BEFORE THE

CALIFORNIA ENERGY COMMISSION

In the Matter of:) Docket No. 09-IEP-IP

Preparation of the 2009 Integrated Energy Policy Report (2009 IEPR)

DOCKET

09-IEP-1P

DATE JUN 08 2009

RECD. JUN 22 2009

STAFF WORKSHOP

ON

ENERGY AND CLIMATE CHANGE

CALIFORNIA ENERGY COMMISSION

HEARING ROOM A

1516 NINTH STREET

SACRAMENTO, CALIFORNIA

ORIGINAL

MONDAY, JUNE 8, 2009

9:00 A.M.

Reported by:
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Laurie Ten Hope, his advisor

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Guido Franco
Kelly Birkinshaw
Pam Doughman

PRESENTERS

Dan Canyan, Scripps Institute of Oceanography
Max Auffenhammer, UC Berkeley
Jay Lund, UC Davis
John Dracup, UC Berkeley
Alan Hamlet, Washington State University
Mark Snyder, UC Santa Cruz
Lara Kueppers, UC Merced
Larry Dale, Lawrence Berkeley National Laboratory (LBNL)
Andre Lucena, LBNL
Peter Larsen, LBNL

Public Comment

Joe McCawley, PE, Southern California Edison (SCE)
Obadiah Bartholomy, PE, Sacramento Municipal Utility District (SMUD)
Richard Halvorsen (phonetic)
Bruce McLaughlin, California Municipal Utilities Association (CMUA)
Suzanne Moser (phonetic)
Nicholas Warden, Center for Energy Efficiency & Renewable Technology (CEERT)
Elizabeth Burton, Lawrence Livermore National Laboratory (LLNL)

Via WebEx

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P R O C E E D I N G S

JUNE 8, 2009 9:02 a.m.

MS. KOROSEC: Alright, let's get started. Good morning, everyone. I am Suzanne Korosec. I lead the Energy Commission's Integrated Energy Policy Report Unit. Welcome to today's staff workshop on Energy and Climate Change, which is being held at the direction of the IEPR Committee. Just a few housekeeping items before we get started. The restrooms are out the double doors and to your left. There is a snack room on the second floor at the top of the stairs under the white awning. And if there is an emergency and we need to evacuate the building, please follow the staff out of the building to the park that is kitty-corner from the building, Roosevelt Park, and wait there for the all clear signal.

Today's workshop is being broadcast through our WebEx Conferencing System and, for those listening and speaking on that system, be aware this is being recorded. For parties using that system who want to ask a question, you can send an e-mail to the WebEx Coordinator and we will also be opening the phone lines during the public comment period and the question and answer periods so that you can ask questions during that time.

Just brief context, the Energy Commission is required by statute to develop an Integrated Energy Policy

Report every two years. It provides an overview of energy trends and issues that are facing California, along with policy recommendations to help the state meet its energy goals. Obviously, climate change is one of the major policy drivers for California. The 2007 IEPR discusses the importance of climate change impacts on California's energy sectors and the Scoping Order for the 2009 IEPR identified several areas that the committee asked staff to look at, to focus their attention on during the 2009 IEPR process, including examining how climate change impacts will affect energy demand, production, and infrastructure.

At today's workshop, our staff will be presenting information on how climate change can impact the electricity sector and we are also asking for public input to use in preparing the 2009 IEPR. We will have a number of presentations today, followed by a Q&A period for each section of presentations and, as I said, we will take comments from people online, as well. We will do people in the room first and then people online. For those in the room who ask questions or have comments, we do ask that you come up to the podium and use the microphone so that you can be heard on the WebEx and, also, it will be on the transcript. And after you are done speaking, if you could give the Court Reporter a business card, that would be helpful so they can make sure your name is spelled correctly in the transcript. So with all that housekeeping out of the way, I will turn things over the Commissioner Byron for opening comments.

COMMISSIONER BYRON: Thank you. Good morning, Ms. Korosec, everyone. Welcome Monday morning, here at the Energy Commission. I am Commissioner Jeff Byron. I chair the Integrated Energy Policy Report and my associate member, Commissioner Boyd, is not here this morning, however he is well represented. I see one of his advisors in the audience. My advisor, to my left, is Laurie Ten Hope.

I would like to welcome everyone to this staff workshop on Energy and Climate Change. I note that the workshop is going to provide insights on how the energy sector may be impacted and how it could adapt to climate change. This is not my area of expertise, certainly, so I am interested in learning as much as I can here today as that impacts our policy-setting at the Energy Commission. We are going to hear about the potential changes in the electric demand, the availability of hydroelectric generation from California and the Pacific Northwest, and it is not encouraging. At this workshop, we are going to also start the discussion on how climate change may impact the availability of renewable resources, including bio-energy, wind, and solar power. And, finally, this afternoon I note that a number of researchers at Lawrence Berkeley National

Lab will present a new methodology on how we could estimate the vulnerability of electricity, natural gas, and energy transportation infrastructure to warming temperatures, wildfires, sea level rise, and severe weather events.

Now, we certainly do not expect this workshop to provide definitive answers to all of these issues; however, the research is critical to give us insights into the nature of climate change, and the preparation we need to make as a society, and certainly at the State of California. I would like to thank ahead of time the presenters and those that are here in the audience. Your input and insights to this Commission are extremely beneficial. I am going to turn the meeting over, I believe, to Mr. Franco, who is going to chair the staff workshop. And I will apologize ahead of time that I will probably have to come and go a couple of times during the workshop. But, again, thank you all for being here. Ms. Korosec?

MS. KOROSEC: Alright, Guido, can you take us through?

MR. FRANCO: Good morning, everybody. Good morning, Commissioners, Advisors. I am going to give a very brief presentation, just to give you some background about this workshop, and also to give you what you can expect from this workshop today, what we should expect from this workshop. So I am going to start with the general objectives. We have three general objectives. The first one is to hear from the different researchers that have been working on climate change and research, and climate change and energy, about the potential impacts of climate change to the energy sector. And then to start discussing, because this is a new area of research, how climate change may impact renewable resources in California. And at the end, like Commission Byron said, we are going to be hearing about a proposed methodology on how we can estimate the vulnerability of the energy infrastructure sector, like admission lines, to climate change. We are going to have two [indiscernible] for these sections, one is this one, this is supposed to be a very enjoyable and informative workshop; but we will also have two White Papers, and the speakers today are preparing these two White Papers, one will be just on energy and energy demand and climate change, including hydropower and renewable resources, and the other one will be, I think, the first ever study on the vulnerability of the energy sector to climate change.

Before we continue discussing all of these projects and these problems, I would like to talk a little bit about past PEER studies that provide some of the background information that will be used for these White Papers. As you may know, the climate change program in the Energy Commission has four overall areas of work, one is Climate Monitoring Analysis and Modeling, the second one is Improved Methods for Measuring Greenhouse Gas Emissions, the third one is studying Options for Renewed Greenhouse Gas Emissions, and the fourth one is the studies on Impacts and Adaptation Issues. So the Climate Monitoring Analysis and Modeling is one of the major activities of this area, and this area of work is the generation of climate projections for California. As we can see in the graph there, global climate models, global climate models can let us know how climate may change in the future on a global level. However, the level of geographic resolution in those models is so coarse that it cannot be used directly for climate impacts and adaptation studies at the regional levels like California. So researchers, like Scripps, for example, they have developed a statistical downscaling techniques since we have information at the coarse level for this historical period, and also we have information at the fine resolution, more or less, cell by cell in kilometers, for this historical period, we can develop statistical relationships between these outputs on the global models and the observed methological parameters. And for the future, however, we only have the output from the global climate models. But using these statistical relationships developed with historical data, we can estimate how climate change in California the rest of the century using these statistical scaling techniques, and the outputs on the global climate models.

However, there are some limitations with the statistical scaling techniques. One of them is that, so far, we have only previews, methological estimates of how temperature and precipitation will change in California. We do not have information about wind fields, solar remediation, and other parameters. But, still, we have a number of climate projections for California that are readily available, and Dan Canyan will talk a little bit about that. So this is the foundation for some of these workshops we have done, not only for the energy sector, but other sectors of the economy.

With respect to energy demand studied by Professor Mendelsohn from Yale University in 2003, he suggested that climate change will increase energy demand for cooling and efficiency demand for cooling, but will decrease energy demand for [indiscernible] heating. And now, today, we are going to hear about a new study by Professor Max Auffenhammer from UC Berkeley that suggests that we may have underestimated the potential impacts of climate change on energy demand.

With respect to hydro power generation, actually, Professor Jay Lund from UC Davis, I think, in 2003, provided one of the first estimates of how climate change may affect low elevation hydropower units; then, in 2005, as part of the -- I believe it was 2005 -- the IEPR workshop, as environmental previews, a report suggesting that, if we do not look at high innovation hydropower units, that we may be missing the impacts. So because of that, we commissioned two studies, one by Professor Lund, and another one by Professor Dracup, Professor Lund with UC Davis, and Professor Dracup with UC Berkeley, looking at potential impacts, not only of low elevation hydropower units, but also high elevation hydropower units, using two totally different techniques. Professor Lund, we will hear later today, used a physical methodology, and Professor Dracup used a more engineering-based method. But both of them seemed to be reaching similar conclusions.

Now, ongoing in future PEER Studies, as you may know, the Energy Commission is developing probabilistic climate projections for California. This is an ongoing work; we started, actually, in 2003. We are going to be developing probabilistic climate projections for California -- surprise. But this time, we are also using dynamic models, so dynamic models are the models that are supposed to simulate the physics involved, and the chemistry involved, and the energy fluxes. But the models that are used are extremely competitively expensive, so it is taking a long time to develop -- to preview these climate projections. The models associated with Scripps, LBNL, University of California Santa Cruz, and Lawrence Livermore National Lab, are using two domains -- in Domain A, we are using a green resolution of about 30 X 30 kilometers, and Domain B, we are using a resolution of about 10 X 10 kilometers, about 7 X 7 miles. The beauty of these models is that, in addition to being physically-based, or at least in theory, physically-based, is that they also produce information about wind fields, solar radiation reaching the ground, you know, clouds aloft, etc. etc. So this is the type of information that could be used to estimate how climate change may affect resources and photovoltaics. The other studies, I have already mentioned this study of climate change on energy infrastructures held by LBNL as a study they just started, and one that we have not started yet, but we hope -- I mean, we are going to hear about some of the ideas about how to address this area of work on climate change impacts and renewable resources. The graph on the bottom indicates how the use for all these spaghetti diagrams on climate projections can be translated into probabilistic information about potential impacts. And I think the probabilistic information is going to be important because we want to know, I mean, not only the potential impacts of average changes in conditions, but also we are going to actually know about the potential changes of extreme events, or low probability high impact scenarios.

We shall deal with all questions for this workshop. I am going to read them. I think they were part of the agenda for today's meeting; the only thing I would suggest is that we will need to ask a lot of questions, we have a lot of very high caliber researchers here with us today, we need to probe them and find out as much information as we can about policy-relevant issues. So with that, I thank you for coming here today and I think Dan Canyan will be next before we open the session for questions and comments.

MR. CANYAN: Well, good morning. Nice to see the Energy Commissioners doing this. Okay, I am going to hearken to the recent climate change scenarios assessment that was released through the Climate Action Team just within the last couple of months, and most of this work is related to that exercise.

Several collaborators -- this has been a fairly broad-based endeavor and I would like to acknowledge funding from the Energy Commission and also from NOAA. The assessments are driven by large scale climate models of the generation that was used in the Intergovernmental Panel for Climate Change, the IPCC, which we have used in this latest round of the California assessment; we have used six of those models. There are actually several more that are available. Those models, along with the demographic and urban projections for California have been to some extent integrated together to look at potential impacts of climate change in California. And, of course, that has been carried through to the economic analysis. This work is ongoing, these are scenarios, they are not necessarily predictions because of the cascade of uncertainty that accompanies both the climate change models, as well as the forcings that drive them, that is, greenhouse gas emissions are, of course, uncertain. Those emissions in this case have been looked at in two different families of emission scenarios, one which is a relatively high carbon fuel intensive global economy, the so-called A2 scenario, in which emissions rise from their present day level to approximately four times that level by the end of the century, and this rises essentially monotonic through the 21st century. On the other hand, we also looked at the B1 scenario in which emissions do rise through about the middle part of the century, that is the lower panel here, but then beyond that, because of a combination of assumed regulations, technology and other social forms of adaptation, they begin to diminish, and by the end of the century, they actually are possibly lower than the present day. And, of course, there is a huge body of work that is going on to look at the emissions scenarios, and look at the necessity for mitigation of greenhouse gas emissions. All this goes on -- this is the next slide, for those that are playing along online -- we have included an estimate of population and demographic change in California where, of course, by the middle -- some time in the middle part of the century, California's population is estimated to reach 50 million people and, by the end of the century, many more than that. And, of course, the areas that are growing in California are, in many cases, areas which are, regardless of climate change, are within a climate that is more severe and more challenging. So that is certainly part of the landscape that we have to consider when we look at demand for energy and other resources in the future. All climate models that are governed by greenhouse gas changes in the atmosphere are warming. It is worthwhile saying that, regardless of whether we continue to have emissions that are exceeding the natural level, which of course they have since man has really been on the scene on earth, we are committed to more climate change because the Earth is still equilibrating to the increased loading of CO_2 and other greenhouse gasses in the atmosphere. So the message is that, even under the best of circumstances, we will have to adapt to some amount of climate change under the circumstances that are produced by these higher end greenhouse gas emissions scenarios. It looks like we will have to come to grips with something in the neighborhood of 2 degrees Celsius, that is approaching 4 degrees Fahrenheit of warming, by the middle part of the present century, and potentially 8 degrees Fahrenheit or more of warming by the end of the century. That is, of course, an enormous challenge. If we, on the other hand, take a more restrained emissions track globally and, of course, this is not only California -- California is only a tenth of the U.S. emissions and a small fraction of the global emissions, so California can only lead the way, but if so, there is probably an easier outcome to adapt to, and that is laid out here in one of these spaghetti diagrams that Guido referred to in his remarks.

Here is a picture of one of these models. This happens to be one of the A2 scenarios under the GFDL, Geophysical Fluid Dynamics Laboratory, laboratory simulation of climate through the 21st century. This is the baseline climatological condition of summertime temperatures across the southern part of the state, and here is the middle part of the century under that simulation. The color shading here is kind of intuitive, where the red shading is warm and the blue shading is cool, and you can see how temperature especially in the interior is warming considerably. One of the properties of the latest generation of climate models is that warming is intensified in the summer period, in general, and in most of the climate simulations, and there is more warming in Continental interiors than there is along the coastal regime.

That was mean conditions. The picture I just showed you was the 30-year average. This portrait here, if you look at the bottom, is a tally account of heat-waves in the San Diego region from the historical period through the end of the century under two different emission scenarios. Under the historical period, under this definition of heat-waves, which is the 99 percentile maximum temperature day, we achieve a heat-wave at a rate of about one and a half days per year, per summer. By the end of the century, even under the B1 scenario, the more environmentally restrained, friendly scenario, we are seeing heat-waves that approach 10 days per year, and under the more intense greenhouse gas emissions scenario, the A2 scenario, we are seeing heat-waves that probably exceed on average 15 days per year. So we are seeing under that higher end scenario, a 10 times increase in the number of warm days, hot days. And those days, if you look at the top chart, are as time progresses through the 21st century, are occurring earlier, are becoming more intense, and are occurring later on in the season. So the heat-wave season is essentially widening through the lens, of course, of the climate model.

Well, sea-level rise is also a great issue for California. We are a coastal state, we have an estuary through which we draw a lot of our water supply. And, historically, sea levels have risen both globally and along our coast at the rate of approximately half of a foot in a century. The climate models, because ocean water is expanding thermally as climate warming proceeds, and because the oceans are accumulating mass, they are accumulating more water as Greenland and Antarctica and some of the other land-based ice stockpiles melt, we are seeing in the future the prospects of sea-level rise reaching something in the neighborhood of a foot and a half to perhaps a bit more by the middle part of the century, and reaching something in the neighborhood, a range of two feet to about five feet by the end of the century. That is an envelope of uncertainty under the methodology that we have used to estimate sea-level rise along our coast here in California. So we have perhaps big big challenges in the way of coastal issues.

So just to sum up in this latest round of scenarios assessments, we looked at more models than we did previously in the 2006 assessment. One thing that I did not mention, but is a glaring problem that seems to be emerging from the latest set of climate models is that there is a drying trend over much of California. If you look at the consensus of climate change models, not all models, but more than half of them are drying out by a few to several percent drier than present day conditions. So that is a property that we will have to keep an eye on as climate models continue to develop and as time goes on. And, of course, the sea-level rise problem is another issue. This report is available online, it is represented here. And thanks for your attention.

MR. FRANCO: Thank you very much, Dan. Now we have time for questions.

MR. BIRKINSHAW: Dan, you do not mention --

COMMISSIONER BYRON: Mr. Birkinshaw, go ahead and identify yourself.

MR. BIRKINSHAW: This is Kelly Birkinshaw. I am an advisor to Commissioner James Boyd. My question has to do about these probabilistic scenarios that Guido referenced in his presentation. Can you speak to what are some of the challenges of developing those probabilistic scenarios? Are we really going to be able to, in the near term, be able to discern the probability of some of these more extreme impacts that you mentioned in your presentation?

MR. CANYAN: Yeah, great question, Kelly. Thanks. Well, we actually can -- if you accept the present day environment of climate models, we can construct for certain variables, we can do just that -- and we have looked at essentially probabilistic climate scenarios for temperature and for precipitation and we can do that for temperature events. We can look at heat-waves under your definition. We cannot do that, so far, for variables such as wind storms, and we cannot do that for cloud cover. So there are certain elements that are relatively, readily downscaled, as Guido mentioned, to the California landscape. I think Mark Snyder is going to talk about this in a bit. But there, we have to rely on more intensive calculations using dynamical models, instead of these statistical constructs, in order to work that out. So we have actually made great strides along those lines. We have been sampling through ensembles of climate models. The basic elements are there and I think we have a foundation that we will build upon, but for some of the more complicated effects that involve wind, perhaps heavy precipitation events which are not necessarily well-captured by statistical gamut, and some other phenomena that probably would be of great interest to the energy producer and consumer, we are still kind of on the frontier. But we are getting there and I think we will be able to do this. The one thing I would say is that this is -- I think we have to accept that these statistics that we will come up with are going to be kind of a moving playing field because, as the global climate models change, which are the source of all this information, and that will happen throughout our careers and beyond, we will have new guidance to drive the regional assessments that we make here in California.

MR. FRANCO: Thank you very much, Dan. Now we are going to go to the next speaker.

MS. KAROSEK: But before we do, I would like to ask if there are any questions from the WebEx people. All right, the lines are open. Is anybody on line who would like to ask a question? Okay, we are going to move on.

MR. FRANCO: Okay, the next talk is by Professor Max Auffenhammer. He has done a new groundbreaking, I think, analysis and I hope you will enjoy his presentation as much as I disagree. Max.

PROFESSOR AUFFENHAMMER: Thank you, Guido. I would like to acknowledge the CEC and especially the PEER Program for funding this work. What I am going to do is I am going through a lot of slides. The whole paper is available right out the door and on the CEC website, so you can look at more details in case I glance over anything that is of interest to you.

California's residential electricity consumption -- and this is what this paper deals with, so we are going to ignore commercial and industrial here -- more than quadruples over the past almost 15 years now. It has gone from a quarter of total electricity consumption to 34 percent, roughly a third. And to put that in perspective, the residential sector in California consumes as much electricity as roughly Finland, or Argentina, or half of Mexico. Californians get their electricity from the three major IOUs and over 100 of the Munis. Now, per capita consumption, California has been held as the example to the world. Up until 1974, per capita residential electricity consumption was growing at roughly seven percent per year, and thereafter has stayed roughly flat. So if we take the period up until 1994, per capita consumption grew at about .3 percent, and if we separately look at the past ten years, that trend is growing a little bit more quickly, still no where nearly as quickly as it did before 1974, but growth seems to have been picking up a little bit, and that difference is statistically significant. So part of the question here is, you know, some of this may be due to climate induced warming that we are already experiencing, or other factors. So this paper deals with looking out into the future, what are the impacts of climate change on residential electricity consumption?

Now, others have done this; there is a literature in *Engineering* that uses these bottom-up simulation models; the take home message here is, most of these simulated impacts on residential and aggregate consumption are pretty small due to climate change, somewhere between 10 and 15 percent. Econometricians have done the same thing, but looked instead of counting air conditioners and refrigerators, and things like that, actually looked at data and fit statistical models between electricity consumption and temperature trends, and then extrapolated out into the future what this means for consumption. The paper that stands out here is by Guido Franco and Alan Sanstad, who, looking at all sectors, meaning total load for California, find something between a 1 and 20 percent increase by 2099, depending on what warming scenario and climate model use. And maybe most interesting here, there is a new paper by Olivia Deschenes and Michael Greenstone who look across states in the United States, over 40 years of time, and find that there is a 15-30 percent increase in residential electricity consumption due to climate change. So what do we do here that others have not done? We essentially exploit the fact that weather still at this point is beyond our control, so we exploit the fact that weather is random, and we look at the correlation between residential electricity consumption and daily weather. So we are going to allow a non-linear form between weather and electricity consumption, which basically means a one degree warming at a low temperature range vs. a one degree warming at a high temperature range will have differential effects, meaning if it is 80 degrees and it gets warmer, we may turn on the air conditioner vs. if it is 20 degrees and it gets warmer, we may actually turn off your heater, so we would expect a differential effect on electricity consumption. Also, California is very heterogeneous, so we are going to allow for how often people turn on and off their air conditioners to vary across the different areas of the state. So then we are going to simulate what aggregate consumption from the residential sector is for different scenarios of warming, different price scenarios that potentially could be due to something like a cap and trade, or a tax, and different population scenarios. And I will give you a brief flavor of those in a minute.

Why did Guido call this paper "groundbreaking?" I like that word. I do not think it is -- it is maybe not groundbreaking, but it is certainly interesting. Thanks to an agreement between the UC Energy Institute and the three investor-owned utilities, we have access to the entirety of the residential electricity bills for four years. So from 2003 to 2006, I observed every single household's electricity bill for the roughly 80 percent of the California households that are served by the IOUs, so I know your electricity bill. The only thing I know about you, however, is which Zip Code you are located in, and how much you pay for electricity, and how much you consumed. I do not know your paycheck, I do not know whether you have an air conditioner or not, and I do not know how big your house is, which is something we would certainly like to know. We also did this separately for the households that get lower electricity prices due to the CARE Program, and we threw out weird households. By "weird households," I mean vacation homes, houses that consume less than 2 Kilowatt (kW) hours a month, and households that I like to refer to have small agricultural home productions, meaning up in the northern part of the states that have just excessive amounts of electricity consumption because we do not consider those representative. So we throw those out, and then we randomly sample from this dataset by Zip Code in order to get a representative sample.

Since I only have 15 minutes, we use all of the weather stations that deliver reliable data, and we match to each single electricity bill, meaning we have the beginning date and the end date for your electricity bill, we sort the average temperature of each day during your bill into a variety of bins, and count the number of days for each electricity bill your temperature has fallen into any of these bins. We do this for a couple hundred million bills, it takes a long time.

This map here shows the data coverage, so green here are Zip Codes which we have households with electricity bills for, the blue dots are the weather stations that we used in our econometric estimation, so we simply match each

Zip Code to the closest weather station and assumed that that weather station is the representative climate -- or weather -- for that particular Zip Code. I refer to letting the correlation between electricity consumption and weather vary across the state. We all know, if you have ever driven from El Centro to the northern end of the state to see some Shakespeare, what you notice is it is really hot and dry in the southeastern part of the states, and then as you get towards the coast and you drive past Santa Barbara, the climate is nice and constant, there is not much need for an air-conditioner at any time of the year, and this certainly holds true along the coastal stretch. So we would expect that how households respond to changes in climate or temperature varies greatly, depending on which one of these climate zones vary. And these are the CEC Building Code Climate Zones, and building codes vary across these climate zones, as well. So we do all of our estimations separately for each of these climate zones.

I am going to skip over 20 pages of statistics and just show you what this energy response looks like. So for each of these 16 zones, using different methods, we estimate how much in percentage terms electricity consumption per household goes up for one more day spent in any of these temperature zones. So let me look at Zone 7, which is the bottom left panel right here, it is roughly a flat temperature response curve right here, that is San Diego. So having gotten my PhD in San Diego, there is very little need for an air-conditioner in coastal San Diego down there. It is 70 degrees and sunny most of the year, as Dan can tell you, and air-conditioner penetration is very low. So at high temperature ranges, we would expect little increase in electricity consumption. Now, San Diego is interesting because we know a lot historically about San Diego electricity consumption, so a lot of the effects we think about when we think about climate change impacts on electricity demand comes from San Diego.

Let me show you another one. Zone 15, bottom left here, this is El Centro, right? So this is the southeastern part of the state, where what you see is at low temperature ranges, you see a slight drop in electricity consumption, that is if it gets warmer, and with cold nights you are less likely to use electric heating, which is scare in California, or you turn up your heater and you use the fans that drive your natural gas heater less frequently, so it is consistent with the drop here. But at high temperature ranges, you see a tremendous increase in electricity consumption. So the take away message from these couple of graphs here is that temperature response is very heterogeneous across California. The areas that are already pretty hot have a rather steep, non-linear increase in electricity consumption at higher temperature ranges than the areas in coastal zones. Now, if we link this to a climate model, here, we use the NCAR PCM model because that is one I have historically worked with, we basically take these response functions, do some proper matching with these households and Zip Codes, and simulate what electricity consumption would be 20, 40, 60 and 80 years out of sample. So linking the climate model, just to see what that looks like, here is the distribution of days, for six representative -- or maybe not representative -- pictures that looked really good -- locations in California, showing the change in the number of days in each of these bins. What you see for Imperial, which again is the southeastern part of the State, you see a huge increase in the hottest number of days, but across all the different locations here, what you see is you see right where it shifts in the number of days spent in each of these bins. So what you get is you get a higher number of days spent in the higher degree bins, and a lower number spent in the lower number of degree bins. The problem with, for example, Imperial, is one more day in the highest temperature bin in Imperial gives you a much higher increase in electricity consumption than one higher day in, for example, San Diego, or Los Angeles in the extreme heat, then, because the electricity response is much less sensitive.

So what this does, the pictures I am about to show you, it assumes that people who right now live in Santa Barbara are not going to buy additional air-conditioners, and it also is going to assume that the CEC and policy-makers in California are not going to pass any new appliance codes. So holding technology constant, and holding consumer behavior constant at the current state, this is what projected per capita or per household electricity consumption looks like over the next 80 years. What you see here is areas that are yellow or red denote increases in electricity consumption, areas that are green denote slight decreases in electricity consumption, but what you see by the end of the century, mostly the Central Valley and the southeastern part in L.A. areas of the state experience pretty significant increases in per household electricity consumption. This is the happy scenario, the B-1 scenario. The more scary A-2 scenario, which is the one with the higher degree of warming, if you look at the end of the century at the bottom right here, the Central Valley, Sacramento Area, L.A., and Southeastern part of the state, you see increases in some Zip Codes in excess of 60 to 80 percent of household electricity consumption due to warming. Now, per household consumption is interesting, but from a planning perspective, which is what this meeting is about, what is most interesting is what happens to aggregate increase in electricity demand. Now, this table has a lot of different numbers in it. The one I want to point out here is basically the first column that says BCC82 (phonetic) Equidistant, so the first column of numbers. That shows for the scenario that has high GHG emissions overall, we see from 2000 to 2019, we would expect a five percent aggregate increase in residential electricity consumption due to climate change over the 1980 to 1999 period, and by the end of the century, we would expect a 48 percent increase in aggregate electricity consumption from the residential sector due to climate change. Under the not so scary emission scenario, B-1, that overall aggregate increase is about 20 percent. So these numbers are significantly bigger than what other folks have found.

We also do some scenarios with prices, so here we assume a price response of residential electricity demand which we do not personally estimate, we have taken out of the literature of people who do this for a living and do a much better job than we could, so we assign each Zip Code a price elasticity or a price responsiveness of electricity demand based on average income there, and go through two scenarios. One is we let prices increase in 2020 by 30 percent, and then a second scenario lets prices increase again in 2040 by another 30 percent, just to put in perspective what the effect of higher prices would be. So the constant price scenario you just saw, that is that 48 percent increase in electricity consumption, if we let prices increase by 30 percent in 2020, and let prices be higher for the rest of the century, we see that the overall impact by end of the century is roughly 33 percent. If we let prices increase again by 30 percent from 2040 on, we see that the increase in aggregate consumption is about 18 percent by the end of the century, so cut by 30 percent.

Now, I want to put a word in caution in here. These are very optimistic price elasticities, more recent work by Severin Borenstein at the UC Energy Institute are used, that the price response may be much less than what the numbers are that we used here, potentially limiting the effectiveness of these price-based mechanisms. But this is very recent work, so we are still working on this. One last thing here is, climate change is important, but relative to population uncertainty, it is roughly minor, so we use the PPIC population projections at the county level out to 2100. We use three scenarios, .2 percent growth, .9 percent growth, and 1.5 percent growth. The high population growth scenario is equivalent to 120 million people living in California by the end of the century, which is, just to give you an idea of what that means, I do not know if we will ever get there. So the low population growth scenario with climate change, which is a .2 percent per year population growth indicates that electricity demand from the residential sector more than doubles, 113 percent; the medium population growth scenario, climate change and population growth, will lead to a 258 percent increase in aggregate consumption; and then that somewhat fantastic 120 million scenario, is that total electricity consumption will be 460 percent higher than it is in 1980 to 1999.

In the paper, we do a scenario bounding the worst and best case scenarios, stepping away from population and prices, again, just looking at climate change where we let the whole state look like San Diego and then we let the whole state look like the Central Valley to show what the importance of this temperature response function is. That is something that policy-makers can actually influence, which, if we let the whole state be like Zone 7, which is San Diego, there is no effect from climate change in this simulation, vs. if we let the whole state be like the Central Valley, aggregate increase in consumption would be 122 percent. So, depending on what this temperature responsiveness of demand is, it really has a great impact on what overall aggregate consumption is going to be.

Too many numbers? The difference between CARE and non-CARE households is not that great. CARE households are less responsive than non-CARE households, which has to do with their smaller households -- sorry, not necessarily less responsible, but the effects due to CARE households are smaller. CARE households are smaller and have lower penetration of these high consumption, high on gadgets is the story we are telling here, but they are not that different from non-CARE households which I did not find that surprising.

So in summary, heterogeneity matters. The take-away message here is energy consumption response to temperature is very heterogeneous across the state. The issue is that areas that are going to experience the highest degree of warming are also the ones that have the steepest response of consumption due to temperature, so if you just look at the average across the entire state, you gloss over that source of heterogeneity, so really treating the state as these separate zones and explicitly acknowledging that there are these different functional forms gives you a much higher estimated impact. One quick thing, what are these scenarios? A-2 and B-1 are the ones we looked at, the black line and the green line, in 2004, actual emissions were much higher than what we saw in this A-2 scenario. So right now, the A-2 scenario seems to be the most likely unless global efforts towards regulating climate change are truly effective. And what trajectory we are on, these are just the IPCC emissions trajectories for $C0_2$ right here, is going to greatly influence what the overall effects are here, and these are roughly beyond the control of California. All right? That is all I am going to say.

COMMISSIONER BYRON: Thank you.

PROFESSOR AUFFENHAMMER: Thank you.

MR. FRANCO: Thank you, Max. So we are going to have questions now. Before you ask your question, just identify yourself and your affiliation.

MR. McCAWLEY: Good morning. My name is Joe McCawley. I am with Southern California Edison (SCE). I have two questions. The first one is sort of a clarification. I am an electric guy, so I like to megawatts, I like megawatt-hours. The water guys and the thermal guys, I am not so sure. You use the word "demand" and you use the word "consumption," you use the words "aggregate demand." Are they synonymous with KWH?

PROFESSOR AUFFENHAMMER: Yes.

MR. McCAWLEY: Okay. With regards to the impact peak, have you done any analysis as to the consumption uses during the day, the impact that would have on peak and the correlation with that is in the potential impact on initial capacity. And I recognize what residential meters, there is no type of use, it is very challenging. I am just wondering if that was any part of your study.

PROFESSOR AUFFENHAMMER: So it is not in this study. We are currently working on utility level estimates using hourly load data and using weighted temperature, hourly temperatures to get the utility specific measure of peak. I know Guido and Alan have, for ISO, estimates of what the changes in peak demand are for the entire state, but we are trying to again say, you know, these service territories are so different. That would be an interesting question. The preliminary figures which I am not happy to write down yet look very consistent with what we are finding in this study, and for the utility you work for, they look rather sizeable, just because of where your service territory is.

MR. McCAWLEY: Sure. The other question I have is, you made reference from a price differential, referencing AB 32, and I think it was the CEC or the PUC, one of their analyses that prices would increase by 30 percent. My understanding is that that increase, 30 percent relative to now, is through now and 2020, so it is more of a gradual. And my understanding in reading your report is you showed it as a -- I think you used the word "discrete" which I think is the same as the step function in 2020, and then again another discrete 30 percent in 2040. I am wondering from an impact standpoint if you had given any consideration for the impact of a gradual price increase on consumption post 2020, vs. a step increase of 30 percent in 2020 to subsequent consumption?

PROFESSOR AUFFENHAMMER: I think that is a really interesting question and we could get into a long discussion about which is the right price elasticity to use here, so these figures we used are these short-run price elasticities that assume that you do not anticipate this increase in prices. If you can anticipate the slow gradual increase in prices, how you are going to respond to that is going to vary greatly. We were given this sort of stepped increase by 30 percent and we have not really done the smooth phase-in. I did a quick estimate using these same price elasticities, which are not the same ones, and the figures looked slightly slower, smaller, because you have got this gradual phase-in, but just from an algebraic point of view, unless you use different elasticities, the numbers are not going to look that much different.

MR. McCAWLEY: Thank you.

PROFESSOR AUFFENHAMMER: All right, thank you. One follow-up to your question is, we used demand and consumption interchangeably in the current version of the report. We have turned around and changed that to consumption in the paper that is going to go out to the academic journal.

MR. BARTHOLOMY: Hi, Obadiah Bartholomy with the Sacramento Municipal Utility District (SMUD), also I had a similar question on the demand question and in particular I have heard the presentation suggesting night-time temperatures will increase faster than day-time temperature, so I look forward to seeing the evolution of this paper with the hourly profiles. Also, it would be interesting to see service territory by service territory, what the impacts are. You mentioned much lower impacts for a San Diego type profile as compared to a Central Valley profile, and I am guessing that these numbers, in summary, probably understate impacts in the Central Valley?

PROFESSOR AUFFENHAMMER: Uh huh.

MR. BARTHOLOMY: So is that going to be better documented in the final version of the paper in terms of the regional impacts on --

PROFESSOR AUFFENHAMMER: We could, I mean, I have these results by Zip Code, so I could easily, you know, I can draw boundaries any way that is interesting. So if that would be an interesting scenario, I would be happy to just draw up these numbers.

MR. BARTHOLOMY: Okay, I know it is going to end up being a lot of numbers, but it would be --

PROFESSOR AUFFENHAMMER: No, that is a good suggestion. So we could throw that in.

MR. BARTHOLOMY: Thank you.

PROFESSOR AUFFENHAMMER: Thanks.

MR. DALE: Larry Dale, Lawrence Berkeley Lab. I should have asked you this a long time ago, but I am just curious to know if the projections in which you are comparing San Diego-like conditions with Central Valley-like conditions, have you looked at a scenario in which San Diego becomes more like the Central Valley, so that more customers have air conditioners? And is that a potential bias in the estimates? When might that be understating the facts?

PROFESSOR AUFFENHAMMER: So, again, the big target in this whole study is I keep things as they are for now, and then we do this sort of boundary -- bounding exercise where the whole state is like San Diego, or the whole state is like the Central Valley. What we are wanting to do next is actually really dive into what is driving this heterogeneity in temperature response by looking at income, looking at air conditioner penetration, looking at all kinds of factors that would, you know, from a behavioral point of view, fact how responsive your electricity consumption to temperature is. So what we are going to do is we are going to interact these response functions with, you know, air-conditioner penetration at whatever spatial level it is available and see whether we can separate out what drives this, and then do more intelligent simulations by saying, "What if air conditioner penetration goes up by 20 percent in San Diego? What would that do to the responsiveness and what would that then do to impact overall?" It is a trickier problem to do statistically because you have to keep track of more variables, but it is doable. So that will be next year.

MR. DALE: Thanks.

MR. FRANCO: We have time for more questions so --

PROFESSOR AUFFENHAMMER: Do you want to ask the online folks?

MS. KOROSEC: All right, we are opening the lines now for the WebEx folks, so if you have questions, all the lines are unmuted. Hello? Can you hear us?

MR. HALVORSEN: Barely.

MS. KOROSEC: All right, can you go ahead and identify yourself, please?

MR. HALVORSEN: I am Richard Halvorsen. I live in Yucca Valley, California, and I am with Energy Management Systems. And I did a different survey, not so much based on weather, but on appliances and how they are used. And I found that the swimming pools use a great deal of energy.

PROFESSOR AUFFENHAMMER: So your question is did we account for that?

MR. HALVORSEN: Yes, did you?

PROFESSOR AUFFENHAMMER: So implicitly, yes. Right? So I know how much electricity you use in your household, I do not know which use that comes from, so I cannot simulate explicitly what happens if, you know, the number of swimming pools goes up by 10 or goes down by 10 percent in the future; but it is in these response functions.

MR. HALVORSEN: Well, I did a study on one home, okay, in Yucca Valley. And his daily usage was -- it was 66 kilowatts per day and then I went in and I showed him the different things that he could do, he changed out the light bulbs, and then we got the usage back on the pool, and we reduced his average daily consumption by I think it was 25 kilowatts a day.

PROFESSOR AUFFENHAMMER: Wow, and then you could do solar thermal, too, which would, you know, you could heat the pool without using your --

MR. HALVORSEN: Well, making people aware of what uses what helps a lot, just to teach them. Most people cannot even figure out their miles per gallon, let alone their electricity bill.

PROFESSOR AUFFENHAMMER: Yeah, that is why we will get these nice in-home displays in real time metering and that will change all that.

MR. HALVORSEN: At what cost?

PROFESSOR AUFFENHAMMER: I do not know the answer to that.

MS. KOROSEC: Yeah, that is a little bit out of the scope of this --

MR. HALVORSEN: What is going to be the cost of it? That is something that we need to determine. Is it better to educate people? Or is it better to put it in and the utilities do it? And the state does it? I think it is better to educate the end-user.

MS. KOROSEC: Yeah. Thank you for your question, and we will certainly take that into consideration. Are there any other questions from the WebEx?

MR. HALVORSEN: Ma'am?

MS. KOROSEC: Yes?

COMMISSIONER BYRON: Dr. Auffenhammer, before you go, if I may ask one more question?

PROFESSOR AUFFENHAMMER: Yeah, of course.

COMMISSIONER BYRON: Very interesting study and I am quite concerned as you indicated about what may be the limited price response that Dr. Borenstein's work indicates, that and maybe another fact that we do not think about very much, and that is an aging population base tends to use more cooling, probably, than less. It is not just the installation of AC, it is what you set it at. So, very interesting study, not encouraging though in terms of the amount of electric use that is going to be necessary to meet the growing demand.

PROFESSOR AUFFENHAMMMER: Or it stresses the importance of, you know, educating people on how to use these appliances and making sure we have the most efficient appliances at a reasonable cost.

COMMISSIONER BYRON: Which leads to another question. Did you assume all the installed efficiency -- I believe you said early on that you did not, that you held everything constant.

PROFESSOR AUFFENHAMMER: So right now it stays constant, so there are no -- so in the estimation, we allow for these unobservable trends, but we did not assume any additional improvements in efficiency. So if you assume additional improvements in efficiency on top of what is already happening, you would have to -- the estimated effects would come down.

COMMISSIONER BYRON: Well, we look forward to more work in this area. Thank you.

PROFESSOR AUFFENHAMMER: Great, thank you so much.

MR. FRANCO: Thank you, Max. Very interesting presentation. The next presentation is by Professor Jay Lund from UC Davis. I think like three years ago, I [indiscernible] to Professor Jay Lund. The energy information on this puts the real deficit on monthly hydropower organization by different units in California, actually, all over the United States, and asked him to take a look because we may -- I thought we may be able to use it to estimate the potential in passive climate change on high and hydro power units. So we will hear about that now.

PROFESSOR LUND: Thank you, Guido. Most of this work was done by Kaveh Madani and, as you will see, we also have a lot of collaborations we have had with the Berkeley Group, particularly Sebastian Vicuna. This data set he sent was really kind of interesting. It is kind of fun to look at a dataset and see what you can do with it and the question was, well, how do you look at hydropower in California without looking at every one of the 150 plants that is out there. There are like 150 to 400 plants that generate hydropower in the state. And so what we came up with was a quasi-statistical, quasi-engineering approach, where -- based on conservation of energy, rather than conservation of mass. So that is the initial result that I show here, but I think the conclusions are pretty robust, no matter which approach you take. And I think Professor Dracup's presentation will emphasize that, as well. I want to cover just a couple of things here today, a little overview of hydropower in California. In California, we have two major types of hydropower systems here. The low elevation hydropower systems that come out of Folsom and Shasta and Orville, from the big water supply reservoirs that are lower down, and then we have the high elevation system which is run by Southern California Edison, and PG&E, and SMUD, and a few others. And these are very different kinds of systems. Here is a picture of a high elevation plant, it was a picture taken in 1929, again, also indicating that many of these plants are really quite old. They were established for decades. This is a very high elevation plant that you will notice the huge pen stock, the huge distance of pen stock between the turbines and where the water is dropping from. The big difference with Folsom is you have the turbines right by the plant and they are very much affected by the water elevation.

Here, the elements of this hydropower system, we have got the high elevation power plants up here, we have the low elevation hydropower system with some pump storage that, I think, become more important over time. We have imports of hydropower, very important imports of hydropower from the Pacific Northwest and a little bit from lower Colorado River. I think Alan Hamlet is supposed to give a talk later today about this, which I am excited to hear. This is a very important component. The power demands, again, nice presentations earlier, a very important aspect because hydropower operates to respond to power demands, and so as you change the shape of the power demands, there will be a nice curve -- from the presentation by Professor Dracup -- that shows the hourly price distribution of power, and then some ability to store water in aquifers, which can change the demands for power. Just to give you a general sense, here is total hydropower of about 25,000 gigawatt-hours per year in 2004, out of 275. This is broken down between a high elevation of about 25,900 for low elevation, we get some out of pump storage, but another nine comes from the Pacific Northwest, and then compared to all renewables, it is pretty large. So this gives you a general perspective on where hydropower fits and the different hydropower elements in California.

So there are a lot of different kinds of climate change effects that you can on hydropower, energy demands and prices, just those changes alone will drive how hydropower operates. The timing and availability of water, certainly, we talked a lot about the accelerated spring snowmelt and things like that. The quantity of water available, if it is drier, there is less fuel for hydropower plants. You know, they are fueled by run-off, so if you look -- all the studies will agree on this, that the hydropower production on an annual basis is directly proportional to the amount of runoff. You can be a trained monkey to do that model.

The availability of hydropower import, I think this is an unrealized importance so far. We add a little bit of thermal generated efficiency that will affect hydropower demand, things like that. And I think another neglected element that we have not studied so much, although we are doing some of that work at Davis now, is to look at the environmental sensitivity of hydropower operations when you have a warmer climate and you are less able to maintain cold water pools downstream of hydropower facilities. We think there might be a looming regulatory problem there. There have been a whole bunch of climate and hydropower studies, certainly at the low elevations. Some folks from my DWR, and we have done our own stuff with our water supply model, CALVIN. High elevation studies, you will see some examples, U.C. Berkeley for the SMUD System, and then the Southern California Edison System, you will see some slides from our results for state-wide, this little model we call the EBOM, Energy Based Optimization Model. Work on imported hydropower availability at the University of Washington, and then electricity demand. There are a lot of studies. I mean, fortunately, we have learned some things out of these. For the lower elevation hydropower, you can see this with a dry planet warming, a paleodrought, we took the worst thing that is on the paleo record and we ran it through our CALVIN model to see what it does to hydropower generation, and you will see that, on balance, for the low elevation system, we have a lot of storage. And we tend to release water from the low elevation system for water supply purposes, so it does not matter very much for that low elevation hydropower when the water arrives, it matters when we release it for water supply purposes, and that is when we generate the power. We will, of course, be reducing the amount of power that is generated if it is drier, so it is very sensitive to the warmer or drier aspects of climate change, but not very much to the seasonal shifts because these reservoirs are so large. This is just another way of showing that.

On to the high elevation power systems. You can see all these blue dots there, there are almost 160 of these plants all over the state. The snowpack helps them out a lot, but they tend to be fairly high head, very little head storage effect on the energy generation. The storage mostly shifts -- allows you to shift water releases from the winter when the releases are less valuable, to the summer when you have those seasonal peaks for air-conditioning, that have a lot more economic value to them. This gives you a sense for how the elevation matters and the inflows to these reservoirs, the green plot here is the lower elevation and then, as you get to higher elevations, you get later snowmelt. Of course, with climate warming, you will look forward to seeing some of that accelerated, or we will not look forward to that being accelerated, as the case may be. But here are some results from the EBOM model of 137 of these 156 power plants, using modified hydrologies from 1985 to 1998, modified for different climates. So again, you can see historic generation patterns. Where we have a dry form of climate warming, you will see that there is generally a lot less hydropower production during the summers and spring, but we see it pick back up during July and August, that is trying to pick up that peak economic value for energy peaks in the hottest part of the season for the air conditioning. So what you will see in our modeling results, and I think the results from Berkeley, as well, is that we are pretty much able to get the worst of it when the energy demands are the highest economic value, it is the rest of the time of year that we see the greatest effects. With a wet form of climate warming, you will see a lot more hydropower produced in most of the season, except for maybe the summer here, and warm only is sort of a balance. In terms of total productions, just to compare the dry scenario that we ran, which had 20 percent less flow, it is important to notice that, when we talk about drier, you could have maybe 5 percent less precipitation cause maybe 10 or 20 percent less runoff, just because of the nature of evaporation up in the watersheds. So it is important when you hear "drier," and if we are talking in precipitation terms, it is very different than in terms of run-off; a small change of precipitation can create a much larger change in run-off. So when we had a 20 percent reduction in run-off, we had about a 20 percent reduction in generation. When we had a 10 percent increase in run-off, we have a lot more energy still, so we only had about a 6 percent increase in generation. You can see the spill changes here -- when it is drier, we have less spill; wetter, we have a lot more spill because most of the reservoirs are designed not to spill in the average year. And in terms of revenues, you will see a muted effect, so we could lose 20 percent of the run-off, 20 percent of the production, and only lose 14 percent of the revenues; with 10 percent more run-off, we only increase generation 6 percent, and we only increase revenues a little over 1 percent. So those are important things to bear in mind. And, of course, if it is warming only with the same amount of run-off, we see it is definitely inconvenient for us in terms of generation and in terms of profitability, but it is not horrible like having it drier, as well. Here, you see some earlier -- shows you storage, much greater spill, essentially energy loss from the system. And this is an interesting slide, too. There is often a group of people that are interesting in expanding capacity, expanding surface storage and things like that, and I think this is an interesting curve. For each of our models, each of our 137 hydropower models that we looked at, we can look at what is the value of increasing the storage capacity for those systems. And so what you see here is sort of the ranking of those 137 plants, from the lowest economic value of expanding storage to the highest for these four different climate scenarios. And so you will see the thin solid line here is with the current climate, and then, as we change it to a warm-only climate, you will see some greater value many plants -- certainly not all of them, but in many plants for being able to capture some of that increased winter run-off for use during the summer when you have higher energy values. Certainly, if it becomes wetter, you certainly value storage more because you think there is more energy out there to capture during the wet season to pull over to the higher valued times of the year. And when it is drier, you will see really a decrease for many plants of the value of storage expansion from what it is today; and then, for some other plants, you probably are closer to spilling more than the average year, some greater value for increasing their capacities. I think that is a pretty important thing to look at, that it is not going to be homogeneous across the state.

Some overall conclusions. Warming will shift snowmelt to winter and reduce total runoff to some degree. Precipitation changes are less certain, I think, in our estimation. These drier conditions tend to proportionally reduce generation; wetter conditions produce lesser increases in generation, predominantly because of increases in spills during the wet season. Warming alone affects generation mostly by increasing evaporation, evaporation upstream. And less by seasonal shift of inflows. I think this is something we have an agreement in all of the studies at Davis and Berkeley. Seasonal flow shifts -- the more we increase spills that reduce generation a little bit, they reduce revenues a little bit more. Energy crises and reduced availability of hydropower imports from the Pacific Northwest actually might be the most important hydropower effects that we see. The in-state system actually has a fair bit of robustness to it. And storage capacity often becomes less valuable with drier conditions since reservoirs fill less frequently. Imagine the value of expanding the number of garage space you have in your home when you have sold off one of your cars. This is the kind of thing we will see if we have a drier climate, that in many cases, storage will become less valuable than it is today. Thank you very much -- and to a lot of people that helped us out.

MR. FRANCO: Thank you very much. Before we go to the questions and answers, we will have the presentation by Professor John Dracup, also looking at the potential impacts of climate change on high elevation hydropower units. His group at Berkeley uses a different approach; they use an engineering economics approach that compliments very nicely the work done at U.C. Davis.

PROFESSOR DRACUP: Thank you, Guido. It is a wonderful pleasure to be here. And as you can see, my talk is on the impacts of climate change in high elevation hydropower. One of the interesting things about the differences in these high and low elevation systems, as Jay alluded to, is here we have plotted the useful reservoir storage across the X axis, and the capacity of elevation storage. And you can see the ones below 1,000-feet are much larger, and this is for California. Also, something Jay alluded to was that the low elevations are more likely to be multi-purpose systems, that they are going to have water supply and, besides hydropower, they are going to have recreation and flood control, etc. However, looking at the energy production here, and by elevation, you see that the high elevation stations disproportionately generate more electricity than the lower elevation stations. So this makes them very valuable, of course. And also, as someone else mentioned earlier, because these high elevation stations can be held in reserve, as you will see later on, that they can be used in the afternoon peak power time periods, electricity is very valuable, of course, from noon to 8:00 p.m., but as the Vice President of Southern California Edison once told me that, between midnight and 6:00 a.m., you cannot give away electricity. In fact, he said that at one time the prices even went negative, they would pay you to take it. So, again, we have this reserve ability of the high elevation hydropower for the peak time periods, so it is much more valuable.

So our study looked at this upper American River project, which is owned and operated by the Sacramento Municipal Utility District and then the famous Big Creek system on the Upper San Joaquin, it is owned and operated by Southern California Edison. And the Big Creek is a lower elevation than the one on the American River. And what we see here on the left is the one on the Upper American River Project, the one on the right is Big Creek. And we have -- for some reason, the four scenarios are not showing up on this slide. They are in the print-out. If you look at your print-out, on the 6th slide, you will see that the black line is the historic and the next line down -- I do not know why that did not show up -- so the next one down is early in the century, the next one is the middle, and then the late century. And what you see here, of course, that many studies have shown, particularly by Dan Cayan, that the hydrograph is moving towards January. We move from the historic in the black here to hydrographic peaks earlier. And so on the left here, on the American River, you get more spills earlier in the year, and less water later in the year. And to me, this is the take-home message in climate change in California. If you get one thing out of my talk, and other people will verify this, many studies will verify this, that we are going to get more water earlier in the spring when we do not need it, and less water during the heavy irrigation season later in the summer when we do need it. So we will need some storage, and that is, even as Jay showed, we may need more storage in the wet times because of these earlier spills. And this is very important. You see on the Upper American River here, it is impacted more than the Big Creek System. I was recently talking to some researchers at U.C. Santa Cruz, and they were talking about a strategic groundwater reserve, which I think is a brilliant idea. It is an old idea, really, they used to call it Safe Yield, or Sustainable Yield in groundwater. But just think if we were to turn San Joaquin Valley into a strategic groundwater reserve for droughts and for the storage we will need during these climate change scenarios. Here again, on the left column we have the Upper American River, on the right, Big Creek; we see here, we are going to have reduction in releases in the summer, here, the scenarios came in. Increases of spills in the winter for the Upper American, reduction in spills in Big Creek. And the summer storage is mostly unaffected. This is one of the interesting things about high elevation hydropower. If you could go over Tioga Pass, for example, in the national park, the forest service wants Southern California Edison to keep those reservoirs full and they can hold them high elevation and wait until the high price peaks in August. You remember the price of electricity varies not only daily, but also through the year. So in the high air-conditioned season in August, prices are high and hydropower becomes valuable because they can save that energy for that time period.

So conclusions, hydropower generation drops in most climate change scenarios. As the climate is drier, hydrological conditions, especially in decreased and increased spills, especially the Upper American River. In fact, these earlier inflows associated with increase in temperature is more evident in lower elevation systems; and in most circumstances, these high elevation systems are able to keep their power capacity close to matching levels during the late spring and summer months because they really -- the system does not need that water. Because these tend to be single-purpose systems, they are energy driven and you can save the money.

I would like to acknowledge these people that helped, of course, Guido and the California Energy Commission. One thing I would like to say, just in closing, since I do have time, is that one thing you do not hear discussed in the climate change scenarios is innovations, and I was having lunch the other day with one of my daughters and her 10-year-old daughter, my granddaughter.

And Marcella, the granddaughter, had a little Mac Computer, white, of course, laptop, we were at lunch and she is taking pictures of me, she can take pictures of me, and then she can manipulate them and she said, "Look, Grandpa, look at this picture," you know, it looked like a funny mirror in the circus. So I was thinking back to when I was 10-years-old and I want everyone in this room to think when they were 10-years-old, and where we were, and I will not tell you how old I am, but we had the radio then -- I actually came to the West Coast in 1948, and you speak of the innovation, that we did not have Google or Tweeter (sic) back then. So this innovation is coming along that we cannot imagine, and how that is going to change this whole -- the way we look at climate change, and how it is going to impact us, well, too much uncertainty, we cannot tell. So thank you very much.

MR. FRANCO: Thank you. So now we have time for questions for both John and Jay.

MR. BARTHOLOMY: Hi, Obadiah Bartholomy again. This is a question for Jay. On your look at the value of storage for different reservoirs, did you consider the year to year variability in the water supply? And specifically I am reminded of a number of presentations that predict increases in variability in annual available runoff as a result of climate change, and I am just curious whether your analysis took the typical year, or whether it actually looked at a good year.

PROFESSOR LUND: We looked at a range of 15 years, so we had some wet years and some dry years in that. Most of the high elevation system is run as within year storage. I think SMUD might have some over-year storage. Lake Almanor has over a year storage. But for the most part, it is a seasonal storage system, so either you are done or you do not, you do not carry it across years very much. So, yes, we did have a range of wet and dry results, and the average value of storage when you are making a capital investment, you want the whole range of wet years and dry years in there, so that is what we have. It is not as wide of a sample as I would like, about 15 years, and as you are aware, that is not a very large sample in hydrologic terms. But that is all we have got.

MR. BARTHOLOMY: Okay, and a second question is related to hydro-relicensing. First, just a comment that you mentioned that there was a lack of data available on some storage and flow data, and I think the between your paper in part capitalized on the fact that SMUD was going through hydro-relicensing, and that a lot of that data public, so just to comment, I think for many in the system, some of that data will be public.

PROFESSOR LUND: Actually, you are right. There is a lot of data, but it would have taken us forever to gather up all that data and to make it into a model for each individual system. We wanted a way to get a quick study of the whole system, rather than be mired forever.

MR. BARTHOLOMY: Just a question related to hydro-relicensing, do either of you have a sense of at what point these modeling and research reports would start to push folks that are going through re-licensing processes to actually use this information in their projections of future year conditions for operations in their facility?

PROFESSOR LUND: We do have a project with data, precisely that, and we will be coming out with some reports in the coming months.

MR. BARTHOLOMY: Okay, great. Thanks.

MR. McLAUGHLIN: Bruce McLaughlin with the California Municipal Utilities Association. I have a question, a clarification, or help me understand your graph on the extending storage on page sixteen. I definitely heard the message from the second presentation, new storage would be a good thing and --

PROFESSOR DRACUP: Well, it has benefits. As someone who studies reservoir operations, you would never forego free storage. If someone is going to build you extra storage for free, you always take it.

MR. McLAUGHLIN: Is it possible to pull up slide 16 so you can help me understand how to read the graph as dollars per year per what hour.

PROFESSOR DRACUP: Right. So we look at storage in energy terms, so it is in terms of megawatt-hours of storage capacity, rather than acre/feet. So we have 137 power plants and we just took the value of increasing the storage capacity related to those plants, and sorted them by size. So for some of the plants, the lowest values we found were zero, you know, a plant where it never fills anyway, you do not have any value to expanding it. Plants over here, they might fill up every year and you would like to store more water in them to carry that energy over to the summertime when the energy crisis is much higher. They would tend to have higher values. Yeah, these shadow prices look at multipliers, if you are a geek.

MR. McLAUGHLIN: And a second question, you were talking about higher elevation and lower elevation, and it sounds like the higher elevation has more value at peak times. Does this data also go towards larger reservoirs and smaller reservoirs here in California, you know, that anything above 30 megawatts is considered a pariah and you think less than that is possibly renewable, so can some of this data -- or does it show anything scientific-wise or engineering-wise that a larger reservoir would be as beneficial in increasing storage?

PROFESSOR LUND: Well, I think you have to look at -- every reservoir is unique, I think, as a person that studies these things. One of the things that I asked Kaveh Madani, who produced these numbers, to do with this graph, I just asked him last night, was to go back in and see if he could find any geographic pattern to where it tended to be the higher volumes of storage, and where it tended to be the lower volumes of storage.

PROFESSOR DRACUP: I think people talk about storage and dams and they, oh, we are blocking the salmon, but I think the future in California will be the pump storage system, it is like the Diamond Valley one that is owned by MWD out by Riverside and LADWP has one between Cascade and Pyramid Lake, etc. I think there are about nine of those systems. So they are going to be offline or offstream, and the sites is the one they are talking about, that is near here? Sites, yeah. And by the way, looking at this slide, this is one of the brilliant things about Jay's study is that those of you who know linear programming, you have prime and the dual, and so what you are showing here -- it has not to do with the value of the resource, but it is actually the value you get for doing this, it is called the shadow price, as you mentioned.

PROFESSOR LUND: I want to just follow-up on pump storage. Thank you, John, for bringing that up. I think in terms of expanding storage, that is probably the major area I would look towards, schematically.

MR. McLAUGHLIN: Thank you.

MR. FRANCO: Do we have more questions from people from WebEx? Um, maybe I will ask a question. Right now, while you are studying these systems, these two disconnected systems, one is low elevation and the other one is high elevation. Is there a need to connect both as a unified model or system?

PROFESSOR LUND: I think so. Some years ago, PG&E developed a huge optimization model called Socrates, then looked at -- I think it looked at both their hydropower system and their thermal power system. You really want an energy model, not a water model, for much of this -- integrated energy model. And I think that is the kind of thing that would be useful to look at. There are various people out there that do those kinds of things and I think they might be useful to look at a whole range of policy issues regarding energy, including climate change.

MR. FRANCO: Okay, questions? If you are participating via WebEx, you have an opportunity now to ask questions.

MR. DALE: Larry Dale, Lawrence Berkeley Lab. On the question of the need for new storage, and, Jay, you were just talking about this, but I guess I want to phrase the question to make a point; it seems to me that the hydropower studies that we were looking at, Jay's technique is a really useful way of summarizing the impact of certain kinds of changes on the value of hydropower caused by climate change, and the more limited studies that Sebastian and John and I were working on were focused on particular basins, and tried to put together a simulation model. And I think we really only began to get the kinds of differences that might appear between a broad scale study and a narrow study. And maybe one of the questions I have is, in your opinion, would the conclusions about the storage change if climate change would bring more variability in future rainfall? I do not think we really looked at that. And also, would the conclusions change if the peak period pricing for electricity got -- the duration of peak period pricing, high prices -- was larger than it currently is? My understanding is that high elevation -- well, actually hydro in general is often focused on making releases during the peak power periods when electricity is most valuable. And might this change if there is changes in variability like that?

PROFESSOR LUND: I tend to think -- and John might have different thoughts on this -- I tend to think that the effect on the breadth of the seasonal peak is probably the most important issue. We certainly have -- I think August is sort of a bigger -- biggest peak now seasonally; if you had two or three months of August, I think then you would have a tremendous value of storing water from the wet season to the dry season in terms of incremental increase in the value of that resource. And it would depend on how many hours per month you could do that because sometimes you can make up that peak with pump storage, but if it is a broader peak than that, then you would like to actually move water seasonally. In terms of the intensity of flows, say big storms vs. small storms, I tend to think that -- my impression now is that the amount of storage capacity that currently exists is pretty good for smoothing those over, from a hydropower perspective; from a flood control perspective, it may be different, but certainly from a hydropower perspective.

PROFESSOR DRACUP: Yes, and so much is driven by air conditioning, of course, and if you have that broad peak. I have a sister -- I grew up in Seattle, which is not known for using air conditioning -- but my sister lives in a suburb and just recently put air conditioning in her house, I was amazed. So obviously we are going to have -- this is a small sample, I realize. But we are going to have more air conditioning. Maybe even in San Francisco where I live.

MR. FRANCO: Do we have more questions? Additional questions? No, okay. So now we have time for a break. We will be back here at sharp -- 11:00. Thank you.

[Break at 10:47 a.m.]

[Back on the record at 11:01 a.m.]

MR. FRANCO: The next presentation if by, uh, Professor Alan Hamlet from University of Washington, and he is going to let us know how much power we will be able to import from the Pacific Northwest for -- in the rest of this century, and hopefully it will be a lot. So, Alan, please go ahead. Oh, Alan will -- is in Seattle, Washington, so he is giving his talk remotely via WebEx. Alan?

PROFESSOR HAMLET: Alright, thanks, Guido, very much. Can everybody hear me alright?

MR. FRANCO: Yes.

PROFESSOR HAMLET Yes, okay, very good. Most of what I will be presenting today is part of the Washington State assessment that the Climate Impacts Group did recently, and the full report is available on the Web, with a lot of other information, as well. So in 15 minutes, I am really going to be giving you the Executive Summary and I hope you will follow-up with details, as needed. So the Washington State assessment, I looked at the IPCC AR4 scenarios, which I believe Dan showed you for California, but looking at Washington State. And there were a number of sectors in the study which are shown on this slide, one of which was energy production. So the energy assessment really looked at just two main factors, how much water and energy will be available to the Columbia River Hydro System, and then also how will the basic powers of demand related to residential and light commercial energy demand for electricity change.

I first need to tell you a little bit about the scenarios, not too much as I think you are fairly familiar with these approaches already, and have seen similar assessment for California, earlier this morning. So here are the projections from the AR4 for the Pacific Northwest Region, which is, of course, the Columbia River Basin is contained within this region. So in the top panel, we see changes in temperature for two emission scenarios, in red going into the future from 2000 to 2100, we see the red is the A1B scenario, which is a kind of medium scenario, not the worst case, but fairly aggressive. We see increasing CO_2 right to the end of the 21st century, with some mitigation. The yellow shows the D1 scenario, which contains considerable mitigation by mid-century, and by the end of the 21st Century, we are really starting to stabilize the climate. And the ranges of uncertainty that you see in these figures represent the 5th percentile to the 95th percentile from the model simulations for the 20th Century, and then the same bands going forward in time. So, as you can see, mitigation and what we assume about emissions scenario plays a really big role in how things play out at the end of the 21st Century, so the difference between the A1B and B1, for example, is about almost two degrees C difference in warming. But by mid-century, not really too much change. So mitigation plays a huge role in how things will look at the end of the century, but for the next few decades, the two scenarios are not that different, suggesting that we have really got to think about adaptation in those timeframes.

You will notice the difference between temperature and precipitation. For temperature, we have a really high signal to noise ratio, even for the mid-21st Century, we are well outside the range of our experience in the 20th Century, both for the mean and for most of the variability, as well. For precipitation in the lower panel, we see a very different picture, at least on an annual basis not too much change in the Pacific Northwest, and there is a lot of noise from inter-annual and inter-decadal variability, which we expect to continue perhaps differently in the future. So what we are likely to see is that, in any given future decade, we may see warmer and wetter, or warmer and drier conditions, and that these things will play out with much more certainty about the temperature impacts than the precipitation. Now, that said, the precipitation effect, we do see wetter winters and drier summers in the Pacific Northwest, which we will see have some important implications.

So using these scenarios, to move forward, looking at the Columbia River hydro system, the system flat sort of flies about 70 percent of the region for electricity, and is primarily responsible for the relatively low cost of energy in the Pacific Northwest, and it strongly affects local energy supplies at the utility level and below, and of course it is strongly influenced by climate. Just to make the case that what happens to the Columbia River system affects the local scale, this is a snapshot of Snohomish County DUD, and currently they have 88 percent of their energy source comes from the Bonneville Power Administration, some of that is not hydro power, but nonetheless, if we see such substantial reductions in the Bonneville Power's basic load resources, this utility is going to be very strongly affected, and that is pretty much true across the Pacific Northwest.

So if we take those temperature and precipitation changes that I showed you, and I am really only going to show you the A1B scenario, just in the interest of time, but we did the same analysis for B1. And so what is shown here is the hydrograph of the Columbia River at The Dalles, Oregon, which basically integrates the entire basin. The dark blue line here shows the 20th Century or historic hydrograph, so this is a very strongly snowmelt dominant basin, not too much flow in the winter time, and then we have this big peak in the spring. As we move forward to the 2020's, 2040's, and 2080's, we see gradually increasing stream flow timing shifts, and this is pretty much true across the west, but in a snowmelt dominant basin, what happens when you warm it up is we get more flow in the winter time, earlier peak flows, and less flow than in the summer time. And we see that pattern getting more and more pronounced as we go through the warming to the 2080s. So if we project this forward, then, using another simulation model to understand the effects on energy production, that is what is shown here, so this is system-wide energy production simulated by the CalSim (phonetic) model, using those stream flow scenarios I just showed you. And so this simulates the effects of all the dams and the basic elements of the reservoir operating policies that are currently in place. So what is happening here, not too surprisingly, as we see those timing shifts, we see increased energy production in the winter time and strongly reduced energy production in the summer time. And you will notice that the changes are very strongly focused in sort of key air conditioning months, here in the summer time.

Now, all those simulations that I showed you, they assume that the natural variability is not changing with global warming, so those are averages looking over a long period of time, essentially 90 years of record; however, if we look historically at the changes in variability for hydropower production across the Western United States, so what I am showing you here is traces of system-wide annual hydropower production from 1917 to 2003, in this case, right at the Pacific Northwest, the blue is the Sacramento/San Joaquin System, and then from the Colorado is the green. You will notice there have been pronounced changes in variability since about the mid-1970s which show increased variance and increased synchronaeity of the two systems. So we have not included this and there is actually no firm evidence to date that these changes in variability are directly related to global warming. But it makes the case that, if we have changes in variability, they may also feed into the impacts in surprising ways. What this shows is that, when we have a dry year, or a wet year, in California, we typically also have the same conditions in the Pacific Northwest, which means that we do not have much ability, at least in this 30-year period, for buffering the two systems by playing off the variability in different regions.

So the main conclusions. By the 2020s, the regional hydropower production in the Pacific Northwest is projected to increase in winter by about 4 percent, decrease in summer by about 10 percent, with annual reductions of 1-4 percent. This gets progressively worse with reductions in summer production, about 15 percent by the 2040s, and by the 2080s, almost a 20 percent reduction. And, as I mentioned, the largest and most robust changes in hydropower production are projected to occur through June through September during the peak air conditioning season in the west.

So part 2. We looked also at how did the primary energy demand for space heating and cooling needs change. So this is a fundamental driver of residential and light commercial energy demand in the Pacific Northwest, strongly influenced by climate, and we looked it affected by heating and cooling degree days as the primary driver. And, as you can imagine, it has important implications for individuals, utilities and also high level planning at the regional and state level. So as we warm the climate, what happens not too surprisingly in the heating season is we have decreases in heating degree days, so this figure shows both historical and then 2020s, 2040s, and 2080s for the A1B scenario, which is considerably warmer at the end of the century, and the B1 scenario. So as we move through the 21st Century and the warming is continuing, we are seeing systematic reductions in heating degree days. The flip side, of course, is that in the summer time, we have increases in cooling degree days. So, again, historical 2020s, 2040s, and 2080s were the two scenarios, let's just look at the A1B in the top row since that is probably the most plausible of these two scenarios. You can see that, for the historic condition, we do not have too many cooling degree days in the most populace areas of the Pacific Northwest, which are particularly along the I-5 corridor here, but as we move forward into mid-century and beyond, we start to see significant amounts of cooling degree days appearing in these populated regions, and particularly for the 2080s, we start to see some significant amount of cooling degree days. And using relationships between cooling degree days and air conditioning penetration at saturation for a number of U.S. Cities, this is from a study by Sailor, et al., so looking at this lower figure, this non-linear relationship between cooling degree days on the X axis, and the air conditioning saturation, we can estimate how much we have changing in the Pacific Northwest. That is shown here, which shows the air conditioning penetration, again, for historical -- you will notice we have very low penetration, we have assumed 8 percent as a base level, but moving forward through the 21st century, we see increasing air conditioning penetration, particularly in these high population regions near the I-5 corridor.

So if we summarize this by dividing multiplying population in each of the locations by the number of heating and cooling degree days, we can get an index for how things will change. So this shows the average heating energy demand, which we assume is population X heating degree days. If we just have changes in the climate alone, that is shown in the green bars of the figure, so as the heating degree days go down, individual energy use for heating goes down; if we just include population alone and keep the historic heating degree patterns, and we see these white bars, that would be increased. So the combined is sort of somewhere in between the two, but it turns out that population wins, and so we have actually some pretty significant increases due to population, despite the fact that the heating degree days are going down. So at the utility level, we are seeing increasing demand, despite the fact that consumers actually may see reductions in their bill.

For the largest effect, at least in terms of percent, is to look at the residential energy for cooling. And what is happening here, so for population alone, we see these relatively modest increases because most of the population does not have a lot of air conditioning penetration currently, or cooling degree days. But as we move forward, there is this simultaneous effect of warming, population growth, and increased air conditioning penetration, which produces the red bars. So by the end of the 21st century, we see really dramatic increases in the amount of residential cooling demand of almost 20 times what we had seen historically. Now, if you put this in context to say that this is not a huge number, you know, currently about one percent of people's energy use at the residential level is related to air conditioning for Washington State as a whole. But by the end of the 2080s, we might see this climb to as much as 10 percent. So it is a significant effect, but I think it will come on more strongly in the end of the 21st century. For commercial energy production where we have pretty much 100 percent air conditioning penetration, then we have less.

So just jumping to the conclusions. We also see likely changes in peak demand in the Pacific Northwest, just related to the fact that we have increasing air conditioning penetration. You can see this pretty clearly by comparing the relationship between maximum temperature and maximum load during the day in the Pacific Northwest, and in Northern California. So we expect to see increasing peak demands going along with the sort of systematic changes in average, as well. So despite increasing in heating degree days, we start to see annual heating energy demand to increase with population, and we see radical changes in residential and commercial cooling energy demand, particularly towards the end of the 21st century.

So to finish up, there are a number of important inter-regional coordination issues. The combination of losses of summer energy production from the Columbia River Hydro System, combined with increasing load in the Pacific Northwest, is very likely to impact the ability to transfer energy to California and the Southwest in the spring and the summer. Development of other energy source technology, particularly if it were solar or wind, could potentially mitigate these impacts, but for the system method it is now, it certainly seems to be that, very likely, we will have less energy to shift south. Interestingly, depending on the future energy development choices in California, we may see increased capacity in California that is not needed in the cool season. And this suggests that there may actually be some important opportunities to move energy from the increased capacity in California and the Southwest in the wintertime. So these are some interesting ideas, I think, that are starting to emerge, as well. Thank you. And I will stop there.

MR. FRANCO: Thank you, Alan. So now we have time for questions and comments.

MR. McCAWLEY: Joe McCawley with Southern Cal Edison. And these are probably more just from my increased understanding. The studies or the scenarios, I am not quite sure the way you phrased it, was A1B and B1, and the earlier presentations, I believe, they did A2 and B1. I am wondering if you can give a reason, and I do not fully understand -- this is the first time I have seen B1 and A1, and A2, with these. So I am trying to get a better understanding, but I believe A2 is more drastic than A1B, and could you give a reason why you would have done A1B as opposed to A2, as the others have done?

PROFESSOR HAMLET: There were two reasons that we choose A1B and A2 and A1B are not hugely differently, particularly in the sort of mid-21st Century region. But there was a larger difference between B1 and A1B in the middle of the 20th Century, so there was some reason to include them because of mitigation effects potentially having some influence in the middle of the 21st Century. Secondly, A1B did include some amount of mitigation towards the end of the 21st Century, where A2 sort of minimizes that in its outcome. So we felt it was important to show how that would affect it and going forward. A1B is sort of a medium scenario, too, where as you mentioned, A2 is a little bit more regressive.

MR. McCAWLEY: Okay, thank you.

PROFESSOR HAMLET: I hope that is some help. These are somewhat arbitrary. We chose those two as presenting a reasonable range.

MR. McCAWLEY: I guess part of my thought process is, when I compare your results to some of the other results, is it fair to equate your A1B results to the other A2 results? Or I really should not do?

PROFESSOR HAMLET: You know, I think one thing to say is that these are scenarios rather than forecasts, and I would not get too hung up on, you know, how do the numbers differ from each other because, you know, there is great uncertainty in how the emissions will actually play out. So I think it is more important to look at the general conclusions. And I think if you look at the general conclusions for A2 and A1B, you would not see anything fundamentally different about those conclusions.

MR. McCAWLEY: Okay, thank you.

PROFESSOR HAMLET: The numbers notwithstanding.

MR. McCAWLEY: Thank you. The other question I have has to do with -- I think the slide that is your second to last slide where it makes reference to peak electrical demands in summer.

PROFESSOR HAMLET: Sure.

MR. McCAWLEY: I am trying to get an understanding of, I guess, what -- I understand warmer temperatures = more air conditioning, but will the peak increase because -- and this is residential, so I also am trying to think, well, is residential low, but many residential people are at work during the day, trying to figure out when is the peak of the day. Are their air conditioners set automatically so they are going to be turning on and affecting the peak if it is a day-time peak while they are work? Or is this -- they come home, they then turn their air conditioning on at home, but it was not on during the day? I am trying to figure out, I guess, I do not know what time of day your peak is and if the residentials have their systems on the thermostat at home that is going to be turning it on, or will they be coming home and turning it on when they come home? And it would be changing the peak?

PROFESSOR HAMLET: And I am afraid I do not have the answer about that, and we really have not approached it at that level. You know, the key thing I am trying to show there, let's look at the 30 degree C as sort of a benchmark here. You can see that, you know, if we increase those, the temperature in Northern California by, say, 2 degrees C, which is something likely that we might see in the middle of the 21st Century, right? That the slope of this line is a lot larger, so we are likely to see a relatively big change in comparison with the Pacific Northwest, which has it as a much shallower slope here. So if what we see currently in

Northern California is the future of the Pacific Northwest in terms of the amount of air conditioning penetration and the amount of -- it sort of changes in social behavior -- we would expect to see increases in peak demand that are not reflected in the historic condition. And so it is interesting that the Pacific Northwest here on the left and in California, it is sort of the flipside, we see a lot of heating degree demand response in the Pacific Northwest that is missing in California. In California, of course, the air conditioning dominates and we do not see that in the Pacific Northwest. But we are going to see something shift, I believe, to something that is closer to Northern California, we see these increases in cooling degree and air conditioning penetration. What time of day that occurs? In the Pacific Northwest, I believe the load is peaking later in the afternoon, and I am not sure, again, how much of that in this figure is actually coming from commercial residential and so forth. It is actually a mix.

MR. McCAWLEY: Thank you.

MR. FRANCO: Additional questions? Comments? Alan, I have one question. By 2020, California is supposed to reduce its greenhouse gas emissions to 1990 levels. And California counts the emissions necessarily with imported power, its own emissions. I know 2020 is around the corner, but, still, based on suggestions from your results that there would be some reductions at the amount of hydropower that we may be importing to California; since that may need to be replaced by conventional power sources, do you see a need to take these effects into account when we study the ways that California could reduce its greenhouse gas emissions by 2020?

PROFESSOR HAMLET: I am not sure whether the legislation permits transfers. You would know more about that. But, you know, I think it is important -- one of the main things that this study is designed to do is really to show that we need very strongly to show increases, the effect of increasing temperature and precipitation. So if we look at the low projections for the Columbia hydro system, if we assume historic conditions, we are likely to grossly over-estimate the supply that we have in the summer months. So it may be necessary to increase those -- decrease the amount of energy that we might see coming across. And I suspect we may see a very different pattern for summer energy production from local sources of hydropower in California. But nonetheless, I think this is, yes, important. So these studies are relative to the 30-year window surrounding 1985, so by the 2020s, we expect to see -- we expect to see about a 10 percent reduction in those key air conditioning months. So this is a pretty big effect and it is expected to continue to get worse. So I think the key message is that, yes, we need to include the temperature and precipitation changes in our projections of the ability to transfer energy across the West. And there are some complicated climate studies to conduct, but I think these results show that there is clearly going to be a large effect from the Pacific Northwest at the very least.

MR. FRANCO: Thank you, Alan. Additional questions. Now, we are open for questions for people participating on the WebEx.

MS. KOROSEC: Alright, any questions from WebEx? Alright, hearing none, we can go ahead and move on.

MR. FRANCO: Thank you, Alan. That was a very interesting presentation.

PROFESSOR HAMLET: Thanks so much for inviting me. I really appreciate the opportunity to do it over the web, it saved a lot of travel money and time, both of which are in short supply.

MR. FRANCO: Okay, thank you again. Our next presentation is by Mark Snyder from U.C. Santa Cruz. He is going to be talking about some pretty new ideas on how climate change may impact renewable sources of energy in California. With that, Mark?

MR. SNYDER: Thank you, Guido. Lisa sends her regards. She is sorry she could not make it today, but I will fill in well for her. What I wanted to talk about today is just some research directions and ideas on the effect of climate change on renewables in California, specifically wind and photovoltaics. Just to give a brief overview, wind power currently accounts for only about 3.6 percent of California's total energy portfolio. If you look at solar power, it is even less, it is only .6 and that includes all sources of solar, including photovoltaics and other types. There is a distinct goal of reaching 33 percent of our total energy production from renewables by 2020 and, if you consider hydropower to be somewhat of a fixed limited resource, I would say that, you know, we would be most interested in expanding wind and solar power to sort of fill in the gap and to increase the total percentage in that way. In that sense, California is really ideally suited for increased solar production. We have large desert areas to receive large amounts of solar energy, very little cloudiness, really ideally suited for photovoltaics. We also have a great potential for wind energy. We have very strong coastal winds and winds through valleys and the mountain ranges along the coastal areas, and also into more of the desert regions, as well, you have great potential for wind energy in those areas.

If we want to talk about wind energy and solar energy and the impacts of future climate change, we most likely are going to be looking to use global and regional scale climate models. And we have talked about that a little bit today with Dan's talk and with what Guido has said, and these models are basically going to provide us with the best available information on the future conditions for wind and solar power. One of the issues with the horizontal resolution of the GCMs, the Global Climate Models, is that a typical grid cell size is 100 to 300 kilometers on a side, and this is quite large. And I will illustrate this again, as Guido had done before, just to give you a sense for California why we think this is a problem. And with RCMs regional climate models, we have horizontal resolutions that are more on the order of 10 kilometers and 30 kilometers, so this is much better for examining a region such as California. So just to go back and talk again about global climate models, they essentially represent the climate of the entire world in grid cell boxes. The big -- main advantage of these type of models, that I will go into, is that you basically can use these models to generate a number of different scenarios that people have talked about. You have heard about the A1B, the A2 scenarios, these various IPCC scenarios, and there are a number of different global climate models available from different groups. The advantage of these models is that they are not very computationally expensive to run multiple iterations, multiple scenarios. The disadvantage is, obviously, the horizontal resolution which is illustrated here. If we look at the top panel, we see the actual topography for the Western U.S. centered over California, and to the bottom corner here, you can see the global topography represented here, and you focus in particular on this one grid cell that I am highlighting here, and you can see the area from the Monterey Bay all the way to Tahoe, as represented by one grid cell on a global model, and this is a 280 X 280 kilometer grid cell, approximately. So this is sort of the standard resolution of the models today. If we take a look at this panel over here, we see regional climate model resolution. This is a 30 kilometer X 30 kilometer, so this is not as fine as you can go, but you can see that there is a much better representation of the topography of California and we are getting much closer to the actual -- and I wish I had a 10 kilometer scale to show you, again, you can see many of the fine details, some of the values such as the Salinas Valley start to become very apparent. And these are going to be the most important tools for looking at the wind and solar power in the future.

So again, with the GCM, the advantages are you have many models, you can produce many future scenarios, so you can ask a lot of questions about how is the future climate going to change and how is it going to affect these. But the big questions that remain are, is the current horizontal resolution adequate for these models for addressing these questions. And I think the simple answer is no, but somebody also raised the point, and I do not remember who, I think it was John, he said that, you know, these models are constantly evolving and, in the future, we may be approaching these better resolutions, but at this time we are not quite there, so we need to employ other techniques. One thing that Dan had mentioned was statistical downscaling techniques, and can these be successfully applied to GCM data, can we take this coarser scaled data, downscale it using a statistical method to get answers that are more useful for impacts questions. And I think the answer is, is you can do it pretty well for temperature and precipitation, but for winds and solar radiation questions, it has not really been tried and there are also issues of the ability to actually do the statistical downscaling in developing the relationships between the observed winds and the actual downscaling. And the same goes for solar radiation.

So now, if we talk about the regional climate models, what are the advantages and the research questions that exist for these? The higher horizontal resolution, we believe, is really critical for addressing the topographic complexity of California. Many of these fine topographic features, the mountains and valleys that you see in the actual observed topography, become much clearer at the scales of the regional climate model, and we also have the issue of the model physics are better suited to fine scale simulations. Most of these regional climate models are derived from weather models and have been developed specifically to look at the much finer scales. And so the physics of the regional model are different than the GCM.

Some of the research questions that we have are what is an optimum horizontal resolution, and how fine of a scale do we need to go to with the regional model. We are looking at 10 kilometers today; do we need to go to a finer resolution to answer the impacts questions? Or is that a good enough resolution to, you know, answer those questions? What is the optimum balance of computation time vs. the number of simulations? With a global model, you are able to do many scenarios, many simulations. With the regional model, you have to be more careful about choosing the simulations that you do, and there are some research programs underway that are looking at ways of sort of developing statistical matrices that tell you what is the best combination of scenarios and different regional climate models to see what is sort of the minimum amount of computation that you need to get a good representation of the sort of climate variable that you are interested in. And the bigger question is, also, can we improve the cloud representations and the models that are in RCMs and also in GCMs.

So the biggest one, I think, is further research needed on cloud models, parameterizations. One of the critical things that is not very well simulated in these models is the marine stratocumulus, and you can think of this as the coastal fog that we see primarily during the summertime. It is very poorly represented in GCMs and not well represented in RCMs. Just to illustrate, we have a panel here that shows the climatalogical observations, in this panel here, of cloudiness and a comparison with cloudiness in the RCM, and this is for low clouds. And the scale bar is a little hard to see here, but basically, the areas that are bluer are areas of greater cloudiness percentage; the areas that are redder are areas of less cloudiness. For the low clouds, we do not have a very good match with the observations in this particular case.

Again, a satellite picture showing you just an illustration of marine stratocumulus and its importance along the coast. When we get conditions where we have penetration of the marine stratocumulus into the interior of California, this dramatically affects the winds and also the temperature of the interior and also the coastal regions, and you can see here, we have penetration of the clouds into the Central Valley, down in the Salinas Valley, and also into the Los Angeles San Diego areas, Santa Barbara. So it is really critical that we look closely at the models that deal with these types of clouds in the Regional Climate Models, and look more closely at how these models are operating.

The next general research direction is to investigate the effects of renewable energy infrastructure on climate. There has been some recent work that suggests that wind turbines can have a climate effect down wind of their location. In many cases in California, placement of these turbines could provide -- could disrupt the airflow at the surface level, and generate some kind of climate impact. This is really new work and not much has been done on this, but it would be something that would be important to look at. Looking at photovoltaic cells and what their climate impact might be, the biggest thing is that when you are installing these systems, you are replacing lighter services with darker services. This is going to lead to increased radiation absorption. If you are planning on installing large arrays in the desert, you are changing primarily light colored surface to much darker colored surface. One recent study, though, suggests that the benefits of photovoltaics in reducing greenhouse gas impacts on climate far outweigh the negatives of the increased radiation absorption, and that is basically to say that the amount of radiation that you are absorbing, the change in the surface properties, is not enough to sort of warrant not installing solar panels because the climate forcing impact of the greenhouse gases is much greater. And it is really critical that, for California, we look at more specific studies, to examine specific areas of the state that would be used for these installations.

Just to summarize, the GCMs and RCMs are very important tools for researching these future impacts of climate change on wind and solar power. It seems likely that the state will add much more in terms of its renewable resources from these sources and, as California adds renewable energy infrastructure, we really need to take a close look at any possible unintended effects of climate. The current research suggests that these impacts may be small, but it is important, nonetheless, to take a look at those. And just to acknowledge funding from the Energy Commission and the help of Guido Franco. Thank you.

MR. FRANCO: Thank you, Mark. So the agenda we have that we will go ahead with the next presentation, and then we will open the floor for questions and answers. So the next presentation is by Lara Kueppers from UC Merced, on Climate Change Bio-energy.

PROFESSOR KUEPPERS: Okay, thank you, Guido, for inviting me to speak a little bit about this topic today.

Initially, I just want to also acknowledge Elliott Campbell, who is here today, who helped pull this presentation together. Unlike some of the earlier presentations, I am not going to be talking about the results of a study, this is a really a scoping out of what are the issues here, something really that the community, I think, is only starting to think about. So what I am going to be presenting is really what we think are the big issues that need to be attended to as we move forward with our investments in Bio-Energy.

So just an initial overview on what is Bio-Energy. Simply put, Bio-Energy is solar energy that has been recently captured by plants and converted into some sort of usable fuel, whether it is liquid fuel, solid fuel -- pellets, for example -- or gas. The diagram here on the upper left shows the simple sort of life cycle of bio-energy resources in that photosynthesis by plants creates the biomass that has been used in energy production. There are residues and byproducts that then are returned relatively quickly to the atmosphere in the form of carbon dioxide, so it is the short circuiting of the carbon cycle relative to what we do with fossil fuels. Bio-energy tends to have a lower energy density than fossil fuels because it has not been compressed over millions of years. Our sources for bio-energy are fairly diverse and so what I will spend most of the time talking about is dedicated crops that have been planted for the purpose of use as a bio-fuel or a bio-energy source. This might be corn for ethanol, for example, or other crops such as switch grass, or poplar, or other perennial plants that would be used in a bio-electricity generation context. So these can both be annual crops or perennial crops, where you are just cutting off the top and leaving the root stock in place. Other sources of bio-energy include agricultural or forestry waste, for example, crop residue being converted into ethanol is sort of a promised future source of bio-fuel, it is not yet commercially viable. Other waste sources are currently already being in uses as generating bio-electricity, for example, thinning from forestry operations or wood products -- byproducts from processing wood. And then, of course, municipal waste sources, for example, land filled biogas, and there is also a lot of development right now in the Central Valley where I live, in developing dairy sources of biogas. Bio-energy is a pretty diverse set of resources. So just some facts and figures regarding bio-energy. About 3.6 percent of California electricity comes from bio-mass, about 2.3 percent of our transportation fuels are from bio-mass. Most of this is corn ethanol -- the transportation fuel is corn ethanol -- which is grown outside of California, and that is something that is important to keep in mind, is that our current source for these fuels, for bio-fuels, in particular, is largely outside of California.

So the landscape could be changing. There is the Executive Order, the Governor's Executive Order, calls for 20 percent of bio-fuel to be produced within California by 2010, and 20 percent of renewable electricity to be bio-massed by 2010. So these are some significant targets and they ratchet up over time to 2020 and 2040, as well.

A recent analysis by my collaborator, Elliott Campbell, has looked into the question of where these bio-energy crops might be grown. Obviously, if we try to grow out bio-energy crops in places where we are currently growing food, we are going to run into some problems, and I think there have been a number of nice analyses recently that have related increases in bio-energy to increases in food prices, potentially, and at least into the area available to grow food crops. So this diagram on the lower left panel here shows actually abandoned agricultural land, which would be sort of a conservative look at how much land is available to grow bio-energy crops, where we would say, you know, we are not going to utilize areas that are currently used to grow food. And his calculation is that about 8.9 million acres of such land might exist in California for use for growing bio-energy crops.

So just a short list -- this leads me to sort of a short list of some of the pros and cons of bio-energy, this is not exhaustive, but sort of some of the big picture ideas here. Of course, one pro of bio-energy is that it can reduce our greenhouse gas emissions, and that the emissions from these bio-energy sources are quickly recaptured, then, by plants for the next cycle. Another benefit is it can make productive use of what is currently marginal cropland for growing food crops. It can decrease our waste from urban and agricultural land; we could turn what is currently waste into energy. And then it also has no intermittency problems, like we experience with solar and wind, at least on a timescale of, say, minutes to hours. There is variability in this resource, probably more like the variability that occurs with hydropower in terms of it being seasonally and inter-annually variable.

Negative aspects of bio-energy include the left cycle accounting that is really required to assess what greenhouse reductions we achieve. There are investments of energy that go into growing dedicated bio-fuel crops, for example. And some of the accounting that has come to light suggest that the benefits may not be so great for some crops like corn. It competes with other land uses, as I have already said. And some of these crops are also resource intensive, so they have additional environmental impacts related to water, fertilizer, pesticide use, and so forth. And then, as I have already alluded to, bio-energy could be vulnerable to climate variability and climate change in a manner perhaps similar to hydropower in that there is a variability in this resource on the order of seasons to perhaps decades.

So this brings us to the key question here, which is how will climate change affect bio-energy resources. Okay, so the first sort of big area where we would expect to see an effect of climate change is on the productivity of bio-fuel, or dedicated bio-energy crops. So to look at this so far, what people have done is to really use models that were developed for looking at the impacts of climate change on food crops, and so I just pulled out a couple of results from a couple of studies done by other people. In rain-fed areas, for example, in the Midwest, the studies seem to be leading in the direction where increases in carbon dioxide concentrations, which is one sure bet we have here, would tend to increase the yield of corn in the Midwest. And increase in rainfall would also tend to increase the yield of corn, so this is all looking good for bio-energy, however, if you look at this panel here on the upper left, which you combine those effects with the effects of increases in temperature, you tend to get a more heterogeneous picture where, in some regions, you see increases in yield, for example, in South Dakota and Nebraska here on the blue colors, and in other areas like in Iowa, for example, you tend to see a decrease in yield where the temperature effects of heat stress are overwhelming impacts, other beneficial impacts, of climate change. In irrigated areas, for example, in California, where the vast majority of our agriculture is irrigated, we see the temperature increases tend to decrease yield. We do not tend to get the benefits of climate change, for example, from an increase rainfall in some region, we just see the negative consequences of increased temperature and heat stress. And that is shown here, again, for corn by a study that was done by Lee, et al. recently where they see -- the effect is not too bad in the early part of this century, but independent of scenario, these are two different scenarios, the thinner red line is the B2 scenario, and the thicker blue line is the A1 scenario, and you can see that the yields for corn tend to decrease over the course of the coming century. Again, this was looking more at food supply issues, less at bio-fuels, but it can be exploited for that. The picture looks different if you look at switch grass, which is this panel I have just pulled up here on the top, where you see increases in yields across the board in the Midwest when you are looking at a switch grass crop. So these effects of climate change are likely to be very crop dependent. And I just wanted to relate these crop yield effects to the energy question by saying that climate variability in extreme events affect yields, but these yields, then -- big changes in yields -- then translate into volatility in supply and price. So there can be storage, of course, with some of these resources, but it is something that needs to be taken into account going forward.

Okay, another area where climate change can alter bio-energy resources is in the regions where these crops are grown. So a suitable climate may shift geographically where, when we look at the potential impacts of climate change on natural vegetation, the ecological community is already thinking about this. And the cropping community, the agricultural community is also starting to think about this. So for bio-energy, that is something we need to pay attention to. Why we would care is because this alters the fuel transportation distance, and that transport distance affects the fuel lifecycle. And so if you change where your crop is coming from, that is going to change your calculation of whether it is a beneficial crop to invest in. This picture on the right comes from a study that was done by Thomson, et al. where they show the core corn growing areas outlined in the yellow, stippling, one crop model on the top shows a decrease in the red of suitable climate for growing this crop, and an increase is shown in the green area, so the top figure shows the results from one climate model, the bottom shows the results from another climate model, so there is a great deal of uncertainty into how these shifts might look going forward, but you do see that the regions that are suitable for growing this particular crop are expected to change to some degree. And this is something I think we are going to want to look into in a little bit more detail before we commit ourselves to growing energy crops in any particular region. Also, these kinds of shifts in the geographic area of different climates will certain affect the distribution of marginal cropland available for growing bio-fuels. So I mentioned before that a conservative approach would be to use this marginal cropland for growing bio-energy. What is considered marginal is certainly partly dependent on what the climate is like. And then I just wanted to call out that a study was done in Europe, looking at this question, in particular, in the shifts for bio-energy crops, in particular, and they found, in general, a northward shift in areas suitable for growing bio-energy crops.

A big issue here in California, I think, is going to be the availability of water supply and the demand for water by these crops going forward. So climate change is -- we have already heard today climate change has a lot -- well, promises a great deal of trouble with our water system in California. And bio-energy crops in California are not going to be most sustainable without irrigation, but right now, California has mostly irrigated cropland. So if we are looking at growing bio-energy crops in California, we have a real question here.

One study that was done by Howitt, et al. looked at the potential for available water in several different agricultural regions in California, going forward, and I just outlined in this yellow box here, due to both changes in the climate and also shifts away from the agricultural sector to the urban areas, which are growing and demanding more water, they are projecting just a limited set of scenarios, decreases in the water available, on the order of 20 percent in these different regions. So that is a significant decrease in the amount of water available for irrigation. Higher temperatures also tend to increase plant water use. Water requirements are certainly specific to different crops, and there was just a study that came out just this week in proceedings in the National Academy of Sciences. It was looking at the water footprint of bio-energy crops, in particular, and showing how different bio-energy crops have different size water footprints, where corn might have a smaller water footprint, for example, than sorghum, which has a very large water footprint, where the water footprint is basically the amount of water to grow, sort of a one gallon equivalent of a bio-fuel. Water is also required by refineries and power plants. Currently the way these bio-fuels are processed, a gallon of bio-fuel costs us quite a bit more water than a gallon of gasoline. I would expect that to change as we move forward if bio-fuels are going to be used in this region. And certainly these requirements are really swamped by the irrigation requirements of these crops. So while this is an issue, it is dwarfed by the irrigation issue.

Finally, another way in which climate change may alter the bio-energy landscape is through the policies that we develop to mitigate and adapt to climate change. Carbon sequestration, one strategy that has been incorporated into a lot of policy discussions requires biomass to remain on-site, while what we are talking about with bio-energy is to remove biomass and burn it. There have been some studies in the Midwest looking at whether native grass systems, for example, are better for use as bio-fuels, or better for use as taking carbon dioxide out of the air and putting it underground into the soils and sequestering carbon that way. So you do not get the work from the carbon in that model, but you get a quick drawdown, perhaps a faster drawdown of atmospheric carbon dioxide. So there are these competing needs for our ecosystems that need to be considered as we develop our policies.

Crop management adaptations, for example, erosion prevention may require retaining crop residues on fields if we are looking at increases in the intensity of rainfall events, for example, in particular regions that may lead farmers to retain more residue on their fields to prevent erosion. Forest thinning for managing wildfires may lead to more woody biomass available for bio-energy, so this could go in either way, in either direction in terms of the availability of these fuels. And then, certainly, any policies we develop that address carbon accounting for bio-fuels and/or mandates for bio-fuels is going to affect the availability of those resources, that sort of goes unsaid.

Okay, so just to conclude, bio-energy resources are quite diverse, some, especially the dedicated crops that I have mostly been discussing are likely to be vulnerable to climate change. But there is a great deal of uncertainty at this point. This has been not well studied at this point and I do not think really much at all studied in California. These uncertainties come from the emissions pathways, as we have already discussed from federal and state policies, they also come from sort of uncertainties in the regional precipitation and temperature changes, and then finally they come from the varying resource sensitivities, for example, the difference between a corn sensitivity or a switch grass sensitivity to these kinds of changes.

And then, another conclusion, bio-energy commodities are subject to national and international pricing and supply, so corn is not currently grown in California in large amounts, it is grown in the Midwest and this is a primary resource that we are looking to, we really need to be paying attention to climate change in the Midwest, not so much in California. So these remote areas are potentially relevant to California climate changes and these more distant areas are very relevant to California. That said, if we are looking to produce a good deal of our bio-energy from California resources as some of our current policies are stipulating, clearly we need to understand how climate changes in California will affect those resources.

Some research needs. There is kind of a long list. This is just the beginning of it, perhaps. I think a major question is how will bio-fuel water demand and yields change with climate change in California and other source regions. I think the interaction between water and climate is crucial. Where will water availability limit the sustainability of bio-energy sources? Changes in land use, climate, and in mitigation and adaptation policies influence where bio-energy crops are grown. I was really taken with that image from the Sanstad (phonetic) Study where they projected urban areas out to 2100, and you see that most of the crop areas of the Central Valley were now covered by urban areas. I am not sure where we are going to grow our bio-energy crops if we have urban areas covering our most productive cropland. I do not know where we are going to grow our food, for that matter. So I think land use is another part of this puzzle. Can bio-energy compliment other renewable, but intermittent energy sources? Unlike solar and wind, you could considerably turn a bio-mass base bio-electricity plant on and off relatively quickly in the same way you can kick on hydro-electric sources. So it could be a good way to compliment other renewables. And then I guess the final big picture question is what would a resilient bio-energy system look like. I think the title of my talk is "We need a resilient system: The question is, what does it look like?" Thank you very much.

MR. FRANCO: Thank you very much. So now we are opening the floor for questions and comments for both Lara and for Mark. And I can start. This is Guido Franco. Rebecca Shaw -- she did a study for the PIER Program looking at how climate change may change vegetation patterns in California, and in general terms, they sensed that it would be net primary productivity of vegetation will go down. So that suggests to me that, at least in general terms, that the amount of bio-mass that will be available will also go down. The study -- is this a rough generalization correct? Can you elaborate a little bit more?

PROFESSOR KUEPPERS: Sure. So I guess if we were to derive our bio-energy resources from our natural ecosystems, I would say that the conclusion, you know, that you bring is probably robust. A lot of the discussion around bio-energy resources, though, is calling for growing crops dedicated to energy. And with that, we are providing inputs to those crops, including irrigation water and potentially fertilizer that may overcome that productivity constraint. That said, that approach is probably less sustainable over the long term and puts a good deal of demand on irrigation water supply. So I think it will depend quite a bit on what the mix of sources is that we want to pursue. If we actively pursue waste streams, you know, we might have a different outcome yet. So, I guess, yes, if we are deriving our primary sources of bio-energy from natural ecosystems which are simply living off of what water is available in the system and with drying growing seasons, I think that is a real constraint to primary productivity in California going forward.

MS. DOUGHMAN: I am Pam Doughman from the California Energy Commission. I was wondering if you could expand on discussion of the Regional Climate Models and some of the challenges in looking at wind, storms, wind patterns, and cloud cover, and maybe if you could comment on a timeline, when we might be able to see sort of advances and be able to use such models to really anticipate possible changes?

MR. SNYDER: Sure. Yeah, as part of the CEC funded project, we are working to produce, as Guido mentioned, projections for future climate at a 10 kilometer resolution, and I would expect that we will have preliminary results by September, if not more from those projections with the hope that, in the next year or so, that we will have complete simulations for future scenarios and we are sort of optimistic that, you know, the data that we derive from that is going to be very useful for planning for our wind energy and also for the solar energy issues for the future. As far as the cloud modeling goes, that is sort of an ongoing research topic by a number of different groups who are working to basically improve cloud models and integrate those into global and regional cloud models. So that may be a little bit further down the road in terms of the availability of better cloud models. It is important to note that, although the models do have issues with the sort of low clouds, they do fairly well with upper level clouds, things that are associated with large scale storm systems. The models do a good job of those. It is simply the lower clouds, this marine layer, that is more of a complex issue and that requires these improvements.

MR. FRANCO: Okay, additional questions?

PROFESSOR DRACUP: John Dracup, University of California Berkeley. I wanted to ask Mark, on these two studies you reference, the wind power climate impacts and the photovoltaic climate impacts, do you have any references to these published in the literature?

MR. SNYDER: Yeah, I can look those up for you. I do not have them offhand.

PROFESSOR DRACUP: Great. Thank you.

MR. FRANCO: Okay, since we do not have anymore questions from the floor, let's open the questions for people participating on the WebEx.

PROFESSOR HAMLET: I had a question about some local scale, more fully distributed kinds of impacts, particularly with regard to sort of solar installations on people's houses, use of the landscape industry to produce bio-fuels, those kinds of things. I wonder if the two presenters could comment on those opportunities and what the implications are for climate change.

MR. SNYDER: I think for solar power, there is certainly an opportunity for greater installation, and I know that there has been a push in California for at least providing economic incentives for people to install solar on their individual residences and things like that. And I know a number of businesses have started to look at can we install enough solar to basically mitigate the energy that we are using. In terms of the climate impact, that is something that should probably be looked at in terms of if you are switching -- if you are changing areas from being in dramatically sort of lighter color to a darker color, you are going to get more solar absorption, but in the case of most, I think, roofs, you are talking about roofs that are relatively dark to begin with, and so I do not know that there is going to be much of an issue there.

PROFESSOR HAMLET: I am particularly interested in, you know, with the solar air conditioning, I think is something that seems to be a win win and can be actually based on hot water technology via ammonia cycles and those kinds of things. It seems like those have been under-explored, and I was wondering about that.

MR. SNYDER: Yeah, I am not too familiar with that, but that sounds like it would be more of an opportunity. I was thinking more along the lines of just the photovoltaics, so if you have any insight on that, that would be interesting to hear from you.

PROFESSOR HAMLET: Yeah, I think a good place to look would be Japan, which is installed. You can buy them right from Japan now just off the market.

MR. HALVORSEN: Hello?

MR. FRANCO: Yes, go ahead.

MR. HALVORSEN: Are the lines still open?

MS. KOROSEC: Yes.

MR. HALVORSEN: I am sorry, are the lines open?

MR. FRANCO: Yes, go ahead with your question, please.

MR. HALVORSEN: Well, what I am as concerned about, I saw this morning in this bio-fuel that the dairy farmers in California were having a hard time getting the food, and therefore they were taking their cattle early for slaughter. Has anything been addressed about the feed for the cattle in the farming community, on the bio-fuels?

PROFESSOR KUEPPERS: Well, there is definitely follow-on effects for sharing crops between fuels and feed, and I think there have been some certainly news reports and a limited number of studies looking at that question. It is not something that I have focused on in detail here. But it is an issue when you have food crops and fuel crops being one and the same.

MR. HALVORSEN: This was on the news this morning, a farmer, he was milking 575 head of cattle and he said, "I just cannot stay in business because the feed has gone up on us and we are losing money on producing milk." So that is a question that we should address, I would think, on that use of bio-fuels.

MR. FRANCO: Yes, thank you very much. We will take that into consideration. Anymore questions?

MS. MOSER: Yes, this is Suzanne Moser. I have a question for Lara, as well. Can you hear me?

PROFESSOR KUEPPERS: Yes, go ahead.

MS. MOSER: Okay. My question is sort of a follow-up to what we just heard and that is there seems to be quite a bit of a debate in the scientific community on the causal link between growing more bio-fuels and the land use changes that that produces, or not produces. I am wondering if you could say a little bit about the sort of empirical evidence for the link, if we grow more bio-fuels, we actually replace other type of land uses and what impact that has on greenhouse gas emissions.

PROFESSOR KUEPPERS: I can take a stab at that. It is not something I have done work on, personally. But I have probably read some of the same studies that you have. So, as you mentioned, there is a good deal of debate right now as to whether there are these competing land uses or not. In particular, there have been some studies that suggest that, as you shift -- at least one study that was fairly high profile that suggests that, if you use more of our existing cropland to grow bio-energy crops, that provides incentives for people to convert new land into agricultural land in places where we might hope not to see further agricultural land expansion, for example, in the Amazon in Brazil. There has also been some work looking at the potential to use bio-energy crops to restore land, for example, using perennial grassland systems as a source of bio-fuels, where you sort of take degraded cropland out of production and, in a sense, restore a native ecosystem, but manage that ecosystem as a bio-energy crop so that you are using less inputs than a traditional cropping system and you are deriving bio-energy benefit. I think these issues are under active discussion right now. A lot of them are sort of scenario and model-based, and I think the concepts are sound; I think the evidence is still accumulating as sort of the net benefit or harm we could cause by going whole hog into bio-energy, and I think it depends a great deal on what resources we pursue.

MS. MOSER: Okay, thank you.

MR. FRANCO: Okay, so do we have anymore questions. No? Okay --

MR. BARTHOLOMY: Obadiah Bartholomy with SMUD. This is a question for Mark on the solar resource assessment portion of the Regional Climate Models. I was just curious whether you guys expect to be looking at the direct solar component of total solar resource, in particular, because of the recent focus on large concentrating solar power plants out in the desert, and I was just curious whether you expect there will be a way for the Regional Climate Models to peel out the direct component and give us some insight as to how that may change in the future.

MR. SNYDER: Yeah, I think we will be able to do that. The model represents a number of different radiation variables and one of those is the direct component. And it also deals with some of the reflected and sort of scattered radiation components, as well. So that should be something we could address.

MR. FRANCO: Okay, thank you very much. Before we close this part of this workshop, I do not know if you noticed that we started with Dan Canyan and myself, two senior people, and then we move to the new generation with Lara and Mark, two Professors of University of California. And this afternoon at 1:30, we are going to move now to climate change and energy infrastructure issues. And I wonder if the speakers are going to get younger and younger. But, we are closing this part of the workshop. We are going to reconvene again at 1:30. Thank you very much.

[Off the record.]

[Back on the record.]

MR. FRANCO: Okay, we are going to start. So the topic of this afternoon's presentation has to do with climate change and energy infrastructures. So there are going to be three talks, all of them from researchers associated with the Lawrence Berkeley National Laboratory.

So the presentations are designed to explain methodology that LBNL has developed to study how vulnerable our energy system is to climate change. So, Larry?

MR. DALE: Thank you, Guido. My name is Larry Dale. I am a researcher at Lawrence Berkeley Lab. And I am here to talk about a study that we are just beginning, which is to investigate the impacts of climate change on California's energy infrastructure. We have about 20 some odd slides to cover, and we have no results to report. So you can relax, this is not going to be a pile of information you need to absorb. We have two excuses for this situation, one is that the study is just starting, in fact, the funding is even now just now arriving to LBL to do this study, although the way these things work, the funding was here a long time ago at the University, but we have not seen it yet. A better excuse, though, is that a large reason for doing this is not so much to present information as to try to elicit information. This is a presentation about a methodology that we are working out to cover the climate change impacts on a very broad set of different kinds of infrastructure. The topic itself is very broad, and we are going to present it in three sessions. I will give an overview of what we are going to do, and then two other people in the group, Andre Lucena, who is from Brazil and working at the Lab, will talk about an application of the methodology that we are considering; and then Pete Larsen, who has done a lot of work with climate change impacts in arctic regions, and is an economist, will be talking about how to summarize these impacts into various indices. Jayant Aathaye, who is the PI, and the first name on this list, is traveling, and you may have seen his name in various IPCC reports, and he is the PI and I am the Co-PI on this study. So, as I said, this is a fairly broad topic. There are lots of different kinds of climate impacts that may need to be considered and there are a lot of different types of energy infrastructure that may be affected by those climate impacts. As I say, the study has not yet begun, apart from the methodology that we are going to consider today. And the study will result in a White Paper later in the summer and an ultimate report later in the year. As I said, I will do the overview, Andre will come next and will present a few slides describing how the methodology may be applied, and Pete Larsen will talk about damage metrics.

This is the key slide from my talk. You might consider what is at stake here. Well, we have fairly complex projections of what the climate may be doing in the future. Of course, there is lots of uncertainty about this, but most of the GCMs and RCMs are telling us things about temperature, changes in precipitation, and with much less certainly about changes in wind, perhaps, and humidity. So this is the raw data that our group is going to take, and then we, either using other studies or developing results on our own, we are going to try to take this data and turn it into physical impacts of climate change. So we can begin with types of climate events such as heating, or more wind, or less rain, this could turn into increased fire risk, for example, which could in turn affect the energy infrastructure. So the first thing to think about is, what are we going to cover, what kinds of climate events should we be most concerned about? The second big issue is, if you think about the energy infrastructure, and here we are mostly concentrating on natural gas and electricity in California, and if you think about that infrastructure, where is it most vulnerable to these kinds of climate events? This is the next topic you have to think about in order to decide what is going to be covered. The time period is important because most people are concerned about the fairly near future. They want to know what is going to happen in 2020. But if you look at the climate model results, they do not show much happening until about 2050. So if you want to see climate impacts emphasized, you need to look further into the future, but if you want to look at economic political relevance, you want to look near in the future. So we are thinking of covering a period between 2020-2050, with some discussion of longer term impacts.

The next issue that we have to determine is how to identify the infrastructure at risk. And we have happened on a fairly straightforward approach, which is going to be to determine -- well, first take from the gather from the Energy Commission, information about the location of the different kinds of energy infrastructure in the state. Happily, they have put this into a GIS format, so we can download this onto maps of the state, which shows where the transmission lines are, where the distribution lines are, where the power plants are, and this will be sort of the raw data for our study. The idea will be to then take information about climate impacts, overlay it on an infrastructure in a GIS format, and then determine where this is a match between different kinds of climate events and infrastructure at risk.

The third issue that we have to talk about is how do you describe -- determine and describe the damage to the infrastructure? You could have rising sea levels along the coast, increasing winds, fires, the foothills, these will all affect, to one degree or another, different types of infrastructure located where those events take place. But what we have decided is that, in order to determine what the likely damages are, we need to work very closely with utility experts, people who have had experience in the past with the kinds of events that we are talking about intersecting with the kind of infrastructure that is at risk. There is very little study out there about this, but we do think there is data and we do think there is fairly good expert opinion, so we are assembling a group of utility experts to help us with that part of the study.

The fourth topic is how do you summarize damages. And this, at first blush, seems quite simple. Well, you just take the cost of the damaged infrastructure and you talk about those. But, in fact, even the simple economics of summarizing damages across the far flung infrastructure is not simple, you have to deal with issues of uncertainty and risk, discounting because these things happen at various points in time, and the costs are often hard to gather about what happens to this kind of infrastructure. Finally, probably the biggest possible cost of these sorts of damages has this very -- almost impossible to measure economically, although there are attempts, but the biggest cost in many instances will be outages, people going without power for various periods of time, and those costs mount up very fast. And what they actually are is next to impossible to measure. But we may be able to come up with estimates of the size of the outages, and I think that is going to be as informative as any economic estimates we can come up with for the cost of outages.

A third thing to think about when you are talking about damages is what are your assumptions? First, what is the baseline, which is fairly straightforward, although often hard to apply in practice. But how do you assume people will adapt to changes in the climate? So you may assume sea levels will be rising, but what do you assume about how that is going to impact flooding at various power plants along the coast? Do you assume people just passively wait until the first incidence of sea level rise, and then they start building walls? Or do you assume that they do not do anything and the plant suffers flood damages? There is probably going to be a mix of the two, but the costs can vary a great deal, depending upon what you assume. I will mention just briefly some of the principal data analysis gaps that we see. You have already heard about problems estimating wind; wind could very likely be one of the bigger economic impacts on the infrastructure, particularly to distribution lines and transmission lines. But there is very little information, climate information, about where high wind events will occur and how much worse they will be in the future. So that is a big question mark. I have talked to Dan Canyan about ways that we might try to get a handle on how wind may increase in intensity in various places, or decrease in intensity, so we may try to investigate doing a side study with him about that impact.

I will mention assembling this expert panel of utility people to help give us an idea of what costs are. We have been contacting some people at the utilities -- SMUD and Southern California Edison. We have not gotten into this in a great amount of detail because we have not really yet known what the boundaries of the study are going to be until we have worked out the methodology. But that is going to be obviously a very key part of this study, so we are hoping to get a lot of support from different people and different utilities.

Finally, not mentioned in the fifth bullet point here, we may in order to get a sense of the types of impacts across the state, we may and are hoping to get access to electricity simulation dispatch and/or dispatch models to get a sense of those types of impacts. So if you lose a transmission line, if power plant efficiency drops because of higher temperatures, what sorts of impacts can you expect across the state? Models can help us do that better than simple subjective opinion.

And I will end with this slide, which is our sense of the universe that this study will cover. And, this, you should probably pay some attention to because it is very possible to miss something important in an area like this. Here, we have five rows summarizing the different stages of how we had planned to conduct this study, and then roughly five columns indicating -- well, starting at the very top, the raw climate data we will be working with, and then looking at the second row, types of climate events, we are anticipating the major ones to be under 2A, inland floods, which could be -- think of Sacramento under water. Think of us underwater now. B, coastal inundation. Sea level rise by a meter or so at the end of the century, a good bit less than 2050, C, warmer air and water, power plant efficiency drops when the air used to cool the plants, or the water used to cool the plants, gets warmer. D, wildfires. Southern California experienced some massive wildfires recently. Those may get more common. Infrastructure is at risk there. And then, E, high winds, tornadoes. And in terms of the stages of investigation, we just talked about the types of climate events, we are going to overlay the location of those events as best we can determine, and on the location of the infrastructure, be it natural gas storage tanks, pipelines, thermal power plants, transmission lines, distribution lines, we will overlay the location of climate events with this infrastructure to determine where there is a match, where we think there is most likely to be infrastructure at risk. And then moving from 3 to 4, we want to determine the type of damage, and this we will do, as I said, by talking to people who we think know best, who have had the most historical experience with this kind of event, this kind of impact. So we have utility people know whenever there is very high wind events in Southern California, Santa Ana winds, they can tell us that distribution lines or transmission lines are falling at twice the normal frequency. We might reasonably extrapolate that into the future and then measure a kind of damage from information that winds will occur more, or in fact less frequently, and thus you have more or less damage to transmission lines and distribution lines.

Now, assuming we have determined the type of damage, then there is the issue of how do you summarize what that means, how costly is it. And here it is a matter of, as I was saying earlier, economics, replacement costs, costs assuming some kind of adaptation, not assuming some kind of adaptation, outage costs, or outage severity, rather, possibly some modeling that we would use to estimate these impacts. So this slide is showing what I think of is kind of the universe of what we are covering, and if you see something missing important, please let us know. We will probably be contacting many of you to ask that very question.

And so, to summarize, before I pass it on to Andre, who will talk -- who used this and come up with one example of how we might go through this step, we are looking -- it is all fairly simple -- we have information about the location of various types of climate events that may be occurring and could damage energy infrastructure in California. We have information about the location of where the infrastructure is, so we locate infrastructure at risk and take that information to utility experts, we ask them, do they have data, do they have analysis, or do they have an opinion about what this means in terms of future damages? And then we try to summarize it using either economic indices of cost, replacement cost, outage events, or outage severity, and possibly modeling output. So that is kind of the overview of how we plan to approach this study. So this is, this Slide 4, is the universe of what we want to cover, and now Andre is going to provide an example of how we might go through one of those steps, giving a little more detail about how the GIS would work, and what kinds of questions we might ask.

MR. LUCENA: Hi everyone. I just want to highlight that this is still preliminary methodological approach that we are trying to -- we have thought about and, given the scope of impacts that we are going to cover, and so since it is preliminary and we are still hoping to get some extra information from the Technical Advisory Committee, so please see this as something that we are looking for some feedback from you all, and so that you can help us to further develop the methodological approach.

I am just going to start with -- I am just going to give you some examples of how we thought that we would approach some of the impacts that we are going to talk about. And as for fire examples, wildfires, there is Professor Westerling's work which we plan to use. He projected the increased probability of fire, given climactic changes in the future. So I just highlighted the branches that I am going to talk about now, within the schematic that Larry presented earlier, so all the way from the climactic variables to the type of damage that we are going to talk about.

We know what kind of damages, what kinds of impacts to expect, we are still going to need some more information on how to assess them in the best way possible. So the first stage of our work would be doing GIS crossing to identify the vulnerable infrastructure in the state. This is just an example, it is just a visual example. On the left-hand side is California's major electric transmission lines, and on the right-hand side is a map which are both from Professor Westerling's work, showing the increased probability of wildfire. So once we put them together, we can identify which of California's transmission lines would be most vulnerable to wildfires. And I think this is also an important result in the work because, besides quantifying and writing out a cost estimate, also analyzing and identifying which specific parts of these infrastructures are going to be vulnerable to climactic changes is also an important result.

So basically, having the location of wildfires and the location of transmission and distribution infrastructure, and crossing them in a GIS program, we will need to have information which I highlighted in red, on an estimate of how many lines are destroyed in each fire. I just was talking now at lunch and I just found out that there is this kind of information, we just do not have access to it. And what we plan to do in the future, so that we can estimate, given the occurrence of wildfires, an estimate of how many lines are destroyed, and given the costs, calculate -- make an estimate of how much would that impact cost in terms of replacement costs and outages. So one other example, I am just going to go quickly through this temperature. We know that warmer air and water temperature might affect, in this case, this particular branch I am talking about now is about thermal power plants, gas-fired and nuclear power plants, and we know that the efficiency of -- the compression efficiency of power plant, gas-fired and thermal power plant -- decreases with temperature. Basically what happens is the compression work of the turbine is higher in warmer air because the warmer air is more expended and so the compression work requires more energy; in the end, you get less electricity for the same amount of natural gas that you are burning to produce that energy. So after we do the GIS crossing with the power plant's location, the projected temperature variation -- I emphasize variation because we need to know the Delta, not the estate, because the power plants might already be operating out of optimum temperature. So once we do that, we are going to have to get a variation and we need also to know how that variation affects the power plant. These are just some examples I have gathered from the literature, and of curves that -- this one is about a nuclear power plant and how the sea water temperature, cooling temperature, affects the power capacity of the power plant. This one is the operational efficiency of a gas turbine, how much decreases with temperature. And these are for wet cooling and for dry cooling power plant gas fired, the capacity of the decreases with temperature. So we know there is the relationship, but what we need to know is what kind of relationship will be representative for the state of California, given the set of terms that are being used to produce energy in the state. So the best people to get information from, I guess, would be the utilities that run the power plants because they know the types and the models of the turbines they use, and we hope to get that information in the future. And one other thing we would have to think about is how are we going to aggregate those power plants because there are 300 natural gas power plants in the states, right? So are there any similarities between them that we could put them like in groups of 10, or groups of 20s, or something else? Well, we do not know. But what we need to know is, to find a representative relationship between air and water temperature and thermal power plants conversion efficiency and power capacity. And once we do that, we are going to arrive to results in terms of loss of efficiency, which in terms means less electricity that those power plants can generate in the future, given the increase in temperature. Also, loss in capacity which mean in the future you might need to store an extra power plant just to compensate for the loss of power given to a rise in temperature. We do not know the magnitude of it yet, but that could be a consequence in the future. So just moving on to one last example, which is about sea level, so sea level would affect, amongst other things, also power plants. And so at this stage, we had some head start. The Pacific Institute has already done the GIS crossing, which saves us some work, but still there is a lot of things that we need to know in order to assess that in a more deep way. So they have identified 30 power plants which totals over 10,000 megawatts, which are vulnerable to 100-year coastal flood with a 1.4 meter sea level rise. Okay, we know that. But we need also to know -- then we are going to have to talk to utilities that run these power plants and ask them, what is actually at risk from flooding? Is it the whole power plant? Or is it just the intake? Or is this the peripheral structures? And more than that, what are the consequences and costs to that power plant in case it gets flooded? Will it reduce the life span of it? Or are there adaptation measures being taken to prevent those floods? And so, like I said, we are going to build at some point from scratch, like from the temperature example, but in some other cases we are going to build from other people's works specifically for these examples, Professor Westerling's work on fire, and the Pacific Institute which has just done a good study on sea level rise, and we are going to summarize it in terms of costs and damages to infrastructure in the California energy sector. And I know -- I am going to pass it on to Peter now, who is going to talk about how to summarize these costs and, well, thanks.

MR. LARSEN: Thanks, Andre. So I am tasked with talking about useful metrics to evaluate what we call "second order climate risks," so what is the level after sort of that we have received this sort of central climate driver information, or climate impacts that are more on the physical side? How can we begin to quantify impacts not only in terms of energy capacity, the efficiency, but actually in terms of planning, more importantly, costs. So Andre touched on part 1, which our one metric is obviously just simply to overlay GIS results from previous studies, and look at where climate impacts may be greatest, and then overlaying where infrastructure is already located, or may be located in the future. Number 2 -- it should say "number 2," not "number 3" -- another useful metric is direct risk to energy capacity. If we are talking about an electricity generation power plant, it would be megawatts, if we are talking about a natural gas pipeline or distribution system, maybe the metric is therms. So whatever the valid measure is, we can take a look at the direct risks to that type of infrastructure. Another metric is obviously output, which is just raw megawatts that are megawatt hours expressed as a component of megawatts times some sort of measure of time. And that is definitely a deliverable that we are looking to put out in this project.

The next bullet is something that I have studied a lot in the last few years, which is direct risk to infrastructure operational and capital costs. And so one way to think about it is, if you think about a cost equation, a typical engineering cost equation contains a fixed component, like a capital cost component, but also a marginal component, or an operational cost component, and so if there is a power plant that is at risk to sea level rise, we may in fact have to replace or rebuild that entire structure, so that is a severe capital cost. There may be many more instances, though, where there is just simple additional maintenance that is needed, so that is more on the sort of marginal or operational side. So, when I talk about costs, or we talk about costs, think of it as two components -- a marginal cost and a fixed cost.

And finally, another useful metric that we probably will not get into too deeply in this study, but we would like to in future work, is looking at indirect risks to other economic activity. Like Larry mentioned earlier, if you have an outage and a hospital is down, are there changes to human mortality, or there are all these issues that happen when you have essentially black-out.

So one example, and this is getting at the capital cost part of the cost equation, is -- it is a little difficult to see, but right here, this is an example with some sea level rise, or a storm surge impacting some piece of vulnerable infrastructure. One way to think about it is, the first thing is, regardless of climate change, structures depreciate, and so this is what is known as the straight line depreciation method, and essentially, without getting too much into the math today, we have a value of what a piece of infrastructure is worth, so a baseline cost of the infrastructure, so maybe a piece of infrastructure if a million dollars replacement cost, it has an assumed lifespan, maybe 10 years, and so what we are saying is, from the economic sense, about $100,000 per year that structure depreciates if you are using a straight line method. We can aggregate up that amount for -- in this example, I have 5,000 pieces of infrastructure -- and we can do it over time so we are annualizing it. So the first step in evaluating capital risk is estimating a baseline, the second step is to look at how a structure's useful lifespan may change due to climate change, some of these impacts we have talked about. So if increased wildfire reduces the lifespan by a couple of years, we can estimate the economic value of that change and then, step 3, if you simply subtract the adjusted replacement cost against the baseline, you come up with a very rough sort of raw infrastructure value at risk with no adaptation assumed. And then step 4 and 5, beyond that, are we know that when human beings, or planners are shown significant risk, both in sort of the subjective sense, but also in this sort of modeled or financial sense, that they do not simply take the risk, or take the loss. People will adapt to change. And so an important component is step 4, which is how do we model or assume different levels of adaptation going forward to hedge away all or some of that risk.

And finally, this is perhaps one of the most important components in estimating capital risk, is conducting scenario-based modeling. So all of these IPCC models have all these, you know, families of scenarios, A2, B1. The economics models, or the engineering models, should have similar scenarios. And so we can run statistical programs to vary the inputs and see how the output of our model changes with those varied inputs. I want to briefly touch on some of the estimation caveats and some important considerations just to throw out there as we sort of wade through the methodology with our project here. And some of the other speakers today have touched on step 1, and I know that Andre had just mentioned some of this, as well. Scaling and aggregation issues -- so we talked about general circulation model scaling, well, engineering and economics models also have scaling issues, and so we need to ask ourselves, given the limited time and budget, do we want to go structure by structure and estimate risk, or do we want to aggregate risk to the county level, or to some other regional metric? And then finally, and Andre was just getting at this, do we want to just group structures into different classes? So do we want to evaluate total risk to natural gas transmission lines? Do we want to evaluate total risk to thermal power plants? And so, right there, you have maybe nine or ten different categories of risk.

Number 2 is something that I have spent a lot of time on in recent memory, is looking at how to communicate uncertainty and discounting future economic risk. So if we show an economic impact at some point in the future, we have to discount that back to the present when we are making our decisions. And the choice of a discount rate, or the savings rate that we assume going forward in time, that choice is very very important in the economics. I want to point out a very very seminal paper that came out just in this last year, and I think it is actually on to publication now, by Martin Weitzman at Harvard University. Weitzman figured out and proved in a paper that what he calls "structural uncertainty," that is when you couple all of these models together, you take a climate model, and you stick an engineering model on top of it, and you stick an economics model on top of the engineering model, when you couple the modeling, it is not a linear growth in the error term, it is a strange fat tail distribution. And so what Weitzman pointed out is that the structural uncertainty in the impacts far outweighs the choice of a discount rate. And that is very important to note, and just tells us that we really need to think about how to communicate the statistical uncertainty of economics models. But it is also important to note that this discount rate choice is still very important; if you change the discount rate by a single percentage point, you can influence the economics results by hundreds of millions of dollars, if not billions of dollars. So a simple percentage change in the economics assumptions can mean, you know, many many many hundreds of millions of dollars and, in some cases, billions. Pat Perez, who wrote a paper here -- wrote a staff paper for the California Energy Commission just back in January noted some adaptation assumptions and these are really important to note, and we need to think about how to potentially put these into a model. And finally, and Larry touched on this, too, what is the period of analysis in the early years of a future analysis, you know, we are seeing probably fair weak impact signals, but as you go further out in time, impacts seem to be playing out in exponential matter, and so thinking about the period of analysis is very important. In my previous job, I worked -- I led a research team to estimate risks to Alaska's -- all of Alaska's infrastructure from climate change, and some of the examples that we came up with in our research are important to note for California. The impacts are very different. California does not sit on 80 percent of frozen ground across the state, but the way that we model them, we think about the math behind the modeling is actually quite useful. So in this example, this is an adaptation assumption model. What we assume is a building has a 30-year lifespan at some point in time, and over time the life span depreciates linearly. We are looking at three different scenarios. One scenario is there is no climate change whatsoever. Another scenario is that the planners simply take the risk and the structure is impact -- this dark blue line -- the structure's useful lifespan is continuously impacted over time. And finally, we assumed some sort of adaptation scenario. In Alaska, the way we programmed our model was, when a certain percentage of the structure's value was impacted, I think we used 20 percent in our first paper, then planners will make a decision and re-build the structure at an earlier point in time at a slightly higher cost than they would have. And what we found out is that, if you actually make a decision, if you are faced with a significant risk and you make an adaptation decision early on in time, you more than pay for that additional cost, that additional adaptation cost. So this is very important and we can think about how to program this sort of thing into a model for California's energy infrastructure.

Another useful image from our Alaska study is how to communicate statistical uncertainty of economics, and in this example we are going to -- I am showing you two different forms of uncertainty. We looked at three different atmosphere ocean general circulation models. We called them "warm, warmer, and warmest." And the reason is that every climate model for Alaska shows significant warming, so we had to come up with some creative names. "Warmer" happens to be the Geophysical Fluid Dynamics Laboratory NOAA model. And this is all just the A1B scenario, so this is a middle-of-the-road A1B. This is one scenario, three climate models. So right here, you are seeing one form of uncertainty as we are looking at three different AOGCMs. Another form of uncertainty in this image is that we have run a Monte Carlo simulation. I should point out the access here. It says $0, $5, $10, $15, these are in billions of additional dollars of Alaska's infrastructure that is at risk. This is risk above normal wear and tear, and assuming some level of adaptation. So this is an amount of money the state is going to have to figure out how to come up with, assuming the model plays out like this, or the reality plays out like the modeling. But the important point to note is that with the Monte Carlo simulation, what we did is we used the mean or the average projections of future climate at some point in time, and then we looked at the last 75 years of annual climate observations and varied -- we ran that standard deviation through the model and essentially had a statistical program show us how the output would change. So, as you can see, there is likelihood that additional costs could be very significant. There is also likelihood that some of the costs may be not as high. But the important point to note is that, when we estimate risks to California's energy infrastructure, we need to think closely about not only how to deal with some of the statistical uncertainty, but also more importantly how do we communicate that to planners so that they make decisions better?

Something that is very important is obviously information. And Andre and Larry sort of mentioned this -- we are going to talk about some of the needs we need as far as sort of climate and sort of physical impacts, and talk about some of our energy infrastructure needs as far as information. Larry touched on this, this sort of dispatch or power simulation modeling output, which would be extremely useful in this analysis, and probably most importantly is how do we get feedback from the utility experts because, really, you know, if you are sitting in an office estimating risks to the infrastructure, you know, and you produce a paper, it is really not going to mean anything if the people that know the most about it have not weighed-in on it. So I am not going to go over every one of these variables, but on the climate and impact side, obviously we would love to have, you know, not only ambient air temperatures, coastal water temperatures, fresh water temperatures, you get into wildfire risk, and a wind velocities and local sea level. By the way, local sea level is very different than global sea level, and it is a difficult task to estimate local sea level, but it looks like the Pacific Institute has taken a great leap towards estimating that. And then, importantly, this does not get talked about a lot, but it is just as important to sea level as what is the storm surge level. And so we need current values, historical values, but also projected values -- at a fairly fine spatial resolution.

The energy infrastructure side, we also need a lot of information. Generally, we need power generator location type, and some basic engineering information, including what the assumed cost of the structure was when it was new. We need transmission line location type and engineering, distribution line location type and engineering, pipeline location type and engineering, and you guess it, fuel storage location type and basic engineering. And when we talk about basic engineering, we are talking about a lot of the relationships that Andre talked about as far as how climate variable impacts the, you know, efficiency of a plant or a pipeline.

So other information needs -- and this is pretty much the end of our presentation -- it would be great, and the question we pose for the CEC is, would we be able to get some power dispatch modeling output if our group and our expert advisors came up with some plausible scenarios. If we were to come up with a list of scenarios and provide it to the CEC, the ISO, and get some sort of simulation modeling output, that could be very useful. And, again, most importantly, what is the most effective way to take all this information from utility planners and engineers to determine the vulnerability of specific types of infrastructure. And here are a couple of the papers that are a lot more, obviously, that have thought about this issue, but with that, I will end our presentation and move on to questions.

MR. FRANCO: Thank you very much. So now we are opening for questions for the group from LBNL. Go ahead.

MR. BIRKINSHAW: Kelly Birkinshaw, Advisor to Jim Boyd. It looks like you are focused on electricity and natural gas. The transportation sector may be vulnerable, as well. I am wondering if you have considered including fuel supply as being a part of the study, as well?

MR. DALE: We have included coastal refinery in California, but not in the gulf states, so we can -- we will try to gather what information is readily available about that, but we feel that a detailed study of, say, the impact of hurricanes on refinery capacity in Louisiana is outside the scope of this.

MR. BARTHOLOMY: Hi, Obadiah Bartholomy with SMUD. First, let me just say we look forward to helping you in any way we can with answering these questions, and they are also ones that we share, so we look forward to the outcome of this research. I did want to ask -- it sounded like you were mixing in some cases damages with impacts in this study, in particular, you are looking at risk of outages in some cases, but you are also looking at things like temperature impact on the operations of a given power plant, and so I am curious to what extent things like drought, as it relates to availability of hydroelectricity would also be something that you would be looking at. I think that is more of an operational side rather than the immediate risk of an unchanged-related event shutting one of these units down.

MR. DALE: I guess I will take a stab at that. Well, one of the questions is going to be what baseline we use, what is the baseline scenario, and how we try to combine all the different impacts into a single impact, through that baseline and through that aggregate impact. We keep mentioning using a large model to try to show those sorts of impacts, but assuming we had such a model, we could start with a baseline with no hydropower impact, unless we need to be importing more electricity, and then some of the risks associated with some of these other kinds of climate events -- downed transmission lines -- would be the costs of the -- the risks might be the same, but the costs could be much higher because we now need to have electricity all the more. So I guess we are sort of leaning towards dealing with that, with some kind of an aggregate model and setting the correct baseline.

MR. WARDEN: Hi. My name is Nicholas Warden. I am from CEERT, or the Center for Energy Efficiency and Renewable Technology. My question is, have you guys considered maybe using your results to make recommendations regarding which types of technology should be implemented in the future? The example that pops into my head is underground vs. overhead transmission lines because one of the main arguments against underground transmission lines seems to be cost, and it seems like this study could make recommendations regarding future costs about technologies that may not be subject to as many climactic events like underground transmission lines, transmission lines being not so subject to high winds or maybe wildfires or something like that.

MR. DALE: Yeah, just -- I think we both want to weigh-in a little bit on that, but one thought is that, in general, we are going to try to deal with that issue through how we -- what assumptions we make about adaptation because the costs, as you say, are different depending upon what the assumption is about how people adapt. Pete, why don't you talk about that more?

MR. LARSEN: Yeah, no, that is a great question. You know, the adaptation example I gave for Alaska was really a capital adaptation of simply just going to rebuild the structure at potentially a new site that is less vulnerable. What you are getting at is a great question, which is there may be operational things we could do differently, too. So we could potentially put in three, or four, or five different adaptation scenarios, not only on the operational side, but also the capital side, and see how those different packages of adaptation scenarios play out through the model. So it is a great point. It would be computationally very difficult and very labor-intensive to come up with every possible technology and run it through the model, but if we were to group up technologies and see how cost savings and things like that play out, we could roughly proxy what you are talking about for a specific technology.

MR. WARDEN: Okay, thank you.

MS. BURTON: Elizabeth Burton, Lawrence Livermore National Lab. First, it sounds like a superb study and I am very happy that you are all undertaking this. But it seems like a huge challenge, particularly in light of the -- you touched on this a little bit, but I would like you to expand on it, as well -- the energy infrastructure itself will be evolving from now to 2050, as much from technology as the previous question got at, as from policy directives. So I am just wondering how you plan on taking into account the drivers like the renewables for pulling the standard, the potential for carbon capture sequestration, can you use all of these additional things to be in the energy infrastructure?

MR. DALE: It is hard to give a detailed serious answer to such a hard difficult question. I think we are going to take a quick stab at trying to estimate what the world will look like, but we cannot focus on that entirely because that would use up -- I mean, that forecast alone could more than use up our budget.

MS. BURTON: Yes.

MR. DALE: So we are relying heavily on the Energy Commission's databases for giving us the infrastructure that we are going to worry about. We can make a couple adjustments to it for future scenarios, but I am not promising a whole lot.

MS. BURTON: Thanks.

MR. BIRKINSHAW: Kelly Birkinshaw again. I was really quite interested in the conversation about discount rate and uncertainty. I am wondering how you are going to be viewing this uncertainty. Is it more qualitative or quantitatively -- how are you going to portray that uncertainty in the final --

MR. LARSEN: This is always a good question. You know, again, this is another -- right now, if you look at sort of the pre-eminent environmental economists in the world, this is sort of the main issue right now. There are two different schools debating the whole discounting issue with climate change on the economic side. How can we deal with it? Well, we can -- I talked about varying the inputs. You know, one thing we could do is run a scenario with a range of discount rates and just see how the numbers play out. I do not want to get in too much because we have obviously a limited budget and limited time, but I do personally believe that it is important to vary the discount rate and look at different scenarios because it is very important on the results.

MR. FRANCO: Okay, I think that is -- we do not have more questions from the floor, but now we are open for questions from people participating via WebEx. So, any questions from the people participating via WebEx? No? Okay, so I think this was the last set of presentations for today. As Larry and the others have said, this work is just starting, so we will need all the help possible from you and also from the people participating on natural gas activities. So with that, I really appreciate all of you being here today. I think this has been a very informative workshop. As I said before, we will have two White Papers on this, and also these studies, in the next two months. Thank you very much.

(Whereupon, at 2:25 p.m., the workshop was adjourned.)

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I, PETER PETTY, a Certified Electronic Reporter, do hereby certify that I am a disinterested person herein; that I recorded the foregoing California Energy Commission Workshop; that it was thereafter transcribed into typewriting.

I further certify that I am not of counsel or attorney for any of the parties to said meeting, nor in any way interested in outcome of said meeting.

IN WITNESS WHEREOF, I have hereunto set my hand this 17th day of June, 2009.

Peter Petty CER**D493