Quantifying the Emission Impacts of Clean Energy Initiatives

U.S. EPA State Climate and Energy Technical Forum

Moderator: Denise Mulholland
June 14, 2011
1:45 p.m. EST

Operator: At this time, I would like to welcome everyone to the EPA Tech Forum Conference Call. All lines have been placed on mute to prevent any background noise. After the speaker's remarks there will be a question and answer session. If you would like to ask a question during this time, simply press star, then the number one, on your telephone keypad. If you would like to withdraw your question, press the pound key. Thank you. Ms. Denise Mulholland, you may begin your conference.

Denise Mulholland: Hi, thank you. Good afternoon, everybody. My name is Denise Mulholland, and I work for EPA's State and Local Climate and Energy Program. And I'd like to welcome you to the EPA Tech Forum for this month, Quantifying the Emission Impacts of Clean Energy Initiatives. This webinar is the second of a three-part series to help state and local agencies estimate the many benefits of clean energy. The first webinar was held on April 28th, and it provided an overview of how the electric system works. Today we're going to discuss emission quantification methods to estimate the environmental impacts of clean energy initiatives.

Our program, the State and Local Climate and Energy Program, provides resources to help states and localities estimate the many benefits of their actions, including the two resources that you see listed on the slide in front of you. In February we released a document, "Assessing the Multiple Benefits of Clean Energy: A Resource for States," to help states and, to some extent, localities know what we mean by multiple benefits and how you can estimate them. The document describes these benefits of clean energy, the energy benefits – many of them we described in our last webinar – the environmental benefits, specifically air and health – we'll be covering air today – and the economic benefits, which will actually be described in a subsequent webinar. The document presents methods and tools available to help you estimate the different benefits, ranging from simple to sophisticated approaches. It identifies when to use them and includes case studies and results others have found.

The second document on the slide, the Road Map Bullet – the road map consists of a main report and it has a decision hub that can help air agencies navigate the various decisions that you'll need to make for meeting the SIP (State Implementation Plan) requirements for four distinct SIP pathways. There are ten appendices that provide much more specific information on a whole range of topics from how the electric system works, to emission quantification methods, to detailed information on each pathway.

We released an external review draft in March. The comment period ended in May. We're currently reviewing comments, and we will have a revised version up in September for you. It will be released as a living document so that EPA can make necessary changes over time, and continue to refine the current case examples and the emerging opportunities for you.

We have several speakers today who are going to build upon these resources and further increase our understanding of the emission benefits of clean energy and how to estimate them. Our first speaker, Art Diem, is going to cover a quick overview of the electric system, the key differences between quantifying the emissions of clean energy initiatives and typical pollution control devices, as well as the multiple approaches for quantifying emissions.

For the presentations following Art we've used a tag team approach where we'll get the state or local agency perspective on the value of using a sophisticated emission tool paired with an expert that will describe how the tool works as well as the interesting results that they've come up with. For our local team, we have Jeff King and Colin Hay. And for our state and local team, we have Marla Mueller, Lisa Van De Water, and Dr. Jeremy Fisher. I'd like to start off by thanking all of you up front for taking the time to be with us today and for putting together your presentations. We're really looking forward to hearing from you.

At this point in the call, what I'd like to do is hand the call over to our facilitator, Catherine Morris from the Keystone Center, and she's going to start us off. Thanks so much.

Catherine Morris: Thanks, and welcome to the call. We had over 300 – this might be a record – we had over 300 participants register, and we have over 150 now on the call with us today, so as you noticed when you joined, all the lines have been muted. But we do want this to be an interactive engagement with the speakers. So what we're going to ask you to do is to use the Q&A on your webinar control bar to enter any questions while the speakers are talking. We're obviously not going to be able to get to all of them, but we will try to quickly prioritize the questions and get to as many as we can during the webinar.

In addition, I just want to make sure that everybody knows that you can download the presentation materials and several background documents at the Tech Forum website – that is, www.epatechforum – all one word -- .org. And that's at the bottom of the agenda.,but also I think we have listed the website in a chat box on the control bar. So we'll mention that a couple of times, because I know that tends to be the most frequent question we get, is how do I get these documents. So we'll remind you throughout the call.

I'm going to turn it over first to Art Diem with EPA. And just to give you a couple of brief bio points about Art – he's been with EPA for ten years, and he's currently in the Clean Air Markets Division, managingEPA's Emissions and Generation Resource Integrated Database, or eGRID for short. He's developed an applied method for estimating emissions reductions for clean energy. And he's going to give an overview of the various methods today in his presentation. Before his tenure at EPA, Art worked at the New Jersey Department of Environmental Protection Air Program. So Art, if you would, we'll queue up your slides and let you take it over.

Art Diem: Thank you, Catherine. So thank you, everyone. I'll be as brief as I can. The next slide, please. So I'm going to talk about a brief overview of how the electric grid works and what a marginal unit is; how clean energy initiatives and air pollution control devices affect air emissions differently; and a few types of methods available to estimate emission reductions from clean energy. OK. So how the electric grid works. On the next slide is a simple visual of the electric grid. Number one, you have power plants, one of many different resources; high voltage transmission lines, number two; number three represents substations which step down the voltage to distribution lines that go into different neighborhoods, transformers, and finally, buildings where the electricity's used. It's a simple illustration except,– the building usage doesn't originate from just the closest power plant. Next slide.

There's a huge network of transmission lines and interconnected plants. Next slide, please. There are many power control areas, often known as balancing authorities that continuously balance the demand for electricity with the amount of generation taking place, accounting for transmission constraints and all the different transmission lines. The power controlling area's where the dispatch of electricity takes place. As demand for electricity rises and falls, the grid operators signal plants to increase or decrease their generation, based on cost or bids priced into the system. Or, if available, they'll increase or decrease imports of electricity from neighboring power control areas. The bubbles on this map represent the power control areas and the lines in between represent the ties between these areas through which electricity can be imported/exported. Next slide, please.

Here's a map of the PJM territory – the PJM power control area. And within it, there are several different utilities. This is usually the case. There'll be several different utilities within a power control area. Next slide, please. Here are just a few pictures of the various control rooms. These are very complicated systems where they dispatch electricity and operate the various electricity markets. Here we have ISO New England's control room in Massachusetts, ERCOT's control room in Texas, and PJM's in Pennsylvania. Next slide please.

The marginal unit is the last generator to be dispatched at any time. On the left is a typical system-wide daily demand profile. Imagine different plants are stacked up to reach the demand at any given time. The marginal unit, the last plant dispatch at 6:00 AM when demand for electricity is low, is a different unit with different characteristics than that dispatched at 6:00 PM when demand for electricity is high. A note on air pollution control devices: generally speaking they tend to be installed on base load and non – I'm sorry, load ollowing units. They operate many hours per year and tend – and peak units sometimes do not have very many air pollution controls installed, because they operate few hours of the year. The graph on the range shows that there is a big seasonal variability in demand for electricity. This chart shows each day's peak load from 1998 – or 2000 in PJM. The valleys are the spring and fall times, and the high peaks are summer peaks. The lower peaks are the winter peaks. Next slide, please.

Let's see. So plants with the lowest operational costs are bid-priced in competitive markets that get dispatched first. Nuclear, hydro, intermittent resources such as wind and coal are typically base-loaded units. And depending on what part of the country you're in, coal may be load-following along with gas. Peak units are typically gas or oil fire units. The chart on the left shows the resource types for New England for each hour in 2007. Nuclear is shown in yellow; renewable's green; coal is black; gas is blue; and oil is red. So this shows that in New England, marginal fossil generation is mostly oil- and gas-fired units. The chart on the right shows a typical generation stack in PJM, very similar, with generation on the X axis and bid price on the Y. The first 40 gigawatts or so are renewables and nuclear generation; and about 60 gigawatts of coal and about 50 gigawatts of gas. And then, finally, oil at peak demand. The different areas have different amounts of these resources available but generally are in the same order. Next slide, please.

So clean energy is a little bit different than traditional air pollution control devices in these ways. Air pollution control devices or end-of- pipe controls reduce the rate and mass of emissions that are designed to be removed – usually one or a few air pollutants. There's great certainty and enforceability in air permits and monitoring requirements. So you know exactly where the emission reductions are taking place, and for which pollutants. Clean energy, on the other hand, is more akin to pollution prevention. And so any significant amount of clean energy will reduce the generation from the marginal unit at the time. Since the marginal units are usually combustion units there will be less fuel burned; therefore fewer emissions; and fewer emissions will generally tend to improve air quality. And you also get reductions in all the different air pollutants that are from the fuel that would have been burned. But the big question is, where do these emissions occur and how much? And that's where we get into the options for estimating emissions reductions from clean energy. Next slide, please.

So we have simple estimates without much geographic distribution. And first let me say that all of these options are estimates. It's impossible to track the exact source and resulting emissions of every single electron used, let alone electrons that would have been orwould have occurred in the absence of the clean energy. However, there are reasonable methods available to estimate what is intuitively evident – that clean energy does reduce air pollution. So the simple estimates on the top are crude methods that explain how much but not exactly where these emission reductions are happening. They're good for screening analysis, to answer whether it's really worth spending more resources for better estimates – an example is the eGRID sub region non-base load output emission rate. This is akin to a deep marginal emission rate weighted more heavily at the peak times, and we have more information about how that's put together in the Tech Forum archives.

ISO New England also publishes annual reports on marginal emission rates in their area. That's another example. Then there are less simple estimates. These are still relatively crude methods, I'm finding out how much, but also indicate where the emission reductions are happening. There's the capacity factor approach; there's also low duration curve approaches where all of the plants are – how many hours they operate a year are basically lined up and you used a low duration instead of exact dispatch on that. And then finally, the most refined approaches are the electric system models. They're dispatch models – for example, PROSYM that you'll hear about later in this webinar. And also capacity factor – I'm sorry, capacity expansion models such as IPM which EPA uses in their cap and trade program development. And also other advanced electric system methods – for example, the RSG's method, which you'll also hear about this afternoon. Next slide, please.

So here's a chart showing the eGRID carbon dioxide equivalent output emission rates for generation occurring within each of the different eGRID sub regions. On the left, showing the total or system mix values. On the right are the eGRID non-base load rates. Just a brief explanation: base load rates, basically where we took out all the non-combustion generation, took out all the generation emissions from the remaining plants having very high capacity factors, and removing some of the generation from plants that have capacity factors between 20 and 80 percent, depending on what the capacity factor is. Last slide, please.

Here's just a brief note about the interaction with regulatory programs. Basically, the cleaner the electric-generating fleet is, the less emission reductions you'll get from clean energy on a per kilowatt hour basis. So basically the more effective your regulatory programs are at reducing air pollution from electric generating units, the less emission benefits you'll get from clean energy. The chart on the upper right is basically showing in New England from 1993 the NOx output emission rate. The marginal rate was about 4.5 lbs. per megawatt hour. And in 2009, on the right, it was less than 0.5. This happened because in New England there are a bunch of regulatory programs that reduced NOx emissions from electric generating units. So that's my – the conclusion of my introduction. I will let it go to the rest of the show.

Catherine Morris: Well, we do have a question that came in. We may have a few. Texas, Eastern, and Western interconnections are not linked. And it's referring to one of your previous slides. And it goes back to the slide with the map.

Art Diem: Yeah, that would be slide five.

Catherine Morris: Slide five. So the question is, are the colors in that slide comparable across those three interconnects?

Art Diem: Yes, that's a good point. Thank you for bringing that up. So, yeah, in the continental U.S. there are three interconnections. We have the western interconnect, which is – these are NERC regions here, which are basically the WECC or WECC NERC regions. You have ERCOT which is the – I guess you could say the Texas interconnect. And then the eastern interconnect is basically everything else, except for I think Ontario there. So anyplace you see these lines with the double triangles on there, basically there are some ties between these interconnects, but there isn't very much power that goes across, because it's basically you have to do an alternating current and a DC current to alternating current, because all the generators within each of these interconnections are synced. So that's the basics on that.

Catherine Morris: Another question is asking about a little bit more elaboration on the distinction between marginal and average emission rates and their appropriate use.

Art Diem: Right. Well, the term "average" gets thrown around a lot. And it could be an average of a whole bunch of things. But generally we're talking about system mix if it came to an average or a total, where you're looking at the emissions and generation from all of the units in a certain area, including nuclear units and hydro units. And marginal emission rates are basically those where someone has made a determination, I'm only going to look at the units that are being last dispatched. And so that's the big difference between the two. I hope that answers your question.

Catherine Morris: Yeah, the question goes on to ask whether or not it's appropriate to be using the average as a more conservative approach to estimating emissions benefits.

Art Diem: Well, sometimes it's more conservative, and sometimes it's not. It really depends on the area. But generally speaking, for most areas, the average will be a little bit more conservative. But the average is really appropriate for looking at emission inventories where you're saying, well, how much emissions are occurring because you're using electricity? Whereas the marginal is a little bit better cut at trying to figure out how much emissions are being avoided if I implement clean energy measures.

Catherine Morris: Thanks, Art. There are several other questions that I hope we might be able to get back to, but I think also our other speakers will possibly fill in some of the blanks. So let me go ahead and introduce the next two speakers, Jeff King and Colin High. As Denise mentioned, they're going to be talking about the application of one specific method in the Metropolitan Washington Council area. Jeff King is our first speaker, and he works for the Metropolitan Washington Council of Governments (COG). And as a planner in the

Environmental Programs Department, he works on a number of issues and develops plans that address air quality, energy efficiency, deployment of renewables, as well as trying to meet greenhouse gas reduction goals for the region. Prior to working at the COG, Jeff was a consultant who's really worked on a variety of Montreal Protocol-related initiatives, including the phase-out of [chlorofluorocarbons] CFC's and other chemicals that affected high-level ozone.

So I'm going to turn it over to Jeff, but before I do, let me go ahead and give you a brief introduction to Colin as well, who is going to talk specifically about the time-matched marginal emissions model that he developed and designed. He's the co-founder and principal consultant at Resource Systems Group [RSG], where he also works on not only this particular model, which he'll explain in more detail, but he's also the manager of the Lifecycle Emissions Analysis Contract for US DOE's Renewable Energy Loan Guarantee Program. So let me first hand it over to Jeff to talk a little bit about his experience with estimating the benefits for the Metropolitan Washington area. Jeff?

Jeff King: Hi. Yes, thanks. Yes, let's get right into it. Next slide. As you heard, you'll hear from two of us involved with this project. First I'll just give you kind of a quick background, and then Colin will really get into the more detailed information on the tool. Next slide. While I work for COG, the work on energy efficiency and renewable energy for air quality planning effort's really on behalf of the Metropolitan Washington Air Quality Committee (MWAQC), which COG staffs. As you can see on the slide, MWAQC represents the tri-state region here in the Metropolitan Washington Region, including portions of Maryland and Virginia, and the District. The membership of MWAQC includes the state air agencies, Departments of Transportation, state/local elected officials. It's supported by a technical advisory committee and a public advisory group. And the map on the right shows the kind of counties and municipalities which are included in or surrounding our designated non-attainment area.

Next slide. This next slide provides an overview of our efforts to include energy efficiency and renewables in our state implementation plans. The first cut at this happened some time ago – more than five years ago I guess – when the SIP for 1-hour ozone standard was developed. For that SIP, local government voluntary initiatives, particularly to procure wind power, was put forth as a control measure to help us attain the standard. Subsequent to that effort when our SIP for the eight-hour ozone NAAQS was developed, the EERE [energy efficiency and renewable energy] component was actually expanded. Local governments offered up significantly more wind purchases; we also tried to include the renewable portfolio standards, and several energy efficiency measures including conversion to LED [light-emitting diode] traffic signals in the District.

For all this work, we followed the EPA Voluntary Measures Guidance and included this whole kind of EERE package in what we call the voluntary bundle. And linking it back to the point of this webinar so that we could meet one of the requirements in the EPA Guidance for inclusion of EERE and SIPs, we really needed a tool to help us document the emission impact of our various energy-related measures. Next slide.

Looking forward to our upcoming SIP effort to meet a much more stringent Ozone NAAQS [National Ambient Air Quality Standards], which I guess we'll learn about next month, which will be, no matter how you slice it, a very challenging one for us to meet, we do have a number of larger kind of energy-related programs in our region with significant potential EERE impact. We certainly will be looking to find a way to include these programs in our control strategy over the next couple of years. Next slide.

And just to kind of quickly go through a few factors, key factors that really contributed to our ability to successfully include EERE and SIPs . Clearly it was a combination of state and local leadership, really very important availability of key federal enabling guidance; and of course some technical assistance and tools, resources, such as the RSG work on the avoided emission calculator. I should note that we did receive funding and technical support from the U.S. Department of Energy, which actually helped fund the calculator development, as well as a protocol document for inclusion of EERE and SIPs. One last note – moving forward, I think it's going to be really imperative that EPA include policy in the upcoming Clean Air Transport Rule that will enable states to retire NOx allowances. This is a mandatory requirement that really needs strong EPA leadership to make sure that particular aspect of our program is on solid ground.

So that really covers what I have to say in terms of background. So I guess I'll turn it over to Colin High.

Colin High: Thank you, Jeff. Can we have the next slide, please? Jeff and his colleagues at the Metropolitan Washington Council of Governments have worked very closely with us in much of this, and have really helped develop this tool, not only technically but also allowed us to see how it applies in the real world of public policy and regulation. And that has been very, very valuable to us. And I should also acknowledge that this work was done with substantial funding and technical support from the U.S. Department of Energy.

I want to talk about how we can create some tools for measuring avoided emissions, and what are the criteria we need to use for that. So first of all, I think we need to acknowledge, and following up upon what Art had said a few minutes ago, that accurate avoided emissions measurements do really require the use of a marginal analysis. And certainly the preferred way is to use a marginal emissions model that takes account of the time variability of EERE's impacts on green electricity.

And Art did describe to you how the system works. So I won't repeat that. But I do want to talk a little bit about what area we should apply this to. The model really needs to be applied to the power market area which is to be impacted by the EERE changes. And I prefer to use the term power market area because that is that area in which the system operator makes decisions about which units will be turned on, off, up, down, depending on both economic factors and requirements for maintaining the reliability and stability of the system. And so we need to incorporate that into the model, and typically we willin fact use regions which are very similar to the ones which EPA uses for its EPA eGRID sub regions analysis.

So the Metropolitan Washington Council of Governments chose and worked with us to use the RSG's time-matched marginal [TMM] emission model in order to provide the marginal analysis that was necessary for their work. And I'm going to describe that model to you in just a moment. But from that, in order to make it practical for, in this case, a multiple municipal agency or a state agency to apply this model in real world of regulation and reporting and so on, we built a simple calculator which was based on the TMM model that enabled the Council of Governments and the local governments who are members of that to quickly evaluate the avoided emissions, at least from the most common energy efficiency and renewable energy measures which were applied in the region. And we set the calculator up so that new measures, new EERE measures, that they want to apply – can be easily added to the calculator. And in fact, some have been done. Next slide, please.

So what is the RSG TMM model? Well, the time-matched marginal model, or TMM, is an 8,760-hour historical dispatch model. It captures the economic dispatch and reliability decisions which are made by the electric system operator in order to calculate the avoided emissions from the EERE projects on an hourly basis. So this is an hourly model through 8,760 hours of the year. And it is a dispatch model, but not an economic – not a pure economic dispatch model. And a little later on you'll hear from Jeremy a little bit more about the difference between an economic dispatch model and this model. But essentially, it does capture the economic decisions which are made. Units for which the incremental cost of operation is higher would tend to be dispatched less frequently and only at peak times and so on. So the time matching in the TMM model is based on actual or simulated 8,760-hour energy savings or generation data from the EE project – EERE projects or programs– that are impacting that power market.

So just to make that clear, that's –let's say for a wind project that you want to measure, you would get either an actual generation profile for the recent year of operation. Or if the project is not yet built and you're deciding in advance whether to include it, you would go to the developer of the project and get that weather data– the wind speed data and convert that into the hourly generation. And similarly for energy efficiency projects you'd get the savings on an hourly basis.

Now this is sometimes difficult, but there are plenty of ways, models which are available to allow us to get that information, even if the developers of projects are unable or unwilling to do it. So that is the EERE generation, savings or generation profile. And that's matched against the 8,760-hour historical dispatch record. So the TMM model is available for all U.S. power markets, states and regions. And it can be – because it has GIS [geographic information system] capability, you can actually define any region, or you can – if you know that there is some transport coming across a regional boundary, you can include that in it, as a custom run of the model. So this model has been applied now to – not only for the Metropolitan Washington Council of Governments and numerous wind and solar developments and a number of energy efficiency projects – in total we have done more than 250 EERE projects and programs in the United States. And incidentally, we've done a few overseas too, but that's not what we're talking about here.

Now the model applications in the case of the COG were to energy efficiency projects, and also to wind and solar projects. But there's a very, very large number of technologies which we investigated, including virtually all of the currently operational – you know, existing energy efficiency and renewable energy technologies – wind, solar, obviously geothermal, biomass and so on. And a very large range of energy efficiency projects from simple lighting projects to projects such as whole smart grids. And we also looked at the marginal emissions effects of nuclear power plants which, there are significant effects from integrated gasification combined cycle, coal plants with carbon sequestration – none built yet, but we've looked at proposed projects – and battery storage, fly wheels and electric vehicle charging are all the kinds of things which the model's being used for at the present time.

So the results of that seem to suggest to us that this is a fairly robust approach, and we tend to get very consistent results for specific regions and specific technologies. So we feel some reasonable degree of confidence in the model. Next slide, please.

Catherine Morris: This is Catherine. I just wanted to give you a time check. We're about halfway through the time allotted. And we wanted to make sure we had time for questions for you at the end. So just to make sure you get to all the important points you want to make.

Colin High: Thank you. So very briefly – and Art has covered some of this – this is for the Mid Atlantic power markets, for the Metropolitan Washington Council of Governments. And you can see, if you look at a typical day here, that you've got peak units, oil and gas intermediates – sorry, peak generation is mostly oil and gas; intermediate generation is coal, oil and gas; and base generation is nuclear, coal – nuclear – very little oil, coal and gas. Next slide, please.

So I want to just run you quickly through the TMM methodology. On the left here we have the steps which we take and, on the right, a look at some of the results. Plus the model identifies the marginal fossil fuel-fired units in a power market for each hour, by using a load-following algorithm to calculate the incremental marginal emission rates.

Secondly, it compiles an annual hourly load – we use, I should say – we compile an annual hourly load profile of the energy savings or generation for the EERE technology and region under study. And then third, we time-match that hourly load profile against the marginal emissions profile on an hourly basis. And then fourth, we calculate the total avoided emissions from the annual savings or generation on an hourly, monthly or annual basis. And looking on the right there are three emissions rate outputs from the TMM model, run for the mid-Atlantic region, approximately similar to PJM power market. And you can see the pattern and notice that NOx really drops – the marginal emission rate for NOx really drops dramatically in the summer months – due to regulation, of course. And CO2 is also very, very highly variable in the summer months. Next slide.

Just a little bit about how the model is produced. It's based on publicly available data – the emissions monitoring data for every hour of the year for all U.S. fossil fuel generating units, and which are large enough to require EPA monitors. The particular pollutants dealt with by the model are CO2, CH4, N2O, NOx, SO2 and PM2.5. So we can evaluate the marginal emissions for all of those.

The model is quite sensitive to regional boundaries, which can change a little bit with power demand and transmission constraints. And so we typically prefer to apply it to what we would call major power markets, which are somewhat the equivalent of EPA eGRID sub regions. But this can also – we can also analyze this down to state, sub-state level or utility service area if necessary. Next slide, please.

So I wanted to just give a little comparison of emission rates. This chart compares the CO2 emission rates using two eGRID methods and the TMM model. And this is done for two areas. One is the Pennsylvania, New Jersey, Maryland – PJM- and adjoining power market that was used for the study for the Council of Governments. And the other one is Upstate New York. ,And what you can see, in all cases of course, is the time mapped to the RSG TMM model, which is of course a marginal model shows higher results – higher avoided emissions than the eGRID system average and the eGRID non-base load average. This is not surprising. I should just point out, of course, that the eGRID system average number is not designed or intended to be used for marginal purposes. So it's – this is not a comparison, which implies any judgment, but rather does show the difference. Because I know that there are still a number of people who are using eGRID system average rather than marginal emissions analysis. Next slide, please.

So we produced a calculator which enables the Metropolitan Washington Council of Governments and their member municipalities to calculate the avoided emissions from specific projects and programs. And there isn't time for me to go into this. I'm showing you the dashboard and essentially, this is simple enough that any staff member with some small amount of training could easily go in and evaluate a project, providing that they have a profile – they don't need a profile because profiles have already been preprogrammed into this calculator. This has been used by the COG quite a bit. And I'll – I think we'll take any questions on that maybe – either me or to Jeff – during the question and answer. Last slide please. Our next and last slide.

So what are the lessons which I've learned from this experience? Well, it's great to cooperate with a COG. That's one thing. The Council of Governments' obtained more accurate avoided emissions measurements compared to their – to some of their municipalities' previous issues of eGRID output emission rate. Using the TMM model marginal analysis results in higher avoided emissions, which shows that – which can have the effect of showing that EERE measures can be more cost effective. Meaning that when you have a more accurate number, you can do a better job of figuring out which of the alternatives that you're using give you the most benefit from your dollar. And then with the use of a model-based calculator, these routine analyses can be completed by agency staff without additional runs of the TMM model. And, if necessary, additional runs of the TMM model can be done, and the model can be updated. Thank you.

Catherine Morris: Thanks very much, Colin. We have time now for a couple of questions. And the first one is, whether or not the TMM model is publicly available? And in addition to that, another participant is asking how you actually – where you would get the data for the yearly hours of emissions in order to input that into the model?

Colin High: OK, let me take the first question. This is a commercial model developed by RSG. And we provide services to run the model for clients and – as we did for the Council of Governments. So the model is available for a fee. (laughs) So the second question – could you repeat the second question?

Catherine Morris: Yes. They're asking where you get the hourly emissions data that you would need as input.

Colin High: I take that to mean the hourly data that you would need in order to match an energy efficiency profile against the model. If that's the question, then what you need is hourly energy efficiency savings kilowatt hours, or electric generation from a wind farm or a solar array, kilowatt hours, per hour for the year. And as I said, I think a little bit earlier, that data is usually available from the people who are running these energy efficiency programs. And I just point out also that NEEP [Northeast Energy Efficiency Partnerships] has been working very hard to produce a larger number of these energy efficiency profiles that would enable states and local governments to do that more easily.

Catherine Morris: Actually, I should clarify, because I didn't have the question right in front of me. They're asking whether or not – how you can get the 8,760 hours of historical dispatch data for a given region – say, for instance, a state like Virginia?

Colin Hay: Very good question. There is no publicly available hourly current or recent hourly data available from the utilities or from the system operators in general. There are a few odd exceptions. But they consider it to be proprietary. I don't want to talk about that. I can't understand why. (laughs) But it is. We create the hourly generation data for all the fossil fuel units by taking the CO2 emissions from the continuous emissions monitoring data and then, with the use of an appropriate factor, emission factor for CO2, per megawatt hour – based on heat, rate and so on – we can get a very close match for the hourly generation of all the fossil fuel units. And the non-fossil fuel units are, in general, not relevant to this analysis.

Catherine Morris: I'm sorry. I had this on mute. There's one last quick question I'll ask before we move on. And the question is, does the model include co-generation as an efficiency improvement?

Colin Hay: The model does not. But the calculation could. What you would do with that – and we have done some CHP [Combined Heat and Power] models – is to take the amount of energy savings in electrical units – what this is, is an electrical model – and figure out what that is at each hour, and then create an 8,760 profile for that. And that's not too difficult, but it could be a little challenging. But the challenge is more in determining how you allocate the savings between the thermal and the electrical part of the CHP project.

Catherine Morris: Thanks very much. We do have some other questions. Hopefully we'll have a little extra time at the end to get back to them. Let me introduce our next speaker, Dr. Jeremy Fisher, who's a scientist at Synapse Energy Economics in Massachusetts. And his work includes the review and development of long-range energy plans for states and regions, as in today's topic, the Development of Techniques to Estimate Avoided Missions from Renewable Energy. And also he has worked on emerging social and environmental externalities with energy modeling.

In addition, joining him today is Marla Mueller, who is the air quality research arm of the California Energy Commission. And she's available to answer any questions you might have about the California Energy Commission's role in funding this work by Synapse. She leads the energy-related Air Quality Research Program. And prior to working for the California Energy Commission she was with the California Air Resources Board. Finally, Lisa Van De Water is joining them from the San Joaquin Valley Air Pollution Control District, and she's going to share her perspective on the findings of the study and how it was used by her agency. So let me go ahead and turn it over to you, Jeremy.

Jeremy Fisher: Thank you very much. So as you've heard from the speakers so far, the purpose of today's Tech Forum is to be talking about – oh, we'll actually say it's almost exactly the title here – looking for emissions reductions from renewable energy and energy efficiency programs. In this case, this is a project that we did for California Air Districts. This project was supported by the California Energy Commission's Public Interest Energy Research Program – PIER – and has been supported over the course of the last year and a half. At the moment, the project is in its final stages of wrapping up, and we're still waiting for a final approval on our draft, but we are near closing. I'm going to skip through the first couple of slides here quite quickly. They're just contact information for ourselves and for Marla at the PIER Program.

But generically speaking, Synapse is a small consultancy. We're based out of Cambridge, Massachusetts. We work for primarily public sector and public interest clients on electric generation and transmission planning, market structures and rate-making, efficiency, renewable energy and environmental quality, including what you're about to see today. The PIER Program is based out of the California Energy commission. I'm sure Marla would be happy to tell you more about it. And they have provided support for this and other worthwhile research in the State of California and in the region.

As you know, what we're looking for in this particular type of research is a mechanism to allow air districts to be able to meet SIP requirements through energy efficiency and renewable energy mechanisms. And in California, this is particularly pertinent, because so many plants in California are already controlled, that really, in order to be able to get additional emissions reductions from stationary sources, we can't do end-of-pipe controls. We really need to be looking for additional mechanisms to start essentially pushing plants offline, or at least into lower capacity factors. So we're looking for emissions reductions from efficiency and renewable energy.

And as Art raised at the beginning of this presentation series, the real question here is, where do these benefits accrue and to whom? We could potentially say that they accrue within California or the particular air district. But it's frankly unlikely that if a load center such as say the City of Los Angeles reduces their load requirements by a significant margin, that generators specifically within the City of Los Angeles – actually this is not necessarily true of them – but generators within the City of Los Angeles might not be the ones that actually reduce; it might occur elsewhere. So this is a pilot project that we engaged in for California. And we've engaged previously on other emissions reductions benefits types of research, similar to what RSG was presenting just a couple of moments ago.

And what we're really aiming for here is what might be considered the industry standard mechanism to use for a simulation dispatch model. And this is what's used by utilities across the country for both planning as well as more complicated versions for instantaneous dispatch for what's getting dispatched within a RTO [Regional Transmission Organization] at that moment. And we're looking to provide a flexible tool for the air districts, such that they can – as Colin was just mentioning a moment ago – be able to walk into a SIP process, plug in a couple of numbers in terms of what an energy efficiency program or renewable energy program might look like, and really be able to walk out with a very good idea of exactly what those emissions reductions look like. And as I noted before, the final paper for this is currently under review by the CEC.

Generically speaking, jumping right to the end of this, using a simulation model in general provides this fantastic benefit of really being able to provide a platform and a mechanism to have a quality discussion between energy planners and air quality planners, which is a discussion that sometimes does not have the opportunity to occur. But given that, it's a complex model. Excuse me. And it has numerous and subtle complications. And it results in potentially very subtle arguments in terms of what actually should be done and how that impacts various elements of the grid. The grid is large; it's complex; interconnected. But we can model it.

When we actually look at the output and the results, one of the key conclusions that comes out of this: the benefits are spread broadly across regions. Displacement can occur incredibly far from the actual source of the actual renewable energy or energy efficiency program. And the transmission and generation layout – the structure of the grid itself – really counts significantly. Ultimately one of the questions in this particular project – and I've got a feeling that Lisa Van De Water, at the end of my presentation, will discuss this a little bit – are signal-to-noise questions – how reliable is information that we're actually getting out of this?

Even though it's a state-of-the-art approach, there are some questions in terms of what can actually be found from this type of process. What I'm going to do is lay out the process of how these models are actually put together from the perspective of a user and operator, and then give a brief overview of the type of results that we get out of using these expectations for how one might actually engage in that. And then I'll pass it over to Lisa at the end of this talk. Dispatch models are considered sort of an industry standard practice. The simulation models are really quite interesting. They're forward looking. They rely on an incredible amount of accurate information. We're talking thousands of generators, all of which have dozens of characteristics.

And errors or questions in any of those characteristics might feasibly result in erroneous results at the back end. Those characterizations include the cost for fuels, cost for operations, energy contracts, hourly demand from the individual power load areas that require that energy, and hundreds of utilities. And then, of course, transmission availability and the shape of the actual grid itself. The simulation model, however, is constructed such that it can use real world rules and constraints, and real economic principles to then optimize the way that power actually flows across the grid and who is dispatched to meet that. So therefore we can get a detailed assessment of system operations. Ultimately this requires a significant amount of expertise. And here's an image of one of our experts busily plugging away at this model.

We look at displaced emissions analysis through a scenario analysis. So what we want to do is set up a baseline, and then set up several different scenarios that can be used as alternatives to the baseline and look at the differences between those two – or those multiple scenarios. We'll be looking at the changes that are at the margin, as Colin was referring to. So we require a baseline run, and then the specific scenarios. We'll be looking at which resources ultimately back down within each one of those scenarios. And then we can look at the emissions that result off of those units backing down.

So in this case, what we have is an image from a fantastic paper from Paul Denholm at NREL from 2008 where they were looking at increasing penetrations of PV [photovoltaic] throughout the West. And I'm just using this as an illustrative graph. At the far left we see dispatch for California over the course of just a single day, where we see different types of resources that are stacked up in a bid stack. And that's how dispatch would actually occur at a baseline condition. Over on the far right, you see what happens if there are approximately 10 percent (portable tag) penetration throughout California at the time that this model is being run. That PV displaces units – primarily, in this case, gas fired units, a couple of imported units and a little bit of coal throughout the region. And what we see is that it essentially digs out an area where generation is no longer called for from other locations. And what we want to do is calculate emissions from those displaced resources.

One of the first things we need to do is choose the size of our analysis window. So say, for example, we're the South Post Air Quality Management District outside of Los Angeles and Los Angeles Basin, we might choose to initially just look at the generators that are within our particular basin. But we know that California is broadly interconnected to itself. And so we might want to choose a slightly large window that actually takes into account other generators throughout California. But we also know that California is heavily reliant on hydro from the Northwest, and also has a return flow back to the Northwest. And there's significant amounts of generation that flow from inter Mountain West, into California and into the West itself. And so instead, we might want to use actually a slightly larger window that incorporates the entirety of the Western region.

So for this particular analysis, we'll be using the entirety of the Western interconnect. That incorporates the Northwest, inter Mountain West, and generally 11 states, including California, even if we are just looking for the benefits that might accrue within Southern California alone. Then we need to build a base case. This is essentially asking the question, what's the shape of the future grid? What's it going to look like? Which types of generating resources will be online and available in a future analysis year? What kinds of road conditions are we going to have? Is there going to be new transmission? Are our sources going to be controlled or uncontrolled? And all of these assumptions form the basis of our base case.

On the right-hand side, you can see the equivalent of, if we are to build out, in this case, U.S. generation out to 2030 according to baseline conditions, as put forward by the Energy Information Administration, we would result in one reference case. If we are to have an aggressive retirement of coal in another direction we might have a very, very different-looking grid that might have a very different type of marginal emissions in a future year. For the California project, we're assuming CEC-based assumptions for the 33 percent renewable energy standard by 2020. We're using 2016 as our intermediate year, with 26 percent renewable energy.

We're using 16 scenarios on top of this analysis that will be looking at four regions and, within those four regions, we'll be looking at four energy efficiency and renewable energy programs. So those four regions are Pacific Gas & Electric, which comprises most of Northern California; Los Angeles Department of Water and Power, which comprises mostly the City of Los Angeles; Southern California Edison, which is fairly intimately connected with Los Angeles and surrounding zones; and then San Diego Gas & Electric which is the far south of California. And between the three ISOs – PG&E, SCE, SDG&E and the large municipal of Los Angeles Department of Water and Power, we're encompassing the vast majority of energy that's actually utilized in the State of California.

Then the four renewable energy programs and energy efficiency programs that we're implementing as this pilot would be the equivalent of if we were to drop 1,000 megawatts' worth of wind into any one of those service territories. Or alternately, if we were to drop 1,000 megawatts of solar PV into those. Or alternately, if we were to drop 333 megawatts of a base load energy efficiency program such as a refrigerator efficiency program into one of those service territories. Or alternately, if we were to do something along the lines of a 10 percent peak saving program where we're aiming for the top 90th percentile of hours and attempting to reduce the load on those hours only. And these are essentially book end processes. Again, this is a pilot program. We're trying to choose programs that are large enough, that'll have a distinguishable characteristic within the overall grid, and we're trying to choose programs that are distinct enough in their load shapes that we can actually distinguish how they actually operate.

Between those four programs and those four zones, we come up with a total of 16 potential scenarios, as well as a number of sensitivities on them. And each one of those gets run. So we plug in all of our inputs; we eventually hit go; and we wait. And six hours later, for each one of these runs, plus or minus all the things that can go wrong, we come out with our results. The results that end up coming out of this are generation emissions. We're looking at, in this case, NOx, SO2 and CO2 for each power plant in the Western interconnect. So that's several thousand power stations, many of which have emissions. And we're mapping all of those plants down to WECC zones, and then intimately down to California air district regions.

So for all of those plants that occur within our entire Western interconnect, they get mapped to either California or one of three Western zones – the Northwest; the Rocky Mountain Interior West; and the Southwest – and then those plants that fall within California also get mapped into a particular air district region. And in this case we've aggregated some regions up to larger regions, just to account for various small regions that might not have very much generation in the middle. We examine our errors and uncertainty, and then like RSG, we also build a calculator from our output results.

So now I'm going to walk through what some of our results actually look like. And this is going to be a fairly intimidating-looking graph, but it's actually quite interesting. And if we take it just one piece at a time – and we'll only take one piece of it – then it will give some very interesting insights in terms of how the system actually operates. So what we're looking at is a graph of the 16 different scenarios across the X axis, and the amount of energy that is displaced by any given renewable energy or energy efficiency program of those scenarios. And what we're looking at is the fraction of that energy which is displaced in any given region.

So for 1,000 megawatts' worth of power coming online, we'd expect those 1,000 megawatts to be displaced somewhere. A hundred percent will be displaced. We just don't necessarily know where. So taking the far left bar as our example, that represents 1,000 megawatts of wind in the Southern – San Diego Gas & Electric service territory. Our results show us that only 20 percent of the energy out of a wind turbine farm, put in SCG&E service territory, actually displaces emissions and its generation within the state of California. The remainder of it – 80 percent – occurs outside of the State of California.

So a vast majority of that is occurring within the Southwest, and the rest of it is occurring within the Rockies in the Northwest. Still sticking to that first bar, we can see that it has three different patterns on it. It has a blank pattern, a solid color, which represents gas; it has a striped pattern, which represents coal; and it has a dappled pattern, which represents other, which tends to be biomass or oil. And of the past part, the resources that are displaced outside of the state of California are a combination of gas and actually a fairly heavy component of coal, at least as shown by the results of this particular analysis.

So the component of generation, which can even lead to displaced emissions within the State of California, is just that first 20 percent. If we translate this into looking at NOx emissions, again, looking at that far left bar, the amount of NOx emissions that are displaced within California – again, due to the fact that California is fairly clean generation, mostly controlled, mostly gas – is a very small number relative to the remainder of emissions that are displaced throughout the rest of the West. The striped pattern, again, represents coal.

And what we can see is that most of the displaced NOx emissions are coming from coal generators throughout the west that are not in California.

So this begs the question, if you're in the air district in Southern California, say in SDG&E, and you're interested in implementing a wind-based renewable energy program for the purposes of accomplishing a SIP within California, you might actually realize very little benefit within the State of California. But you might be realizing a significant benefit across other regions of the West which are not accounted for in your own SIP, but could have significant impacts elsewhere. And the results of this change significantly by whichever region we're implementing the program, and also by what type of program we're actually implementing, and the hourly load shape of those particular programs.

Finally, if we take that green bar down at the bottom and we really want to know what's happening within your own air district within the State of California, we would take that green component and split it out. Now, it looks quite small here, and it is quite small on a relative scale, but we can parse it by the air districts within California. And again, looking only at that first bar on the far left side – displaced NOx emissions within California – we're looking at wind for SDG&E. And if we were actually the San Diego Air District, that would be the third bar down in this particular case – I'm sorry, the second bar, the second slot down on the first bar; so the very dark red color – and you would see that it's actually displacing fairly little NOx within SDG&E, even though the primary wind turbines are put in that service territory. And this changes across various regions.

Finally, there's a calculator that looks very similar to RSG's calculator from the standpoint of an air district. One can put in the type of EERE measure one is interested in – in this case, say, wind – and the utility region in which it should be implemented – Los Angeles, in this case; and a linearly-scaled project size; and the output out of this calculator is the expected energy displaced within the WECC regions in general. This is the bottom left box showing California Northwest, Rocky Mountain Southwest, and we have both displaced energy as well as the different types of emissions, and then the displaced energy and emissions by the California air districts.

And what this chart shows is not only the amount of emissions and generation that are displaced, but the uncertainty limits on those particular elements. And so the lower number represents the uncertainty; the upper number represents the absolute. If the uncertainty exceeds the absolute, the entire box is grayed out. That is a value that we would find generally untrustworthy in this case. So in this case, wind, which is implemented within Los Angeles, has a very strong impact within the South Coast region, but not within other regions within California, and generally not within other regions within even the West, except for the Rocky Mountains.

In a general conclusion, we've seen from this that the benefits are generally spread over large geographic regions, at least from this particular run, in this particular part of the project. There's a significant displaced generation outside of California, and a significant amount of that is coming from, in this case, coal. The displaced resource type varies significantly. There are some non-intuitive results from this particular type of process. And we know that the grid is complex, but it really is analyzable. We have specific constraints on locations that really do need to be looked into. And there are a number of interesting outputs that come out of this that indicate that this requires closer looks than we might otherwise expect.

As my final slide, I just wanted to talk half a moment about what types of expectations either an air district state or other department might have working with a technical group on a displaced emissions analysis coming from a dispatch simulation model. And the big headline here is that it's fairly restrictive; it requires extensive input assumptions; there's a significant amount of build-out that's required in order to get your scenarios even set. It requires well-calibrated model inputs. That requires a fair bit of expertise; it requires a fair bit of time. But the good news is that there are groups that are able to do this. And these models have been developed, and there are good baseline data sets that are available for use in most places in the country.

That having been said, the expertise is expensive. The licensure just to even be able to run these models – they are proprietary models – is also fairly expensive. And unfortunately, the data that actually goes into this are proprietary. Not by our doing, unfortunately, by the doing of the companies that own this in the first place. The regional studies, however, that can come out of this are of very high value. For a project like the one that we conducted here, it might not even make sense to do it on a California-specific basis. We might want to consider doing a project like this for an entire Western basis. There's no reason that this model couldn't have also included energy efficiency and renewable energy programs, say in the state of Utah or New Mexico or Washington State. The model would have remained the same, and the marginal cost of including a larger economy of scale would have been quite marginal.

The good news is that the output can be published in numerous forms – we can put it out in calculators – and there's a lot of information to be learned out of it. So many thanks to all of those who have worked both at Synapse and at our partner organizations in helping put this together. Our contact information and the contact information for our sponsor is on this page. And you can find this, I believe, on the EPA website. And with that, I'm going to actually pass over the speaker to California Air District Lisa Van de Water from San Joaquin, to give her perspective of what it looks like from an air district standpoint. Thank you.

Lisa Van De Water: Thank you, Jeremy. This is Lisa Van De Water, and I represent the San Joaquin Valley Air Pollution Control District. And if you remember back to Jeremy's slide that showed the delineations of the air districts, we were that large lavender blob in the middle of California. To give you a little bit of geographical context, essentially we have jurisdiction over eight districts from Stockton in the north to Bakersfield in the south, and from the Sierra Nevadas in the east to essentially I-5 on the west.

So we do have a large jurisdictional area. And we were very interested in the work that Jeremy was doing, what Synapse was doing. And I want to really thank PIER and Marla Mueller and Jeremy for involving the air district. It's been invaluable information. And certainly, even though the conclusions, especially at the district level, may not have been what we had hoped for in the amount of emission reductions that we would likely incur from energy efficiency or renewable energy, the overall impact of the information will certainly enlighten us as we move forward in the attainment plan planning process, and in the near future.

The district, in the past few years, has been really promoting energy efficiency and renewable energy measures as we look for every opportunity to reduce emissions, criteria of pollutant emissions within the San Joaquin Valley, where we're a non-attainment for ozone and PM2.5. And so every opportunity that we can develop, whether that be through regulatory or non-regulatory measures, we want to investigate that and use that if we can. Ideally, we want to be able to include those reductions, to take credit for them in the SIP – in our SIP planning process at the state level.

As we've been looking at different energy efficiency and renewable energy potential projects, in the San Joaquin Valley, we've looked at the potential initial emission reductions from these measures. And we've had a pretty back-of-the-envelope calculation about the potential emissions. I mean, we know the number of plants in the Valley – electro generating plants in the Valley; we know how much the Valley consumes; and we had a very simplistic view of the import-export model. And using, you know, just the simple eGRID data, we came up with a ballpark emission rate per kilowatt hour to kind of talk generally about potential projects that we might have. And what the Synapse model has done for us is kind of enlightened us as to the true regional nature of our energy generation and use. Until you can see how and where energy is dispatched, it's very difficult to look at the impact in a region – and we think of our air district as a big district – but when we're talking about where all this energy is coming from, it is quite small compared to the Western region where potential energy resources are coming from.

Jeremy's slides, they're excellent slides, we've been very impressed with how he's been able to portray the information that has come out of this. And it's hard to kind of focus in on one particular district, but the San Joaquin Valley sees very little emissions reductions based on this model for the various scenarios. But that's not to say that the model is not a valuable tool. Certainly the greenhouse gas emission potential is stated well in this model. And if we look at the model from a state's perspective, there certainly are opportunities to reduce emissions in California and in air districts. We're, ironically, at a disadvantage. We have a very clean energy generation pool. And we've done a lot as a state in energy efficiency. So our incremental benefit may not be as great as other regions in the country. But they are real benefits.

We're just beginning our next ozone attainment planning process. And this tool will inform us as we move forward in that process in evaluating potential energy efficiency measures and informing us as to how we spend our resources in getting the maximum emission reductions for our next SIP process. Because I think one of the most beneficial aspects of this model and this tool – and Jeremy mentioned this – is that it gives the air districts a platform to move forward and have conversation with state agencies that are implementing statewide energy efficiency programs and renewable energy programs, and really stay involved and inform those policymakers and decision makers so that California and, in turn, the air districts, can maximize their benefits from those statewide programs. And the tool allows the districts to have a piece in that discussion, and potentially quantify the individual benefits for each district. So with that, I'll open it up – or I'll turn it back over to Catherine and we can proceed with questions. Thank you.

Catherine Morris: And thanks very much, both Jeremy and Lisa. One of the questions that came in while you were speaking, goes to one of the points you made, Jeremy, on your slides, about how the tool could be used for a longer-term estimate of how the generation mix might change over time, given these types of efficiency and renewable programs. I'm wondering if you could expand a little bit more on how specifically your tool can be used in that way?

Jeremy Fisher: Sure. There are two things to be taken into account when we're looking at a forward-going process. And one is that generally – assumptions about what the shape of the grid will look like, what generators will be available and what types of policies we'll have in place. And the other one has to do with how the grid will actually be acting in that future time period. And for the purposes at least of this project, we had to make an assumption about the former. We had to assume that California had a statutory requirement to meet its 33 percent renewable electricity standard, and that the way that the California Energy Commission had implemented its model in a forward-looking basis was going to be an accurate standpoint for how it was going to meet a statutory requirement.

And what we were looking at was then the operational margin of the overall grid in that future year. And so we were looking for the displaced emissions benefit from incremental energy efficiency and renewable energy above and beyond. If one is looking in a purely forward-going fashion, and you don't have a good sense as to what the grid might look like in some future, there are other models that help develop the sense of how the grid might expand, grow and shrink, depending on your various constraints in an economic fashion. It also requires significant numbers of assumptions. But then the changes that actually occur are occurring not on the operational margin, but on what we call the built margin. And that's a very, very different type of analysis. And I think even from EPA's standpoint, that would be a very different type of analysis. So in this case, we set up a baseline for either a future year or a series of future years in terms of what we believe and understand. And I think that probably requires some common understanding from stakeholders as to what the grid might look like. And then we're looking at displaced emissions, above and beyond.

Catherine Morris: Thanks. We only have a few minutes left, and I wanted to go back to a question for Jeff. While you were talking, Jeff, the question came in regarding how you actually use the estimates of averted emissions in the SIP planning process?

Jeff King: Well, the voluntary bundle is an interesting approach to including some of these kind of local voluntary programs in that it allows you to establish an actual emission reduction credit for the whole bundle, and then leaving a kind of flexibility and implementing the programs within it. So ultimately where there was commitment from the local governments or the District of Columbia to put in a measure in the bundle for credit, the calculator was used to estimate the emission reduction, and then that was equated into the actual credit taken.

I should say that we certainly used the tool to analyze the whole range of different EERE programs that were put forth, but not all of what was put forth actually ended up in there for credit. For instance, our building efficiency efforts were just kind of qualitative. We have high electric demand day, which was kind of more of a weight of evidence. I think the two that really rose to the top were the wind tower and the LED traffic signal retrofits in the district.

Catherine Morris: We had a number of other very specific questions that we weren't able to get to. But I wanted to point out that each of the speakers has agreed to provide their contact information, both on their slides and posted on the website, so that you can follow up with them if you have a specific question. In addition, I want to remind folks that there is going to be a recording of the audio and webinar portion of this present – of all the presentations. And there are background documents that can be downloaded in addition to the presentation materials at www.epatechforum.org. And we'd welcome you to check back there again for the recording, if you weren't able to join for the entirety of this presentation. So please do follow up with the speakers. And I'll turn it back to Denise to close up.

Denise Mulholland: Well, thanks, Catherine. I just wanted to take the time to thank all the speakers for your time. I know I certainly learned a lot, and I hope that the rest of the folks that joined this call did. I do want to thank all of you who called in today. We really appreciate you taking the time, and hope that you find these calls beneficial to you. I had wanted to just give folks a little advance notice that we are having our third and final webinar in the series. It's going to be on estimating – understanding estimated economic benefits of clean energy. And we expect to schedule this to be a little bit later on in the summer, maybe late July or so. And we will send out a "save the date" notice as soon as we get that date nailed down, so that you can know when it's going to happen. So with that, I'd like to thank everybody for their time, and thank you for joining us. Look forward to talking to you or hearing from you on the next call. Thanks, everybody.

Operator: This concludes today's conference call. You may now disconnect.

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