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CALIFORNIA ENERGY COMMISSION

COMMISSIONER WORKSHOP

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CALIFORNIA ENERGY COMMISSION (CEC)

CALIFORNIA ENERGY COMMISSION

THE WARREN-ALQUIST STATE ENERGY BUILDING

ART ROSENFELD HEARING ROOM, FIRST FLOOR

1516 NINTH STREET

SACRAMENTO, CALIFORNIA

THURSDAY, MAY 02, 2019

10:01 A.M.

Reported by:
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Patty Monahan, CEC Commissioner
Clifford Rechtschaffen, CPUC Commissioner

CEC STAFF PRESENT:

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Michael Nicholas, International Council on Clean Transportation
Ajay Chawan, Navigant
Nicholas Chase, U.S. Energy Information Administration
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PUBLIC COMMENT

Sara Rafalson
Nehemiah Stone

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P R O C E E D I N G S

MAY 2, 2019 10:01 A.M.

VICE CHAIR SCOTT: Okay, now we're ready to get started. Good morning, everybody and welcome to our status of the Zero Emission Vehicle Market 2019 Integrated Energy Policy Report Workshop.

The objective of our workshop today is to understand the recent trends in the zero emission vehicle market including the size and trajectory and key drivers for growth in different markets spanning California and also globally.

We want to take a look at the continued acceleration of the ZEV market because it is needed for us to decarbonization transportation which as you all know accounts for about half of California's greenhouse gas emissions, about 80 percent of the smog forming nitrogen oxides and about 90 percent of the diesel particulate matter.

So, we're so pleased this morning to have researchers and analysts from Bloomberg, the International Council on Clean Transportation, Navigant, and the US Energy Information Agency. And they'll highlight for us how technology components and electric vehicles designs are changing in response to regulatory requirements, innovation, and to pace with customers involving preferences.

And I also want to say a warm welcome to our fellow commissioner from the Public Utilities Commission, Cliff

Rechtschaffen. And a welcome to our newest commissioner at the California Energy Commission Patty Monahan. So glad to have you both here. Any opening remarks that you would like to make?

COMMISSIONER RECHTSCHAFFEN: Just want to thank you for holding the workshop and we look forward to our continued collaboration with our sister agency, the Energy Commission on all these important issues. We've had an excellent partnership over the years. We're doing our part. We all have different parts in the state. We released a ruling in our Omnibus Transportation Electrification proceeding either yesterday or this morning to articulate what we're going to be focusing on over the next several months and year in our shop.

I look very much forward to learning what the future holds from our experts. If you could tell me how many games the Warriors are going to take to win the championship, that would very helpful too. But that may be harder to predict than the price of batteries over the next ten years.

MR. CHAWAN: Seven or fewer.

COMMISSIONER RECHTSCHAFFEN: Seven or fewer. Okay. I'm going to put my money on it right there, great. Thank you.

And I'd also like to welcome -- look forward to working with new Commissioner Patty Monahan on all these

issues going forward.

COMMISSIONER MONAHAN: Good morning, everybody. So this is my day -- the -- my third day on the job. So I really am learning as I go. And I'm used to being out there, which it's a very different feeling here. I was talking to my friends from the ICCT and Navigant about the role of commissioners in terms of asking hard questions, trying to embarrass people, maybe even make them cry, so we'll see how successful we are. I promise to be nice.

And I just want to say how excited I am to be here at the Energy Commission. My background is in transportation, I've been working in transportation for 20 years and it is a time of great change and opportunity. And I feel like to be here in California working on clean transportation, I just feel like we are the center of the universe on clean transportation, pushing the envelope all the time on policies and incentives to help decarbonize transportation.

We are at this important moment where electric vehicles, the price of batteries is plummeting, in some way due to the fact that China has adopted the California Zero Emission Vehicle mandate and is helping to drive down battery prices for the world.

So I'm really looking forward to this panel, really looking forward to learning from all of you. And I was just kidding about the crying. I'm not going to make anybody cry.

I don't do that. But looking forward to learning from all of you.

There was a flyer out in front, I don't know if you all saw it. But there's going to be a ribbon cutting at 1:00 today. I'm going to go to it. Chair Hochschild is also going to it. And it's the first fast charging curbside charging in the state of California. So pretty exciting. This is where we need to go to be able to support all consumers but especially those that are Lyft and Uber drivers that really need to have fast charging in the middle of the day. So hope you guys can come after the -- after the workshop.

VICE CHAIR SCOTT: All right. Great. Well, let me turn it over to Tim who I think is going to moderate our panel this morning.

MS. RAITT: Commissioner, actually if you don't mind.

VICE CHAIR SCOTT: Oh, sorry, Heather.

MS. RAITT: Sorry, I just have a couple things I -- housekeeping things I need to say.

So I'm Heather Raitt, and I just need to let folks know that our workshop is being recorded. It's being broadcast though our Webex conferencing system. And so we'll have a verbal recording posted and we'll also have a written transcript posted in about a month.

And so folks on Webex, feel free to raise your hand

to let us know if you'd like to make a comment. At the end of the day, we will have an opportunity for public comments to -- at the end of the day. It will be three minutes per person. And that's basically it.

And also, just wanted to let folks know that all the materials for the meeting are posted on our website and also available at the entrance. Thank you.

MR. OLSON: Thank you, Commissioners. So we're going to go through presentations by four -- the four panelists this morning. First, two of them will be done remotely and then this group in the room here. And then we'll go into a panel session. You're welcome to ask questions at any point but we do have some timeframe for you to probe and ask questions. And then the panel could also involve, when we get into that section, interaction between the panel members too.

So we're going to start with Logan Goldie-Scot, he's online, he's going to do his presentation remotely. And with Bloomberg New Energy Finance. And as many of you know, this is one of the -- we have the -- we think the best talent in the room here today that -- not only just electric vehicle battery technology, charging technology but in a whole range of different kind of transportation technologies, fuels, options.

And we'll start with Logan to do his -- start that

presentation focused on battery storage in technology.

So please go ahead, Logan.

MR. GOLDIE-SCOT: Perfect. Well, thank you for hosting the workshop and I really look forward to discussing the topic. I'm sorry I'm not able to join you in person but hopefully next time.

So as Tim mentioned, my name is Logan Goldie-Scot and I head up the energy storage team here at Bloomberg NEF. So I can't tell how many games the Warriors will take to win since I'm British originally and we're more focused on soccer. But I feel for the next 15 minutes or so I can share some insights on really a remarkable set of developments we've been tracking on the battery front.

And for those of you who are not aware of us, Bloomberg NEF is Bloomberg's primary research service. So we focus on clean energy, advance transport, digital industry, and commodities. So it's great to be here.

If you could move me forward to the next slide, please.

And over the next few minutes, I'd really like to give a bit of review on what we've seen in terms of battery technologies and prices. How expensive a battery is to various things that you would consider -- seen in the market such as silver, very volatile commodity prices. And then, really the crux of this is what are the implications for

electric vehicle uptake?

So, if we move to the next divider slide and onto the first chart, please.

Perfect. So at Bloomberg NEF, we've been tracking battery pack prices since 2012 really going back to 2010. And what you can see -- what you can see on this slide here is that sort of incredible cost reduction that we have observed over the last eight years or so. And so since 2010, we've seen the average battery pack price for 85 percent reaching $176 a kilowatt hour at the pack level by the end of last year.

Now within this, as I mentioned this is the average price, there is a range of prices that we publish in sort of in a more detailed report. But essentially the lowest price we observed in the market and that we tracked in this and on my survey which will add $125 a kilowatt hour for 2018 with the highest price typically for lower volume and niche applications being close to sort of 400 or so, but the -- here there is a range but you can't see this pretty incredible cost reduction over time at the pack level.

Now if we look at the next slide, what you can see is that we're splitting that up and hopefully adding a bit of clarity on what we mean when we say what's a cell level. Because I think it's often confused. Often data points are confused between one or the other and so battery low prices

that you sometimes hear disclosed from automakers or others are often only at cell level prices.

Where is what you can see here is the underlying cells and then the pack and really the cell from 2018 anyway it was making up around 70 percent of the overall cost here.

Next slide, please.

So we've tracked this sort of significant cost reduction over the last few years. And as we look forward, we expect battery pack prices to continue to fall. And so the way we've done this is we've taken a top down approach looking at sort of experience curves which is proven to be a very effective way of looking into the cost reductions over time when the future is inherently uncertain, when technology advances are inherently uncertain.

And so we've looked at the learning rate of -- between 2010 and 2018 and observed prices and then the volumes that we were tracking the market. And then if we apply that going forward based on the demand that we expect to see from California and China and elsewhere, you end up breaching that sort of a that critical $100 a kilowatt hour mark in 2024 from the average price. And then getting as low as $62 a kilowatt hour by 2030.

And so we do generally believe that there is significant further room for cost reductions in this space and that this -- that the level of technology advancements in

these other economies of scale that we are observing in the market will help enable that to the next -- over the next decade or so.

And if we look at the next slide, this is just one way of thinking about this. So we -- one way of looking at future prices is using an experience curve methodology and looking at learning rates and how those change over time.

We also, at Bloomberg NEF, have a proprietary bottom up battery cost model that allows us to essentially look at how much does it cost if we build -- if we mock up a building a battery manufacturing facility depending on our chemistry choices, depending on our design, depending on are we building this manufacturing plant in -- outside of Shanghai or are we building it here in California? And what you can see here is just one example of where we see potential for further cost reductions.

And so, looking on the Y axis here, you have the dollar per kilowatt hour. So the cost of the battery but really just looking at the materials in particular. And for NMC, so nickel, manganese, cobalt 62 battery. We believe that there are significant cost savings by moving that cathode from the ratio of 6 to 2 to 2 to an 811 cathode. So apologies if this is becoming sort of a bit too technical, but essentially advance at the cathode so they keep actually component result in decreased cost of the material and at the

cell and pack level. And that is one way in which some of these future cost reductions could be achieved.

And then if you look at the next slide, another way is by actually ignoring the cathode and then the changing things on the anode side so now the key component in the battery where moving to the silicon anode, or silicone do anode gets you further down that cost curve as well.

And this is really just an illustrative example of how -- why we do not believe that -- why do we not -- why we do not believe that cost reduction will plateau at the moment. And why we see a lot of potential for further cost reductions for lithium batteries in the future.

Then if you look at the next slide, the other thing that we find incredible exciting here, in addition to those cost reductions being driven by technology advancements and economy to scale, the other thing that we -- the other thing that we find particularly exciting here is what we see in terms of battery performance.

And so the battery energy density for many of the major players we're tracking, many of these major chemistries is improving significantly. And then so if you look here going back to 2010, you can see the cell energy density was sort of for some of these chemistries was sort of below 100 watts hours a kilogram.

And then as you look towards today how the cell level

you start seeing energy densities to over double that. And then moving forward with some of these sort of more step change technologies again, you can see the progress is fairly clear.

So all in all we're pretty excited around and -- well, the industry is often pretty excited about sort of where we have come over the last sort of decade or so. And also the potential on a performance side not a cost side for a huge amount of movement over the next decade.

If we look at the next slide, or we could move through the next divider slide and just go to the first chart. One of the questions we often receive when we talk about this sort of future battery cost decline is what will be the impact of changes to the underlying commodity price? And this is incredibly important because and it really came to a head in sort of late 2017 because the underlying price for metal such as cobalt or cobalt sulfate, as you can see on this chart, throughout 2017 increased significantly and increased from sort of a below $40,000 a metric ton. It's actually over $110,000 a metric ton into the end of 21 of last year.

And through out that sort of that rise, there's a huge amount of anxiety and concern within the industry or if this continues or even if that peak is sustained, what will happen and how can we reach these prices in the face of this?

The understanding that volatility is going to be or is incredibly important for car companies, policymakers, and the battery manufacturers themselves. But what you can see is that rise has eased off and we're now closer to where we were back in the sort of a flat appeared throughout 2016.

Now cobalt is one important metal here. If we take a look at the next slide and look at lithium, what you can see is similarly it's just important to be aware of -- to be aware of some of this volatility and especially this near-term volatility which can change usually on a month to month basis. And you can see lithium prices here rising from just about $5,000 a metric ton up until over $20,000 a metric ton before sort of falling off again.

And so it's incredibly hard to predict future prices of these metals, but understanding and building in some sort of adjustments of a value to that or sort of at least being able to compensate for that is going to be very important.

And what we did when looking at this is and if you look at the next slide, is we bought a tool that is sort of available to our clients, which is sort of more dynamic and then here's just a screen shot, which looks at how sensitive battery pack prices are to these sort of swings in the underlying commodity prices.

Now this is -- I promise this is the most complicated chart I'll show today. But essentially, the -- what you have

on the sort of X axis for each of these is the metal price as of -- as December 2018.

So in both cases for cobalt and lithium, one has fallen off a bit. And then you can see four rows of colors so lithium, cobalt, nickel, manganese. Now what this shows is that for an NMC 811 chemistry, if the metal price for lithium for instance, had doubled from -- had doubled from that sort of December 2018 point, or had increased by 50 percent. You'd be looking at sort of a three percent or so increase in the overall battery pack price. Where a bit smaller increases for the cobalt is from that lower exposure.

So commodity prices matter and they matter a lot in terms of understanding the future of this industry and potential scarcity concerns. However we do not think these on their own are likely to derail that lower cost outlook that we've sort of articulated in the earlier slides.

Now if you move through the next divider slide and let's just wrap up by talking about some implications for electric vehicle adoption. Now this is the analysis that we put out in 2018 and then you can speak to my colleagues in the room or myself in questions on some of the 2019 analysis.

But essentially falling back in prices ensure the electric vehicles become cheaper than internal combustion engine vehicles so that's the yellow series, apologies for the labeling, become cheaper than the internal combustion

engine vehicles in the mid-2020s.

Now this shows the analysis for a large vehicle segment and you can see that crossover in around 2025. And then if you look at the next slide, which shows a small vehicle segment, you can actually see that crossover happen sort of a bit later. So it's harder to electrify smaller vehicles cheaply just because of the total cost of those vehicles is much lower.

Now if we look at what's changed between the 2018 analysis and our 2019 analysis, the big change is battery prices actually fell -- or our outlook on battery prices fell quicker than expected and as a result, some of these sort of inflection points have moved earlier by sort of the high-level completion here.

And then if you just look at our final slide and just to give a bit of scale or sort of where are we now and where do we think the battery industry is going. Lower prices, more energy dense and better performing technologies and taking in to account some of these major advancements over time along with policy support in different markets and sort of, you know, different consumer -- consumer preferences help on depend rapidly increasing battery demand over this period. And so you can see where we are sort of just shy of a couple hundred gigawatt hours of annual battery demand in 2019 rising to over well, over 1,800 gigawatt hours of annual

demand across battery electric vehicles, e-buses, consumer electronics, and then station energy storage by 2030.

Now we -- I think in a couple of weeks or later this month we will be releasing our 2019 electric vehicle outlook which will also include commercial trucks and other commercial vehicles. And we also sharing those numbers accounting that ends up also being a meaningful source of sort of additional battery demand over this period.

And every time we add more segments and we're able internally to analyze more segments with confidence, you're likely to see sort of greater -- a greater battery demand and this is really because of this -- the marketable set of developments over the last sort of decade or so around battery prices and battery technologies.

So with that, thank you very much for having the opportunity to present here. I hope that was useful and I'm looking forward to hearing the other presentations and then the Q&A discussions.

MR. OLSON: Thank you, Logan.

Commissioners, do you have questions for Logan?

COMMISSIONER RECHTISCHAFFEN: Can you go back to your slide about cell energy density? And maybe give us a little bit more -- I'm interested in a little bit more information about what you project in terms of improvements in density. In particular, how -- what that might mean for the market for

larger vehicles, trucks, and so forth.

MR. OLSON: Logan, are you still on?

MR. GOLDIE-SCOT: Yes. Sorry. Can you hear me?

MR. OLSON: Yes.

MR. GOLDIE-SCOT: Okay. Perfect. So the way we look at forecasting energy density is we take into account this energy density, but what we actually base our four cars on pack energy density, so which ends up -- and ends up being sort of a bit lower than this. But as for passenger electric vehicles and then also third commercial truck segment, we do see that sort of increasing steadily over this period. Not to even taking into account actually some of the more step change sort of requirements such as solid state.

Our future energy density sort of outlook is really based on better cell -- cell and pack design and imprint and more energy dense chemistries. So the actual -- the specific numbers can be found in the -- in our electric vehicle outlook.

COMMISSIONER RECHTISCHAFFEN: Well, just kind of getting at -- are there going to be breakthroughs with larger vehicles in your forecast? The same way you -- for heavy duty vehicles which -- for which density is a much bigger concern or need?

MR. GOLDIE-SCOT: So I don't want to jump the gun too much because of the report is sort of due out in a couple of

weeks and they're still going through sort of the finalization. But from what I understand and from what we published so far, you start hearing meaningful opportunities for sort of a last mile delivery. So for the smaller, medium sort of a truck segment, long haul trucking for normal trucking it looks further outlook based on their technologies that we know and model today.

VICE CHAIR SCOTT: So I had a question for you back on -- this is Janea Scott, on slide five and Logan, I want to say thank you so much to you all for being here. I know you have a new report that's coming out with brand new numbers hot off the press in a few weeks, but I appreciate having your data and information here today. So thanks, thanks so much for being here.

Back on slide five when you look at the price dropping down -- through 2030, are you comparing the price of that pack? It's similarly sized, right? So if you had a pack that could go 300 miles and that's the number that you had on the 2010 line, is that the same pack that could go 300 miles, for example, and that's the same that's down here on the 2030 line?

MR. GOLDIE-SCOT: So that is the -- because that ends up having to do with -- well, I think there's two things. One is the energy density, and so that as you have a -- have more energy dense systems, that does mean that you can --

that does end up being sort of accounted for here. So it's the evidence is not static throughout this and density is one way as to one technology sort of advancement of achieving these lower prices. Because if you have a more energy dense cell, then the same production line can produce sort of more and use the same production rate than you can use more cells on or more kilowatt hours on sort of on that line in the same period of time.

So this does -- this chart here takes into account sort of -- implicitly, sort of advances in energy density. It does not look at specific battery pack sizes because that's done when we sort of take these numbers and apply them to different vehicle segments. So a small vehicle segment will have a sort of a smaller battery pack size and thus a sort of a different sort of range calculation to one of the larger SUV segments that we also model.

VICE CHAIR SCOTT: Got it. Thanks.

COMMISSIONER MONAHAN: Logan, this is Patty Monahan.

First I want to say I love BNEF data and for a long time you guys were the crazy ones in the room, everybody thought your projections for battery cost drops were insane and it turns out you were always slightly underestimating what the drop was going to be. So kudos to you and your team for being aggressive on the optimistic side of the equation.

And I'm afraid I might ask you -- be asking you a

question that's beyond -- because I'm going beyond your slides. Which is that you had done an analysis previously on what the vehicle standards rollback would mean for vehicle sales in the United States with the Trump Administration gunning for weakening the standards and potentially even taking away the ZEV mandate. Are -- could you speak to any of that data or is that just outside -- should I just stick with the slides?

MR. GOLDIE-SCOT: It's a -- it moves somewhat beyond my focus, but I can talk to it at a high level. In 2018, the North America -- so predominately the U.S.A. in this case, was the second largest market globally in terms of electric vehicle sales to 2018. In 2019, based on sort of a -- what in our view, anyway the U.S. ends up being overtaken by Europe as the second largest market, the largest market being China.

Now a major reason for that is in the -- since we're ahead of these major tipping points in terms of sort of a battery sort of cost competitiveness, a major reason for that change in position is increasingly stringent policy requirements in Europe around sort of a automakers' fleet and sort of a emissions from those which are not -- which is a different policy environment I guess to as what we have federally in the U.S. at the moment.

So, I -- I'll defer to colleagues on our sort of

advanced transfer team on some of the details, and we can certainly sort of speak offline.

But in general, we do see -- what eye level we see more stringent policy requirements in other regions outside of the U.S. having a very meaningful impact on sort of accelerating adoption of electric vehicles versus a more gentle increase in electric vehicle adoption in the U.S. this year in the absence of sort of comparable measures.

COMMISSIONER MONAHAN: I would love to see that data.

One last question. For your future research, are you all looking at this integration of EVs into the grid and ways that we can capitalize on the economic value of that stream so that it's not just the reduced fuel cost but also the grid benefits that could accrue if we charge vehicles correctly? Are you getting involved in that quantification and the opportunity for savings that way?

MR. GOLDIE-SCOT: Yes, we are. So what we have is two of our big flagship reports. One is our electric vehicle outlook which comes out later this month and then the second is a new energy outlook which is more focused on sort of on the grid and power markets.

Now the new energy outlook takes -- it -- the reason why it follows the electric vehicle outlook is because we need the electric vehicle numbers to understand what electricity demand -- what -- to help be the final piece in

that jigsaw of what future electricity demand will look like, and what the shape of that demand will look like as well. Because it doesn't just change the absolute amount that changes sort of when do we expect that to be electricity demand.

And so we certainly account for sort of electric vehicle charging requirements and also how flexible is that demand. Sometimes they'll -- what does -- yeah, in terms of how easy is it to move that and that ends up being influenced by how much public charging infrastructures there, what does that look like, what does the fleet look like, et cetera?

So we account for that explicitly in our new energy outlook. There's a -- so that's really look at sort of non-dispatchable measures looking, focused on sort of an electric vehicle charging. So that's like tower space and availability of charging.

We don't at the moment include in our main outlook more sort of a dispatchable measure such as bidirectional charging, so with vehicles, audio radio infrequency or reserve or capacity markets, et cetera.

We've written a series of recent publications on that but that market remains relatively early stage with most projects being at the pilot stage and so it doesn't -- so once we write about it, it doesn't formally call out by longer term view.

COMMISSIONER MONAHAN: Thank you. It might be a place for collaboration between the work that's going on in California at the -- there's a VGI work group that CPUC is convening that our -- we're also participating in through Noel Crisostomo, sorry for doing a terrible job with your last name, Noel. But just an opportunity to think about how California with its cutting edge, I think, probably the most sophisticated in the world, thinking about how to integrate EVs into the grid in a way that provides benefit that we can quantify and then start driving, charging at the right time and having consumers actually save money that way.

I think that's going to be a big value stream, especially when we start talking about heavy-duty electrification that we can take advantage of.

MR. GOLDIE-SCOT: I agree that that it's hugely important.

VICE CHAIR SCOTT: Logan, I had one more question for you, this is Janea Scott again. On page 16 -- on Slide 16, and you showed the electric buses component in there, looked like it was fairly steady state. One thing that I've heard is that adoption of electric buses might go faster actually than the adoption of passenger electric cars.

And then you sort of hinted in your comments a little bit earlier that there might be more meaningful opportunities in the last mile delivery and that we might see this chart

change a little bit as you get the 2019 data.

Are you anticipating or can you reveal before the 2019 data comes out a change in that e-bus slice of the pie there?

MR. GOLDIE-SCOT: I can't speak to a change in the upcoming report, yeah, for various reasons. But I believe the reason why the chime -- the reason why the e-bus number looks like we'd be flat there is a -- it's actually around this speed of which this is already happened in China. And the -- yeah, and so, I'm afraid I'd have to defer to my colleagues on the transport side on some of the nuance there ahead of the reports coming out in a couple of weeks.

VICE CHAIR SCOTT: Okay. No worries, thanks. We will all -- we all stay tuned with bated breath for the release of the report.

Tim, shall I turn it back to you?

MR. OLSON: Yes. Thank you very much. Thank you, Logan. I'm hoping you stay around because there's one area I'd like you to kind of look at. I'm going to telegraph one of the topics for our panel discussions and that's looking into the supply, the actual, what has to happen on lowering the cost of manufacturing from a business standpoint and I'd like you to think about that because I'd like to raise it in the panel session.

But we need to go on to the next speaker to keep on

track here.

So next speaker is Michael Nicholas, he's with the International Council on Clean Transportation. Longtime expert in this area, also had done previous work related to this same topic with UC Davis Institute of Transportation Studies. So, Mike, please go ahead.

MR. NICHOLAS: All right. Thank you, Tim. First, I'd like to thank the Commission for inviting us here today to talk about some of our research.

Introduce myself. Thank you, Tim. Yeah, I'm Michael Nicholas, I'm a senior researcher at the International Council on Clean Transportation. And I'd like to also acknowledge a lot of the numbers in this presentation that I'll show you come from -- the principal author is Nick Lutsey. So some of the hard questions I'll, if they're too hard, I'll say I just don't know even if I might.

But -- and then finally thank you to BNEF Logan Goldie-Scot for going over a lot of the detail which I don't have to go over so hopefully we'll build upon that to look at some vehicle scenarios and a little bit more global perspective on that.

So with all -- I will start the presentation. At the International Council on Clean Transportation we follow global trends so I'll show you some of the U.S. work we've done going more high level, looking at what's driving a lot

of these economies of scale towards the vehicle market.

And this is the U.S. electric vehicle sale history. So up to 2018, we see the number of vehicles on -- this is yearly sales on the left and then the percent of electric vehicle the share -- electric share of new vehicles is for light duty on the right. And so, we're up to about two percent in the United States, with about two-thirds of that in the EV, ZEV states.

So it shows the role that policy plays in driving some of this market. But I will say with all the effort that's been put in in the ZEV states, there's a lot of them very recent uptake in non quote, unquote ZEV markets and so it's working like you'd hope it would where we're seeing a pick up more broadly.

So if you look at those bars I just showed, that's the very, very small blue bar on the bottom of this chart. This is global sales and we see the same right axis, the annual electric vehicle sales. So in 2018, that was 2 million electric vehicle sales including plugin hybrids and BEVs, driven mostly by China. And that's the big red bar, little bit of Japan and then Europe is in generally green and then North America is in blue at the bottom there.

So the point here is that it's a much bigger market than the U.S. and a lot of what's driving sales is sales around the world. So looking at the economy of scale it's

important to realize that.

So, this is another way to look at the data. We looked at again, going on the economies of scale track, we see that there are -- this is sales by auto manufacturers and we show ten distinct auto manufacturers here in the right -- sorry, the left graph and then that accounts for just those ten manufacturers, about 1.5 million vehicle sales in 2018.

And so Tesla's at the bottom, I won't read all of them. But the other thing to notice is that there's a little more consolidation in the battery space. And so this is driving some of these economies of scale and some of those lower costs that we've see -- that we saw presented with BNEF which we take advantage of very much and are very appreciative of those projections at ICCT. So we see a little bit -- a different picture but still it's driving those economies of scale.

So this is a little more context to the BNEF line that was just shown and we -- that black line is labeled there, it's the second from the bottom, BNEF 2018. And we look at some other studies around so a little audit -- this is a combination of bottom-up studies, automaker announcements, and reports such as BNEF.

And we see there's general agreement on the lowering of battery costs from 2018 out to 2025 and then some of those more speculative -- not speculative, some of those more

future looking studies which breakdown the costs based on trends and what we could expect in the future, so with bottom-up studies and other studies.

So I'll show numbers based on today and 2025 or actually 2020 and 2025 costs in the next slides which there are a little more -- there's a little more data out there or at least studies that look at those costs.

So I'm not going to go through this slide, but please read our report because this is to say we did look at -- take a kind of a sector-wide look at the battery costs, and you can read these there.

So in the next five slides, I'll take you through a little bit of a shell game, but I'll tell you where the ball is underneath the shells and I'll point to it. So the important point here is the top numbers, this is the total manufacturing costs for a conventional vehicle and three ranges of electric vehicles. And we do it different ranges because people talk about equivalency in what is an ICE equivalent. It's for one person, it's 150; for another person, it's 250; for another person, it's 500 miles. And so we look at that -- this on those different costs.

And on the bottom we show the largest cost driver which is the battery cost based on those studies, going from $7400 to the $13,000 from 150 miles to 250 miles. And this is also just to show, I'm not going to go through each one of

these but to show that there is -- we did go through all these different cost components based on some other studies including UBS which was -- they did a very good teardown cost study of the bolt and then we scaled those costs to different types of vehicles.

And then of course there's vehicle assembly and indirect cost and that's -- that includes R&D and it turned out to be a fairly significant cost in the case of electric vehicles, whereas a lot of that cost is already learned out in the ICE conventional vehicles.

And so also there's one cost component that is not in the electric vehicles and that is the engine and that's the yellow. And so that becomes important for PHEVs as well.

So now I'm going to tell you, I'm -- we're going to take a look at those -- these four bars and they're still there, but they're just on -- they're the 2018 costs and you see again those total manufacturing costs from 25,000 to 39,000 in 2018 on to the left. But then we also show what does it mean when we start looking at those economies of scale primarily in the battery pack space but also in a lot of those cost components for power controllers and other things on electric vehicles which are expected to drop slightly but the main driver is the battery pack costs.

And if you look at, let's say the BEV 150 in 2018 versus a BEV 150 in 2025, we see that it goes for about

$7,400 to $4,000 so not quite half, but the pack cost does decrease driving these costs.

The other important thing about this chart is looking at the manufacturing costs. So this is for the car segment not the SUV or crossover segment. But we see again, the cost for conventional vehicles rising slightly to comply with vehicle regulations, greenhouse gas, improving fuel economy. So it goes from $25,000 to $26,000 for the conventional vehicle between 2018 and 2025. But we see that cost for the BEV 150 for example, go from 33,000 down to 24,000 for two main reasons, the battery pack cost and the indirect cost. Where that manufacturing early -- the research and development that is spread over more vehicles and there's less new technology by 2025. But it's mostly about the number of vehicles with that cost that's spread over.

And we see that by 2025 for the car segment, both the BEV 150, that's a BEV of 150 miles, and a BEV 200 are either at cost parity or lower than the manufacturing costs for -- to the conventional vehicle. So that's very encouraging, still slightly higher for the BEV 250.

So again keep your eye on those top numbers, there's eight numbers there, and we show the same eight numbers in the next slide. So it goes from $25,000 on the left, $28,000 on the right and there we go, $25,000 on the left, $28,000 on the right.

And so, what that bottom blue bar is, is that total manufacturing cost that it should but it's one cost. And so if we look at the price of a vehicle, there -- the manufacturing cost, but then you have to add on the profit margin for the manufacturer and then the dealer markup, and those are those two other bars. So the price that the consumer might see would be the top of the blue bars.

And then also we show on here the electric vehicle ownership, the cost of the first-year owner over five years, how much will it cost to operate that vehicle? And the biggest drivers of this or the biggest difference is -- are the yellow bar, which is fuel/electricity so the fuel is going to cost more in a conventional vehicle than the quote, unquote fuel or the electricity in an electric vehicle.

So that's what is slightly less, but the cost of the vehicle is more. And then also the maintenance is less in an electrical vehicle projected than a -- the conventional vehicle.

Now one other thing you may wonder about and I'll just mention it because it's kind of important and it's -- but it's -- we don't need to talk about it too much because it's different for every consumer, is that top replacement cost.

It would put that in to reflect what is the quote, unquote inconvenience cost of owning an electric vehicle.

What can't a BEV 150 do with just home charging? And so, there's a certain number of miles based on the -- if you guys want to get in the weeds, the SAJ 2841. Who knows J 2841, oh, yeah, we got a couple three -- three people. Okay, so I just talked to three people.

So anyway there's a utility factor which says how many miles can you do with an electric vehicle with a certain battery arrange size? And then those extra miles are priced, so there's an extra cost to having an electric vehicle. We put that in there just as a recognition of that. And that can go up or down. It could be zero for some people. It could be very high.

So the real costs are to the top of the, I guess the pink bar. But the important thing about this after all that is that in 2018 the cost without subsidies for an electric car is higher than a conventional vehicle. So 42,000 is less that $51,000 or 57 for the BEV 250. But by 2025 because we see that drop in cost, we see that if you take the manufacturing cost, the price, all those things and then add in all those savings from the electricity, using electricity the cheaper cost per mile, and then the maintenance savings, we see that all the BEVs even long-range BEVs become cheaper over five years than a conventional vehicle even though the price is higher.

So that was a lot of explanation. I hope -- I hope

you got it. Okay. So again, going from this slide to the next slide, I'll show it in a slightly different way. Those costs are going to be in a chart over many years. So we only show two years here, 2018 and 2025. And so those costs are -- you can find them, actually 2018 is a little bit off the chart here looking at when will we see vehicle price parity. So it's that vehicle cost, plus the dealer markup, plus the manufacturing profit.

And so that vehicle price that people will see -- we see it going up slightly in a conventional vehicle to get more technology on the vehicle to comply with regulations. So it get's slightly higher for the conventional vehicle from 2020 to 2030.

But we see for those three different ranges which I showed plus a 300-mile case which we added for this. The point at which the price parity crosses, so if you have a very small or not -- a fairly -- the smallest range we look at, 150 miles, at around 2023, that crosses the cost parity for that class of cars. This is just cars. We have a different one in our paper, please go to our paper at the bottom here. Four different classes, there's cars, crossovers, SUVs. And this is for the cars. And so, by 2028 all of these vehicles cross the price parity barrier with a conventional vehicle of the same type.

So we come to PHEVs and this was one of the questions

in the slides and we see that because it has both an engine and a battery, even though it's smaller, we don't see that gap closing with the conventional vehicle.

Now there is -- the reason I spent some time on that cost of ownership slide is because with the cost of ownership, we do see these costs converging in the PHEV is better than a conventional vehicle based on the operation cost savings. So the maintenance quote, unquote fuel or electricity and we do see those crossing. We don't show it here but just keep that in mind.

Now, all -- for the last three slides I'll go a little bit further out we just went into the weeds. But this is the classic Rogers' Diffusion of Innovation Curve and where are we in the market. And even though we're not at the same scales as this is presented, it's suggestive to say that U.S. is around two percent. So we're potentially emerging in a way out of the innovator space. California in many places is over ten percent, so you might say those markets would be in the early adopter stage. But there's, you know, there's more to say about that and how you might compare these two trends.

But also there are markets like Norway where we see 40 to 50 percent market share for the year 2018. And they, you might say that they are in the early majority, if you take this chart and use it liberally.

So this is a -- next to last slide is automaker announcements versus what we expect with regulations. And so if you want to get into details of this, please read these resources below. But we project based on regulations. This is what the market will look like in 2025 -- little bit over ten million between Chine, Europe, and U.S.

And U.S. is not really driving this global volume for batteries but we do show it. And then we also show it next to the automaker announcements. And I think it's suggestive that the automakers are gearing up for this. They're gearing up for more than what is required.

Now there's, you know, announcements taken for what they are intended, their projections and goals and so they haven't happened yet. But we've added up these for 2025 and they are higher than what is expected through regulation or being force by regulation -- or I guess, being what regulation would suggest the vehicle sales will be.

So, finally looking a little bit at different sector infrastructure versus electric vehicles, we see that the infrastructure is different in Europe and China, with China having many more electric public chargers per electric vehicle than the U.S. And so all these things will go different. There are some advantages we have in the United States with a lot of home charging available, and access to home charging so I think that drives a lot of these numbers.

I also will not read all of this just trying to get through this but I think that there's three points that I'd like to make, you can -- we left these up here just so you can read them later.

But it's a global market, there's a lot of trends that are in batteries and electric vehicles that are driving this and driving these numbers down to a very, very -- to lower and lower pack costs and electric vehicle costs, and volume is the key to that. And as we showed, manufacturing cost parity, cost parity could come as early as 2024 and then we show different ways to look at that. And there's manufacturing cost, parity, price parity, and then total cost of ownership parity. And those do come at different times. But between -- but by 2030, we see a lot of these three different ways to look at it -- converge.

And then policy could shift from incentives as we cross cost parity to regulation to help encourage the market. But there are still problems that remain, most notably infrastructure. And then we may just to get that early majority, late majority, we may need incentives in different areas to ensure access to electricity and in charging.

So they -- even when we have manufacturing costs parity, if somebody can't plug it in, it doesn't really matter. So, think about that. In some of the rules we might look for hydrogen and PHEVs.

With that, thank you very much for everyone's attention.

MR. OLSON: Okay. Thank you, Mike. We have about six minutes for questions, from the dais. If you have questions, please go ahead.

COMMISSIONER MONAHAN: Nice job. I just have a really easy question for you which is I was confused about the fuel price -- the fuel cost numbers in that slide. I mean, if it's -- is it just for a year, like what is that fuel, electricity, what is that comprised of?

MR. NICHOLAS: Yeah, so this is the five-year cost of ownership so all the fuel over five years. Looking at what we assume for the miles per gallon of a conventional vehicle, I think it's in the 20s maybe 30 by 2025. And then the electricity cost over that same period.

COMMISSIONER MONAHAN: Okay. Weedy, I'm sorry, one weedy question --

MR. NICHOLAS: Yeah.

COMMISSIONER MONAHAN: -- you'll refer me to the detail. What's the cents per kilowatt hour you were assuming?

MR. NICHOLAS: We looked at, I don't know offhand, but it was the EIA prices and so we looked at the average residential price for EIA. So in -- and it does -- it's a very good point -- that does vary --

COMMISSIONER MONAHAN: A lot.

MR. NICHOLAS: -- extremely by utility. And I think that's -- that's something that -- in California, it tends to be a little higher, honestly, unless you have time of use but then there's other issues with time of use. And that's maybe another discussion. But, yeah, it does vary a lot. Thanks for pointing that out.

VICE CHAIR SCOTT: Yeah, a follow up on that one is also the cost per gallon of gasoline that you use. Do you know what number that was as well?

MR. NICHOLAS: I don't know offhand, but I know that was also EIA, so we took their projections and said -- use those and I don't offhand. But that's -- I can look that up for you and send that off.

VICE CHAIR SCOTT: Question I had also -- great presentation, thanks so much --

VICE CHAIR SCOTT: Thanks so much for being here.

On slides 10 and 11, where you are talking about the different battery cost reductions, are you using numbers similar to the ones that we saw Logan present, or others?

MR. NICHOLAS: Yeah, that's a great question. And I'll go back to -- so Logan's line is this the black dotted one right on there. And ours are slightly higher than that, so but just slightly, so they're very similar but it's in the same ballpark.

COMMISSIONER RECHTISCHAFFEN: I had a couple of questions. Could you go to slide 13? I just want to clarify what you're representing here, is it your best guess that we'll be at ten million vehicles in 2025?

MR. NICHOLAS: Yes. Electric vehicle sales.

COMMISSIONER RECHTISCHAFFEN: So, what's the -- there's a descript -- that's sort of what the regulatory mandate which you -- so are you saying that's going to be the ceiling?

MR. NICHOLAS: No, that's not the ceiling, that's the floor, I think, that's what we expect based on the mix of, you know, how many electric vehicles do you need in the market to comply with greenhouse gas regulations. That mix would equal this with the competing improving conventional vehicles.

COMMISSIONER RECHTISCHAFFEN: So even though by 2025 we'll have parity in cost of purchase price and earlier than that total of cost of ownership, we're going to be going.

MR. NICHOLAS: Right.

COMMISSIONER RECHTISCHAFFEN: You're still staying we're only going to see the number of vehicles needed to meet the regulatory mandates?

MR. NICHOLAS: I think that's -- it's a conservative way to look at it but yeah, I think that's the floor. And I think once cost parity is reached, then we'll start to see

probably a major uptake around that time.

COMMISSIONER RECHTISCHAFFEN: You started by saying -- you started off by saying we're now seeing an uptake in non-ZEV states --

MR. NICHOLAS: Yes.

COMMISSIONER RECHTISCHAFFEN: -- in sales anyways, which would argue a little bit against this point.

MR. NICHOLAS: Well, I think that, you know, there's an uptake it's certainly more than it has been. And I think it's something like if you take the last two years, it's, you know, 100 percent improvement in some of the states that are like non-ZEV states. I think that as strong, you know, complimentary policy as such as we see in California are still -- have a very, very important role to play in those states. And those can happen, since there's no state or national push to those beyond the federal tax credit, we see cities pushing this a lot. And that's where we see a lot of the -- in utilities as well. Because they see a positive case.

COMMISSIONER RECHTISCHAFFEN: I would just, not that we're interested in broad opinions, I would just offer that it's a pessimistic view that we are ten years later just going to be limited to what we're required by regulation. Because the whole point of our regulations and others is to spread a much broader market not just to incentivize and

stimulate activity within California and other ZEV states. But that's a broader discussion.

MR. NICHOLAS: Yeah, it's conservative, yeah.

COMMISSIONER RECHTISCHAFFEN: I have another question and Patty opened the door asking unfair questions about things you're not presenting about.

MR. NICHOLAS: Yeah.

COMMISSIONER RECHTISCHAFFEN: In the past, ICCT has estimated the amount of money needed -- the delta between basically the amount of subsidy needed between now or whatever point in time we are and the time where there's cross parity that would need to be made up by subsidies and other incentives. Do you still have a number that you use or a number that you could point to?

MR. NICHOLAS: I would say that the numbers keep changing and I would say they're relatively correct. I'm not actually as familiar with those as I could be, so I would have to defer that question to later, but I think from these numbers I presented today, you could come up with a similar number -- outside numbers.

COMMISSIONER RECHTISCHAFFEN: We'll we're very interested then in California since we're trying to figure out how long we continue -- you have a variety of subsidies, obviously, and we're very interested in thinking about how long we have to have them and what amounts.

MR. NICHOLAS: Right.

COMMISSIONER RECHTISCHAFFEN: So, you -- those would be useful for us.

MR. NICHOLAS: And in what sectors. And that's what I think there will be a shift as a, you know, around as we go through smaller and smaller subsidies and more towards regulation that's driving this, and a focus -- increase in focus on infrastructure.

COMMISSIONER MONAHAN: Tim, will you give me 30 seconds?

MR. OLSON: Yeah, of course.

COMMISSIONER MONAHAN: I promise, 30 seconds. Yeah, just building off this, it's not -- may be more of a comment than a question. But, you know, the BNEF data that I saw previously indicated having an EV sales if the vehicle standards are frozen. And so there is a big impact on what's going to happen in the near term in terms of potential impacts on EV sales from the terrible actions that are happening by the Trump Administration.

I also think that as California develops more aggressive regulations for 2030 that number, I mean, the green bar will go up, right? Because California can pass extremely aggressive ZEV mandate for 2030 that could even have implications for pre-2025 sales.

So all of this, like the idea that this is a floor,

is accurate spot on, and it would be great to get ICCT's advice for us in California about what are these ancillary policies like the infrastructure and investments that are going to matter the most? Which aren't also going to factor -- nobody knows. Like if you put in the EV charger, what is that mean for EV sales? We know it matters, but how much? And you guys -- you can nerd out on that one.

MR. NICHOLAS: Yeah, that's a tough one the causation on that. We have -- we do have a report on what -- based on historical performance what is needed to support a certain number of vehicles. But as far as like putting in extra and how much does that split a market, I think that's a difficult question on the causation. But I would say we have a partial answer for that and I'll send you that paper.

MR. OLSON: Very good. Thank you, Mike. And going back to the commissioner's comments -- both commissioners. Any -- and this is for the whole panel, any other detail you can provide on the cost of what would be considered a subsidy to reach that parity point.

If you're number 2012, David Green estimated that cost to be $16 billion for North America including the infrastructure and the differential on the vehicles. So any new data would be very -- of great interest to us.

So let's go on to our next speaker and that's going to be Ajay Chawan from Navigant. He's going to cover some

background on Electric Motor Innovation and the Effects of Automotive Design Strategies.

All -- by the way, all these speakers have very similar expertise in many areas and we've asked them to kind of focus on one or two topics but at the panel we will invite them to comment on everything. Please proceed, Ajay.

MR. CHAWAN: Thank you very much. Thank you to the Commission and all the commissioners for having me today, I'm really excited to be here.

I'm going to start off with the -- I don't want to overlap or repeat the points that have already been made by fellow presenters but I want to start off with this one slide so if anyone needs to take a nap just please remember this slide and these will be the key points that we're going -- that I'm going to talk about today.

The point's already been made that China is driving EV sales globally. And as a result of that, the equipment manufacturers -- vehicle manufacturers both the incumbents as well as many new entrants into this space because of its -- of how rapidly it's growing are coming in and developing more vehicles for the market.

At the end of the day, what does this matter for California? How is this going to impact you? You're going to have a lot more choices in the EV space. Is it -- this is a win for California.

Before I get started -- before I dive in, I just wanted to give a brief introduction to myself. I said, I'm Ajay Chawan. I work in the transportation grid team at Navigant Consulting. I've been with the firm for about a year. I've been in the EV space since 2012, so back to when some of the charts start, I was back there then. I stared off by leading the production launch of the Nissan LEAF in North America. And then from there, I joined Audi of America at its electric mobility program manager launching its first plug-in vehicle, the Audi A3 e-tron and the getting the plans ready for the launch of its electric SUV that's starting sales this week here in California.

So, I'm an EV diehard through and through. I've secretly lust -- not so secretly lust for a Tesla Model S, my wife has said, no not yet. Even though I demonstrate to her that I could take a Costco -- make a Costco run with three kids in car seats and get, you know, do the $500 Costco run with diapers. So that's my personal story, a huge EV fan. Again, that's why I'm really excited to be here.

So just to add some more color to the points that have been made earlier about EV sales globally. So we'll -- our projections line up very well with the projections that have been shared by my colleagues. So just looking at the top three global markets for a projected plug-in sales in 2030; China's going to be about a third of them, Europe a

little under a third, and then North America about a quarter. Those three geographies take up -- account for 85 percent of EV sales -- or projecting EV sales in 2030. I want to put that in context as far as we've talked about market size, but just to put a little bit more perspective around this particular market size.

So China we -- everyone keeps talking about China, China sales about 28 million cars a year in its market. For comparison, Europe, just -- Western Europe is about 16 million. And the U.S. ranges between 15 and 17 and a half. Last year was a banner year with 17.4 million cars sold in the U.S. A healthy year is somewhere around 15 to 16. If you get more than that, it gets a little bit overheated.

There are a lot of new models that are going to be fueling these -- this growth in 2030. So for example, Ford has announced 14 new EVs by 2023, six of those are for North America which leaves the other eight for China. Similar with the FCA, they've announced six different Jeep varieties that are exclusively for China. And then GM has announced 20 EVs -- 20 EV models that are primarily for China.

So the China is definitely driving the EV market and what I've seen in my previous life is that if we wanted a market a vehicle for the U.S. market, the first question is does China want it? If the answer is, yes, then you can get it; if it's no, then maybe not. Or you need to get it in a

very China friendly way. And as an example, where do you put the charge port on the car? In China, apparently the right rear quarter panel is where you want to put the charge port. And so if you want your charge port on the right rear quarter panel, then you can have that car is what we were told. Even though he said it didn't align with the rest of our vehicles, there's no consistency it's like no, this is what you get.

EV pro -- sales we've already talked about EV from where we've been, where we're going, so I'm not going to get into that. What I want to highlight here is that in 2018 when -- 2018 like we achieved the -- achieved over a million sale -- oh, sorry, about 200,000 sales with 16 models. Just want to keep that -- just to put that in perspective. That's not a whole lot of models for just one percent of the market.

And those -- those models were provided by the OEMs that you see on the left side of the screen. So those like the Chevy Volt -- Bolt EV, the BMW i3, all the Tesla vehicles that we mentioned before, those -- this is where those 18 models came from.

You have, now, if you look to the right side of the screen, you see a whole bunch -- you see a whole new slew of automakers. The -- the top two German companies on the top row, I think you recognize them. They are coming out with their new electric vehicles within the next 12 to 36 months. The Mercedes EQ family of vehicles are coming out, it's their

SUV. And then Porsche the Taycan, it's their full electric super high-performance sedan will be out next year, I believe. I know they're already doing some testing out here. Rivian is a -- is an EV startup that we're going to talk a little bit more about later.

Now when you get into the second and third rows, I want to talk about -- these are brands that you may or may not have seen. These are primarily Chinese funded EV companies. Because of the huge incentive for EVs in China, there's a ton of EV startups for a lack of a better term in China. And the government is taking an active role in playing -- kind of picking winners.

So I've listed a few of those companies here and I just wanted to highlight one which is JAC Motors which is on the right side of the second row. They've been exhibiting in the -- at the U.S. auto shows for the past few years and they've been exhibiting with a full line of vehicles. So we're talking pickup trucks, SUVs, sedans, and including an EV vehicle called the Inverge that they are -- that they've public stated will be build in the U.S. and they've previously have stated they're going to start sales this year. I have not seen progress toward that, but these are claims that they've made and I think they have the potential to do it. It's not a matter of if the -- if these Chinese manufacturers will try to sell vehicles here in the U.S.,

it's a matter of when.

Just thinking back to when I started in the auto industry over 20 years ago at Ford, that's when KIA first came to the U.S. market if anyone remembers that. It was when they were just -- they were a no name, I would talk to dealers and they're like I'm making a ton of money on these cars on warranty because they were terrible cars, they were always in the shop. So the dealers loved them because they were always in there for warranty and the automaker covers the warranty.

Now KIA is a high-quality vehicle today. It's owned by Hyundai which is one of the largest industrial conglomerates. So China is going to be the next step with this. You know, first as the Japanese automakers in the '70s then it became -- I think today it's going to be these new Chinese automakers.

So we've talked about EV sales on the national level. I want to talk about where are vehicles sold in the U.S.? And so, I'm an engineer by training. By background, I'm a rocket scientist by training, Aerospace Engineering, and so I love data, I love charts. It's anytime I can -- I was chatting with a colleague at breakfast this morning and we used the word R squared for correlation. And she said anytime you can use R squared, you know, before 9 a.m. in conversation, you know, you're in a good spot. You were

talking about nerding out earlier, so this I think is our opportunity to nerd out.

So what I wanted to do is do an analysis on a state by state level of where are vehicles sold overall. And if you do a correlation between where vehicles are registered in the U.S. and where people live, you have an almost perfect correlation a .985, R squared value and that's what one would expect.

You'll see, like on the chart on the left, you'll see the one outlier the dot below the line that's New York, that's because you have a whole ton of people in New York City who don't own cars.

Now, if you go to -- now if you do that same exercise for a BEVs, you see a much different story. At the top right of the screen is California, you guys are way over indexed on electric vehicle sales. We already -- and we already know that it's the, you know, more -- about half of all EVs registered in the U.S. are here in California.

One of the reasons for that is the long continuous support that the state has provided for clean transportation. So I think back to the '90s when the original -- the orange carpool stickers were issued. These were available before there was even a hybrid vehicle out there. And the first-generation Prius was the one that was able to take advantage of that.

So you -- so the state has done a great job of promoting clean transportation and that's part of the reason I think you have a -- you have California as the outlier.

I've labeled the other states so that -- just that you can see who else is above the line. And surprising it's not all -- necessarily all the ZEV states but Georgia for example is above the line because they had a very generous incentives a few years back for the Nissan LEAF and then as soon as that incentive went away, sales plummeted. So, when I say plummeted, in the first half of that year they sold in the state of Georgia, there's about 7,000 LEAFs -- leaves -- LEAFs were sold. Kind of like to try out the maple leaves, I guess. And then after the incentive went away, it dropped by more than an order of magnitude. So it was significant. So incentives at this point in the adoption curve really matter. And I this point's been made before.

So, this is overall, like just the overall vehicle markets sales. I want to dive deeper now in to the premium segment because there's an interesting story to look at there. And here's some statistics, and we're looking at premium segment and ZEV states.

And as I was reviewing this -- these slides with some of my colleagues, they asked me to define ZEV. I'm like wait a minute, you should know this, you're in the space. So I'm assuming most of the people here know that but for everyone's

edification, I defined what ZEV states are. So we're talking about the ten states that have adopted the zero emission -- the ZE -- the Zero Emission standards under Section 177 versus the LEV standards.

So we have ten ZEV states. Those states represent about a quarter of the population, 28 percent of the population. And your very close correlation to the 20 -- to the number of vehicles that are registered in those states.

ZEV states also have almost two-thirds of all ZEV registrations. But here's the interesting point, those ten states have almost half of premium vehicles. When I say premium vehicles, these are your brands like Cadillac, Lexus, BMW, Audi. Almost half. And so in my former life as a -- doing product marketing for premium vehicles, we paid attention to ZEV states because those ten states made almost half of all of our sales.

And now if you look at premium -- looking in the premium market and think back to new innovations in technology, that's where they all started. So looking back at cruise control, power windows, the intermittent wipers, all these things started in the premium segment. So the premium segment has always been the starting point for new innovation.

And this is going to be especially important in the electrical vehicle space. That's why you see a lot of the

new product announcements in the EV space have been for premium brands. Like so Mercedes has its EQ brand, Audi is the flagship for the Volkswagen group on this and so forth. Making EVs is -- making vehicles in general is extremely acid intensive. Its margins for a company like Ford globally is about five or six percent. I mean, it's just like the gross margin you get it's extremely -- rate within margins over a huge capital outlay.

Premium brands have a little bit more pricing power but that still doesn't always work. So if you look at Tesla, again I've mentioned I'm bias so but I'm going to try to keep as fact based as possible, you know, I want them to do well but they had two profit -- two quarters of profitability recently but then this last quarter they lost $700 million. And they're charging premium prices. Part of the reason why I can't get one is my wife says you don't need $110,000 car. It's like, me, I said need, yeah, I could argue differently. But what this -- it's going to be -- any of these new innovations are going to be largely driven -- or primarily driven from the premium market.

And because of that need, that's where you see these global automakers put it -- focusing their efforts through premium brands to bring out new technologies. The -- as we talked about before, EV market demand is growing, I mean, we're all in agreement on that, our EV demand is growing, we

all agree on that. And so automakers are now saying, okay, we really need to put some R&D to make these products good. And so I'm going to give you -- just share a couple of examples that Audi had done with its upcoming e-tron SUV.

So they've -- their electric motor, they've invested a lot of time and money into this to -- in order to have repeatable performance. For them it's a really big deal to have -- to be able to do -- to have repeatable lap times. And so they have a electric motor that is a -- it's a synchronous motor so it doesn't require rare earth elements. You can turn the motor off so that when needed -- you can turn it on and off so it essentially just becomes a spinning wheel so that you can have either front-wheel drive, rear-wheel drive, all-wheel drive or just what they call torque factoring so you can put power to the wheel where you need it. It gives you really, really good control of what you want to do.

And then we've had some discussions about battery. One way that Audi, the Volkswagen group are looking at looking to get the batteries -- the battery cost down is to have -- is a modular batteries where you can use different chemistries. You can use different -- from different manufacturers in a battery pack.

So I know I'm running out of time, so I'll just quickly get to the end. We've talked about Rivian and Ford.

Ford recently announced a half a billion dollar investment in Rivian to gain access to some of its EV technology that just developed for a new platform. Ford the leader in trucks from my point of view has said, hey we're going to outsource, we're going to buy this from someone else which is something that would be unheard of in the past.

People that are looking to do -- that are to do -- putting EVs in commercial spaces which is where I think you're going to see the first adoption which will help with market acceptance and consumer acceptance and then market acceptance of EVs is another startup called Workhorse, working with UPS to do delivery vehicles that are electric. And especially in cities that are going to have congestion charging, like New York just announced recently, California may do some of that in some of its cities in the near future. Europe is already talking about this. This is a way to get EVs out there so that people become familiar with them.

Fleet vehicles, we talked about buses already. There's a school district here in the Twin Rivers District is already doing its own trials that you're probably familiar with.

And then lastly, I want to say that you can't look at EVs without the overall ACES that -- without autonomous, connected, electric, and shared. You can't look at that -- you can't look at EVs without looking at the rest of the

technologies that are going to change transportation as we know it.

And so I'll skip over that. And so lastly as I said for the point that I want to make, California is in a good spot, you're the leader in the space. I think that the rest of the nation will -- can learn from California and the change is definitely coming.

And as far as making a big impact for air quality in California, sure mobility -- the future of mobility fleets is where you're going to have the biggest impact. You can get much more impact on a shared mobility fleet than a personally owned vehicle.

So if you have fewer vehicles driving more miles, you have fewer assets that you need to build, and you have -- you just have better utilization which will help with the overall business case.

So as I said, I more than -- as I said, I'm more than happy to chat about the -- to do the Q&A and have the discussion. So, I appreciate the opportunity to be here.

MR. OLSON: Thank you, Ajay.

Any questions from the commissioners, clarificat -- request for clarifications, any embarrassing questions you want to ask?

VICE CHAIR SCOTT: Thank you so much, Ajay, for being here.

I had a question for you back on -- on Slide 9 where you talk about the technology being cell agnostic. Can you tell us a little bit more about that? And I think it's really intriguing, I think it was a couple slides back where you were mentioning the premium brands and how there's lots of really neat things like the, you know, the power windows --

MR. CHAWAN: Yeah.

VICE CHAIR SCOTT: -- other things that have come from that. So it seems like cell agnostic is one --

MR. CHAWAN: Yeah.

VICE CHAIR SCOTT: -- that we might see. So the second question is are there other things like that that we might -- you think we might see coming in the electric vehicle space?

MR. CHAWAN: I think -- absolutely. The way I think the battery -- if you look at what makes an electric vehicle different, it's the electric motors and the battery. So that's where a lot of effort has been focused on by the automakers to develop that competency. They've been building gas motors for 100 years, and so they know how to do that really well, and there's only so much more efficiency you can eke out. This is a whole new space which is what's attracting all the folks like Rivian and Tesla and Workhorse to come into this space. And it's now forcing the incumbents

to invest money in it.

In the -- just on this battery pack case, the realization was made that we're trying to sell a global product and we need to -- but we also always need to have some sort of local content, local factors to it. It doesn't make sense logistically if you can -- to build a battery pack in one place, ship it to another place to put into a vehicle, and then that vehicle could come back here. You know, and to -- and so what we're trying to do -- well, what Audi is looking to do is have a -- is to have its battery pack design such that you can put in a pouch versus prismatic modules. You can have different chemistries from -- they're starting off with LG and switching to Samsung down the road.

So if you have that intention going in, you can design your battery management system and your pouch can fit -- I'm sorry, your battery pack configuration to accommodate them -- that -- those variabilities.

VICE CHAIR SCOTT: That's cool.

Do you guys have questions?

COMMISSIONER MONAHAN: Can you go back to Slide 8 really quickly?

MR. CHAWAN: Absolutely.

COMMISSIONER MONAHAN: I've never seen that data point on the percent of premium sales. I'm going to use that in the future --

MR. CHAWAN: Please do.

COMMISSIONER MONAHAN: -- so thanks for that new piece of information.

One thing I was noting on this slide is that because California is half of all -- maybe more than half of all zero emission vehicle sales in the country, it -- the progress in the other ZEV states is actually not so good.

MR. CHAWAN: Yeah, sure, yeah.

COMMISSIONER MONAHAN: I mean, it's better than most states but it's still nowhere near where we need to be --

MR. CHAWAN: Right.

COMMISSIONER MONAHAN: -- to reach our decarbonization goals. So just to highlight that. I mean, California is basically we're throwing the spaghetti on the wall in terms of policies.

MR. CHAWAN: Uh-huh.

COMMISSIONER MONAHAN: And now we need to refine those policies and really think through which ones are the most effective and, you know, as Cliff was saying, as Commissioner -- the Commissioner was saying, we can't put incentives forever, right?

MR. CHAWAN: That's correct. Correct.

COMMISSIONER MONAHAN: And so this idea of like how, I mean, has any of your research been around the policy design that we should be thinking about in terms of

optimizing our impact per public dollars spent?

MR. CHAWAN: Like I said, it's not particular with this but we're involved in another project that it's public domain so I can share. We're working with the alliance to save energy in Washington D.C. on this very topic right now. And I'd be happy to chat with you more about that --

COMMISSIONER MONAHAN: That would be great because --

MR. CHAWAN: -- separately.

COMMISSIONER MONAHAN: -- I haven't seen Navigant -- because you guys are firewalled and you're kind of expensive, it's awesome to get this kind of access. So I would love to learn more.

MR. CHAWAN: Yeah, happy to help. In short, yeah, it's something we're looking at because it -- that policy is just one lever to look at. And I always go back to the chart here on the right. I call it, you need to peanut butter out or smooth over the demand. If you do an analysis of a, you know, the analysis of where vehicles are -- EVs are sold on a state by state basis, then even down to a dealership level, you just see a huge variation.

And what you need to get happen at the automaker level is vehicle sales for all powertrain vehicles and put everything in there as one, you know, fuel cell, plug-in hybrid electric, full electric, that needs to be more similar to conventional vehicles than it is today.

And so that's the -- so the policy level, it's not just at the federal, it's not the state, it's not just the local, it has to be at all levels.

And then the other point really, too, we talked about there were models that are coming out. We could have up to 40 models to choose from in the next two years. And as you get into the body styles that are more -- they're more -- customers want. So as I -- when I had an electric vehicle for the -- for two years, I had a Nissan LEAF for a while. And then when I started -- my family grew, I had three kids in car seats, they didn't fit in my LEAF. And so I looked at an SUV and if I could get an SUV today that could three car seats in the back, I'd be great. So I ended up buying a Honda Pilot because there was no SUV that was in my price range that could allow me to do that.

So you give me and what we're seeing in the EV -- sorry in the vehicle space, the appetite for SUVs across the globe primarily in -- especially in the U.S. is just insatiable. Like every strategist we -- product planning strategists I've ever spoken with has gotten this projection wrong. And so right now we're about 60 percent SUVs versus 40 percent sedans and it doesn't show any signs of slowing down.

So when you see new product announcements for these all powertrain vehicles, look at the powertrain as well as

the body style.

COMMISSIONER RECHTISCHAFFEN: Well that brings me -- I really want to ask you what R squared is but instead, when's the prognoses for electrification of the SUV market if it's -- that is --

MR. CHAWAN: It's happening, it's absolutely happening. And because that's where -- the automakers want to make -- they want to sell vehicles at the end of the day. And they know that consumers want SUVs. And so it makes sense to bring out SUVs that -- body styles that people want and then give them the powertrains that -- right now legislatively, automakers have to, but ultimately as the -- as we go from a push to a pull system for EVs, they'll -- it will be the body style that people are looking for.

And that's where -- that's why the announcement I showed with Ford and Rivian, that's what -- that's why that's part of the reason I think like for my inside information shows that Ford made this investment.

So a new vehicle program is about a billion to a billion and a half dollars, like that's how much a company needs to spend. And so Ford is saying, hey, instead of spending a billion to a billion and a half dollars to develop this new platform which platform is strictly speaking as -- locator holes and weld points. You know, think of it as a floor plan on the car, but it's strictly locator holes and

weld points.

So instead of developing its own new platform, it's saying I would rather just buy this startup or invest in this startup that is well on the path of this and then I can build vehicles with my, you know, with my know-how of how to build cars at my distribution system of how to build cars and it just saves me a lot of time and money.

COMMISSIONER MONAHAN: Yeah, I thought you would be pining for the new Rivian. Because it is beautiful.

MR. CHAWAN: Like I say, it's expensive.

COMMISSIONER MONAHAN: It's spectacular, though. I know -- and I'm sorry to be doing a product endorsement, but it is quite something.

COMMISSIONER RECHTISCHAFFEN: Can I ask you one other follow up question?

MR. CHAWAN: Of course.

COMMISSIONER RECHTISCHAFFEN: You mentioned that a lot of the startups in -- that are oriented toward China or are in China or -- I don't know what you -- what word you used sponsored by the Chinese government or --

MR. CHAWAN: They're China based, I wouldn't call it -- some of these are startups like Nio and Lucid would be a startup, JAC Motors having his -- they're a full-fledged organization.

COMMISSIONER RECHTISCHAFFEN: Well I have a question

that maybe Bloomberg be better suited to answer, maybe can get into the discussion. But I'm interested in new capital that's coming in to create these brand new companies. We -- Rivian was just funded by venture capital. We see this in the autonomous vehicle space with new companies that are not associated with any of the traditional OEMs.

Do you have any observations on the amount of capital that's coming in to create altogether new companies especially in this country but more broadly?

MR. CHAWAN: I think in the -- I had a report on Autotech capital and I put this under there. So you have to look at the -- depending on what you're -- how you -- what datasets you look at. So I think of Autotech, it's not just a -- starting a new car company because the car building part of it is the most -- it's the most acid intensive and that's not where the real value is added. The value is really added on the technology that goes into the vehicle. So battery technology development, software and hardware development for systems, and advanced driving systems, and so forth.

From a report I did -- presentation I did last year, the Autotech investment was coming in around like five and a half billion dollars -- I want to say five and a half billion dollars or something to that effect, investment in new businesses. And most of that money like two-thirds of that money came from outside of the automakers like the incumbent

automakers. So these are venture capital funds, private equity funds and other tech companies like Apple, like Waymo, that are investing in this space.

COMMISSIONER RECHTISCHAFFEN: That doesn't sound like that much.

MR. CHAWAN: But that's why I have to -- it depends on what specific thing you look at. So but like I say, $5 billion over -- spread out over a few startups like, you know, you get, you know, a few million dollars of Series A and so forth. That is -- that's how it's -- that's how I believe it was defined. I don't have that report in front of me right now, but it's a -- there's definitely a significant amount of money coming into -- coming into they call it the Autotech space.

MR. OLSON: Thank you very much. Okay. Any more questions? Okay. Let's go on to our final speaker for the morning here. And that -- and it's going to be two people I think, Nicholas Chase and John Maples. They're also going to do their presentation remotely and I think Nicholas is doing the presentation.

Both of these gentlemen are with the U.S. Energy Information Administration, this is part of the U.S. Department of Energy. They do -- this part of that organization collects a lot of data and another group produces the annual energy assessment, pricing, lots of the

data that this agency, Energy Commission, ARB, PUC use in our forecasting.

And so welcome Nicholas, please proceed with your presentation

MS. RAITT: Nick, we can't hear you, if you're on mute possible.

MR. OLSON: Nick, are you online there?

VICE CHAIR SCOTT: You've unmuted on our end, right? Okay.

Nick, we still can't hear you, if you're there.

MR. OLSON: Hello, Nicholas, are you still there on the line?

MR. CHASE: Hello, this is Nicholas Chase.

MR. OLSON: Hi, Nicholas.

VICE CHAIR SCOTT: Hi.

MR. CHASE: Sorry about that, we had some mix-up on our end here with the connection.

MR. OLSON: Okay. Nicholas, this is Tim Olson, please proceed with your presentation and hopefully you can stay around for our discussion panel after you complete that.

MR. CHASE: Sure. Sure. Thank you.

Good morning to everyone, and thank you again for the opportunity to speak to you. My name is Nicholas Chase, I'm lead economist with the U.S. Energy Information Administration on the Transport Team. We're going to be

talking this morning about zero emission vehicles and automated vehicles and some of the uncertainties in energy implications with that.

Next slide. And next slide. Taking a very high-level view here before we delve into some of the zero emission vehicle discussion. In our reference case projection, transportation energy consumption actually declines between 2019 and 2037 and increases in fuel economy and fuel efficiency more than offset growth and vehicle miles traveled or travel demand across the various modes.

On the left-hand graphic you can see transportation, energy sector consumption by mode and the big movers here are light duty vehicles declining by about a third, aircraft increasing by well over a third, and medium and heavy and light commercial trucks increasing somewhat.

On the right-hand side you'll see the same, transportation energy consumption but by fuel. And the big changes here on our projection we have motor gasoline declining by about a quarter, distillate actually declining slightly and jet fuel is growing quite a bit by about a third. Electricity is growing a lot, too, and starting from a very small amount but we'll get into this. There's a lot of light duty electric vehicle sales. Next slide, please.

Here we're looking at light duty vehicle sales by fuel type on -- and across our projection alternative or

electric vehicles gaining market share in a reference case but gasoline vehicles do remain the dominate vehicle fuel type through 2050. On the left you can see the breakout in our projections. The big grower here are electric vehicles, they increase from just a percent or two of sales to around 15 percent and PHEVs are another three percent by the end of the projection where HEVs are about six percent.

On the right-hand side you can see it's broken out in a little bit more detail of new vehicle sales. And you can see the total battery electric vehicle sales are growing strongly, especially in the near term and much of that action is from 300- and 200-mile EV sales. Next slide.

So how do we model this and what does that mean for some of the uncertainties. This is a wordy slide, but when we model vehicle choice in our NEMS model, our domestic model, this involves manufacturers building vehicles and consumers buying them. Manufacturers are building vehicles they're adding technology onto vehicles, they are different vehicle fuel types, and there're different performance attributes. Consumers then see these vehicles and buy them, they buy them across 16 vehicle size classes for passenger car, light truck and they're looking at different attributes of vehicles. We do ensure in our model that manufacturers meet CAFE. So there's an interaction and iteration between manufacturers building and consumers buying. Next slide.

Next slide, please.

Okay. We're there. Okay. Previous slide, sorry. We have a little bit of a lag in our computer here.

Policies play a large role in promoting electric vehicle sales. We do model California Zero Emission Vehicle Mandate, which has been adopted by nine other states. We have California SB-32 for greenhouse gas reduction. As part of our modeling and we have a representation of that in the transportation sector that further increases electric vehicles share and also decreases VMT.

We do have tax credits in our modeling. Specifically we have the federal tax credit up to a maximum of $7,500. But that does phase out and it phases out in the relative near and medium term because of the 200,000 vehicles per manufacturer limitation.

We don't actually model state tax credits and incentives in NEMS and that's something we paid attention to obviously in the example that was brought up early about Georgia. In Georgia, the tax credit went away and it had an impact on sales. Next slide, please.

In terms of battery cost -- this has been mentioned several times by different presenters probably most applicable or appropriate would be the bottom curve here which is showing -- the yellow curve is showing the EV 200 to 300 much longer-range battery electric vehicle.

We have the cost coming down somewhat in medium terms in the 2020s and then a more gradual, you could call it maybe very evolutionary type. This is a retail battery price to a consumer so we have a markup in here on top of a manufacturing cost. And then this is just showing the breakout by different types. If you have a PHEV 10, for example, that's got a more expensive dollar per kilowatt battery cost than let's say a EV 200 to 300. Next slide.

How do we model the mandate NEMS? We do capture this by our census divisions that we model by census division. And we have ZEV states that must sell a minimum amount of ZEV -- meet the credit requirement specifically. Credits can be banked and spent and they can travel. So we do try to capture some of the nuances of ZEV mandate. We use the optional compliance pathways and vehicles are sold according to a least cost optimization. Next slide.

What are some of the key uncertainties as it relates to ZEV vehicles and batteries and such? Well, one, policies and this has been discussed a few times by some of the discussions.

What might be the future of light duty vehicle CAFE or greenhouse gas emission standards? We currently have in our reference case current law and regulation which would have the augural standards in place through 2025. But that could change as a proposal could change that.

There could be changes in state polices that could either benefit or could hurt perhaps ZEV-type vehicle sales. That could include changes in the tax credits which we don't actually capture but or it could include change in regulatory authority to issue own standards and mandate.

Second, there could be battery technology breakthroughs. There could be solid state batteries or ultra-fast charging capabilities that could certainly impact the sales projection we have in our reference case. If there are much cheaper batteries or they're very easy to refuel, so to speak.

And then finally, vehicle automation or changes in mobility, what could that do to sales patterns, travel, powertrain choice, et cetera, well that's a very open question and it's something that we'll talk a little bit next. Next slide.

Look at vehicle automation some. And it looks like the graphic didn't show up on this but the point of this is that when we're defining vehicle automation here, we're talking about without driver input, or connected or automated vehicles. This would include what's called a Level 4, which would be in the graphic that you can't see here, but Level 4 high automation or fully autonomous Level 5 automated vehicle. Next slide.

So really driving this interest in vehicle automation

and the potential -- are the potential benefits that this technology. But there are a lot of uncertainties and obstacles related to vehicle automation. Benefits, road safety. There's a lot of potential for increased road safety. Interestingly, that's been a real concern, an obstacle as well over the last year. And there's a potential for increase system efficiency especially when you have connected vehicles, about harmonization, reduced congestion; there's potential for increased mobility for underserved populations; less driving time, right? Could be in the vehicle and either working or doing other things that you enjoy for leisure.

Obstacles. So consumer acceptance, there's still a lot of fear of this technology. Technology costs, it's an expensive technology that is likely to change significantly over time. Cybersecurity, cyber discussions anytime you're talking connected vehicles and such, there's huge concerns on that front. Legal framework, infrastructure, policy, all of these factors come into play. That's not to say that vehicle automation couldn't happen but it's just to say it could impact the rollout of the technology. Next slide.

So what might vehicle automation do for energy? And that's the big question for us because that's what we do. And looking at literature, this study was done a couple of years back but we looked through literature to try to see

what the range of energy impacts might be of autonomous vehicles or highly automated vehicles.

This graphic shows in the middle bar, light duty vehicle energy consumption in the year 2017 which is about 8.3 million barrels per day or equivalent to the U.S. If you were to have a lot of energy efficiency gains through vehicle automation with perhaps less driving, even. It would get the left-hand bar which is a 60 percent reduction.

If you go the other direction and say what if there's not much efficiency gain and there's a lot of VMT increase, travel demand increase from vehicle automation, you could have a 200 percent increase, or a 24.9 million barrels per day oil equivalent.

The difference between the left-hand bar and the right-hand bar is equivalent to about the amount of energy consumed by all commercial and residential buildings in the United States. So that tells you how much of uncertainty there is looking at the vehicle demand of vehicle automation. Next slide.

Looks like this one didn't show up very well either, unfortunately. So we don't have to worry about it too much other than to say, on the travel demand front, there's much more increase in energy pressure than there is decrease in energy pressure. The right-hand graphic that you can't see here shows that in terms of vehicle fuel efficiency, there's

a lot more that vehicle automation could do to reduce energy consumption, such as platooning or eco-driving or V2I. Next slide.

There are additional ways that vehicle automation could affect transportation energy consumption. Could be alternative fuels or energy efficient powertrains that was talked about in one of the previous presentations. It could be the electric vehicles. It could be applications in commercial trucks that could change, either the energy consumption by platooning or perhaps even the travel demand by making the movement when it gets cheaper.

Mass transit, another big uncertainty. Would this be a big benefit or would it be a big competitor and a big harm to mass transit? It's an open question. Next page.

We did some work a couple of years ago that tried to look at some assumption's scenarios. So we'll talk in the next couple of slides about some scenarios we did that were assumption driven that tried to look at what some of the potential energy impacts could be. We've done a lot more work recent years.

Last year we did a lot of work trying to break up the model in more detail and do some costing much more accurately. And this current year and in future years, we're looking at trying to explore much more thoroughly the travel demand component. But for this exercise we looked at some

assumption driven scenarios.

In our reference case, in the high level we have a very small amount of autonomous vehicles that enter the light duty vehicle sales, about one percent by 2050. Either driven like taxis or driven very intensively about 65,000 per year and they're scrapped more quickly. We had them in this scenario be 100 percent gasoline and you'll see the reason why we did this shortly. They impact mass transit, they increase use of commuter rail and they decrease use of transit bus and transit rail, these are by assumption. Next slide.

We did two scenarios trying to say what could happen if a lot more autonomous vehicles came into the market? What is specifically about one-third of new sales by 2050 were autonomous.

We have them going to fleets that drive like 65,000 miles a year for the vehicle and we had them going to households which we had those vehicles drive about 10 percent more on average than a regular household vehicle.

We had again commuter rail affected and transit rail affected, we had transit bus affected but we allowed transit buses to become autonomous as well by the mid-2030s so those started to increase. We also, and they -- we also allowed some truck platooning to come in in this scenario. Next slide.

Our two scenarios did differ by the vehicle fuel type. So we had one scenario where almost all of these vehicles were electric vehicles by the end of projection. We had another scenario where almost all of these vehicles were hybrid electric vehicles by the end of projection. Next slide.

This just shows the reference case on the last per vehicle sales by fuel type and we already saw this in an earlier graphic for the reference case. The middle graphic shows in the battery electric vehicle case about 30 percent of the sales by 2050 are electric and then the hybrid electric case about 30 percent of them are hybrids. Next slide.

I can't really see this well, looks like some of the graphics didn't show up here as well. But the overall results for that, we increased travel demand by about 30 percent. The energy consumption was about the same as the reference case despite the fact that we increased travel by a third. And that was because we had much more efficient hybrid electric vehicles are much, much more efficient battery electric vehicles coming into the market. We did have some fuel switching where we had less motor gasoline and more electricity in the autonomous battery electric vehicle case as you would imagine. Next slide. Next slide, please.

And with that, it looks like I made my 15 minutes.

We covered a lot of material. I do have some backup slides if anyone wanted to talk to some of our ongoing updates to vehicle automation. But thank you very much and I appreciate the time.

MR. OLSON: Thank you, Nicholas. I wonder if you can go to -- just quickly talk about on your additional slides we'll show Slide 25 and Slide 27.

MS. RAITT: I don't have them. I don't have them.

MR. OLSON: Can you show that, Heather?

MS. RAITT: I don't have them.

MR. OLSON: Oh, you don't have them. Okay. Well anyways you have the slides. We have them here. We have hard copies here. Can you comment about the -- Slide 24 was the kind of levels of the automotive vehicle kind of those categories?

MR. CHASE: Yeah.

MR. OLSON: And then I want you to comment about the vehicle cost part of Slide 27.

MR. CHASE: Sure. So the work we did last year, we tried to break out vehicle automation into more discrete levels of automation categories because it mattered a lot for the cost of the vehicles.

And specifically we broke the Level 4 for the highly automated vehicles into two levels the 4a or a 4b. And the 4a would be an automated vehicle that can operate

autonomously in a geofenced area that's low speed. A 4b is a highly automated vehicle that can operate autonomously in a geofenced area that's high speed, like may be a limited access highway land or something. And so those have very different LIDAR requirements and resolution requirements for that technology and so they have different costs.

A Level 5 fully autonomous vehicle is one where that vehicle can operate autonomously on all roads and at all speeds. And so a Level 5 has even further levels of resolution and requirements for that technology.

In Slide 27, that's costed out. But we have the L0 to 3, those are conventional vehicles and some people in the room may actually have Level 1, 2, or maybe even a 3 level of conditional automation technology. The 4a technology, you're adding LIDAR cost on as you are on the 4b and 5.

The way we've modeled that is we looked at LIDAR cost today but as the high resolution and low resolution and we allowed those to have R&D that drive down costs and to have a learned production cost function that allows it to go through a revolutionary, evolutionary, or into a very high-volume state. And so that's what you see driving those costs down.

On the right-hand side, I might have hinted at this but we did work on our model to break out our model into much more detail in terms of the taxi fleet or an on-demand mobility fleet that could be like a transport network

company. And so we have vehicles that are on-demand mobility and they're looking at costs of having a driver, they're looking at return in investment type of calculation, and they're looking at these vehicle cost information. And they're trying to determine whether to purchase vehicle automation and not have a driver and what that might mean for revenue given that these vehicles scrap out very quickly they use very intensively.

And so you can see that as the cost comes down and we do have some parameters in there that limit obviously the penetration of these from being immediate but you can see how if the cost comes down let's say a fully autonomous vehicle that they pick up more of the share in this example on the ride-hailing fleet.

So that's what's -- that's -- both of those two graphics that you would have in front of you.

MR. OLSON: Okay. Thank you very much. So, Commissioners, do you have any questions for Nicholas?

VICE CHAIR SCOTT: Yeah, absolutely. I want to say Nicholas, thanks so much for the great presentation.

Before we take questions from the dais, I want to remind folks in the audience if you'd like to make a comment, at the end of the workshop, please grab a blue card and then get it to our IEPR team and that's how we'll know you want to speak. And I -- we're going to base the dialog on how many

blue cards we have to make sure we have enough time. So please, please get a blue card to Heather or raise your hand on the Webex.

And let's see, so, I had a question for -- oh, and the other thing is we will -- the hard copies we have, Nicholas, here in the room have the full graphics. We'll make sure that the copy in the docket also has the full graphics from your presentation.

I had a question for you.

MR. CHASE: Okay. Great.

VICE CHAIR SCOTT: Thanks. Back on Slide 8, which is where you were showing different battery costs, and it sounded a little to me like what's in your battery cost is different than what we saw in the Bloomberg new energy finance battery costs and I was wondering if you could just walk us through what was in there so that we can compare apples to apples as we're looking at the numbers.

MR. CHASE: Sure. And I think that was a question that did come up in part of the Q&A earlier. The yellow line, the EV 200 and 300 are, I think, if I'm not mistaken may be more representative of some of the discussion that's been in some of the other presentation.

We do have a retail price equivalent on top of the manufacturer cost to produce these batteries. We do have the battery cost if you were to go back to 2010. It's a very

similar looking line to what was presented earlier, we just have some -- we have retail price equivalent that are put on top of the -- in terms of the breakout and again this is a full pack cost which is the sale of the housing at a retail price equivalent to a consumer which has gone down a lot.

Similar to what I mentioned earlier and in fact we got the idea from these battery costs when we modeled the LIDAR cost. We have the R&D over time that goes into this and we also have a production base cost. We do try to monitor this frequently as much as we can to try to see where costs have changed. And as technology changes and as we get information, we do change these costs that go in to our reference case.

In terms of a PHEV 10 versus a PHEV 40 versus an EV100, we also have these variations that you can see in this graphic that are based on the different vehicle types. And I think that was touched on by one of the earlier presenters as well.

VICE CHAIR SCOTT: Great. Thanks. I think we're having a little of trouble pulling up the slides here, but that's okay.

The other question that I had for you and then maybe we'll take another question or two burning from the dais and turn to our moderated conversation.

Is -- it's back on Slide 19 when you were talking

about the scenarios for autonomous vehicles and you divided up by fleet and by household.

MR. CHASE: Yes.

VICE CHAIR SCOTT: And I'm wondering out in 2050 folks have been talking a lot about a shared vehicle economy. Are you -- is that included in your numbers out in 2050 kind of this more -- this idea that folks will share cars more than own cars or is it kind of working on the assumption that each household will have one or two or three or four cars per household?

MR. CHASE: We don't -- when we model the fleet vehicles those would be on-demand type of vehicles and so when we talk about 96 percent of the fleet vehicles for example here being battery electric, those would be ones that would be on-demand. We don't try to make any kind of change to, I don't know, passenger travel energy efficiency based on an increasing amount of people riding that single vehicle.

So we don't actually try to model increase, ride-sharing sort of speak in the fleet. For the household vehicles, we don't change the ownership rate --

VICE CHAIR SCOTT: Uh-huh.

MR. CHASE: -- in these projections. And so we have more autonomous vehicles coming into the households. We don't try to say anything about autonomous vehicles going into the fleet causing a decrease in the number of vehicle

sales to households.

VICE CHAIR SCOTT: Got it. Okay. Thanks.

MR. CHASE: We do make the assumptions in there that the fleet vehicles that are being used autonomously are driven around 65,000 miles a year which is similar to a taxi. And for households, we assume that they're driven by -- they're driven about ten percent more than a typical household vehicle.

VICE CHAIR SCOTT: Okay. Got it. Thank you.

Commissioner Monahan.

COMMISSIONER MONAHAN: Yes, Nicholas, thank you for this presentation. And this also may be a better question for the discussion period, but, you know, it's clear that the numbers that you have are -- on electrification are not consistent with what we're hearing from BNEF, ICCT, Navigant, the folks that are looking at this from a global perspective and how global demand for EVs is going to cause battery prices to drop, cause an improvement in the technology, and eventually these vehicles should out compete ICE engines.

And I'm curious your thinking about why the data continues to be so pessimistic in the U.S. compared to what we're seeing globally?

MR. CHASE: In terms of the U.S., a lot of the sales, at least in recent history and perhaps even in the short term, and this has been talked about I think pretty openly in

the discussions we've had earlier, there's been a lot of policy incentives or a lot of push to try to incentivize electric vehicle sales. And we see that being a very strong component of what we have in terms of sales in our projections we have the ZEV mandate and we do have the representation of SB-32 in California. And so you see a pretty big uptake in our model in the 2020s of better electric vehicles.

When it comes to international, we don't explicitly try to link our production based function say in our model to global sales, although we do have a global model that we model as a different product that EI does. And we do try to look at electric vehicle sales globally in that sense.

But it is a very interesting question what might happen. You got the example of Norway, that was a very heavily policy driven sale. China, you know, for example in our modeling we do have countries like China having a big growth in EV sales in our international energy outlook. Again, a lot of that there is a strong policy push in China. That's not to say that's the battery cost coming down or having that price crossover path or just that unforeseen or not in the reference case breakthrough battery technology. Even if it's foreseen, it's just not in our reference case. That could have a big impact.

In terms of infrastructure is also an important

issue. So we do try to look at these things and we try to look at what are some of the -- or all of the factors as many as we can capture that and we do see policy as being very important and we do see battery cost as being important. And certainly, those are uncertainties in our modeling and it's a fair question to ask about that uncertainty and what it means in our reference case.

COMMISSIONER MONAHAN: Can I ask one other quick question and then I know we need to get to the more -- to the discussion, which is -- I'm a user, I mean, I've used NEMS and I think on in terms of the power side of the equation, it's amazing. On the transport side, it's less amazing, let's just say. And I'm curious about whether you're considering updating the model to be more robust on the transportation side like it is on the power side.

MR. CHASE: I'd say I think we have a pretty robust model on the transportation side. I disagree with that assessment. That's not to say that there aren't areas we really need to improve on it. We try to keep as much as we can, we try to pay close attention to changing dynamics because these things change.

Some of the dynamics we have in the model again, because we have the fuel economy standards in 2025 in place in the reference case around that time and thereafter the conventional gasoline powertrains given the technologies that

can go on them and given -- we've taken those technologies from the rule makings. You can get a very fuel efficient that's not relatively that expensive of a cost competitor and then conventional vehicles. But that's not to say that certainly when it comes to the battery cost and such that there's not a lot of uncertainty about that, that we shouldn't look at that and try to update how we're costing out the batteries and such and how that might impact price. So I would say that that's a very important consideration certainly.

We do have a lot of detail in the model. We have different manufacturers. We have a lot of detail in places and we're always trying to improve it.

But yeah, that -- that's all I've got on that. I'm happy to take any more questions.

VICE CHAIR SCOTT: Okay. So thank you very much.

I think what we'll do, let me look to Heather real quick to see.

Did you receive any blue cards or any hand raisers?

MS. RAITT: I didn't, no.

VICE CHAIR SCOTT: Okay. So Tim, why don't you -- we were planning on ending this workshop around 12:30. Why don't you go almost to 12:30 with the moderated discussion, I'm really looking forward to hearing some of the questions and some panelists debate potentially. And then we'll wrap

up when they're done.

MR. OLSON: Okay. Very good. So I'd like to invite Noel up to the table to -- I'd like to have him participate in this too.

So I guess, we have a number of areas that there's -- thank you for raising these points during your comment session about differences between some of the presenters. And I'd like to kind of wade into a couple areas and just get some clarifications on the differences between the market growth of PHEVs and battery electric.

And I think Mike, Nicholas, you had in your presentation you shared a crossover plan and cost parity between BEVs and conventional ICE engine vehicles but you also had PHEVs. And it looked like the cost reductions occur -- differences between PHEVs and BEVs around 2024, 2025. Can you clarify why you think that's happening? And the other panel members I'd like you to weigh in.

And by the way, for this discussion, panel members can ask each other questions. Just a few rules, no kicking, no biting, no scratching for.

MR. NICHOLAS: All right. Thanks Tim. So yeah, I think you were looking at this, and yeah, it really is the fact that you still have an engine which is in a conventional vehicle and the battery system. So you have the battery system, electric motors, albeit smaller. And so there is

this manufacturing cost parity plus the, you know, the markup and all that to come with the vehicle price.

But if you go to the previous slide -- or two back, yeah. This one I think is the point where PHEVs, you know, they -- they show that on a lifetime basis those -- the operation costs. So over the lifetime of the vehicle, the PHEVs do make that up. But that might not be so obvious to the consumer. Do they value those future savings? You know, as is -- in policy, you can still support PHEVs but there is still a challenge of upfront cost.

I would say, though, that the cost difference isn't -- it's I think we show -- if you go down two slides to 11, it's a premium of potentially on the order of four to five thousand dollars, and so if it provides that utility for someone who doesn't have great home infrastructure, that may be the reason that they would choose the PHEV and the couldn't choose a BEV.

So, there's a lot of things outside of cost parity that I would encourage people to, yeah, keep in mind.

MR. OLSON: Ajay, do you have any other comments on that distinction? And also Logan, do you have any other comments?

MR. CHAWAN: I think on the development, I think I would also add in the development costs. Developing a vehicle, as I mentioned, is extremely expensive and so if

you're going to develop a vehicle with two drivetrains, it's just it's more money you have to spend developing a vehicle with two drivetrains that doesn't necessarily move the needle as much toward the zero emission vehicle requirement or a fleet requirements that an automaker needs to hit.

And so it's a matter of like, do you -- where do you get the most bang for your dollar -- bang for your buck, number one. Number two, the maintenance costs on a plug-in hybrid electric vehicle aren't as low as they are for a battery because you still have a gas engine that you need to service. And so you have that -- you have two drivetrains to manage so two systems that things can go wrong with. And you need to get them to play together nicely which is a challenge.

MR. GOLDIE-SCOT: And it -- yeah, I agree with what my fellow panelist has said. If I could just add one of the things we do at BNEF is like tracking the numbers, models being announced by different automakers. And so if we look forward to Q1 next year -- the Q1 2020, which again 384 EV models that should be available globally by that point. 248 of those, so roughly two-thirds, are battery electric vehicles where the bulk of the remainder being PHEVs, and then only around sort of 10 fuel cell electric vehicles.

And then another way of looking at this is of the 5 million or so electric vehicles that we've tracked sold to

date globally, yet 63 percent of battery electric vehicles were the 37 percent being to the PHEVs.

And so that gives some indication of the balance in terms of market share between two -- these two technology types. And so we expect PHEVs to play a really important role in meeting fuel economy regulation and EV mandates between sort of now and 2025. They're similar towards being sort of discussed and what you see on this slide faired the shell of EV cells begins to drop once battery electric vehicle production costs fall below those of ICEs.

MR. OLSON: And Nicholas Chase, do you -- it looks like you -- your slide had -- I don't know if we saw it here internally here but it looked like your data shows the same kind of trend that battery electric vehicles will have a -- at least with a battery technology will have a quicker price drop than PHEVs, and it will be continual difference in that price over time

Is that correct?

MR. CHASE: That's correct, yeah. In our projections we would have growth for PHEVs and all the different battery electric vehicle types but the strongest growth would be the longer range that are electric vehicles.

MR. OLSON: So, Nicholas, I'd like to give you the opportunity to -- is there a question you'd like to raise to the other panel members? You heard some of the

presentations. Any question you have, clarification, just a point of interest?

MR. CHASE: I think the analysis is very interesting. Certainly we're -- I'd love to be able to see the studies and in terms of a clarification when it comes to the pricing of the vehicles, there's a lot of detail in a lot of the pricing that we don't actually get into in our and we don't explicitly try to look at differences, say in total cost of ownership type of metrics.

Some interesting questions for us might be looking at those different costs and then also I think very interesting would be what some of the take is. I noticed some of the discussion about indirect cost what that retail price equivalent might look like. How might we represent some of the battery cost versus the price to consumer. And then certainly some of the different -- what some of the opinions are and some of the most popular battery ranges that we could see.

MR. OLSON: Okay. And Logan, I'd like to extend that same opportunity. Do you have a question of any of the other panel members or an area you'd like to probe more?

Well unmute your phone. Hello, Logan are you there?

MR. GOLDIE-SCOT: Yes, sorry. I wasn't sure if you had direct that to my chart. No sort of additional question from my end, just I guess in response to the previous one. I

mean, our battery price survey it is looking at the price of the sort of the delivered battery to the manufacturer. So and we assume the same margin for ICE and for electric vehicles, just in the absence of getting more granular on, model by margin -- model by model margin data.

And so yes, I think that is somewhat already accounted for. I mean, the key is not getting every single average battery pack price because the type of chemistry and the size of the battery and where you would source that from is naturally very different depending on if it's a small, medium, large, or SUV passenger electrical vehicle, whether it's a fleet electric vehicle or something -- or something else.

And if you listened -- if you listen to or if anyone actually of you attended the sort of Tesla autonomy or autonomy day a couple of weeks ago. And one of the interesting things that came from that is this idea that if you're looking at a battery pack for an autonomous battery service that would last sort of many more miles in the example that, you know, you must use, that would be a million miles.

Now that target has lapped ten times the current sort of warranty mileage for a 50 kilowatt hour Tesla Model 3. So if you're trying to make that leap from current sort of a -- well, current technology in cycling over battery, depending

on the use, you're looking at a different -- a very different sort of types of chemistry that you'd use and what, you know, sort of mentioned as the example that which I think is a very interesting way of thinking about this is -- it's just to achieve a million miles with a 250-mile range pack, you would need to cycle that battery around 4,000 times to achieve that target.

Now that is sort of in line and even at the lower end of the expected cycle life for a stationary storage system. But it's sort of much greater what you'd typically would see in some of the EVs today. So it's around finding the right battery and right chemistry and the right price for the application rather than just getting lost on a single average.

MR. OLSON: Okay. Thank you.

COMMISSIONER RECHTISCHAFFEN: So Logan, can I. Sorry, Tim, can I interrupt you and just go back to a comment you made two comments ago when you were talking about the number of brands that would be offered in 2020 and then the number that we had to meet of the 5 million that are -- on the road -- in the market worldwide now. Is it -- are you aware that there's this many brands for this level of sales as compared to conventional vehicles or is this typical that you have a plethora of models to reach a certain sales target?

MR. GOLDIE-SCOT: So I think would be the importance of that piece size, that is also a global number. and so if I look at -- I can actually just pull up the -- pull up the between the company but the number of models that would be made available in any single market instead of it's clearly much smaller than that.

There -- I think what is -- if I focus on the U.S. market about -- for instance, yeah, you'll see a much lower number of models. The number of models is incredibly important in terms of encouraging sort of a encouraging uptake from the consumer. Yeah, so a North American number for Q1 2020, let me check just check, is 110 and so it's sort of about a third of that. And then and that's if you look across North America so the number the single market may well be even smaller than that.

So the number of models is really important in driving consumer uptake because consumers want choices even if they ultimately actually all converge around sort of a smaller number of models. They want the idea that they're not being sort of pigeonholed into a decision.

So, I wouldn't say it's abnormal I'd actually say it's a sign of sort of a -- the necessity in terms of whether -- where the market is going. If you compare that to sort of the number of models in total that were available Q1 2011, there were only ten models back across North America

that you could pick from.

And so this is an important and necessary sort of evolution in the market for consumers to get on board with this technology.

MR. OLSON: Okay. I'm going to give the other panel members a chance to ask that same kind of question but I'd like to delve into another topic area. And that's this kind of balance between R&D on technology and then the manufacturing capability. And we -- today we saw some breakdowns of the different cost components, different structure of that cost, and of course battery. It appears to us that battery technology cost reduction is the really key part of this. And that the markets for growth of vehicles, China as we heard from every speaker, China dominates that.

And I guess, I'm not sure if many of you are aware of the CEMAC this is the National Renewable Energy Lab, the Clean Energy Technology Manufacturing Analysis Center has done some really good studies looking at what are the key reasons for clean tech manufacturing cost reductions over time, and then the end product cost is reduced.

And they looked at the solar photovoltaics, wind power, all of the renewal electricity, they also looked at battery technology and they concluded from all of those kind of assessments of what's happened worldwide that there's three main factors that generate that. One, is that there's

a continual growth in demand for the product. We see that, whether it's generated by market forces or government intervention.

The second one is achieve a threshold point for come to scale manufacturing. And batteries they concluded not only come to scale but also some significant control of the supply chain. And they concluded with electric battery manufacturing that that was a -- we achieve 1.2 gigawatt capacity to service equivalent of 35 gigawatt hours of charging in vehicles or other equivalent market storage and other.

And that the third factor was getting cheap financing to build those plants. And we see now at least five Chinese manufacturers, LG, and Samsung, and Korea, that the European battery allowance. So if China is the real market to -- for growth, what's triggering all that in China and what could impact that?

And I guess another question is if we're growing and we have basically Panasonic, Tesla as a manufacturer here, and we need say 10, 12 gigawatt factories in this say western U.S. or United States, what's the potential? Are we going to be an importer of that or can that be built here? And what's the real driving factor in Chinese growth of EVs.

VICE CHAIR SCOTT: Let me quickly note that we just got about four or five minutes left so maybe we'll have each

panelist kind of just give your high-level answer on that for about a minute and then we can get more data from you in follow up.

MR. CHAWAN: Absolutely. So the main driver in China is air quality. If anyone remembers the 2008 Olympics, they -- in order to get the air clean enough so you could see the mountains, the banned 90 percent of the cars each day. So it's air quality. Period.

MR. NICHOLAS: I'd say, yeah, the driving regula -- it could be air quality but then ZEV mandate drives a lot of their -- that makes the reason why they can maybe politically drive a ZEV market.

But I also say there's a different kind of car in China. They tend to have smaller cars so the cost parity comes a little bit quicker, they're not necessarily the highest speed cars. So when we look at the Chinese market versus the U.S. market, they're different cars and so it might be easier to get those cost parity numbers down with a smaller vehicle and lower speed. And so I think I'll just leave it at that for the high level.

VICE CHAIR SCOTT: Sure. Logan.

MR. GOLDIE-SCOT: Yes, I think in China in addition to air quality, there's a clear ambition around industrial policy and elevating Chinese automakers and battery manufacturers to -- or enabling them to sort of expand --

expand beyond their domestic market. So air quality may have been a catalyst for that but I don't think it is the sole factor.

And as a result, because of that demand, I mean, we're looking around 1.6 million passenger electric vehicles to be sold in China this year as of 2.7 million total. And so you end up -- we're creating that huge demand in that domestic demand in the country which incentivizes additional R&D investment and a larger pool of very large manufacturers.

The only other thing I'd add is we are beginning to see as the -- as global battery manufacturing capacity scales up, we're tracking around 300 gigawatt hours of cell production capacity globally. And based on company announcements, we expect that to over triple by 2023.

A lot of that new demand is actually -- sorry, a lot of that new manufacturing capacity is moving closer to demand centers. So if you look at SK Innovations, 10 gigawatt hour of production facility here in the United States or if you look at some of their CATL and announcements in Europe, we are beginning to see manufacturer capacity move closer to demand and that's just a really important thing to be aware of, and there's a big difference to what used to happen in this market.

VICE CHAIR SCOTT: Nicholas.

MR. CHASE: This is Nicholas Chase. I would say

strong policy support that was mentioned at different ways by the other discussions.

VICE CHAIR SCOTT: Great. Let me -- I think that we're about at the end of our time. So I really want to thank Tim for his excellent moderation and all four of our panelists for the -- their expertise and the data they've provided. We really appreciate you sharing your information and knowledge with us at the Energy Commission and the Public Utilities Commission as we're thinking through different policies and incentives that we put in place.

Before you go, let me just check because this is such a big and exciting and interesting topic, again, just like 30 seconds but if there are an interesting trend or something that you didn't have an opportunity to raise that you think we ought to keep in mind as we're looking through all of this, right? China's impact on it, the battery cost coming down, solid state batteries coming in, the innovations going on in the electric motors, this would be a great time to just give us 30 seconds of -- is there anything else you wanted to say that we missed.

And why don't we start with the folks on the phone, maybe Nicholas first. If he's still there.

MR. NICHOLAS: I don't have anything further to add, I thought it was very comprehensive the different topics that were talked about.

VICE CHAIR SCOTT: Great. Thank you much.

How about Logan?

MR. GOLDIE-SCOT: Sure, so since I think the -- it's actually just looking at the question around investment earlier. So a couple of numbers were sort of bounced around. If we look at just pure investment in electric vehicle startups, we're tracking around $18 billion of total funds raised by EV startups, private entity, public markets, and debts since 2011.

And then you have around $30 billion of investment in -- well, sorry [indiscernible] and then tens and tens of billions in additional investment into the related services down the supply chain.

So I wouldn't want to take away from the earlier discussion to be as to the investment going into this space because I think it would be misleading.

VICE CHAIR SCOTT: Great. Ajay.

MR. CHAWAN: Thank you again for having me. I've really enjoyed being here today. The -- I would just keep looking for continued collaboration and entrance from nontraditional players in this space. As you -- as the vehicle becomes more -- less of a just a piece transport to a rolling piece of technology, you're going to have a lot of -- lot of attention being paid both personally and then financially by nontraditional players like we've heard about

Apple potentially getting into this space. Waymo's -- there's going to be a lot of people getting into that next IOT device.

VICE CHAIR SCOTT: And Mike.

MR. NICHOLAS: All right. So I think I'll just reiterate some of the points that -- strong policy and coordinated policy becomes increasingly important. So there are a lot of things outside of cost parity. We have cost parity in Norway but still they sell internal combustion engine vehicles and PHEVs as well. So I think there's just keeping that integrated policy focus, keeping an eye on infrastructure, making it easy for people to charge and own electric vehicles is still extremely important.

VICE CHAIR SCOTT: Thank you so much to our panel. I really appreciate your insights and to Tim and to Noel for putting it together.

I do have one public comment here. So let's transition to our public comment period that is Sarah Rafalson. Please come on up to maybe this mic, yeah, right here.

MS. RAFALSON: Hi, thank you for having me as well, and thank you to the panelists for their remarks. I'm Sarah Rafalson, I work for the policy efforts for EVGO based in Los Angeles and question I have. I heard a lot of discussion today on personal use of -- personal ownership of vehicles

and a lot of talk about for example New York being highlighted as a place where people don't buy cars but they certainly use taxis for example or ride-share. And you saw on our network last year one-third of the gigawatt hours dispensed are 25 million electrical vehicle miles coming from ride-share and car-sharing programs.

So just wondering as the panelists look at their projects, how they factor in a lot of the new shared mobility options because maybe that's not coming from personal use and I just heard you say that we need to make it easy for people to own a car but as fewer people are choosing to own a car, how does that factor into some of these e-sales productions. Thanks.

VICE CHAIR SCOTT: If you like, a brief answer is okay.

MR. NICHOLAS: Okay. A brief answer. I say we haven't delved into that as much as the exact of the magnitude of that. And I would say it's equally as important as ride and hail owners to be able to charge. And I think that the fact that you can have fast charging and provide that convenience is showing a lot of promise. But there's also a role home infrastructure for ride-hailing to get those costs down.

So short answer is that we do have some data on the but certainly not as much as we should.

MR. CHAWAN: I would say that we're also, we're looking at that --

VICE CHAIR SCOTT: Ajay, can you make sure the folks can hear you.

MR. CHAWAN: That we're looking at that as well and still looking at the factors of total miles traveled is one of the key things that -- so you have total miles traveled, number of vehicles on the road, utilization, and how utilization will change with more advanced driving systems coming into play. So they're all -- they all -- all those things are factors in the modeling work that's going on.

VICE CHAIR SCOTT: And then that's the only blue card I have. Do we have any other public comment in the room?

All right. Do I have any public comment on the Webex?

MR. RAITT: Yes. Actually, it's more of a question it's from Nehemiah Stone and I will read it aloud for him.

Does the projected cost of ownership include the dollar value of time for commercial users since it takes significantly longer to get 300 miles of energy from a fast charger than it does from a gasoline or diesel pump?

MR. NICHOLAS: Not in the analysis that I showed but we do have a specific ride-hailing paper which looks at the opportunity cost of charging, including the cost to go refuel your vehicle, it's very small, but the cost of refueling and

the time associated and the role that fast charging would play in there.

So not in what we showed but yes, there is a report on that which I encourage you to look at on our website.

VICE CHAIR SCOTT: Any other public comment from the Webex?

MS. RAITT: That's all we have.

VICE CHAIR SCOTT: All right. Let me -- let you, Heather, go to the slide for our next steps.

MS. RAITT: Sure. So next steps are public comments are due on the 17th and so the notice has all the information for how to submit comments. We welcome any written comments that you'd like to provide.

VICE CHAIR SCOTT: Indeed. And with that, another thanks to our panelists. Really do appreciate your expertise and your energy in bringing your data and information to us.

And with that, we are adjourned. Thank you.

(Thereupon, the hearing was adjourned at 12:34 p.m.)

--oOo--

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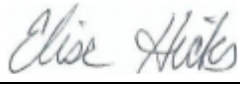

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