these areas really aren't going to be surprises to us, but, as we move forward, as sea level rises and the rates accelerate, we're going to see more frequent, higher-magnitude events in lots of these areas, and new areas as well.

We've actually been shielded somewhat from global sea level rise over the last 30 years. This is a satellite map showing sea level rise rates across the Pacific, and you see we've had sea level rise suppression here in the cooler colors over the last several decades. This is from satellite altimetry.

In recent years, we've seen a significant shift in the sea level rise signal across the Pacific, and we have resumed to rates that approximate the global, or even above the global average, along the West Coast. So there's other dynamics that are going on here, these regional oscillations of sea level, and we've actually been protected from that for some years, and now we're seeing significant acceleration along the West Coast.

Now, I'll try and frame the problem in the big picture, here. By midcentury, over a billion people will live in the coastal zone globally, and in California, about 27,000,000 people currently live in coastal counties. The upshot of this is, through all of our modeling work, this is really the take-home message here. I'll get it out of the way right now.

If you look at an extreme sea level rise scenario of about two meters -- and, actually, the state guidance suggests we should look at three meters as the extreme -- plus a significant storm event, an extreme storm event, over half a million people in California would be exposed to flooding by the end of the century, and about $150,000,000,000 in property at risk, and this also includes about half a million employees, thousands of miles of roads, and dozens of schools, fire, police stations, medical facilities, et cetera.

If you take inflation into account, this number grows to about $1,000,000,000,000 by the end of the century, and no matter what inflation numbers you use, really, the key metric here is, what percentage of GDP would this be? And it's on the order of about five or six percent for California. It's just a very, very big number of property exposed, and it really highlights the concentration of wealth and public infrastructure along the California coast.

Another thing I really want to emphasize is that we're going to talk quite a bit about just static flooding. It's really these extreme storms that are super important. I mean, look at socioeconomic exposure, especially in the lower sea level rise scenario, as the kind of scenarios we can expect over the next few decades. These kinds of exposures can increase by a factor of about seven when you consider storms. So storms are very important.

This is the approach we've taken with CoSMoS to look at coastal vulnerability. There's a first-order approach, where you can look at just sea level rise, and just tides, and do bathtub modeling. This really highlights your everyday impact of coastal flooding. That's a good place to start. It's basically a screening-level tool to understand what your daily impacts will be, but this is going to underpredict flooding hazards, because you're not considering storms, and this is a case in point here from Foster City.

With just 25 centimeters of sea level rise, you see a region which is highly vulnerable to flooding, shown in green here, but not connected to the bay. So this is not actually flooded under a no-storm scenario, but once you add an extreme storm event, this is the picture for Foster City. This is that tipping point where you go from no storm to an extreme storm, and see the actual impacts for a particular community, and this varies considerably throughout the state.

These thresholds are different for any given community, and the idea that we want to develop here is to be able to drill down to this local scale through our modeling and make these kinds of projections for everywhere across the region, across the state.

So that's what we've done with CoSMoS, is add all the dynamic impacts that you can experience during a storm event, so not just the tides and the sea level rise, sort of the background that's going on, but also the seasonal effects, like, during El Nino, water levels rise about a foot. Water is warmer; it expands. Storm surge.

So wind and pressure drives up the water levels. Very locally, river discharge can play a factor, but waves are the dominant driver of coastal water levels along the California coast, so we wanted to include all these different elements, a full range of sea level rise and storm scenarios, and deliver it at the local scale for planning purposes.

This was how CoSMoS was sort of thought and framed and developed, as a physics-based numerical modeling system for looking at coastal hazards due to climate change, and using a full range of possible sea level rise scenarios and storm scenarios, from your sort of extreme events that could happen this winter to one that could happen at the end of the century and beyond, cover all the different scenarios that were rolled out with the Fourth Assessment, and do this using the most sophisticated modeling tools available, and do it in close collaboration with all of our federal, state, and local partners to make sure that what we're creating is something people are actually going to use on the ground.

So, generally, how the model works is we go from the global scale, we take the kind of global climate models that Julie's group uses, and their downscaling products from the Fourth Assessment, to develop global wave models, and then we translate that to the more regional scale, like the Southern California Bight. We bring in locally generated waves, locally generated surge, the tides, et cetera, and then continue scaling to the local scale where, ultimately, we're making predictions every two meters of what's going to get flooded during an event, be it no storm versus an extreme storm, no sea level rise versus extreme sea level rise, and also include long-term coastal change along the way.

All this information, these tens and tens of gigabytes of data, is then moved over to Our Coast, Our Future, a web tool where all the information is served up, interactive, very easy to use, and then further translated into the HERA web tool, which I'll talk about, which translates this information into socioeconomic impacts, how many people in the hazard zone, how many employees, how many roads, et cetera, et cetera.

So we bring in all these different physical processes for all these different scenarios, 10 different sea level rise scenarios ranging all the way up to five meters, the most extreme one that we model, and then storm conditions from your average daily wave conditions to your 100-year event, and this ends up with 40 different scenarios, all served up in this interactive viewer on Our Coast, Our Future.

Anyone can go in there, no signup required. You can interact with all the data. It's a Google Earth interface. You can pick what sea level rise scenario you want, what storm scenario you want. There's a lot of different shapefiles for looking at different types of infrastructure.

What most people do is, they find their area of interest, for example, here the San Diego airport, and start clicking through different scenarios to see where those tipping points are, where their infrastructure begins to be affected, and use that to develop their coastal plans.

Similarly, up in the Bay Area, for places like really critical transportation corridors, like the Bay Bridge approach, you go into this tool and you start clicking through scenarios to understand. This is when you start to cross these thresholds. In this, we're looking at just 25 centimeters of sea level rise.

With uncertainty and extreme storm, we start to see the potential for the Bay Bridge approach being flooded on an extreme event, but sometimes really what's a critical threshold is what happens annually and sub-annually, and so I'm just going to click through these different scenarios for this particular region, looking at just the annual storm, and you start to see, as you get to one meter of sea level rise, one and a half meters of sea level rise, that's when this area really starts to become affected on an annual basis, and for the most extreme scenario, the so-called "Hansen scenario" of five meters annually, we're going to have to do some serious reengineering of this area.

Okay. In concert with this, we also do shoreline change, cliff retreats, and, in some cases, cliff retreat is going to compromise some of our really critical transportation corridors, not just, you know, local city streets, but also like the 101 corridor in Gaviota, for example. We're going to see cliff retreat rates increase by about double by the end of the century, as the base of these cliffs are attacked more and more with higher sea level rise.

All that information is in there as well, but then the first question is, what does it really mean? you know, if we see a big flat map that's flooded, what does it really mean? So then we move this into our socioeconomic tool to look at how many people are involved, how many employees, roads, railways, land cover, et cetera, through all these different scenarios, and so now, for the Bay Area -- this is a blowup here of the Bay Area before the whole state.

We've done this for about 96 percent of the urbanized coast of California now, so all of Southern California, all the Bay Area, about 25 to 27,000,000 coastal residents. This flat map now means something a little more to policymakers, because we can say, "Okay. This is the area that's flooded on a 2D map. What does that really mean? Well, it means, you know, over half a million people and $150,000,000,000 in property at risk."

And then it has a lot more pull when you talk to policymakers and the governor's office and the like.

So, focusing on the transportation highlights, all the major airports in the Bay Area, and also San Diego, are susceptible to major flooding by midcentury, and, actually, San Francisco SFO, with just 25 centimeters of sea level rise, is already vulnerable to even the annual storm, so it's among the most vulnerable airports in the nation.

Major roadways like Highway 1 and stretches of the 101 corridor are particularly vulnerable, especially in San Diego, Orange, and L.A. counties, all across the Bay Area. We know from the king tide work that there's numerous portions of the Bay Area that see regular flooding on an annual basis.

For just a meter of sea level rise, which is right in the median of the Fourth Assessment projections, about a thousand miles of roadways could be permanently flooded, and that is everyday tidal flooding, not storms at all, and if you add storms to this one-meter sea level rise scenario, the amount of miles of roadway would increase by about 70 percent. So storms matter.

If you look at an extreme event today, the amount of -- compared to end of century, for example, there's an increase of about 10 times the amount of roadway affected by an extreme storm today, versus the end of the century, so significant increase in the frequency and magnitude of flooding. Caltrans is currently using this work to conduct their statewide climate vulnerability assessment.

What's not included here is another topic we've just started to dive into, is groundwater impacts, and that is, typically, the water table is very close to the surface along the coast, and so, as sea level rises, that water table rises as well, and so we're going to see some cases, with certain coastal geomorphic settings, that, as the water table rises, it's going to intercept the land surface, and effectively turn some of these areas into swamps.

The other factor is saltwater intrusion. As sea level rises, the saltwater wedge moves further inland, and this can compromise agriculture and freshwater wells, but we're addressing this at USGS right now, and what we're seeing is that, in some areas, is groundwater inundation is going to happen much sooner than overland flooding from waves and storm and tides, et cetera, and, as you expect, these low-lying areas are most vulnerable, especially these reclaimed estuaries.

There's many, many communities in California that are effectively reclaimed estuaries, and this is just an example from Huntington Beach here, in blue showing areas that could be affected by three feet of sea level rise by overland flooding, and green areas where the water table is likely to intercept the surface. So, in some of the communities, it's going to be a much bigger factor than overland flooding itself.

We're doing the modeling on this now. We're going to deliver statewide flooding maps. So we'll have both overland flooding with groundwater inundation across the state by the end of 2018.

I'll end there. There's a report citation, and the tools, the HERA tool, the Our Coast, Our Future tool, and in the back here is just some end users we work with across the state, and a bunch of references if you want to follow up, for more information. Thank you very much.

MR. STOMS: Thank you, Patrick.

Our last speaker is going to be WebEx-ing.

MS. WILHELM: Yes. Juliette, are you unmuted?

MS. FINZI HART: I am. Can you hear me?

MS. WILHELM: We can hear you. Thank you so much for joining us after a busy week at the adaptation forum.

MS. FINZI HART: Thank you for accommodating me and letting me join this way. I do hear an echo, so I don't know if you hear me twice or just once.

MS. WILHELM: We hear you one time.

MS. FINZI HART: Okay. Perfect.

MS. WILHELM: Thanks.

MS. FINZI HART: Okay. Well, thank you very much. I'll speak quickly, to try to get us back close to time, and so I'm presenting on behalf of myself and my project partner, Susi Moser, so if you can go to the next slide.

So, just to kind of set the context, and I'll do this pretty quickly, but I just want to define what teleconnections are, because that's not necessarily a term that's very well known to most people, but it comes from the physical sciences, so something like an El Nino, where you have something occurring in one part of the globe that has impacts on other parts of the globe. Those are teleconnections.

So what Susie and I have been looking at over the last few years is the societal analog to that, which we call "societal teleconnections," and so this is looking at the human-created interconnectivity among different systems.

So, in the map on the upper left, you see the trade routes. That's the most common thing that people think about when they think about these connections among humans, you know, market drivers, having factories in one part of the world that get flooded, that then have rebounding implications for the coastal U.S. or other cities in completely different geographic locations.

So what we did for this project, for the Fourth Assessment, which was -- if you recall way back to the RSP, there was this one line that was Group 11, which were projects that were focused on what research is needed in the future, once we get past this Fourth Assessment, and so that's where this project fit into.

So we were sort of trying to look ahead into what needed to be looked at, and so this project fell in there, and we wanted to take what we had been thinking about in terms of societal teleconnections, and then bring it sort of to the local scale with the energy sector, and bring it even more local to thinking about downstream impact, and how these teleconnections from afar would then trickle down through the community through impacting critical lifelines.

We had developed a paper back in 2015 where we tried to provide a framework for how a community could think about everything else that's happening in the world, recognizing that, you know, most communities are still just trying to get a handle on what's going to happen along their beaches, or with their own personal key islands, and so we're now we're telling them, "And now you have to think about what happens in Thailand, and everywhere else in the world."

So we wanted to try to bound that, and we developed this framework that you see in the lower left, where you have location one here, location two, which is there, and how we tried to break this up so that it was manageable was to define three different categories in which you could think about these teleconnections. I think it might be easier if we go to the next slide, so I can actually talk you through it. Thank you.

So, for instance, looking at the energy system, we thought about three different categories. The structure, basically the hardware that connects point A and point B, so, if you're thinking about the energy system, that would be things like the transmission lines or the power generation, and getting that to the end user.

Then the second phase of it is the process, or, if you want to think about it, it would be the software, so what is actually moving substance A between location A and location B. So, bringing it back to the energy system, that would be supply and demand, energy markets.

So it's all sort of the process and the governance components around connecting two different locations, and then, ultimately, the substance that gets moved, and so that would be the data, so thinking about electricity, oil, and natural gas when you're thinking about the energy system.

So, you know, the energy system as a whole is already thinking about this a lot, but what may not be happening is, then, how this can potentially link to considerations in adaptation planning, and it's more complicated than just ensuring that the energy can get from point A to point B, but that, in the whole interconnected system, these different components are speaking to one another.

So this is where we drilled into with our project, where we really wanted to look at, once the energy system is impacted, what happens downstream? You can go to the next slide, please.

So we focused in on -- you know, we started small. We went for L.A. And, technically, we were focused on the city of L.A., but, really, you can't think about this at just the city scale. You have to think about it at the metropolitan region. So we focused on speaking with folks from the city, but moved in county and regional people as appropriate, and we tried to have this intersectoral focus.

So we impacted the electricity system. It was sort of agnostic as to what the impact was, but then the goal was to then see how that impacted the critical lifeline, so telecommunications, water, transportation, emergency response, and public health. Next slide, please.

So the goals when we set out were -- the first was to test this framework that we had created on paper, and actually try it in the real world and see how it worked, and then, as I mentioned before, the goal of this project fell into that category of the future research needs.

So really the bulk of what we were trying to do was understand where the stakeholders were that we were working with, and what they're doing on a daily basis, and where they have future, you know, research needs, and where they're finding some action barriers, and then, if we were successful, we were hoping that this would be useful to other metropolitan regions, and we've already been starting to talk to other areas to sort of test what we've done, to see if it works in their community. Go the next slide, please.

This is the overall approach that we took. You know, the first phase was understanding and refining the interconnections, then looking at the teleconnections, so what was happening outside and coming in, and then going to the cascading impacts, and really the most important part of this is that this work was -- we didn't do a literature review, but everything that I'm going to talk about today came from discussions with our technical advisory group. That was a substantial group from all the different agencies within the city of L.A., and some external advisors.

We also pulled in some folks from USGS on the earthquake side, because they have had a lot of experience at thinking about critical lifeline obstruction, and so we used some of their experience with the HayWired scenario, which was being developed at the same time, and were able to pull that in.

The next slide shows just the beautiful cover that was released on Monday, and we're really excited to be part of the release on Monday, which went really well, and the website is beautiful, so kudos to all those who made it. The next slide, please.

So the key insight, just to give you the big overview, and then I'll dig into these a little bit, are that what we found is that there's not really a unified map of the interconnected lifeline system in L.A., or really anywhere, and when we were talking with people, that's what they wanted to see. They wanted to see it all in one place.

The other thing that we came away from it was that it works. You know, somehow everything is functioning, and it's just kind of -- it's doing it through this emergent property. There's not an over-arching control spot. You know, there's not this czar in L.A. that's kind of overseeing everything, but yet it's working.

But, that said, everything is dependent upon everybody else, and so we wanted to pull out those nodes of interconnection.

Then I definitely want to caveat this, because, when we did this study, we wrapped it up right before the first fire in the fall of 2017. So, at that point, we hadn't really been through anything really significant. We're really eager to get our group back together and talk to them now, and see how they feel about some of the things that they were saying after we've been through the fires and the floods and the mudslides, and everything we've experienced in this past year. So we can go to the next slide.

So our first goal when we thought of this project, we were like, "No problem. We'll just make a map." Well, and there you go. You got the teaser, so next slide. After lots of conversations, this is what we got. So you're not supposed to be able to read it. It's meant to just kind to show you the complexity of over, you know, a year's worth of work, and talking to a limited group of stakeholders of about 15 people, but a key 15 people who really knew the inner workings of the city and the region of Los Angeles. This is what we came up with, and if you'd click one side, one more time, and one more. Sorry, back up.

So, basically, we ended up with 139 nodes, so items that were connected somehow. They were connected in 343 different ways, and the type of modeling that we used here was causal modeling, and I won't get into that, but basically we found 17,000 different ways that all of these different things, these different nodes, interact. So it's complex. If you'd go to the next slide.

Some of the gaps that we found, though -- sorry. This is going to be one of those -- just go and click it, I think, four times. Let's see where we land. And one more, please. We'll just do it this way. That way, I can talk through it.

So some of the gaps that we found were -- the main thing was, the communication among folks really happened in an informal way. You know, there are the people on the books that you're supposed to call, but then there's the people that you know and you trust that you call, and so a lot of the -- when things happen, when things go wrong, or when there's an emergency, people call the people they're supposed to call, but they also call the people that they know will help them get what they need to get done, and that's part of that emergent property of the system, and that's what makes it hum and makes it work, but that's also limited to making sure that the same people are in the same positions over many years, to make sure that those connections stay.

The other parts that came up were, you know, there's the deferred maintenance component of our infrastructure, and so clearly that's going to have impacts on our infrastructure and make it more vulnerable. There's staff capacity issues, and I will note here, too, that a lot of this that I'm saying here runs in parallel to work that we did on AB 2800, the Climate-Safe Infrastructure Working Group, and there, John Andrew, who's on the panel after this, was one of the working group members, and Keali'i, Guido were part of that process, but a lot of what we found in the teleconnections study we also highlight in the forthcoming AB 2800 report.

There's historical legacies in place. There's limited experience in terms of, you know, at least in L.A., really big disasters. So we haven't really been tested, and then there's various degrees of adaptation planning. We can go to the next slide.

We have a whole chapter where we looked at the science that is available for L.A., and so we heard two presentations from Julie and Patrick about the advances that there are in climate extremes, but there's still a lot of research that needs to be done, and one of the two areas where the stakeholders found that they needed more research was on what happens when you have sort of longer-duration events that kind of keep going, a heatwave that lasts for longer than you anticipate, or multiple storms at once, or what we saw last fall and winter, which was the flood following the fire.

Then, you know, maybe lack of concern is maybe not the right term, but there was -- you know, people are aware of it, but dealing with their daily issues is still all-consuming, and so, among different components of government, you have folks that are thinking about it, but then you have the people that are just trying to keep things going as is, and that kind of feels like something that's off into the future. Next slide, please.

There's a lot of different ways out there already to look at this interconnection among systems, and the utilities have this. You have incredible systems in place that are already managing untold amounts of connection. And so the point of this project was never to replicate that. It was to think about how to connect those to other lifelines, their own models that manage everything.

There are big consulting firms that do this kind of work, but, ultimately, you know, that's not necessarily accessible to your average small community, and really what we wanted to try to figure out was how we can help the smaller communities and do this. What we ended up working with was something called the Elephant Builder, and this is a collaborative systems modeling tool that allowed us to look at all the information on line, sort of on the fly, and get user input as we were going along. Next slide, please.

So, turning back to the key study insights, you know, there's variable and overlapping geographies in all of the teleconnections. You know, there's everything from the service area where a critical lifeline is serving. There's supply chains. There's management areas. There's governance across scales. So, when you're thinking about these connections, there's lot of different scales to think about it, and then each critical lifeline has their own teleconnection, and that may or may not impact someone else's teleconnection.

The other side to that is that as, let's say, telecom is impacting something, energy is impacting that same event at the same time, and how those are getting impacted may either hurt each other and be sort of a double whammy, or there's not necessarily that connection among the two lifelines to figure out how to manage an event at the same time, while your own resources are depleted, and then trying to be available to the other for what they need. Go to the next slide, please.

In response to the key research questions, and one of them about does this paper-based framework work, what we found was that it's really good for getting people in the room and thinking about issues, and so, ultimately, this is something that, once you have people in the room, it can be used as a tool, but, when you are really thinking about your teleconnections, and all the different cascading impacts, it's bigger than just this kind of simple framework.

Once you sort of have kind of an area of what you want to focus -- for instance, let's say you want to focus on the connection between telecommunications and energy -- then this helps you tease apart the various components and assess the risks among them. Go to the next slide, please.

So, in terms of the research that's needed, it, you know, more research, of course. The frame is on the extreme events, and it gets to the smaller or the higher-resolution downfield information that then the lifeline managers can actually use. There was a lot of discussion on the legal context, liability issues, and the governance components of this. So, you know, what one agency is regulated to do may impact what another agency is able to do, and so trying to tease all of that out will be important.

The tools that are available need to be at the right scale, and so, in some cases, they are. In some cases, they aren't. If we can go to the next slide. Click one more time, please.

The action opportunities that we identified -- and I want to keep us on time, so I'm actually going to skip to the third bullet there, which is this regional lifeline scenario planning exercise. This is something that we actually heard at the CAF Adaptation Forum earlier this week, that there's kind of this coalescing around this need to think about all of these potential connections at one time, in one place, and seeing how these play out, so how do you think about multiple climate impacts at the same time, and then how those multiple climates then impact multiple sectors, so having transportation, telecommunications, public health all in the same room working through these exercises. And one more slide, please. Yes. If you can click four times, I think. There we go -- one more, please.

So these are the five kind of big barriers that we came across. The way that the system is built currently is that it's hard to build back better after disasters. So we had a lot of discussions with Cal OES, and this again trickled into our discussions with AB 2800, but trying to find ways that we can coordinate all of the planning that happens so that, when the event happens, there's already a system in place, so that you can just move into building back better.

So that might be getting contractors lined up ahead of time or, you know, having permitting prepared ahead of time. In the case when you have an emergency, there's often these post-disaster waivers, and so finding ways to ensure that, when you have these waivers, they don't actually have a negative impact in some other respect.

There's identifying the common sequences of extreme events, and, again, that's what we saw last year, with the fires and then the floods, trying to find -- maybe focusing -- when we do those kind of regional lifeline exercises, maybe it’s focusing on those kind of (indiscernible) events that really take a life of their own.

Then the challenge among identifying the interconnections and the interdependencies among all of the different sectors. The really interesting finding from the Elephant Builder, when we could sort of tease out some questions, was that the number one node and connection point always came back to community wellbeing. So, if none of these are working, or if one of these is not working, and is impacting one of the others, it's community wellbeing that gets impacted. So that was one of the things that emerged entirely on its own. It's something you suspect, but then it was really interesting to see the model kind of spit that out for you.

Unfortunately, through our efforts, we had very little engagement from telecommunications until the very end, and they were invaluable once we got them in the room, and so there definitely needs to be some work on bringing in the telecommunications folks. And last slide.

So, ultimately, you have all these different components that all work together, right? We need to initiate the climate change conversation. We need to, you know, change the information flows throughout the disaster cycle within and across organizations, investing in workforce development and organizational cultures.

All of this kind of all comes into the human factor, and no matter how many models or tools or whatever it is that you have, we can't separate the human factor from all of this. So I think the biggest take-home from any of this is just to keep having these conversations, keep having these workshops, keep getting the scientists and the engineers and the architects and the practitioners in the room together and talking to one another, and learning and preparing.

With that, that's my last slide. I think I have my contact info and Susie's on the last line. I don't (indiscernible), so thank you. If you need additional --

MR. STOMS: Thank you, Juliette. That's great.

Do you want to do questions now?

CHAIRMAN WEISENMILLER: Yes. I think it makes sense to do some questions now.

MR. STOMS: Okay.

CHAIRMAN WEISENMILLER: I was just going to make an observation that, when we did the event at the National Academy, that the second day was dealing with the rest of the U.S., in terms of what they were doing on climate impacts and adaptation, and some of the more interesting ones were sea level rise, you know, the sort of Hampton Roads area, the various bases and cities, just sort of an amazing story there, and also down in the Miami area, you know, when you're trying to deal with sea level rise, the Everglades salt intrusion, you know, but certainly, again, these are areas – which we're seeing sea level rise impacts now. The others tended to more, you know, sort of Indiana, Nebraska, which were looking at the impacts on agriculture, and, again, certainly it's an area, even in those states, was that people were very conscious about what changing climate means.

MS. INMAN: I think my comments -- and I was delighted to see Juliette at least had a little freight goods movement image in there, but, Patrick, when I was listening to yours on the economic impact, I think, if you look at So Cal, if we go back to the lockout of 2002, our ports were losing a $1,000,000,000-per-day impact to the United States from the fact that goods weren't moving there. So I think, if we really looked at your economic impact, it would be a lot larger, given the fact that we estimate a third of the jobs in our state relate to goods movement and the supply chain.

So I'm happy to work with you on that, to see if we can help really understand, but earlier this week I was on with Maersk, one of our major ocean carriers here, and talking about the impacts of disruption, and (indiscernible) there likes to talk about the "networks of networks." I always talk about the "system of systems," but I think a lot of the things that we're talking about today really relate to the codependency that happens to any of us when something doesn't work, and, clearly, what we're understanding from the research is there's lots of things there likely not to work if we don't get to one of those lower trend lines. That's great. Thank you.

I want you to know that we are working on it. Your staff was gracious enough to provide my District Four Caltrans Climate Assessment, but we still have a lot more. This is fairly current, January of this year, and I know we're updating our goods movement action plan, our freight plan, again trying to be cognizant, but there was one of the slides that talked about folks in their siloes, and I think we all are guilty of kind of being busy doing the stuff we always do, and it really is important, I think, to have these cross-integrated discussions to really think about what we could do, and how we could do it, and how we could learn.

For all of us, I think it's huge, whether it's the disasters -- we've spent hundreds of millions of dollars. Yes, you know, FEMA is coming, but the way that work is we get paid sometime, hopefully. So there's huge financial impacts, too, not to mention the loss of life or the loss of homes. So I think, for all of us, it is important that we continue to bring as many stakeholders to the table as we possibly can to think about short-term and long-term, because there's, you know, things that we can do better, immediately.

MR. BRIGHT: I think, I mean, what's interesting to me is that, you know, as a culture, as a state, as a people, we're really tuned to big events, and we Californians, we're used to major shocks to our cities and our ecosystems, through fires or earthquakes or whatnot, and what we're not so good at is understanding sustained impacts coming at us that really fundamentally change the places we live and the places we like to go enjoy.

The groundwater maps, you know, the groundwater flooding maps, really stood out as one of those impacts that is going to sneak up on a lot of people, and I don't think it's really on the radar of those communities, that they will see the first flooding come from their front yards and not from, you know, overtopping of beaches and coastal areas. So, you know, really, it's about getting in front of that, those impacts, and getting not only the governmental agencies, but also the people that live in those regions, ready for those types of things, and just appreciate all the presentations. They were very enlightening.

MS. INMAN: That was my 1978 station wagon in Newport (indicating).

MS. GUBMAN: Maybe I'll just ask a question. This is Joanna Gubman, for those on line. I was curious. There was some discussion of the outputs are changing. We're hearing even more sobering information, and the Antarctic data is -- or what we know is changing in the OPC guidance. That's one thing, and then the Fourth Assessment has other things, and it's continually evolving, and, in a sense, that's a great thing, that we are continuing to know more.

On the other hand, do you have any thoughts for how we, as policymakers, find ways to put our foot down and say, "Okay. We're going to actually use this as a parameter or as a guidance," or if people say, "This isn't quite ready yet," that we have some way of saying, "No, this is ready. We're going to move forward"?

DR. BARNARD: On the sea level rise front, I mean, definitely, the extremes keep increasing, and the more we understand about Antarctica, and a lot of research going on there, and how unstable those ice sheets are -- I think, for policy people, the thing to consider is that, you know, the goal of Paris was to keep temperatures at one and a half degrees Celsius, and stabilize below two degrees, and in the recent geologic past, we know that two degrees Celsius equates to about eight meters of sea level rise, about 26 feet.

So, once the ocean equilibrates to this new temperature, eventually we are very, very likely to have, you know, tens of feet of sea level rise. It's not going to happen in this century. It may not happen next century. But it will happen. So I think, no matter what, if we stop emitting today, we're going to get at least two meters of sea level rise, and Paris, which it looks like we're going to hit, probably, by 2030, 2040, is going to eventually equate to, you know, tens of feet of sea level rise. And so anything we do today is going to have a positive impact in terms of our adaptation capacity in the future.

MS. KALANSKY: Could I just add to that? In looking at the Rising Seas Report, which the OPC guidance is largely based on, they talk about the use of triggers, or, you know, that because there is this uncertainty, that to have an adaptation plan that monitors really well, and understands when certain thresholds are being met, and that, if that threshold is being met, whether it's once a year or once every three years, depending on what it is, this adaptation will take place, and I think that's really important in looking at the acceleration of sea level rise.

So, if you don't have something in place, once it starts coming, the potential for the flooding to happen, people will play catch-up, but, if you have a plan in place that acknowledges that there is uncertainty, once it starts happening, we have a plan to start adapting and having that buy-in, thinking about ways to fund those adaptations and other things, I think, is really helpful, and that is something that the Rising Seas Report does highlight.

MS. FINZI HART: If I may add something there as well, this is something that we really talked a lot about with the AB 2800, the Climate-Safe Infrastructure Working Group, and the report that's going to be released next week, there is a lot of discussion about exactly that. How do you keep moving forward in the face of uncertainty? So wait a week, and you can read all about it.

MS. GUBMAN: Okay. Thank you

MR. STOMS: Okay. We'll turn to our panel now for reaction to the presentations, and I guess we'll just go in the order people are sitting. So first is Brian D'Agostino from San Diego Gas and Electric, and I'll let each of you introduce yourselves as you see fit.

MR. D'AGOSTINO: All right. Well, thank you very much. I appreciate the opportunity to be here. My name is Brian D'Agostino. I currently am the Director of Fire Science and Climate Adaptation for San Diego Gas and Electric, and Julie, Patrick, Juliette, thank you for all this information.

Our role in the Fourth Climate Assessment was really taking some of this and applying it to the electric system in San Diego, and looking at kind of putting it into action, like you mentioned at the beginning. So part of how we've done that -- we'll start talking about the first project, which looked at sea level rise on our coastline.

We took the latest information from CoSMoS, which we just looked at, and looked at an extreme scenario midcentury, and what that showed us was that there are four substations down in the San Diego area that could be prone to flooding by the middle of the century. So this gives us the ability to start taking action.

In particular, the report came out with some recommendations for us, and part of it comes into developing flexible adaptive pathways, and that's kind of the next step, where we move with this, and then we also start looking at real-time coastal flood modeling, because that helps us make smart decisions day in and day out when operating the system down in San Diego.

So thank you for that, and then, Julie, when we looked at the wider-scale extremes with temperature, precipitation, we looked at all of those and compared those to the operation of the natural gas system in San Diego as well, and then this gives us good information on managing the system moving forward. So I'll keep it brief, and pass it along to the colleagues. But just wanted to give some examples of how the information from the Fourth Assessment is really being put to use in San Diego.

MR. STOMS: Thank you, Brian.

So next we have Kathleen Ave from SMUD.

MS. AVE: Yes. Good morning, and thank you for the invitation to be here. I manage the climate program in SMUD's Energy Strategy Research and Development Department, and I also chair an organization called the Capital Region Climate Readiness Collaborative. I'm going to talk a little bit more about that later.

We've been working, assessing climate impacts, really, since 2009, and have summarized findings on an every-four-year basis, and I think most of the trends that have been highlighted here this morning in some of the other parts of the Fourth Assessment are pretty similar to trends that have been reported in the past. So far, I haven't seen anything, you know, that really knocks us of the path we thought we were on.

Most definitely, the data about heat is of extreme concern, you know, as we implement time-of-use rate structures and collaborate with others in our region to prepare for heat impacts, which is such an enormous public health issue, as well as a major impact to our local economy. This wasn't part of the Fourth Assessment, but did get a lot of attention last year, a study out of Berkeley that identified a four-percent hit to GDP for every one-degree Celsius increase annually. So those numbers will get very large over time, so a really, really big concern there.

Then, just on sea level rise, we do have a portion of Sacramento County that we serve that is vulnerable to impacts from the Delta, and then, of course, you know, West Sacramento is a port city, so those things are coming. They may affect us more in terms of migration, climate migration, over time. It's not really clear yet.

I really want to focus on the last presentation, this idea of adaptation blind spot and societal teleconnections, and I appreciate the author’s acknowledgment that "lack of concern" is probably not the best terminology.

I think, when I first read that presentation, I thought of CaLEAP, the work that the Energy Commission sponsored back in 2012, 2013, because it focused on dependencies and interdependencies, and key assets in a community, and my recollection was that that work was hindered by local government resources. You know, getting people to the table to participate in those discussions was challenging even back then, before a lot of these impacts were well known, and, nonetheless, incredibly important, because they really do get at cultural change, and change within the environments that utilities operate in that go beyond our borders.

That, I think, is really where these regional climate collaboratives are so essential, and I was sort of surprised not to see them mentioned in the report, because they do exist in California. There are, I think, now seven that are formally structured, and here in the capital region, we have Sierra CAMP. We have L.A., San Diego, the Bay Area, North Coast, and now the Central Coast, and they all work together in an Alliance of Regional Collaboratives for Climate Adaptation, ARCCA, which happens to be meeting now. I'm not at that meeting because I wanted to be here to share, you know, that these collaboratives are the place where this multi-sector dialogue is happening.

Utilities participate in almost all of those collaboratives, if not all, and for example, here in the capital region, we have regional sanitation. We have our transportation planning agency. We have our air districts. We have private engineering and environmental and architectural consulting firms, as well as local governments, and the emergency service groups that support them.

So they are a vehicle that is in place now, a structure. They are not formalized. They are operating now as membership organizations, in some cases, informal groups that are together without formal authority, necessarily, but attempting to be productive, you know, assets in the community, moving from just communication and alignment types of networks to actually production networks, where we create plans that can't be created in single agencies with single, you know, agency focus.

So I would really encourage everyone here in the Commission to consider the next steps with respect to formalizing those climate collaboratives, which are a great springboard and a big asset for the state, as we move forward.

Finally, I also want to mention, just from a utility perspective, how we are approaching preparing our community. At SMUD, we've been attempting to do some innovative work around natural refrigerants, and introducing programs that help our community with greenhouse gas emission reductions that go beyond, you know, our own emissions, and that's going to continue to be important as our board is in the process of considering a net carbon zero by 2040 objective. That's not formally adopted yet, but it's under consideration as part of our IRP.

One of the other programs I just wanted to mention, because it gets to these multiple connections across sector, is an accelerator program that we piloted this year, focusing on the proliferation of living future buildings, and I know that just two blocks from here is California's only fully certified living building. It's the Arch Nexus Headquarters, and I know that many CEC staff have toured it.

I've not sure if you have, Chair Weisenmiller, or any of the rest of you, but they welcome participation and tours, and I'd love to try to arrange one for you, because ILFI, the International Living Future Institute, has developed these frameworks both at a building level and a community level, and they support electrification.

They support distributed generation, which will, of course, increase the nodes that we saw in that last presentation. They support a very rigorous analysis of supply chains, looking at not just the content of the materials that go into the buildings that, you know, support the health of the occupants, but also the location of those materials, with a preference for materials in the local environment to minimize the transportation impacts.

In the process of creating these buildings, all of the policy, building code, and other roadblocks that they run into are illustrative of the siloed approach that we've taken in the past, and so helping to facilitate more of these in our community is one of the things that we think will really help us integrate some of those, you know, barriers in the future, and not only that, move into this sort of regenerative future, because the whole point of ILFI's work is to ensure that our buildings and communities are not just less bad than they have been, but actually regenerative, providing community benefit, whether it's through the energy they generate, the water they capture and treat on site, the interaction with the community and understanding of the place, so a very, very powerful framework, and one that we're evaluating right now in terms of how we take our accelerator work forward.

We now have, in addition to Arch Nexus' amazing work with this building, which is not only the only fully certified ILFI building in California, it's the only adaptive reuse project in the world that's been fully certified, we have another, nearly a dozen projects that are now in the ILFI pipeline, whether they be individual buildings, multi-family buildings, and even the Sacramento Valley Station is registered as a community challenge project. So, very hopeful about that. Thank you.

MR. STOMS: All right. Thanks, Kathleen.

Our last panelist is John Andrew from Department of Water Resources.

MR. ANDREW: Thank you, David, and thank you, Chair Weisenmiller, and to the California Energy Commission, for allowing me to be a part of the panel today.

I know it's been a sobering week. I think that word has been used two or three times already this morning, in terms of the results of the California Climate Change Assessment, the Fourth Assessment. In addition to my work at the department, I'm the Assistant Deputy Director over the climate change activities. I also have the recent pleasure of being on the editorial board with Susan, Guido, and perhaps others in the room.

I just want to say that, in addition to the sobering results, there's, I think, a real celebration of climate science this week, and I really want to make that point, that in seeing many of these studies, including the ones that we've heard today, sort of grow up, as part of the editorial board process, we are so blessed in this state to have just world-class climate scientists, and to be benefitting from their work.

So thank you to -- I think this is the first time I've actually met Patrick and Julie, but I've read your work for many years, and so that's nice. I've gotten to know Juliette over the past several months as part of the AB 2800 panel. I have a lot of respect for her as well.

Let me just quickly, as David asked, some reactions to what I heard today. One, again, maybe being more, again, on the optimistic side, is I think this is the first time I may have seen, in Julie's presentation, a slide where there's at least a little bit of a divergence from RCP 8.5 in the recent past. Now, I'm not going to get in an airplane and fly out to an aircraft carrier off San Diego and declare, "Mission Accomplished" or anything like that, but I think that's a glimmer of hope that things may be going in the right direction.

I really want to validate, also, what you said in terms of it won't stop at 2100, and I often think that the use of 2100, which is common among all of these studies, and common among all of those that speak about climate change, in some ways, is a bit of a disservice because, on the one hand, people do think that when the slide ends at 2100, it's over. It will not be, by any means, as Patrick noted as well in terms of sea level rise, but I think there's also a bit of indifference, if not fatalism, that develops looking at some of the numbers at 2100.

I often use 2050. I think, like with a lot of things with climate change, it may be good to use a range in the future. Some of these thoughts, I should have said, are looking more for what we would do next, in the next climate change assessment, that we might want to look at 2050, 2100, and 2150, in light of things that are happening now, and that they don't stop at 2100.

Speaking of 2100, going on just quickly now to Patrick's presentation, the impacts, again, 600,000 people affected, 5,400 kilometers of roads, I think he said five to 6 percent of gross state product, it strikes me that those 600,000 people are -- those are largely unborn people. They are not around yet, and they may have a different relationship, or may interact differently with the Pacific Coast than, you know, the last couple of generations.

If you look over the history of California settlement, not everybody has rushed to the coast, and even now, with the ridiculous housing prices along California's coast, it may not be as attractive a place as it has been for many of us. It's for me an iconic part of California, and one of my favorite parts, but likewise with the 5,400 kilometers of roads.

We're entering, I think it's safe to say, a revolution in surface transportation. If we're going to meet our very aggressive GHG goals in the state, we have to have a revolution in surface transportation. So the concept of a "road," quote/unquote, in 2100 is something that might be put into question, is "Are we going to need to 5,400 kilometers, or, if we do, are they going to be used in a different way?"

So I think that's just, again, something to look forward for in maybe the Fifth Assessment, is, how do we think about 2100? Certainly, a lot of times, when we do these climate studies, it seems like the climate is the only thing that's moving, but there will be a lot of other moving parts as we move forward and we need to keep that in mind.

Then, just to close out with Juliette's excellent presentation, I will just reflect that in, I guess now, my 30 years of experience in water resources, working on a lot of different aspects of it, the work in climate change that I've been doing in the last 10, 12 years has been the most cross-sectoral, and that's one of the most rewarding parts of it.

That said, it's clear from Juliette's and Susie's study that we could do a lot better, and, as Juliette mentioned, I think, emergency operations, you do see a lot of that coordination that you don't see in sort of a more relaxed time, when we're doing more long-term planning, so whatever we could tap, the energy and the connections that happen during emergency operations, perhaps looking to the military, to large corporations that have, you know, very long supply chains with global reach, you know, how they deal with some of these issues.

I would just add to Juliette's, something like we need to be looking at multiple climate impacts, multiple sectors, I totally agree. We might want to add multiple hazards, things like earthquakes and tsunamis.

So, anyway, just some quick reactions. Again, thank you all for inviting me to participate this morning, and some things to think about for the Fifth Climate Change Assessment.

MR. STOMS: Thank you, John.

Any other questions or comments from the dais?

CHAIRMAN WEISENMILLER: Yes. Let me make a couple. Actually, when we had the National Academy event, Jonathan Parfrey was there, and really emphasized the regional collaboratives and their role, but one thing I was going to say. To the extent that we have the nine regional workshops coming up and also the environmental justice, basic -- anyway, all the workshops -- we would like to figure out a way to partner with the utilities, to really push out the regional local areas.

You know, I know one thing that's just really interesting was the contrast between Hampton Roads, where you just have all these, you know, dominant Navy base, Air Force base for the U.S., but like 70 different entities trying to do the planning, most of which they can't do because the regional planning is tied up at the state level, while in San Diego, you have, basically, the Navy and the Port get together. They actually should be able to deal fairly effectively with sea level rise.

The other thing I was going to say was -- that also popped out -- although, basically, the presentations, the slides, and then the videos will be on line -- I'm not quite sure how soon -- and then the report from National Academy. So we will docket at least the connection there.

You know, the thing that came out was, once you look at the fact there's going to be extreme temperatures, then you really get to, what are the public health effects? And we didn't do enough in that area, frankly, but, you know, you have a lot of population that's going to be -- could be really adversely disadvantaged or killed by these extreme heat events. So one thing that's important, I think, for all of us to start thinking about is, how do we provide protection for people in those times?

MS. AVE: Thank you. Yes. Just a quick comment.

We already experience in excess of the state's average in heat-related illness and death here in the Sacramento area, and absolutely that is just going to increase, unless we take some really concerted action, and that's why our regional collaborative has made a pollution reduction initiative a focus, and that crosses -- we're focusing on transportation with an SB 1 grant, actually, but it will affect, you know, all the sectors as well, and they'll be able to use those findings, really critical work there.

Then I just wanted to mention that we're working with Ben Holton. I was on the stakeholder group for the Sacramento Valley report. So we're looking forward to hosting him at our last regional climate collaborative meeting of the year, to share those results and help spread the word.

MR. D'AGOSTINO: My only additional comment is, it goes back to part of our resilience to wildfire, and I think of some of the partnerships that have been developed with the American Red Cross and community emergency response teams, and I feel like that's going to serve as a really good foundation when we look at cool centers and other ways that we continue to focus on public health moving forward.

COMMISSIONER HOCHSCHILD: I'd just like to chime in and offer my thunderous agreement to the Chair's point about the value of expressing these impacts in terms of human health, because we're really at an almost schizophrenic moment in our country now, where we're living through the very worst impacts of climate change in the United States.

Each year, the fires get -- you know, we're setting records, and, you know, in cities like Sacramento and San Francisco, having the worst air quality we've ever had. On the other hand, there's many states in the country where the majority of citizens are not persuaded that climate change is a real issue, and I think, when you express it in terms of human health, you have the best chance to reach people, and there's many dimensions to that.

There's, you know, deaths from heatwave, but also the expansion of the tropical disease belts and so forth, and just going forward, as we look at how to communicate this to the greatest degree possible, expressing it through the impact on the health of children and families, you know, I think that's how we reach people, and send the message most effectively.

MS. INMAN: I just want to build a little bit on John's comment about the externalities and the other dynamics that are going on and will continue. I would be the first one to guess that we're not going to live our lives exactly the same way in 2100 that we do today, and I'm watching all my colleagues here who are all connected with at least one other device or something. So, if you look at how the world is changing -- and the technology changes at rapid-fire pace.

So I think that having the flexibility -- I think one of the comments in one of the reports said, "Make sure we're flexible and we can adapt," because I think it's beyond us, really, to understand exactly if the chip will be in my ear or where it might be, to help me do my job. But I do think there's lots of them, and, you know, if we look at our demographics and our aging population, certainly, you know, when it's 105 and I'm 10 years old, versus 105 if I'm 80, you know, I feel it a little more. So I do think -- and then, finally, just affordable housing.

We've just had Ben Metcalf at CDC, and we're probably going to bring him back on a real regular basis, because there are huge transportation impacts related to the fact that we don't have housing for the residents of California. We're a million-plus dwelling units short, and so what do we see? Longer and longer commutes, less than ideal situations. So I think that there's so many of those externalities that we also have to try to help influence or mitigate, or figure out some viable solutions, and perhaps, you know, building more inland, you know, might make some more sense, and there's lots of communities that -- got to get the jobs there, too.

So the only other thing, putting on my real day job as a private sector businessperson, I think that really getting the businesses to the table and listening and learning -- you know, it's hard for most of our business partners to look at a plan for 2100. Most of our business plans are written, max, five years. Most of them tend to be about three. There's a lot of innovation that takes place on the private side. So we've got to figure out a way to learn, and, hopefully, figure out what's best for all of us.

CHAIRMAN WEISENMILLER: Let's skip the break and go on to the next panel.

MR. STOMS: One last applause for our panelists and speakers.

(Off the record at 11:46 a.m.)

(On the record at 11:51 a.m.)

CHAIRMAN WEISENMILLER: Let's get the introductions.

MR. FRANCO: Good morning, this is the second panel for the IEPR workshop, and we're going to be looking at impacts of climate change at the local scale. We're also going to emphasize in most cases extreme events, so it will be a combination of local-scale impacts and extreme events.

So we have a wonderful set of speakers this morning, starting with Professor Max Auffhammer from UC Berkeley (go Bears) and so he's going to be talking about the potential impacts of climate change to both electricity and natural gas demand. I think the way he does it is unique. He's not perfect. So I have to say that. But I think it's an innovative way, and I think it's closer to reality, at least for the next 20 to 30 years.

Then we have Doctor Ben Brooks from the U.S. Geological Survey, talking about something that we may think that's it's old news, that the levees – the top of the levees of the San Joaquin-Sacramento Valley are subsiding, but the prior research was based on satellite data, and some people may question the satellite data. So this time, for the assessment, what he did is direct measurements using lidar.

Then we have Professor Radke, also from UC Berkeley, and he's going to be talking about the impacts of climate change to the petroleum system, but also he's going to be talking about his interconnection with other sectors, including the electricity sector.

For the panelists, we have Doctor Mike Anderson from Department of Water Resources, so he's going to be reacting to what you will hear from the speakers, and via WebEx, we have Brian Chen from Southern California Edison, also providing his insights about what he heard this morning.

So let's start with Max. Yes.

DR. AUFFHAMMER: All right. Thank you very much for inviting me here. I also wanted to thank the agencies for supporting this important ongoing work. I also wanted to single out Guido Franco, who is just one of the greatest science managers in North America, not only herding disorganized academic cats, but also providing really substantive academic input, which has really improved the work here. So thank you all.

What I want to talk about briefly, and then we can discuss this more, is our thinking about what's going to happen to the big unknown, which is energy demand going forward in California, and the basic idea behind this work here -- and there are several papers out there -- is pretty simple.

If you live in El Centro, you would likely have an air conditioner. If it's hot outside, you turn on the air conditioner, and your electricity consumption goes up. If you live in San Francisco, as a hipster, you would never have an air conditioner when it's hot outside. You go outside, eat ice cream, and complain about how hot it is, but you don't have an air conditioner.

However, if San Francisco inherits Fresno's climate, even the hipsters might install air conditioners in their apartments, and in a hotter future, we might see a higher penetration of air conditioners in San Francisco. So, to make a long story short, I call this "temperature response," if you could think of the bottom graph right here being current-day San Francisco temperature response, and the top one would be San Francisco's temperature response and electricity consumption in a hotter climate where there are more air conditioners.

So how do we figure out what air conditioner or electricity consumption looks like, you know, in an end-of-century-type climate? There are two ways of doing it. One is, you build big simulation models, and you make very heroic and best-guess assumptions about what the energy system looks like by end of century, and then run these simulation models. I'm not in that business, because I was never smart enough for that. I'm a statistician, so I like to work with observed data, and looking at what people's behavior actually looks like in revealed data, and trying to tease out responses in what we call a "causal setting," because we're not casual, we're causal, right? A change in weather causes what kind of change in electricity consumption?

So what this study does is, it comes out with a new and, as Guido already pointed out, imperfect, but I think quite neat, way of teasing out both what is San Francisco's electricity consumption response to hot days today, and using information from hotter areas that are otherwise similar to San Francisco, in statistical terms, to help us think about how that response function changes in the future. So here what I'm trying to do is, at a highly disaggregated way, simulate a California electricity consumption response with a differential change in air conditioner consumption in a future climate relative to what we have today.

We did the same thing with natural gas consumption, and I think the interesting policy-relevant finding from the study here has to do a little bit about with what happens to the electricity in the summer, to what happens with natural gas in the winter, but I'll get to that in a moment.

So I also want to single out -- and I can't thank them enough -- California's investor-owned utilities have been great collaborators over the past five to 10 years in terms of helping us get access to data in a confidential setting, but it's really led to a revolution of energy and electricity economics. I'm the climate guy at the UC Energy Institute, but, you know, these data settings here have led to interesting studies on energy efficiency, energy pricing, and things like that.

The beauty about access to these data for the state of California is, California is, I believe, thanks to Brexit, now the fifth-largest economy in the world. It also has a very heterogenous climate, from desert climate to sort of cool coastal humid climate, though it really is both, in terms of its economy, very, very large, but also spatially heterogenous.

As was pointed out in the opening remarks here, this really lends itself to look both at, you know, how spatially different are these impacts on electricity consumption across this large, diverse state -- I always want to call it a country -- state -- but also thinking about, how is this seasonally going to affect consumption? Right now there are differences in summer to winter, which is something we couldn't do previously because we had to rely on annual data, and now we have these fancy consumption data that we get access to.

So, to show you heterogeneity here -- so I'm going to try in one minute to explain something that took us a year and a half to do. So, if you think about San Francisco's temperature response curve, that cartoon I showed you in the beginning, you would expect it to be relatively flat, not a lot of response in the summertime, right -- electricity consumption doesn't go up very much -- but also probably not very much change in the wintertime because, in San Francisco, we also don't really heat with electricity. There's some, but not very much. So you would expect it to be a much flatter response than what you would expect in El Centro, right?

In El Centro in the summer, you would expect a huge response in the summer, but also in the wintertime, when it's cool. There's a fair amount of baseboard heating, and if you don't believe in baseboard heating, if you burn natural gas, and you blow it through your house, that fan you’re using to blow the hot air around uses electricity, as far as this economist understands it.

So what you expect is, you would go from sort of a flat temperature response to one that is curved. So what we do is we can estimate one of these response functions for every single zip code in the state that has people in it. So I have 1,300 of these response curves that are estimated based on a billion electricity bills, so really cool statistics here, and what you're seeing in this particular picture right here -- I'll use my pointer so the WebEx folks can see it. That's a very aggressive pointer right there. So El Centro would be at the top envelope of this curve, and San Francisco would be down here. So this summarizes the electricity response for California.

Then we looked at natural gas. So I sat back and I said, "What would you expect to happen there?" Warmer winters should lead to lower natural gas consumption, right? We use most of our residential natural gas for heating homes. So what I expected is the downward sloping function that sort of goes flat in the summertime, and this is the moment when you hit "Run" on your python code, and then a figure pops out, and you just hope it looks right, and there was a happy dance in my office here. It was sort of exactly what we expected. There's an almost linearly decreasing natural gas consumption by households that flattens out at roughly 60 degrees right here.

So you can already sort of see where I'm going with this. Warmer winters, right, lead to lower natural gas consumption, which is a benefit to California consumers, yet, you know, warmer summers lead to higher electricity consumption in the summer, and only slightly lower consumption in the winter, being a cost to consumers. So, an economist's favorite, there's a tradeoff here.

If we map this out -- and this is in the report, and you can sort of zoom in in different areas, but it's a nice way of showing heterogeneity if we impose end-of-century climate onto today's Californian economy, so same population, same energy efficiency, same incomes, and this is where Guido's remark of "This is imperfect" certainly stems from.

A referee remarked that this was an incredibly well-done study, but fundamentally uninteresting, because we need to know what income and the energy system looks like by end of century. But I still would argue what we're seeing here, which is really interesting, is the baseline, right? So, against these effects right here, we're seeing what was going to happen anyway, population growth, changes in electricity prices, changes in technology.

What climate change is going to do for electricity demand is, it's going to add additional pressures to this, because people will consume more electricity, especially during the really hot times of the season, and I will get to that in a second.

So there's numbers in here, and I always tell my graduate students, "Don't ever put up a table on a slide," but I'm going to point you to two important ones. So, if we take the hottest scenario of climate change, again holding income and population constant, we're thinking roughly a 15-percent increase in residential electricity consumption for the entire state, including these additional air conditioners that we adopt by end of century, so 15 percent by end of century.

That's not a huge amount of increase. Think about a California with maybe 50, 55,000,000 people in it. That might have much larger impact, but we're seeing significant decreases in natural gas consumption, almost a 20-percent decrease in natural gas consumption, from these warmer winters right here.

So, to do a back-of-the-envelope calculation here, we could think very carefully about, "Well, natural gas plants generate electricity, so we have to think about this in terms of primary energy." I'm thinking about this in terms of end use here, but a back-of-the-envelope calculation here leads to sort of a net decrease in energy consumption, again holding the world constant, because there's this massive drop in natural gas consumption in the winter.

I'm going to use my last -- I have 5.1 minutes left here, on my timer here, to make what I think is a really important point. Economics is often called "the dismal science." I would rather be called "the marginal science," not because we're marginal, but we know that making decisions based on averages often leads to, really, the fundamentally wrong decision. So we really have to think about, what's the value of one more kilowatt hour demanded at different times of the day and year?

So, to me, the most interesting and important thing we should start -- are already thinking about, but continue to think about, is, what are the impacts of climate change on peak load going to be, both in terms of the frequency of peak load events as well as the intensity of those peak loads? So are we going to see our three hottest days more frequently? The answer from this morning is yes, but how much bigger is demand going to be at peak load going forward because of climate change and this increased adoption of air conditioners?

So we had a nice study that was actually inspired by a paper that Alan Sanstad and Guido did for California. We did this for the entire United States -- it's in PNAS. If you don't have access, I'm happy to send it to you -- where we essentially imposed, again, climate change on current-day society, and just tried to simulate out what happens to frequency and intensity of peak loads, and the answer is, it's going to be big, right, even holding the economy and population constant.

So, from a methodological point of view, what we've developed here is a framework that doesn't let us just say, you know, "Annual load goes up by, you know, two percent or three percent," but we can simulate loads at the daily level, and come up with these nice distributions of what the distribution of peak load looks like in a world with and without climate change. We can do this by ISO, by grid, so this is ERCOT. This is Texas. We have this for California, too. I just couldn't get into my server, so, longer story. I have this picture for California as well.

The take-home message here is, the impact on peak load is very variable across the country. Some places see relatively large impacts on the intensity and frequency of peak loads. Other ones, like if you think about the Northwest right here, where you see sort of a shift towards a winter peak, warmer winters, might drop winter peak down a little bit.

The take-away message here is, again, the table. We're seeing on average nationally a percentage increase in the peak of daily load of around 10 percent. If you're just looking at the five-percent most peakiest days, that daily peak load and intensity goes up by roughly 17 percent. So, thinking about what we have in terms of capacity reserve margins that are required here, I think thinking very carefully about what happens to the intensity and frequency of these events is important.

If you're thinking about what happens to the percent change in frequency days with peak load of the current 99th percentile -- stop speaking jargon, Max -- how often are we going to see peak days that have intensity higher than our currently three peakiest days? Goes up by roughly 1,500 percent. So I've termed this "peakiness," right? So we should think about the peakiness of demand really, really carefully, because climate change is going to play a major role in this one.

So I'm in, you know, this room. I'd be amiss to not sort of at least put out what I think some take-away messages for policy are here. We know that electricity consumption is going to rise from the residential sector because of incomes and population, right? The demand forecasting folks at CUC have great models that do this, but figuring out what temperature is going to do here is really important.

Of course, the great energy efficiency programs, many of which, you know, arose from this particular building right here, DRM, smart pricing policies -- I've bolded "smart pricing polices" because I'm an economist and I really care about smart prices -- will offset these increases in demand, yet the thing that's going on in the background here is this policy push, which I think is a smart avenue to go, is this notion of electrifying a number of sectors here.

So what we're seeing, then, is -- which I'm not telling you anything new, but this electrification might shift peak, right, if everybody plugs in their vehicles at night here. This is the "within" day, but might also change the way we do things seasonally, if electricity is used for heating instead of gas, right? But it will increase demand further.

So, if we're thinking about electrification and decarbonization at the same time, I think the thing we should really keep in mind here is there are, of course, these greenhouse gas benefits to electrification, and we have to think very carefully about how much energy we need for that, but it's going to lead to dramatic reductions in conventional air pollutants.

So some very recent studies, one of which is part of this particular project here, show that the massive benefits we get from fewer particulate matter molecules ending up in our kids' and adults' and, you know, the elderly's lungs -- right here the benefits from that are so big, we need to keep those in mind when we make these decisions.

The one takeaway message from my work here is, we've got to make sure that we size our system to meet peak demand, and this is going to be a much trickier exercise than it's been over the past 20, 30 years in this brand-new world. All right. Thank you very much.

MR. FRANCO: Thank you, Max. Okay.

DR. BROOKS: Hi, everybody. Thanks very much for the opportunity today. Just as a side note, because I live at the beach in San Francisco, I realized for a while that

I'm a canary in the coal mine for climate change studies, but now I realize we also have to be the center for the hipster air conditioning resistance.

I'd like to acknowledge a large group of collaborators from academic (sic), as well as U.S. Army Corps of Engineers, and I'd also like to acknowledge Guido and Susan for their guidance over the course of this study.

I'm going to talk about high-resolution measurement of levee subsidence related to energy infrastructure in the Sacramento-San Joaquin Delta today. The takeaway points I'll just read to you. Our new measurements find the mean subsidence rates for some of the levees in the delta are on the order of one to two centimeters per year. That's on the order of the sea level rise increases themselves. This subsidence compounds the risk that sea level rise and storms could cause overtopping, or failure of the levees, exposing natural gas pipelines and infrastructure to structural failure.

At the rate of subsidence, the levees may fail to meet the federal levee height standard of a foot and a half above freeboard, above the 100-year flood level, between midcentury and towards the end of the century, depending on the rate of sea level rise.

Here's a location map of the Sacramento-San Joaquin Delta, very close to us right now. The map is color-coded so that only elevations between minus 10 and 10 meters are visible, and the cooler colors are elevations below sea level.

So the delta itself has subsided below sea level over the past century, and the delta islands themselves are surrounded by levees whose structural integrity is important to the natural gas and energy infrastructure within the state and to its whole population. Some of that is shown. On the map in red are the pipelines throughout the delta, and then the black boxes, indicated with the little letters, are the local study areas for this report.

It's a simplified cross-section of a levee. These typically tend to be earthen levees. And we see on the right sea level rise indicated. We know that sea level rise is going on. As was mentioned earlier, in the delta, there's been subsidence, historically, and so the combination of sea level rise and the subsidence, which we call "vertical land motion" or "negative vertical land motion," can exacerbate any kind of risk to the interior -- here, I'll get the -- to any kind of infrastructure on the interior of the levees.

The vertical land motion, the subsidence processes, have been discussed a lot in the literature. There are typically three components. One of the components is compaction of peat soils. That's a popular one. Another component is an anthropogenic effect of the compaction of structures themselves, the fill used to either create or remediate a structure, and then a third component is a general background subsidence of the whole delta sediment column, which has been laid down over the quaternary period.

For our study, what we did was just estimate a rate. We're sort of agnostic about the process itself. We just estimated a rate that we use for our projections. So the combination of a levee going down and sea level going up makes it much more probable that a levee will overtop in the future, so that's the simple objective of the study, is to estimate when that might happen.

This is how we do our analysis. We start off with a sea level rise curve, which was provided by the Cayan 2016 projections for this assessment. We then add to it an overtopping standard, which in this case we're taking, again, the PL 84-99 federal standard of one and a half feet above the hundred-year flood, and we add to that, then, the height of the hundred-year flood, which is estimated in this case from Army Corps of Engineers projections. That's variable throughout the delta, and so this is a different height for each location in the delta.

We then take our measurements of vertical land motion, which is shown with the blue. So those additions come up with a corrected sea level curve. We then take a vertical land motion projection from our own measurements. We site it. We start at the initial height of the levee, and then follow it as it subsides down. When the two curves intersect, that's the time when this particular portion of levee will now be susceptible to overtopping, and will no longer be meeting the standards. So we're fundamentally trying to get this what we call "time to overtopping" metric.

The uncertainties are dominated in this projection by the sea level rise projections, which we heard about earlier in the first session, so what we did is we tried to get a reasonable range of projections to express uncertainty. Again, we took the sea level curves from the Cayan, et al., study, 2016, the RCP 8.5 99th-percentile curve, which was talked about earlier, and RCP 4.5 50th-percentile curve. So this range of uncertainty dominates all of the uncertainties in the other components of the study. This is just a description of how those sea level curves were arrived at, and it was discussed earlier, so I won't go into that now.

So what we did was, we fundamentally put these lasers on the back of a pickup truck, and drove on the levees. The lasers are also called "lidar," which is a popular term now. We, at the same time, operated a continuous GPS station, and we have an inertial motion unit on the truck that takes out the motion of the vehicle, and in the end, what we're left with is a very, very high-resolution topographic map, known in absolute space to better than two centimeters.

This is a description of our -- a technical description of our processing flow. We set up static GNSS control. We process the kinematic trajectory of the vehicle. We integrate it with an inertial motion unit, and then we do a couple of different calibrations for the laser. All of that results in what's called a "point cloud," which is referenced in absolute space to better than two centimeters accuracy, and there are billions of points in that point cloud. I think you all have seen pretty lidar pictures before.

What we then do is we reduce that even further. Those are two-centimeters accuracies for every point, but what we do is, we create a mesh for the individual levee crown roads. That's what we're most interested in, is the height of the levees themselves. That process of smoothing the data actually beats down the noise of every individual point, and so our VLM estimates are -- the uncertainties on the VLM estimates are on the order of millimeters, two to five millimeters.

For this study, we primarily did mobile laser scanning. We also did some airborne laser scanning, which is basically a similar technique, just done from a plane so you cover more ground.

So here's one of the maps. In the report, we have maps for each of the individual islands. This is Bacon Island. What we do is, we take our current measurements. We made them from 2016 or -- yes, 2016 to 2017 -- and we reference that to the delta-wide airborne lidar data set that was collected in 2007. So we have a 10-year time change, from 2007 to 2017.

Guido mentioned earlier that previously we had done satellite studies. There are a bunch of different groups that have done satellite studies. I led a couple of those studies. They suffer from the problem of satellite radar to decorrelate with vegetation in the delta. Lidar doesn't have that same problem, and so we're able to make a one-off 10-year subsidence map. So these are 10-year vertical land motion rates, so any kind of variability that goes on in those 10 years doesn't encompass (sic).

So, on this map, the gray scale is the elevation, the topography. The yellow lines are the pipelines, and then the colored dots are the VLM rates, and the cooler colors are the higher rates of subsidence, on the order of two centimeters per year to less than a centimeter per year.

So the other thing that jumps out of this, aside from the average rates on the order of a centimeter to two centimeters per year, is the strong spatial variability. So you can see, for instance, if you're interested in this pipeline over here, just off to the margins, you have significantly higher subsidence rates, a factor of two higher subsidence rates than right where your pipeline is. So, basically, we can have vertical gradients on the order of a centimeter to two centimeters per year over tens of meters, and that's what this mobile laser scanning technique really brings out.

This is a summary of the VLM results for the whole region. This is just the vertical land motion now, presented just as simple histograms for the different regions, which encompass about two-thirds of the delta, and what this just shows is, generally, the subsidence rates, and in this case, I'm only showing the negative rates, because the delta is generally going down, so it's a one-sided distribution, generally on the order of a couple of centimeters per year, but there's a lot of variability. Sometimes, in the tails, you can get certain locations that have rates, you know, a factor of five more than that, and some places where it's less. So this is just the overall subsidence that we're measuring.

So now what we do is we go back to that analysis of the time to overtopping, and these are two scenarios for that same Bacon Island, the RCP 4.5, so this is the slower sea level rise scenario, and the RCP 8.5, "business as usual," faster sea level rise, and it's pretty straightforward.

If you go with a slower sea level rise, your typical times to overtopping are on the order of 2075 to 2100, so a little bit later than if you have a faster sea level rise. In this case, these times to overtopping are in the order of 2050, so not next decade, but pretty soon, we need to start thinking about this.

This is another example just from Jersey Island, which shows the strong spatial variability. All the spatial variability comes in from the spatial variability in the vertical land motion process. It doesn't really come from the sea level rise projection, and I should say I forgot to mention, these sea level rise projections are all projected up-delta from San Francisco. There's some variability in the process associated with that, but for this, for first order, we took the sea level rise projections from San Francisco.

So, again, if you were managing Jersey Island, you're probably going to have a problem over here, in the northwest portion, before you have problems elsewhere. If you took one measurement of VLM for that one island, it wouldn't be representative. So the MLS can really help with prediction and mitigation planning.

This is now that same summary, in this case just the time to overtopping again. So here's our map. Here are each of the different study areas. The red curve now is for the fast sea level rise, and the blue curve is for the slower sea level rise. Again, this just shows that, basically -- and it's interesting that, throughout the delta, it's roughly similar. Around 2050 in the RCP 8.5 scenario, we'll start to get big problems with the heights of our levees.

So the conclusions, then. Again, our new measurements find subsidence rates on the order of sea level rise rates throughout the delta. The subsidence compounds the risk of sea level rise through its risk to energy infrastructure, and at this rate of subsidence, we're looking at 2050 to 2080 as a critical -- one of these critical thresholds that have been talked about earlier.

Now I'll just put in a plug, given the high spatial variability, given that the vertical land motion that really causes the spatial variability, a continued program of laser scanning or other type of monitoring would permit updated projections and mitigation prioritization. Thanks.

MR. FRANCO: Professor Radke is going to talk to us now about the petroleum system. I just want to mention that, for this study, the Energy Commission received a one-time funding to study the petroleum system. So we can not use natural gas funding or electricity funding from EPIC to study what may happen to the petroleum system. So this is just a one-time study.

DR. RADKE: The nice thing about going last is, Max and Ben thanked everyone, but, also, Guido and Susan, I want to thank you. They were critically important.

I spent the last two months in the backwoods of Canada, trying to figure out how could I ever tell anybody what we just did with this research project? It's so vast. So I also want to apologize for the length of the report, but I assure you, it's one-fifth the size it was at the beginning of the writing of it.

Just like the real world, and just like dealing with the transportation fuel sector, we have a cross-section of people. This group represented multidisciplines. It also represented multi-age. I had 21-year-olds talking to 80-year-olds inside the research group. I tried to manage it by breaking it down into three subgroups.

So you're going to see a lot today, and I'm going to apologize again. I'm going to speak quickly. I've got a lot to cover here, and, hopefully, this is the first time

I'm attempting to tell anybody what just happened over the last two years, and what we have to go forward with. So this is the talk. I'm going to try and do it. We're going to look at the transportation fuel sector.

So what is it? I thought I knew what it was 18 months ago, but it's very different now. It hasn't changed. I've changed. Well, actually, it also has changed. It's very dynamic. But that red bar down in the bottom is critically important, because that fuels most of the transportation, and that's coming from -- we'll simplify it by saying the "oil sector," but it's not. It's much more complex than that, but we can break it down. So I'm going to simplify, and break it down into big chunks.

So we can also recharacterize it as the "feedstock," the pre-refinery stuff, and the post-refinery stuff, and it took a long time to get to the refinery as maybe the breakpoint between this industry, because the industry is so complex.

Some interesting facts. Thirty-three percent of what we consume comes from California. The other 66 percent is coming from offshore, other sources. We refine, and 63 percent of it we're burning, essentially, we're burning in engines, et cetera. We're also burning this aviation, but if you think about it, a lot of those planes fly away, so that carbon is going elsewhere.

We do have the cleanest refineries in the world. That leads to a lot of problems, more problems that I wanted to even care to get into but I did get into them. But the cool thing is that airlines come to California, and they top off here because our fuel is cleaner, and actually is less wear and tear on their systems. And, of course, nine percent marine fuel.

Now, let's go to the pre-processed system. It is complex, and this is as simple as I could possibly make it, and then, when we go to the post one, it gets even more complicated. Why am I showing you this? I'm trying to talk about the intraconnectedness of the system itself, because in there lies areas that we should be concerned about.

It's one thing to know where sea level and fire -- and that's what we're looking at, sea level, fire, and climate change -- how that's going to change, and what's going to be stressed, but I also want to point out the little part in red. I'm not going to point to it. You can see it, that little box in red. That's 75 to 85 percent of the volume of what goes on here in California is going through that product pipeline.

So, if I had to be concerned about something, if you said, "Pick the low-hanging fruit," product pipelines, we'd better make sure that they are not compromised. I also want to point this diagram out because something could break in this diagram, and there is a cascading effect.

So what we did was we turned this diagram, this conceptual diagram -- we turned it into a topologically structured network of the transportation fuel sector in California, and I tasked the team with "Follow the oil molecule. Follow it from the time it gets into the system to the time it goes out into -- if it's going to a tank in a vehicle or by the time it gets there."

Then, of course, we turned that into "Can we turn that into what it looks like in the real world, where it is spatially?" because, remember, we're in a pile of flooding and flooding change and fire change, fire risks, on top of this, to see "Well, which parts of the system are at risk?"

Look at the extreme connectivity, intraconnectivity, in the system itself, and I want to point out that these are mostly private sector or invested-in companies, and I want to point out that they have contracts with each other. That's really their connectedness. They're connected physically, but they're also connected over and through contracts. I learned more about this industry than I wanted to.

We may think that they're vertically integrated, and some of them, on paper, are vertically integrated, but the vertical integration of the flow of that molecule is not controlled by any one entity, and that also is important because we are at risk because of contracts and deliverables, and so the system itself has issues, and you have to understand that.

This is just looking at California, a bunch of nodes, a bunch of links, because, in our topological model, we turned the system into points and lines and connections and relationships.

Direct and indirect exposure. So I might be a pipeline somewhere, and I might be in the delta, and Ben's prediction comes true, and I get overtopped, and I'm suddenly at risk, but, also, because of the intraconnectedness in the system, there is this indirect exposure.

What we found -- we ran some little experiments, and what we found was -- we just built Northern California into this topological network. This is really important. Don't try and see a map in this that you could see. This is a very abstract notion. Economists love these kinds of things.

This is abstraction, and it's only a small portion of the system, but what happens if there's a break in the system, a disruption? The system, there's cascading failures. So everything that doesn't have color in it, that just got wiped out by some small connection failing, so something getting overtopped or maybe a fire takes place, and there are these ripple effects.

The only reason I point this out is, this system is incredibly complex, and there's a lot of risk involved here, and we've dodged lots of bullets up until now, and that's even if we take climate change away, we dodge bullets. Now we've got climate change coming on, adding stressors to the system, and these kinds of things could happen.

Add to that, Guido pointed out, the interconnectedness with other critical infrastructures, like electricity, gas, water, chemicals, telecommunications, hazardous wastes, the law. I didn't throw the law in here, but there are legal issues here as well.

I attended a lot of emergency response forums to find out how they interact when there is an emergency taking place in real time, and how they might plan for that. Well, we're now trying to look at where these things are more likely to occur, these emergencies likely to occur, because of climate change, so the system becomes even more complex.

Okay. Let's get into looking at our flooding. My model logic here, "Let's look at the science-based possible scenarios." I'm really pleased everybody went before me, because you saw a lot of the science that we consumed, then synthesizing that, mapping the physical infrastructure and the connectedness, and then doing a vulnerability assessment of "What happens if it gets exposed, and when does it expose, and does it increase? Does this vulnerability increase?"

So let's look at flooding, climate change. I love modeling. People always say, "Can't you just give me one?" No. I love modeling. Uncertainty increases over time, so the scenarios, the vast scenarios, could be different, and the uncertainty increase over time. So I love that funnel.

I try to explain it to my students who really can't identify with this, "If I gave you $20,000, and you went to Las Vegas, and you got to play a game where you had, let's say, an 80-percent probability of winning that game, what would you do?" And they say, "I'd lay out all the $20,000. I'd keep doing it, and if I came away from the end of the weekend, I'd likely have a lot of money, maybe 80 percent more money than I had when I started." Then I say, "The reason why you do that is because you're not a parent."

I think, in the room here -- and I think this entire effort, this climate change effort, is because it must have been stimulated by parents or people that have that gene inside them that is a parenting gene. I said, "If I gave it to a parent, and I said, 'Here is your $20,000. You have an 80-percent probability of going to Las Vegas and winning, but, if you lose, your children cannot live anymore, because they have nothing to eat, et cetera,' the parents say, 'Okay. I'm not going to gamble the money.'"

That's what we're sort of dealing with here. That's why I love the idea of this science. I modeled a whole range, and by modeling the whole range, I said, "Can you live with the consequences?" I think that's the question we ought to be asking, "Can we live with the consequences of failure?" because the probability of failure is that young 21-year-old gambling at the table, saying, "I'm going to win," but the consequences of failure are going home and telling the kids, "You're not going to eat."

We broke this down after modeling these. We had 24 different scenarios for each little tile, and then we ran that through 20 planning horizons, because it became very clear that this industry has planning horizons, and we wanted to take up to 2100.

You've seen these maps before. There's Ben's delta in red, and it quickly starts to overtop, because I'm not just talking about looking at Ben's subsidence. We're talking about storm surges, and so we're talking about waves breaking over, and usually I bring along cool pictures of someone from Department of Water Resources standing, and a wave breaking over their head, during just not a 100-year storm, just a bad storm.

So this is Northern and Southern California. What you're seeing here are maps that are static maps. I hate static maps, because it's really dynamic and it goes through an entire range, but let's look at the statewide exposure again, RCP 4.5, 8.5, and we started to look at the kinds of things that are getting exposed, and this is coastal flooding.

We then took the infrastructure that we had, because we had it mapped. We looked at it through those planning time horizons, and looked at the percentages of the assets, and what they were getting exposed, and, of course, we see -- we start off with these terminals getting exposed, and if the terminals are exposed, the fuel is not moving in, not moving out.

Then we looked at things like docks, and docks being exposed over time. Now, you might think, "Wait a minute. Docks? What about a -- they're down in the ocean. As the sea level rises, we'll just build them higher." Not so easy, if you bring a supertanker in there and you're trying to unload oil. It becomes very, very complex, and very expensive. They're all aware of this, by the way. The people that run the terminals, run the ports, they're all aware of these problems. Climate change is right up there on their desks, because they know they have to deal with it.

Then we can look at refineries and exposure to coastal flooding, and I just took these two examples because this is down in the Long Beach/Los Angeles area, where a majority of our fuel is refined, and we see that they are going to be suffering inundation as well, and, as it was said earlier and people have mentioned, we have to come up with either some engineering solutions or we need to rethink this, because it's not a win situation.

Then product pipelines, and the reason I just do this, back at that other diagram where I had a circle in red, this is the 75 to 80 percent of the fuel going through this particular group of pipelines, and if this goes down, you're not moving the fuel. If you're not moving the fuel, by the way, we only have 48 hours of storage fuel in the system.

It's not like that gas station sitting there with a lot of fuel in its tank. Why would they? They have money invested in it. It's going through -- that's why, when you go to Costco, which is a super-refueling depot, every time I go to Costco, usually, there's a fuel truck there, filling them up, and we're emptying them out. Anybody know where the largest amount of fuel storage is in California? It's in your gas tank. They're not storing it. You're storing it.

So, exposure to wildfire. Westerling did some amazing work, and I thought, "How am I going to reduce Westerling's work to a few diagrams to get the attention of the transportation fuel sector?" And it took several attempts and several guinea pigs, but we eventually did it, and what we did is we came up with "Well, let's show them this trend," and those blue blocks are the different scenarios we ran, the different climate scenarios we ran under fires in different areas.

Now, this grid, the large grid, is Westerling's grid, and if someone -- we found that the fuel sector -- and you'll see this in my concluding remarks -- they had a difficult time looking at climate change studies and understanding how it was going to impact them, and they had a difficult time dealing with scaling and downscaling, and I realized they weren't getting it. When we were showing them the next map I'm about to show you, they really weren't getting it. They were kind of saying, "Well, we really don't see it."

This is the Tubbs fire. That's four and a half hours. It went over 10 miles, I think, in four and a half hours. Those are Westerling's grid cells. So, if you think you're living in a Westerling grid cell and you're safe, you're not safe, because it's coming awfully fast. And so, when I showed them this map again, after showing them that map, they were listening, they were watching, and they were on board.

This map is showing the change over time. So the red is the change over time from the previous planning horizon, and whether things are getting worse or not. That means, if you look at red on the left, it was bad then, and if it's still red on the right, it's getting worse every planning horizon as we go through time.

What's the most exposure to fire? Roadways, for a lot of reasons, then railways, then airports, and we find out that terminals are the least, because they're sitting down -- they have exposure to fire. They will burn. But they usually don't have wildfire, wildland fire (sic) around them. They're usually insulated, and they have very good fire brigades and protections. There are instances when they are concerned, though.

All right. Stakeholder engagement. How do you engage with the oil industry about climate change in 2017 and '18? It's very difficult, I thought, except I realized that the oil industry, the transportation fuel sector, is made up of us. It's made up of the same backgrounds of my research team. It's made up of the same background as everybody that lives in California and the United States.

So I found people in that transportation fuel sector that are really keen on climate change, and really keen on the adaptation to climate change of that sector, and so what I thought would be difficult wasn't that difficult, and they came on board, and they gave us lots of information.

Now, stakeholder engagement led to fine resolution, better captures the exposure of the asset scale. When I was showing what was going to happen in a region, regional, they were tuned out, "You know, I can't really see it."

When I took it down to a fine scale, saying, "Hey. Those are your tanks," or "Those are your pipelines, and this is the risk, and it's coming from a neighbor or a neighborly area," then they got on board.

Also, stakeholders are more interested in near term, because they're doing their daily job, and they're planning on 20- and 40-year horizons to the asset, and they're not worried about what's going to happen 50 years out, because, as one oil industry member said to me, "We might not be an oil company. We might be the same company, but we might not be peddling oil in 20 or 30 years," as he was pointing out the window, I guess, at a passing electric vehicle. As Max pointed out, the system may completely change.

Stakeholders identified several locations for fine-resolution modeling, so we went to those locations. So, in this interaction, they were pointing, "Could you do this? Could you model this? Could you model this?" And we did, and, again, for flooding, the real interests were the Martinez area and the Long Beach area.

We went to fine-scale resolution modeling, and we modeled both from the sea level rise and also the landscape, the watershed, collecting water, building up the energy in the amount of water there, and flooding streams, and coming down, and we ended up showing it coming from both directions, and, again, going through the different planning horizons, different RCP, different climate models, and we then presented that to the stakeholders, "Here's your infrastructure. What do you think of this? What do you think of this, and how do you respond, and how would you react?" And that's what this was all about, what is their response? How are they adapting to climate change?

Areas of interest with fire, Sierra Nevadas, and areas where there's lots of wildland. Obviously, it caught their attention, and they directed us there to do some modeling. The idea of roads, railways, pipelines, it's disbursed throughout the state, and they're more exposed to these large fire hazards. We did a model showing where all the biomasses died over the last 10 years, so where's the large biomass that has increased its probability of catching fire and burning and causing big heat, and they were very interested in that.

They have had incidents where fire has got in their way and slowed them down, but they have always been able to overcome that, and as one person who is the logistics expert in California said, yes, they have dodged a bullet, but that is getting harder and harder to do.

Fine spatial resolution modeling with fire really helped them understand their asset and its risk. So we went down and we went down looking at individual trees, and their other assets. We came up with the rate, the flame, the fire intensity. So we ran some fire models, came back to them, and they then started to talk about what they felt their exposure was.

What they're all trying to do is, going from the upper right to the lower left, if they were all in the green, then they have a fighting chance. That's what everybody should want to do, and this leads to mitigation strategies. So, if we showed their particular area where their infrastructure was in the red or even in the orange, then were strategies to try and get to the green.

By the way, this is just a simple diagram. The report talks about what this diagram is about, but as you move into the red, the firemen, firewomen, fire people, they're not coming. They're backing off. They're letting you burn because they don't want to die, and that's how fire is fought in California. Until people understand that, they won't understand how they need to mitigate to protect their assets.

All right. What have we learned? It's an extremely complex industry, physically and organizationally. I mean, the sector functions because of these contracts and agreements between all stakeholders, and that gets into legal issues as well. So it's a complex thing, and when it breaks, it could break for more than just climate change and flooding and fire. It could break for other reasons.

No one stakeholder group has a complete overview of the transportation fuel sector except, after this study, I think there are three people in all of California that come very close to having that comprehensive knowledge of the transportation fuel sector -- I'm not one of them, but one of my research team is -- or has the ability to respond reliably to all exposure risks and uncertainties, because they can't. They don't see them.

If you interconnect it -- if I'm interconnected and I depend on your electricity, and I know where my system is at risk, but I actually don't know where the electric company is at risk, where I'm at risk -- where I feel I'm not that at risk could be even more at risk if the electric company is at risk.

So it's this cascading effect, and so, if anything, what the CEC, in this climate change research, has done is it's got us all to look and realize it is a connected set of entities, and we need to communicate and understand where we're at risk and how we might attack this.

The transportation fuel sector is interconnected with the energy sector. The stakeholders underscore the importance of the interconnected external industry infrastructures to the successful operation of their industry, and the idea, the necessity, to add finer and finer modeling, which goes up in size, terabytes and terabytes and terabytes, and hours and hours and hours of processing time, but we've overcome that, amazingly enough. In the last 18 months, we figured out how to do that.

Refined product pipelines are critical assets. I pointed that out earlier. Central distribution terminals are critical assets. I pointed that out as well. Climate change could end up being the biggest terrorist we face, because it could take out some critical parts of this fuel sector, in which case, if there is a disaster, the rescue people can't come to get us, because they can't fuel their vehicles to come get us. In the Tubbs fire, really lucky, dodged a bullet.

There happened to be -- one of the suppliers of fuel in that area of the country happened to have a storage facility where they could actually fuel vehicles, and it was set up because it made it easier for them to deliver fuel to their customers, and I'm talking at not the retail level, but at the wholesale level, and it turns out it was very close to where the Tubbs fire was. So the vehicles could rotate through and refuel, and it made it very, very convenient for them to fight that fire.

Okay. Last slide. I guess what I want to say is, we can't look at the transportation fuel sector without seeing the larger picture, that it's part of a much greater system, and that, in fact, climate change, flooding, and wildfire are going to have a huge impact on that sector as a whole.

MR. FRANCO: Chairman, would you like to --

CHAIRMAN WEISENMILLER: Yes, a couple comments. I mean, when there are fires, the Energy Commission ends up with people stationed out in the operations center, and our responsibility is the fuel site, you know, trying to make sure people can get to fuel. So, again, this is a key issue.

I was going to say, from my past experience, I would say certainly the fuel system is vulnerable. In the first Brown administration, when we had the Iranian oil embargo, basically, people started filling up their tanks, and the fuel supply shifted. So the amount of gasoline we were getting out of the refineries dropped pretty dramatically, and that's why we had those long lines.

More recently, when there was a strike down in L.A., we came close to having refineries shut down, affecting gasoline and jet fuel, because, you know, it was building up at the refineries, and they had no way to export it, and when they would hit the level, they would have shut down. Fortunately, the strike settled before we hit that point, but that was certainly a tough, sobering week or two that I was working at the governor's office.

The other thing I was just going to add is I worked with a refinery 20 years ago, but a lot of these refineries have been around for more than 100 years, and so, at that time, 20 years ago, they were discovering, basically, toxic waste around the refinery sites, you know, and they had no idea what people did in 1890 or 1900 with stuff, and so, if you get to the flooding, it will be scary.

MR. FRANCO: Additional questions or comments? No.

So now we are going to the panelists. We'll be very brief. Mike.

DR. ANDERSON: All right. Just a few quick comments. One of things I like about the work that's been done is we're starting to look at not only bringing it down to the local, but understanding what to do with the information, so it's not just assessing, "Here's how bad things are going to be."

You start to look at, well, as you hit these issues, what are your options, what are your consequences, and finding ways to build on that, and go forward, and folding that back into the assessment. As we adapt, as we build in policies to move, can you fold that in, too, so the next projection accommodates that as well?

Next element is on the monitoring, and the iterative monitoring, and the role of monitoring as it plays both in assessment, response, and adaptation, and finding ways to work that in, finding ways to manage working across federal, state, local governance and program activity to make the best use along all three levels of governance to carry out those programs, something to tackle moving forward, what's actionable information, and the consequences of once you have that detailed information.

I think, in the San Diego report, when you start talking to communities and pointing out, "Your house may become flooded in 20 years," and the property owner is saying, "You've just messed with my property value," there are consequences there, and not to shy away from those challenges, but to figure out how to work with those and be productive in moving forward.

With that, I really appreciate the opportunity to be part of this, and the great work that's been done.

MR. FRANCO: Thank you, Mike.

Do we have Brian?

MR. CHEN: Hi. Can folks hear me?

MR. FRANCO: Yes. Please go ahead.

MR. CHEN: All right. Well, first I wanted to thank the Commission staff for inviting us to participate. It was really insightful to hear all the information that was presented, and the real significant amount of work that has been put in as part of this effort.

I wanted to kind of point out some observations. I think with Professor Auffhammer's study really kind of highlights what the effects of climate change can have in terms of the future demand, not only from a peak perspective, but as, I think, the energy infrastructure is changing, in the way we deliver electricity with greater renewable energy, is shifting.

We also need to look at how ramping and flexibility is also needed on the system. This is something that, you know, for instance, Southern California Edison is looking at very closely in terms of increasing electricity demand with, I think, the over-arching policy goals to the state to try to achieve greenhouse gas reduction. I think the investor-owned utilities can provide a pathway for increased electrification, either in buildings or in transportation.

I think the study itself, the framework, seems very intuitive. I think the innovative aspect of it, of looking at the extensive adoption of AC for those hipsters that don't normally have that, is something, I think, worthwhile to explore. These types of studies really provide kind of a baseline input for how utilities will be planning, and to the degree studies like this can inform the IEPR process, that can really help provide a more integrated look for longer-term planning.

I think Professor Radke's study kind of highlights not only the interdependencies between the different sectors, but, you know, this is something that is -- the information that was shown specific to the transportation fuel sector is very much transferable to the electric sector, and those are things that Edison is looking at right now in terms of the impacts of climate to our facilities, whether it's direct threats to infrastructure, changes to how the infrastructure becomes maybe less efficient in the increasing temperatures, but we're really operating kind of in a new normal, I think. Many of us are following the news with the almost daily wildfires that are going on.

So I think understanding the profiles of flooding and wildfire risk and other external threats can help provide us with direction and guidance when it comes to planning, and so the studies that Doctor Radke was showing, I think, can help us inform where we want to harden the system, provide greater resiliency overall, and then, kind of lastly, we've been thinking about what is really the right level of resiliency.

There are certainly things we can do to harden our infrastructure, but we also need to recognize that we need to prepare the citizens of California to also kind of be resilient themselves, and understanding what's the right level of investment within the infrastructure, and that balance, I think, is something that the policymakers are actively discussing.

So, again, appreciate the opportunity to provide input, and I thank the Commission for the invitation.

MR. FRANCO: Thank you very much Brian.

Okay. So, with that, we end this panel -- there's a comment from the public via the Internet?

MS. WILHELM: So are we moving into the public comment period now?

CHAIRMAN WEISENMILLER: Yes. I was going to say, let's move into the public comment period. So we do have any blue cards or anyone in the room?

MS. WILHELM: I don't believe we've received any blue cards, but I was advised by the public advisor to invite people to the --

CHAIRMAN WEISENMILLER: Right. I was going to say -- no. The first question is, does anyone in the room have any comment? And then the next question, is anyone on the line?

MS. RAITT: So I can go ahead and read it:

"Question for the speaker. When you get the questions, this assumes gas continues to be the primary fuel for heating. How does decarbonization of building energy use, meaning of heat pump technologies for space heating, water heating, and possibly induction cooking as well -- what is the impact on peak load?"

DR. AUFFHAMMER: So that's a great question. What I pointed out here, which is, you know, one of the big drawbacks of the study, is we're holding current technology constant in the simulations, but, going forward, if we're thinking about not just on the generation side, but on the consumption side, if we're no longer heating by combusting natural gas in the household, you would, you know, get overall higher electricity demand in the wintertime, but, if winters are warmer, you're going to demand fewer heating services than you otherwise would.

So this is a really complex question that's going to require further work, and I don't know if Guido wants to add anything here, it's a big question of what are climate change impacts on the sector going to be in this world that's very different because of policy-induced technological change, and just, you know, regular technological change.

MR. FRANCO: Yes. This is Guido. So we have three studies. One of them we have is already posted, thereby E3. I don't want to (indiscernible), but, looking at how the energy system should evolve, different scenarios to achieve the 80-percent reductions by 2050, we're also taking climate change into account. So the effect of electrification is taken into account in those scenarios. If anybody is interested, I mean, we have those reports available.

CHAIRMAN WEISENMILLER: And they're sort of part of the Fourth Assessment, but published separately.

MR. FRANCO: Okay. So I think we don't have any more public comments. Chairman, do you want to close the workshop?

CHAIRMAN WEISENMILLER: Yes. You know, I want to thank everyone for their participation today. I think, in terms of the Fourth Climate Assessment, just to remind people, this event was to look at the impact of changing climate on the energy system, but for fire, which occurred earlier.

We will have workshops in October, early November, throughout the state on the regional studies. I think only a couple of those have been scheduled so far, so stay tuned. I think what, early November in Long Beach, and Riverside, I think, also in early November, but certainly there's -- anyway, the details will come sooner or later on when the events will be.

I again thank everyone for their assistance today, and stay tuned. Thanks. The meeting is adjourned.

(The workshop was adjourned at 12:59 p.m.)

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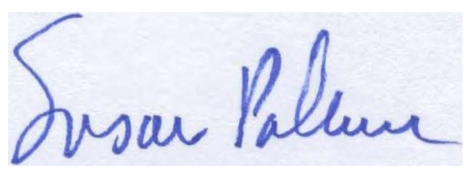

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