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CALIFORNIA ENERGY COMMISSION

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IEPR COMMISSIONER WORKSHOP

HYDROGEN AND FUEL CELL ELECTRIC VEHICLE MARKET STATUS

REMOTE VIA ZOOM

SESSION 1: HYDROGEN SUPPLY AND INFRASTRUCTURE STATUS

THURSDAY, JULY 2, 2020

9:30 A.M.

Reported by: Peter Petty

APPEARANCES

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J. Andrew McAllister, Commissioner
Rhetta DeMesa, Advisor to Vice Chair Janea A. Scott
Karen Douglas, Commissioner

STAFF PRESENT:

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PRESENTER:

Dr. Xiaoting Wang, Bloomberg New Energy Finance

PANELISTS:

Jacob Teter, International Energy Agency
Wayne Leighty, Shell
Shane Stephens, FirstElement Fuel, Inc.
Dave Edwards, Air Liquide and Hydrogen Council

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P R O C E E D I N G S

JULY 2, 2020 9:30 A.M.

MS. RAITT: So we'll go ahead and get started. I'm Heather Raitt, the Program Manager for the Integrated Energy Policy Report, or IEPR for short. Welcome to today's Workshop on Hydrogen and Fuel Cell Electric Vehicle Market Status. This workshop is part of the 2020 IEPR Update Proceeding.

So I'll quickly go over some housekeeping items. Today's workshop is being held remotely, consistent with Executive Orders N-25-20 and N-29-20 and the recommendations of the California Department of Public Health to encourage physical distancing to slow the spread of COVID-19.

Instructions for attending or participating in the meeting were provided in the notice and include both Internet and call-in options. Notice is available on the Energy Commission's webpage.

This meeting is being recorded. We'll post a recording and written transcript on our website. Also, today's presentations have been posted on our website.

We're holding this workshop in two sessions today. This morning we have a presentation to provide a market overview of hydrogen and the fuel cell market. Followed by a panel discussion of hydrogen supply and fueling infrastructure. We'll break about noon and come back at 1:30

for Session 2, which is -- will be panel discussions on heavy-duty and light-duty fuel cell electric vehicles.

And just to let people know, we -- we just posted a slightly revised meeting schedule for this afternoon. Just a correction to the moderator names. Please note there will be a separate login for this afternoon's session.

We're working on making the IEPR workshops more engaging in this remote environment and we'll be using the Q&A function in Zoom with a capability to vote on questions posed by others. So attendees, you may type questions for panelists by clicking on the Q&A icon at the bottom of your screen. Before typing a question, please go ahead and check and see if someone else has already posed a similar question. If so, you can just click the thumbs up to vote on it and that will move it up in the queue. And questions with the most thumbs up or clicks are voted to the top of the list. So we'll do our best -- our best to respond to questions but are unlikely to elevate all due to time restrictions.

So now I'll go over how to provide comments for the material on today's workshop. There will be an opportunity for public comments at the end of both sessions today. In Zoom, you can click the raise hand icon at the bottom of the screen to let us know you'd like to make a comment. And you can click it again if you change your mind and want to put your hand down. For those not -- oh, excuse me, for those on

the phone not using Zoom, press star 9 to raise your hand and we'll open your line during the public comment period.

Alternately, written comments after the workshop are welcome and they are due on July 23rd. Again, the meeting notice provides all the detailed instructions for providing written comments.

And with that, I'll turn it over to Commissioner Monahan for opening remarks.

Thank you.

COMMISSIONER MONAHAN: Thanks, Heather.

Good morning, everybody. I've said this at previous workshops, but I want to reiterate that hydrogen fuel cells are the other electric vehicle. I think there's, we have de facto been assuming that when we talk about electric vehicles, we're only talking about battery electric vehicles. And so I just want to emphasize that really this is, you know, hydrogen fuel cells are another form of electric vehicle.

And California I think has really been leading the way globally towards commercialization of fuel cell vehicles and hydrogen infrastructure, as well as setting a course for reducing the carbon intensity of hydrogen. So there have been a lot of very interesting announcements in recent times about more investment in fuel cell, in hydrogen in particular. And this panel is really going to be discussing,

you know, where we are in terms of developing hydrogen and building out the infrastructure.

One of the issues I've been particularly interested in is how do we -- how do we seed the California leadership to other parts of the globe? I mean, the way we are going to be able to commercialize fuel cells and hydrogen is by global investment. And California has been a leader on this for a long time. For a long time we were the leader on -- leaders on battery electric vehicles too. And then we saw global investment, others following California's lead. That -- that really built scale, drove down prices, and helped to lead to a pathway to commercialization. And that is the same trajectory that we want to encourage in the hydrogen and fuel cell world.

So excited for this day of workshops on hydrogen and fuel cells and looking forward to hearing what the panelists have to say, and learning.

So I turn to other members of the dais. I think right now we just have Commissioner Douglas on the dais. Commissioner Douglas, would you like to make any comments?

COMMISSIONER DOUGLAS: You know, just very briefly. I've been watching the hydrogen vehicle and infrastructure development over many years as well as, of course, battery electric vehicles. And I'm really interested to learn more about where things are today and where we really reasonably

can see this going. So very interested in this topic and look forward to the workshop.

COMMISSIONER MONAHAN: We also have a representative from Commissioner Scott's office.

Rhetta, do you want to say anything?

MS. DEMESA: Yeah. Sure. Happy to.

First of all, thank you both for allowing me to join you on the virtual dais this morning. For those of you who don't know, my name is Rhetta DeMesa. I'm an advisor to Vice Chair Janea Scott. Today's topic is of importance to the vice chair and she was really hoping to be able to be here today. Unfortunately, we weren't able to make it work with her calendar, so she asked that I pass along her apologies.

For those of you who don't know, Vice Chair Scott is lead commissioner overseeing R&D efforts here at the Commission. And prior to that, she was lead commissioner on transportation. So our office is very familiar with the opportunities and challenges of the hydrogen market, particularly here in California. We know that to meet our energy goals, including getting to a 100 percent in zero carbon resources we're going to need a mix of fuels and technologies, and we very much think that hydrogen is going to be a part of that.

Hydrogen is an interesting energy source in that it has the potential to cut across multiple sectors, including

both transportation and electricity while providing multiple benefits. So it can play a role in not only in decarbonizing transportation, which we're going to talk about today, but also integrating renewable resources, providing energy storage, and adding resilience to the grid.

We recognize that there's a lot of work to be done in the hydrogen space, but we see a lot of opportunity for innovation to help drive the market forward. So some of the things that we're kind of looking at in the R&D Division, research opportunities that can reduce the cost of renewable hydrogen production, supporting the development and demonstration of expanded use of fuel cells in mobile applications that are harder to electrify like locomotives and harbor craft. We're looking at technologies for hydrogen and building decarb, and also the role of hydrogen in long-term storage.

So we certainly recognize that hydrogen can serve as an important pathway in helping us get to a clean energy future and I'm just really interested and looking forward to hearing the conversation today. Listening and learning.

So thank you.

COMISSIONER MONAHAN: Heather, are there any other members of the dais or can we move on?

MS. RAITT: I don't see any others available right now. So I think we can go ahead and move on.

COMMISSIONER MONAHAN: Okay. Great.

Well, let me introduce our first speaker, Dr. Xiaoting Wang from Bloomberg New Energy Finance, who's going to provide an overview of the hydrogen and fuel cell market to kick off the day's workshops.

DR. WANG: Thank you for the introduction, Commissioner Monahan.

Good morning, everyone. It is my honor to have the opportunity of sharing the recent findings from Bloomberg NEF with the great audience here. So the scope of my presentation today will cover the economics of different segments along the value chain for the emerging hydrogen industry.

Let's move to the next slide.

Okay. I will like to start with a very general context about the demand of hydrogen. So in 2018, electricity made up 19 percent of final energy consumption, while the remaining 81 percent was consumed in the form of molecule-based fuels like coal, oil, gas, and biomass. All provided directly at peak. If the world continues along its present path, the global economy is to consume 54 percent more energy by mid-century as population and economies expand with electricity taking a 25 percent share.

Intergovernmental panel on climate change offered a perspective of what it might take to achieve an emission for

battery that limits global temperature rise to 1.5 degree. The whole package includes four solutions. Radical improvements of energy efficiency, or electricity from zero, or low carbon sources. Massive electrification that pushes up the share of electricity in total energy consumption to 53 percent. And finally, the other 47 percent energy consumed in form of molecule-based fuel would need to have very low emissions in capacity. So this is actually the potential market for a clean molecule like hydrogen or bioenergy and for continued use of fossil fuel with CCS.

Next slide please.

So today some cultures have policies to encourage adoption of hydrogen in road transport. While there is a wider spectrum of potential application for the molecule, manufacturing, power, and the supply, although they heat, could be significant sources of demand for hydrogen as well.

Next one.

In 2018, about 120 million metric tons of hydrogen was produced with 41 percent generated as a byproduct from various industry. For the remaining 69 million tons made deliberately, most came from gas, coal, oil-based reaction. And only 4 percent was yielded through water electrolysis, which does not release carbon dioxide in the final process, but does utilize electricity from the grid, which generally make it even more carbon intensive.

So in terms of consumption, almost all hydrogen is used as feedstock in the manufacturing of chemicals and basic materials. And hydrogen produced by water electrolysis have mostly supplied more and a distributed application, such as food and glass processing, (indiscernible) purification, et cetera. And the use of electrolysis in this application. Actually, it's not generally motivated by reducing carbon emissions, but because electrolyzers provide better economics when the required hydrogen purity is relatively high, the volume is more as the demand site is far away from the centralized production factory.

Next one.

So with this context, it's not surprising to see a very small shipment volume of electrolyzers nowadays. And China is so far the biggest market where manufacturing industry, in general, is still rising. In China, the more commercially mature alkaline electrolyzer is a single dominant for that type.

Next.

The production cost of gray hydrogen depends on the spot price of fossil fuels. And here we define the benchmark and 1 to 1.8 dollar per kilogram for countries with access to relatively cheap gas or coal.

The cost of making green hydrogen varies for different electrolyzer technologies and power prices. Here

we only consider alkaline and proton-exchange membrane, or PEM, electrolyzer that are commercially ready. So for the 2019 benchmark, we assumed electrolyzers are to source electricity from wind power plants. In general, green hydrogen production cost is two to five times that of gray hydrogen nowadays. But as the market of scale goes up, we expect electrolysis based to green hydrogen production to achieve cost comparable with gray hydrogen in ten years. And the former is likely to be 20 to 45 percent cheaper by 2050.

Next one.

So that prediction is based on our forecast of electrolyzer price and also LCOE of renewable electricity. Both will experience significant reduction in the following decades.

Next one.

During the past five years, the most mature two electrolyzer technologies, alkaline and PEM, had realized 40 to 50 percent cut as system capex based on data reported in Europe and North America.

Next slide, please.

And more dramatic contrast occurs between alkaline product installed in China and in Western countries. The number in China provides a better benchmark in terms of what is achievable. And we deal with the forecast for electrolyzer cost after scaling, based on this value.

Next one, please.

So PEM is less mature compared with alkaline electrolyzer, but it holds great potential in cost reduction. As suggested by the 20 percent learning rate observed in PEM fuel cells which are based on singular product structure and working principle at PEM Electrolyzer except that (indiscernible) chemical reactions are all the opposite direction.

Next one.

So by 2030, we expect regional capex to converge. Just as demonstrated by the history of EV industry. And alkaline electrolyzer capex will fall by 30 to 40 percent, even compared with the value observed say in China. And another 30 percent cut is likely by 2050. PEM will be more, still more expensive than alkaline electrolyzer by 2030. And it will be more suitable for small scale applications with an advantage of more compact physical design. But it is likely to achieve cost comparable with alkaline by 2050.

Next.

So the other side of the story is that renewable electricity is also becoming more affordable. We expect the LCOE of both EV and winds will fall to $30 per megawatt hour by 2030 in the regions with relatively descent natural resource. And to further drop to $20 per megawatt hour by 2050.

Next one.

Note these values do not include the impact of emerging hydrogen industry to the market the size of PV or wind and is therefore free to connect to the utility projects. The electricity cost will be even lower if we revise the two assumptions.

So first, by applying the PV and wind LCOE learning rates, which are 22 percent and 15 percent, respectfully, to the potential market boost introduced by hydrogen demand, we can derive the LCOE reduction.

Next one.

So the additional demand for PV can be 200 gigawatt, or 2 terawatts by 2050 for the conservative and optimistic hydrogen market scenarios which will result as one or 8 percent PV LCOE reduction compared with the scenario without demand of green hydrogen.

Next one.

And the potential cost of wind LCOE is two or 12 percent.

Next one.

Another assumption change for bringing hydrogen production cost is that instead of sourcing power from a remote PV or wind project, an electrolyzer can get electricity from a captive PV or wind power plant which can save spending on long distance cable transformer and a grid

connection fee. And more specifically, the electricity generated by PV and the power directly consumed by an electrolyzer are both of DC type. So for a captive PV plan for electrolyzer or the DC to AC or AC to DC conversion components can be removed. So here I show a singular story for PV coupled with battery which also directly charge or discharge DC electricity.

Next one.

So in the DC coupled solution for PV plus storage, some hardware can be removed and the overall conversion efficiency is higher.

Next one.

Overall, the power price of electrolyzers can be lower than our LCOE forecast or stand-alone PVs or wind system. So by 2030, the values will be in the range of 24 to 28 dollar per megawatt hour. And before 2050, power cost will further drop to 15 to 17 dollar per megawatt hour.

Next one.

So the production sector ends with a conclusion that the green hydrogen could cost less than $1.4 per kilogram by 2030 and $0.8 per kilogram by 2050.

Next one.

So the next story on the supply side is storage. Among many options including compressing, liquifying, and combining with other molecules, the most popular method being

used today is pressurize the container which is good for small volume and short duration.

Next one.

But if hydrogen can come to an influential scale and replace natural gas as most the roads it is playing today. The required storage volume will be comparable for the to -- to type all gases. So the average fall rate for natural gas in major market is about 10 percent of any demand.

Next one.

For large volume and the long duration, salt cavern is the best option. But salt deposits are necessary for the setup. Not many countries have the preferred geological conditions, especially those in China, while U.S. is lucky on that.

Next one.

So the next best option is rock cavern, although at a cost about three times more than salt cavern.

Next one.

But the good thing is that if the scale goes up, the storage in rock cavern in the future can achieve the same cost as the salt cavern for today.

Next one.

So the last section on the supply side is hydrogen transport. The most often observed approach today is by truck for small volume and short distance. When the volume

comes to the level of several tens of tons per day, developing pipeline can be justified and it will offer the lowest cost until the distance increases to 5,000 kilometer beyond which ships are probably cheaper.

Next one.

So similar to the previous two sectors, there is great potential for further cost reduction for storage, although the magnitude is different for various options.

Next one.

So depending on the assumptions, the final price of green hydrogen can fall to 2 to 3 dollar per kilogram by 2030 and 1 to 2 dollar by 2050. Of course much higher prices are likely if the condition are far away from the assumptions we used here, including monthly storage in salt or rock caverns and 100 kilometer of transport by our distribution pipeline.

Next one.

Fuel cell vehicles garner a lot of attention today thanks to the initiative of several large vehicle manufacturers, incentives from low-carbon fuel standards and some other common subsidies. There are much fewer projects, however, that demonstrate the use of hydrogen in other downstream applications like fuel production or shipping.

Most of the factors feature a small project pipeline with only ten or fewer sites proposed. And weak economics for hydrogen, relative to traditional fuel, is one reason for

the low number of projects. And another challenge is technical immaturity. So the equipment to use hydrogen in some factors has a low technical readiness level indicating it is further away from the commercialization.

Next one.

Despite the technical unreadiness at this moment, there is no fundamental hurdle that prohibits successful development of commercial products in the future that will allow adoption of hydrogen for multiple applications. So we conducted a series of bottom-up sector by sector analysis to evaluate the economics of using hydrogen in the future compared with the current solution. At about delivered price of $1 per kilogram in 2050, which was mentioned at the conclusion for the supply session analysis.

Hydrogen could enable emission reduction across many of the hardest to abate sectors as reasonably low carbon prices. So the chart here shows the greenhouse gas emission at oil factors where hydrogen could be used for and the carbon price that would be required for hydrogen at $1 per kilogram to compete with the cheapest fossil fuel in each use case.

And for road transport application, here we assume the final price of hydrogen as the fueling station is $4 per kilogram, based on which no subsidies would be required to compete with fossil fuels.

And in 2018, carbon dioxide emission from oil factors where hydrogen could be used amounted to 12.3 gigatons or 34 percent of global greenhouse gas emission from fossil fuels and industry. So this analysis suggests that up to 7.4 gigatons, or 20 percent of emission in 2018, could be decarbonized with the use of hydrogen for carbon price of less than $100 per ton for carbon dioxide.

Next one.

So theoretically, the long-term demand of hydrogen can be as high as 1.4 billion metric tons which is 20 times of the delivery production of hydrogen in 2018. Considering that not all potential users will fully replace existing solution with hydrogen from the economic consideration, we applied different penetration levels in each factor and expect about 700 million tons of annual hydrogen demand in 2050, assuming a strong policy support globally. And this would account for 24 percent of the global final energy consumption in 2050 in global warming of 1.5 degrees narrow that is described at the beginning of this presentation. And in this case, transport factors would consume 43 percent of all hydrogen.

So this is my last slide for today. And we will have some time for Q&A.

COMMISSIONER MONAHAN: Thank you, Dr. Wang. That was really interesting and exciting.

I'm wondering, you know, California has a target of a carbon neutral economy by 2045. And, you know, so the -- the presumption is that, you know, we're going to zero. At least from an economy-wide perspective. And am I correct that the analysis that you've shown today isn't based on a how do we reach deep emission reductions by 2050, but for what are the economics of hydrogen, you know, separate from that long-term decarbonization target. Is that -- is that correct?

DR. WANG: Yeah. So those comprehensive charts are based on assumptions as a 1.5-degree temperature control can be realized and also to prevent more neutral position analysis. For every factor, we provide a conservative and optimistic scenario analysis. So the optimistic is based on assumptions that every country, or most all of the influential countries will set a strategy or policy to lower the carbon emission.

Yeah, but definitely we -- it means that the tempo, or timing for each country will be quite different.

COMMISSIONER MONAHAN: Well, and I was also curious about the slides that you showed about the different ways you can make hydrogen more efficiently. And, you know, one of the critiques of hydrogen, vis-a-vis batteries, is that it takes about three times more energy from an electricity standpoint to electrolyze than it does to just use grid power for batteries. And I'm wondering, with the charts that you

show, are there ways that the production of hydrogen, the efficiency could be increased so that that three times number could get reduced?

DR. WANG: Yeah. Sorry for the confusion. So that chart actually is not about hydrogen production, it shows a similar story in terms that the DC to AC or AC to DC conversion components can be removed for both PV powered electrolyzer, and a PV plus storage.

So because there is no commercial product to show the concept for the PV powered electrolyzer, I justified an example in the PV plus storage device. So they follow the same principle. So in that design, we estimate that capex can be like reduced by about like 10 to 15 percent. And the energy conversion efficiency can be boost by like about 2 percent. So we can expect like similar, in fact, in PV powered electrolyzer system design.

COMMISSIONER MONAHAN: And has Bloomberg Energy Finance done in the equilibrium models where you're evaluating, you know, well from our perspective, what's -- what is that deep decarbonization pathway look like and what's the relative reliance that we should have on different fuels? What's the optimal place to put those fuels where we don't have a ready solution? I mean, you identified some of the sectors that are harder to decarbonize and, but they're more expensive to decarbonize.

I mean, transport is hard to decarbonize. I don't want to, that is -- that's definitely the case. But has -- have you at all done any analysis about sort of what's the optimal pathway for decarbonization across different fuels?

DR. WANG: So we don't have a very comprehensive like single seconds conclusion on that so what we have right now is to look into individual sectors and compare the relative economics. Like in terms of like level wise to cost and see how more expensive hydrogen would be compared with the current or traditional solutions based on fossil fuels.

So with that, we know from economic side like how far it is for like to convince a certain industry to adopt hydrogen. But in terms like the optimum, I think that's really depends a lot of factors. For example, some industries have less priorities on the carbon reduction because it needs to secure international capability on competition. So for those sectors it's more challenging to convince the industry to adopt like green hydrogen or low-carbon solutions.

COMMISSIONER MONAHAN: I mean, I'm curious and then I'll turn it over to Commissioner Douglas. I don't want to take all the air in the room on the dais.

So I've, you know, I've read about Japan investing in brown hydrogen in Australia, basically using coal to produce hydrogen and then assuming that CCS is going to work. And

it's those kind of projects that make me nervous. Where I think wow, that is really the pathway we want? And I mean your analysis is quite bullish on the we can make these zero carbon, in fact we can do it pretty quickly. And yet the investment, some of the investment that's happening globally is, I think, less than optimal, shall we say from a carbon perspective.

DR. WANG: Actually, we did also conduct an analysis about the CCS and the quick conclusion is from the economic side. So it's called blue hydrogen. So we still use fossil fuel to generate hydrogen and coupled with CCS. So the blue hydrogen will introduce, like the best case is 0.5 to 1.1 dollar per kilogram after cost on top of the production cost by 2030. And 0.1 to 0.3 dollar per kilogram reduction could happen by 2050.

Actually, a more fair comparison between the blue hydrogen and green hydrogen is green hydrogen coupled with storage. Because one advantage of blue hydrogen is you can get a steady supply of hydrogen because you can control the fitting of fossil fuels. But even that, considering the storage cost is only about 0.1 to 0.2 dollar per kilogram. So from the economic side, green hydrogen still wins over blue hydrogen, based on CCS.

But I guess that is a case by case study if you have the perfect geological conditions to store the carbon and you

can do it immediately. Because that very low cost, promise to buy green hydrogen is based on large scale. And it's not going to happen immediately. So I guess before the green hydrogen becomes super cheap, it still makes sense to use CCS if you have the right geological condition.

COMMISSIONER MONAHAN: Yes, it (indiscernible) CCS work anywhere. I mean, I hope it works. We need it and yet there's not a lot of optimism around CCS. When it really comes down to which projects have been successful, we don't have a track record.

DR. WANG: Yeah. Yeah. So far there are only four large-scale CCS projects in North America, including the U.S. and Canada. And three of them are not for like low-carbon application. It's designed to capture carbon dioxide to use in their in-house oil, like recovery.

COMMISSIONER MONAHAN: Commissioner Douglas, do you have some questions?

COMMISSIONER DOUGLAS: I just have one question.

And, you know, I don't -- it's not directly related to your presentation, actually, Dr. Wang. So but my understanding is that there is an increased effort to export renewable hydrogen, produced by offshore wind out of the UK. And Australia is moving, as I understand it, reasonably aggressively into exporting renewable hydrogen.

And I was just curious if you could help me

understand just the market dynamics around that. You know, what are the price points? What are the markets? Where is this going? Do you see this growing? Do you see this as something that California with our abundant sunshine and other renewable resources should be thinking more about?

DR. WANG: So okay. Those projects are deployed as a demo type and it's very hard to define a clear timeline. Because when we look at (indiscernible) announcement for renewable hydrogen production, in total more than 3 gigawatt projects have been accumulated by the middle of 2019 already. And I know the pipeline is still going on.

But if you look at them, most of them are at the early stage called feasibility study. It's definitely for the, like the huge ones at several hundred megawatts. But there is a clear reason why the electrolyzer should be coupled with optional wind projects if you have the natural resource. It's because the capacity factor also by offshore wind pumps is much higher than other renewable projects, especially compared with PV.

It matters because if we are designing electrolyzers to be powered by the renewable projects the levelized equipment cost will be much lower, if the capacity factor all of the power plant is higher because that suggests a high utilization grid, all of the utilize -- all of the electrolyzer facility. This is a very important because --

moment. Most of all of the electrolyzer offered with, like western brands are very expensive.

COMMISSIONER DOUGLAS: So just as a quick follow-up question. One of the best, really the best region in California for offshore wind is a region that is very much cut off from the rest of the state's electricity grid. And so it's been a challenge to think about how offshore wind could scale up in kind of far Northern California. But obviously, if you were doing an offshore wind project that included -- designed around an electrolyzer and with a fundamental purpose of producing hydrogen, you could use that resource. And I would imagine transport the hydrogen out of the region.

I mean, could you help me understand, you know, what -- what that might entail. You know, are you shipping the hydrogen? Are you, what's -- is there a ready market for such a thing? Is the technology close to there?

DR. WANG: Yeah. I would say the final system image will be quite different depending on the final application. As you mentioned, if the offshore wind resource is far away from, like the central like parts of a certain city. It's not an issue if the final application is having chemical production. For example ammonium production. You can just build your electrolyzer close to the wind resource. And also you can build the ammonium production site close to the

electrolyzer site. It's not a problem.

But if the final application is, let's say road transport, which means the final application will be very distributed so that could be a problem. It's likely that, although the electricity is cheaper or the final hour edge or levelized because the hydrogen could be cheaper if you put that facility close to the offshore. If you make sense to use distributed PV as a power source, considering it can save the transport cost. So there is no like consensus about the system because at the moment, it really depends on the final application.

So that's why we think like PV industry and wind industry is so easy compared with hydrogen. Because hydrogen is about, like a whole system. It's not only about upstream. Like for PV or wind, it's just is the upstream from the electricity system. This is about like or infrastructure for StarRay Transport and or so the final application.

COMMISSIONER DOUGLAS: That makes sense. Thank you. That's helpful.

COMMISSIONER MONAHAN: Heather, do we have time for a few of the Q&As from the audience, or do we need to move on?

MS. RAITT: We can just take a question or two, I think.

Jonathan Bobadilla from the Energy Commission is moderating the Q&A. If you could go ahead, Jonathan.

MR. BOBADILLA: Yeah, we have a question from Sarah Kurtz.

Dr. Wang, do you have a projection of the efficiencies of the hydrogen generation by PEM and alkaline electrolyzers? What round trip efficiency do you expect for electricity to hydrogen to electricity?

MS. WANG: Okay. So it really depends. The definition of efficiency. And if we use high heating value as the, like the standards, the efficiency as a system level is about 75 percent for a megawatt scale electrolyzer. Of course efficiency would be lower if we go to smaller scale projects. And the round trip efficiency, it depends what technology is being used as the final end.

If we are using fuel cell, so the round trip efficiency would be around 40 percent at this moment. But if as a final end we are going to use hydrogen gas turbine, by the way, that product is not commercial rate mature yet. Although the, like the equipment manufactured can make a turbine that is compatible with 30 percent hydrogen, plus 70 natural gas. So for the gas turbine solution, right now the round trip efficiency is about 30 percent.

MR. BOBADILLA: All right. Thank you, Doctor. And I'll recommend that the rest of the questions be saved for public comment. Thank you.

MS. RAITT: Thank you.

MS. RAITT: Thank you so much, Dr. Wang. And thank you, Jonathon.

So now we will, this is Heather Raitt. We'll go ahead and move on to the panel discussion of hydrogen supply and fueling infrastructure. It is moderated by Jane Berner from the Energy Commission.

And so, Jane, if you could go ahead and take it away. Thank you.

MS. BERNER: Sure. Thanks, Heather.

Good morning, everyone. I'm Jane Berner, a member of Hydrogen Refueling Infrastructure Unit within the Fuels and Transportation Division of the California Energy Commission. I am part of the team that administers clean transportation program funding that supports the building of hydrogen refueling infrastructure for fuel cell electric vehicles.

In this role, I have been privileged to work with many of today's panelists and it's my pleasure to moderate this morning's discussion on the status of Hydrogen Supply and Refueling Infrastructure.

The panelists joining me in this discussion are Jacob Teter from the International Energy Agency. Wayne Leighty from Shell. Shane Stephens from FirstElement Fuel. And Dave Edwards from Air Liquide, who will also be speaking about the hydrogen council.

So first let me explain a little bit about the format

of this morning's panel. Each panelist has prepared a short presentation. So I will introduce each panelist one at a time and they will each have a turn at the mic. After all the panelists have made their presentations, we will take questions and comments from the virtual dais. So from our commissioners and commissioner's representative. And then following that, I will guide the panel through some additional discussion. And we will close the panel by taking some questions from the audience.

So without further ado, let's get started with our first panelist. And that is Jacob Teter who is an energy analyst at the International Energy Agency. He joined IEA as a transport energy modeler and policy analyst in 2015. And now leads the team of transport analysts in the Energy Technology and Policy Division.

In this role, he aims to contribute to the global dialog on policies to promote transport technologies and services that improve quality of life while minimizing pollutant and greenhouse gas emissions and other environmental and natural resource impacts. So Jacob brings a unique perspective to us because he knows California. He earned his PhD in Transportation Technology and Policy at the University of California, Davis. But he's also a man of the world. He can give us an international context. And today he's joining us live from Paris.

So Jacob, thanks for spending your evening with us, and I will turn it over to you to kick us off.

MR. TETER: Thanks a lot, Jane.

So thank you, everyone, for the invitation to present and discuss these issues today. It is quite an honor and kind of a virtual homecoming to have the opportunity to discuss in this form. I think, actually, the next speaker was a -- was a colleague of mine at UC Davis so we are stacked a bit heavily.

I learned quite a bit watching that presentation already from Dr. Xiaoting and I am assisted in pulling together this presentation that I'll show quickly today by my colleague Jose Miguel Menendez Bermudez who is the IEA's kind of point man on the role that hydrogen can play in the clean energy transition. And especially for questions focusing on production and storage, kind of supply-type questions, I will have to resort to his help. And there may be bit of pause in giving detailed answers because I focus more specifically on the transport side of things. So system level questions I would be happy to do my best to answer, but I'll also be in contact with him.

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So as national and regional policymakers are beginning to coalesce on the fact that hydrogen will be an essential part of the energy transition and countries

recognize that decarbonizing, especially the hard to abate sectors will require a role for hydrogen, investments have also followed. What we see here is the growth of early stage investments in storage, hydrogen, and fuel cells. And that's in the light purple. These investments in start-ups with new technologies have grown, you know, global Seed A and B investments have grown even as investments in low-carbon transport, shown here in the light blue, primarily in batteries, cell in 2019.

Among the deals for hydrogen technologies, most were for firms with novel hydrogen production devices such as pressurized or photocatalytic electrolyzers. Other indications of growing interest in the investment community in hydrogen come from higher levels of growth equity, despite lower follow-on deals that investors are making in storage and hydrogen -- and hydrogen in general. Venture Capital has also flowed increasingly into hydrogen. As for instance, with Totiles investments in Sunfire.

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So the momentum has been diversifying quite a bit to the countries where policy support is the strongest and in terms of deployment of fuel cell electric vehicles and hydrogen refueling stations, things have evolved rapidly even since 2018.

So in 2017 when the U.S. and basically California accounted for about half of the fuel cell electric vehicles on the road, the picture has evolved quite a bit. In Japan, the sales of FCEVs have continued to grow steadily and Korea has gone from about a hundred fuel cell cars on the road in 2017 to more than 5,000 in 2019. Sales in Germany, France, and the UK as well as other European countries have -- have risen as well.

But I think the most interesting story is the rise of fuel cell vehicles in China. And this has incurred -- occurred almost entirely since 2018. And what stands out there in China in contrast to all the other market leaders in FCEVs is the disproportionate focus on light-duty trucks and buses. That is on commercial vehicles.

Indeed this strategy that China seems to be pursuing in first adopting fuel cells and hydrogen, in these applications is very much in line with one of the niches where the IEA finds, IEA analysis finds hydrogen in road transport applications to make the most sense in terms of

competitive total cost of ownership. When comparing the total cost of ownership across various road modes, various applications of road vehicles it may come as no surprise that the best near-term value proposition seems to be in heavy-duty vehicles with high energy and power needs, operating on fixed, ideally hub and spoke routes. Fueling at a single large hydrogen refueling station.

Also, China by going the route of commercial vehicles that operate intensely has very quickly paid back the initial high capital costs that come with fuel cells. At a time when, you know, learning hasn't yet resulted in rapid decreases of the cost of those fuel cells. China's also taken advantage of byproduct hydrogen coming from chemical industries like chlor-alkali production. So in short, China has found this niche where in road vehicle applications where hydrogen seems to make the most competitive sense.

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So where do we find ourselves, then, in terms of what many countries are hoping is the initial stage in a ramp up of fuel cell electric vehicles that will mirror in many ways the rapid market adoption of battery and plug-in hybrids. In terms of vehicle stock, we went from just under 1300 fuel cell electric vehicles on the road in 2018 to more than 25,000 in 2019. So almost a doubling. Sales more than doubled over those same two years. From a bit more than

5,700 in 2018 to over 12,000 in 2019.

If we compare this, of course, to the 7.2 million electric cars, battery and plug-in electric cars on the road, and to the 2 million EV car sales in 2019 then, you know, the lag of a little less than a decade is quite evident. And this means that about actually less than one percent of zero-emission vehicle sales globally were fuel cell electric vehicles in 2019.

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But the countries backing the scale up of fuel cell electric vehicles have bold targets. Starting with Japan who target sales figures of 200,000 in 2025 and more than 800,000 in 2030. Korea, as shown here, 81,000 fuel cell electric vehicles targeted by 2022. Netherlands, France. Our estimates are that achieving these targets would mean that the FCEV stock of road vehicles in 2030 would be around 10 million vehicles. And this kind of speed of the scale up would indeed be something similar to what we've seen since around 2012 in electric vehicles. And replicating that for fuel cell electric cars over the coming decade.

But I would argue that the challenge is even greater than -- than what we saw and what for most was unexpected in terms of the scale up and adoption of electric vehicles just because a parallel infrastructure is needed in the case of FCEVs and because China isn't listed among these countries on

this slide with government targets. There is, of course, a roadmap in China just as there is in the California hydrogen and fuel cell partnership.

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So, you know, there are economies of scale that come from the fact that the two largest cost components of building a hydrogen station are the compressor and the storage tanks. But there are risks about scaling up hydrogen stations because there's an uncertainty about the utilization. And so there's a tension between scaling up the refueling station size and the certainty on the demand side. And of course, just as in the case of electrolyzers, by getting higher utilization, you can amortize the capital costs.

So it is exactly this uncertainty that, you know, just taking one piece of the overall systems level puzzle leads to a lot of the -- the difficulty and complexity, even just within road transport of analyzing the potential for hydrogen.

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So we can see here global public RD&D investment totals that are indeed lower than they were in 2008, which was the peak of interest in hydrogen, but have started to grow. In contrast to the last time around, though, there seems to be a growing engagement in the potential ways in

which hydrogen really will be needed to help reduce emissions, starting in heavy industry, steel making, chemicals, fertilizer production, refineries, and in transport. Likely in road freight, but certainly also, I would argue as a -- as a feedstock for making ammonia or even for synfuels for aviation. More concretely, governments are taking heart in the recent successes, as Xiaoting showed. In RD&D funding as -- as catalyzing the tremendous cost reductions we've seen already in PV and wind, and in lithium-ion batteries.

Linking hydrogen production to these variable renewables, as was shown in the previous presentation, together with the cost reduction potential in electrolyzers has the potential to make this production pathway competitive in various applications with incumbent and mostly fossil fuel-based technologies.

Similar economies of scale also have great prospects to bring down the cost of fuel cells. But in transport, the question of where hydrogen makes the most sense and where it will be indispensable, where it can complement batteries and where it can serve as a hedge to hurdles, and further battery development I think is still a question up for debate and I hope that we can engage a bit on these questions as well today.

Thanks a lot.

MS. BERNER: Great. Thank you, Jacob.

So we'll turn next to our next panelist. Wayne Leighty is the Business Development Manager for North America for Shell hydrogen. Shell has received clean transportation program funding for eight hydrogen refueling stations in California. And I know I always like to hear Wayne speak because I think you'll see he has a deep technical knowledge about hydrogen, energy, and transportation. But he also has the business acumen to use that technical knowledge to evaluate opportunities and risks in the hydrogen market. And I guess this makes sense as Wayne has earned both an MBA and a PhD in Transportation, Technology and Policy from UC Davis.

From my perspective, Wayne has been integral in getting the hydrogen community to focus on how to scale up the hydrogen market such that there's a strong business case for hydrogen as a solution for decarbonizing the transport and energy sectors and achieving the emissions reductions that we need.

And I'd just like to personally say his involvement in our staff workshops have been a great value as we have discussed how to use our transportation funding dollars, put a hydrogen infrastructure as efficiently as possible.

And so with that, I'll turn it over to Wayne.

MR. LEIGHTY: Thank you, Jane. A very kind introduction.

Can I just confirm you can hear and see me?

MS. BERNER: Yes.

MR. LEIGHTY: Perfect. Thanks.

So it's a great pleasure to be with you. I'm Wayne Leighty, as mentioned, Hydrogen Business Development Manager for Shell since 2017. And indeed continuing the theme of UC Davis alums. Did my graduate work there over a decade ago with professors Joan Ogden and Dan Sterling and others. And my dissertation was on these transition paths to our emission reduction goals that we are now all working to achieve. So what a great privilege to -- to be working along with you on those paths. So I really look forward to our discussion so will try to just offer some comment on topics that may be of interest.

If you go two slides ahead, the next one is just our normal caveats. Thank you.

We created our New Energies Organization in Shell several years ago from the observation in our Strategy and Scenarios Teams of the underpinnings of the energy transitions. Changing fundamentals and the economics combined with the policy signals. And so Shell now, like you, is navigating and in and toward a multi-fuel future and decarbonized future. We're working across this full range of new fuels which gives us perspective on how the alternatives compare and compete and in fact complement each other in

transportation and energy systems. And it also creates some unique insight for us on the progress needed with each one to unlock the opportunity.

I think the benefits of hydrogen in transportation are becoming well known and don't need to be belabored. It's fast refueling of a zero-emission vehicle with a high energy density by mass, and economies of scale that are unlocked. All the benefits of an electric drive train in the torque and the quiet and effortless experience without compromise in the refueling, in the cost, the convenience, the capability of that vehicle whether you're a private owner or commercial fleet, and the freedom to move.

So the salient question is how to realize that potential in a commercially viable offering. A compelling better product in the vehicle performance in zero emissions that achieves cost parity or better. I think California policy calls for acceleration and scale. Nothing short of tipping points in majority adoption of these zero-emission vehicles. So a few observations if I may.

There are practical constraints. Customer choice is essential for this widespread adoption and wires and pipes are needed in California energy systems. An orderly transition is key to avoid imposing dead weight loss on Californians. The transition path matters. The area under the curve of emissions mitigates climate change and improves

human health. Success really requires new entrance in vehicle makes and models and expanding infrastructure. And at the end of the day, customers choose. So focus on customer segments and value propositions more than vehicle classes and use cases. So I think our focus is the same. Customer value proposition for the adoption of these vehicles and the business case for investments in California.

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I think it's important to recognize that hydrogen is a flexible, molecular energy carrier. So let's expand our viewpoint to sector coupling. It is essential for the reliable, resilient, and affordable energy system in California. It is essential for this hard to abate sector in transportation where the LCFS trades at about ten times the cap and trade. But there are also other hard to abate sectors where this molecule will -- will serve well.

And the diversity of these pathways for how to make hydrogen is a strength for making use of in state resources and solving environmental challenges with closed loops. These are the win-win opportunities for environmental improvement and economic development in California. So I think California policy has the right approach, focus on carbon intensity and renewable content for zero emissions, while leaving open what pathways are used. This is an important area, clearly for continued policy work. To

activate and enable scale, to couple sectors, to harmonize across policies. It's not easy. Neither is what we're doing on the industry side. So we're happy to work with you.

And I would say the opportunity is bigger than achieving the emission reduction goals. Already a tremendous challenge, it's also about infrastructure, stimulus, reliable and affordable energy systems, and continuation of the California energy industry. The ARB's analysis of self-sufficiency shows about 6 percent public funding leveraging 94 percent private sector investment.

Next slide.

I just want to touch on the pace of progress in hydrogen. This is our next refueling station. It's large. It's rapid. The number of vehicles in quantity and diversity is growing. The station infrastructure is starting to move from single stations to programs. In Germany, a new station opens every two weeks or so. Here in California, the cost of refueling stations has nearly halved, while doubling in capacity about every three years. One more halving and doubling would put hydrogen station on cost parity with gasoline. Hydrogen is now priced in California at parity with fast charging, while offering about ten times the level of service in the rate of charge. Shell is selling today in California 100 percent renewable hydrogen.

The public funding for ZEV infrastructure has been

approximately equal across the zero-emission vehicles on a per vehicle basis. And I think this will be decreasing in hydrogen. Pay attention to the CFO 19602 applications when they become public. And we're developing heavy-duty refueling stations for dredge, trucks, in the ports of LA and Long Beach.

Last slide to close, then.

Your policy signals are so very important. California is investable because the policy is stable. Otherwise it's often a very difficult place to do business. So please don't lose that. At Shell, our business planning is under way for this year and the signals like the multi-year approach to funding, the HRI pathway in low-carbon fuel standard. The ACT and ICT regulations. They work. They influence our thinking and our business planning.

We are asking hydrogen to be cost competitive with gasoline and diesel at a very small scale. Something like 1/1000 the scale of gasoline. And longevity, something like 1/100, and yet we start to see that it's possible.

That's -- that's it for me. Thank you.

MS. BERNER: Great. Thanks, Wayne.

So next we're going to turn to Shane Stephens. He is one of the founders of FirstElement Fuel and serves with the company's chief development officer. FirstElement Fuel operates the world's largest network of retail hydrogen

stations under his True Zero brand. And Shane oversees the company's station development program, business development efforts, and government relation activities. Shane has a PhD in Engineering from UC Irvine, and previously worked at UC Irvine's Advanced Power and Energy Program.

So from my count, FirstElement has been awarded Clean Transportation Program Funding for 31 stations, 20 of which are open today. And I think it's hard to overestimate the importance of the contribution that Shane and FirstElement Fuel have made to the development of hydrogen refueling stations in California. Their work has enabled automakers to release fuel cell electric vehicles in California and allow Californians to experience the fuel cell technology.

And from what I've seen and all of Shane's responsibilities, he's always moving from one meeting to the next. I always find it strange to see him sitting in one place for a few hours. So I want to say thank you, Shane, for -- for joining us and for these -- these next hours and for sharing your perspective. So I'll turn it over to you.

MR. STEPHENS: Thanks very much for that kind introduction, Jane. And let me also just do a confirmation that folks can see and hear me okay.

MS. BERNER: Yes.

MR. STEPHENS: Excellent. Well I appreciate your kind words, but let me say that I and the team at

FirstElement are so grateful for the opportunities that California has given us. Our company would not exist if it weren't for the visionary policies that have been implemented at the state. Everything from the ZEV program to the LCSF program, and of course for our little company, most importantly, the CEC's Clean Transportation Funding Program has been, you know, the enabler for what we've accomplished so far.

And -- and I will also say that we've just had a fantastic experience working with previously Commissioner Scott and now with Commissioner Monahan and with the staff. The staff of the hydrogen program is just outstanding. So -- so thanks very much.

If we can go forward to the next slide, please.

What I wanted to do today was just briefly touch on some of what we've accomplished so far and then just quickly go through a few lessons learned that I think address some of the topics that this panel is trying to -- trying to achieve, get to.

So first, what FirstElement Fuel has done, Jane stole my thunder a little bit. So we -- we have put CEC grant dollars to work. We've built what is today, from our count, the most heavily used network of hydrogen refueling stations in the world. We have 20 stations open with 19 more in various stages of development. And our network also from our

count has the highest availability in the world. That means that, you know, we have a better uptime record and more hours open. You know, a lot of 24/7 open stations, making it the most accessible and available network of hydrogen stations in the world. We've completed over 550,000 fills. We've replaced over 113 million gasoline miles with zero-emission vehicle miles of fuel cell cars. And we've avoided over 71 million pounds of CO_2.

These statistics are important to us because part of our mission statement is to address the economics of driving, but also to reduce the impacts of driving on the environment. So for the layperson, 71 million pounds of CO_2 avoided, that's the equivalent of planting a forest about three-quarters the size of the city of San Francisco. So, you know, that feels good that we're at an early stage of this and already being able to make that kind of accomplishments.

We've raised over 90 million dollars in private financing and so that actually now greatly exceeds the amount of public investment that's been put into us, primarily by the California Energy Commission. So that's exciting for us because, you know, I'm a believer and our company's a believer that for clean energy solutions to be successful, they do have to make business and economic sense. And we've created hundreds of California jobs in the process.

Looking more broadly at the CEC's Hydrogen Refueling

Infrastructure Program, the program has enabled the launch of fuel cell electric vehicles in California. As Jane said, customers can now drive these cars seamlessly throughout the State. A customer buying a fuel cell car in San Diego on day one can drive to Lake Tahoe to go skiing on the network with just swiping a credit card and doing four-minute fills along the way.

Private sector companies are learning how to achieve scale. Wayne alluded to this. I think this is very exciting. To achieve scale in the performance of hydrogen stations. And what this is doing is now driving interest from others sectors, like transit, commercial, and heavy duty. So, you know, thanks to the success and the learnings of what we're seeing in the light-duty market, other sectors are starting to embrace, yes, hydrogen is getting ready for primetime and the scale is getting there to where we can deploy these other vehicles.

Market initiation in this sector has a lot larger private investment. So I talked about just the private investment for FirstElement, but many more private investments beyond that taking place as well. And the key policies that we have in California are achieving greater renewable content driving aggressive carbon reduction in this sector.

Next slide, please.

So first learning I'll briefly talk about, getting to scale in higher capacity is critical to success. So the top portion of this slide you see several of FirstElement stations that we deployed in the first generation. And we early on learned that these stations were going to struggle to keep pace with demand when the automobiles started hitting the road. So you see three stations here with lines of cars waiting to refuel. This is not an encouraging customer experience, right, for people that want to get into a fuel cell car or for the automakers that are trying to bring the car to market. You know, I show three stations here. We actually have about 10 to 12 stations, I would say, that experience lines on a regular basis. So if you're the fourth or fifth car in line here, you're waiting, you know, fifteen, twenty minutes to fuel. That's not acceptable from our point of view.

We did identify this issue early on and we've worked to develop higher capacity fueling stations. Of course that investment and that development takes some time. So we're finally seeing the benefit of those stations hitting the road, kind of last year and this year. But multiple fueling positions are now possible and we're also seeing that there's a significant reduction in cost to the -- to the consumer. So we've already, at our higher capacity fueling stations, aggressively began to reduce the cost at the pump.

So just to give you an idea, that small footprint that you see there on the left, that's two hydrogen dispensers, four fueling positions. That can do about 300 hundred cars in a day. So think about that real estate and what you're achieving in terms of zero-emission fueling with that small footprint. It just shows the potential for hydrogen to achieve scale.

Next slide, please.

And I know I'm a little over time here, so I'll try to go quickly.

The second learning that I wanted to share is the hydrogen fuel supply chain needs to be dedicated and more robust. So I don't think it's any secret to anybody that one of our early challenges and stumbling blocks has been the availability and consistency of hydrogen supply. I think we relied on kind of traditional industries and byproduct hydrogen to -- to serve our stations. Again, this was an issue that FirstElement identified early on, but it's -- it's taken time for the investments to materialize into infrastructure assets.

Excitingly, one of things that we did is we worked with Air Liquide to come up with a strategy for a dedicated renewable supply. Air Liquide has invested $150 million to build this new liquid hydrogen production facility that is dedicated to the mobility sector. And there's just some

photos here of the earthwork that's being done. I think that photo was actually taken a few months ago, so it's a little further along now. And the -- the plans for what the plant will look like. And excitingly, this is also a 100 percent renewable hydrogen facility.

Next slide, please.

That's a good transition, I think, for learning number three, which is that the policies in California are achieving aggressive renewable content in carbon reduction in the hydrogen for the transportation sector. So what I show here is some comparisons with electricity, and I do that for two reasons. One, although hydrogen in its use is like a molecule, right, we can store it, we can refuel quickly with it, it's energy dense. In terms of how it's produced, it's actually more akin to electricity, right? There are multiple sources in ways to produce hydrogen. It has the advantage of being able to be produced locally. And it can be done in, you know, cleaner or less clean ways, depending on how policy structures and incentives are set up.

I also wanted to use this because, you know, we look at California as a model for success in terms of renewable penetration for electricity. And you can see how compared to the rest of the United States, California has a 30 percent renewable content, much higher than the rest of the U.S. electricity grid.

But excitingly, the policies in California have incentivized us to number one, we are required to meet a 33 percent renewable hydrogen standard, so already higher than the 30 percent electricity in California. We are heavily incentivized by the LCFS program to hit a 40 percent renewable hydrogen content. And actually, it makes it -- the way the policy is structured, it makes it feasible to even go to a much higher renewable hydrogen content. So today, our hydrogen feedstock is actually 100 percent renewable for all the hydrogen that FirstElement is distributing.

You can see in our graph here that we do have some percentage of fossil fuels and that actually comes from two things, one is the transport of hydrogen. So we do have a small amount of petroleum which accounts for moving hydrogen around and delivering it to our stations. And then the rest of that accounts for processes where we have to depend on electricity like compression and refrigeration. So we do have some fossil fuels in our Well-to-Wheels supply from some of the process energy that we use.

So I think -- I want to stress that there is a real opportunity here, you know, with the policy mechanism done correctly to keep the renewable content very high. I also want to just take one extra moment before I conclude to say that with the production and distribution system that FirstElement is implementing, I would really excited to look

at the potential for using remote wind energy like offshore wind in California and being able to move that into the urban areas. So I would be very interested to work the Energy Commission on looking at that potential.

So I'll conclude with that and look forward to the Q&A.

Thank you.

MS. BERNER: Great. Thanks, Shane.

And now we'll move on to our last panelist who is Dave Edwards.

He is a director and advocate for hydrogen energy for Air Liquide in the United States. Dave is responsible for establishing and maintaining internal and external partnerships with industry academia and government entities to advance the technology, business opportunities, and hydrogen energy.

Dave has been with Air Liquide for more than 20 years in a wide range of energy-related roles. And I also want to mention that Air Liquide has developed and operates three hydrogen refueling stations in California.

So today Dave's going to speak not only about Air Liquide but also about the Hydrogen Council of which Air Liquide is the founder and co-chair. Launched during the 2017 World Economic Forum, the Hydrogen Council is a global initiative of more than 80 leading energy, transport, and

industry companies with the united vision and long-term ambition for hydrogen to foster the energy transition.

And I just want to say a few more words about Dave. Even though he resides on the East Coast, he has become a fixture at our CEC workshops and Air Resources Board workshops and really any meeting in California related to hydrogen. He has become an expert in many of our programs and policies. And I really appreciated the insight and the meaningful feedback he's provided in our staff workshops that have helped us understand issues related to hydrogen supplies which have enabled us to improve how we structure our funding opportunities.

So thanks for joining us, Dave, and I'll turn it over to you.

MR. EDWARDS: Thank you, Jane. Just to confirm that you can hear me.

MS. BERNER: Yes.

MR. EDWARDS: Excellent. So one of the advantages of going last is that most of my messages have already been presented by somebody. I think that Dr. Wang did a great job of giving the overall economic picture from a global perspective. I'm going to look a little bit more on the U.S. side.

And then my, you know, colleagues from Shell and from FirstElement really, you know, hit the ground running with

where things stand today and where they can go.

So if you go to my first slide.

The first thing I'm going to do is give people a homework assignment. And that is that there's some additional information out there, the Bloomberg report is a fantastic reference. This is another reference, one that was put together about six months ago by U.S. Industrial Partners. Most of us being members of the Hydrogen Council, but to give a U.S. specific roadmap, this is very much around the economics of the roadmap. I am not going to go through the details of this. I think the most telling takeaway from the entire report is actually the inside front cover that lists the companies that participated in developing the information in the report.

I think that just a few years ago, had we put this roadmap together, the participants would have been the hydrogen producers, a subset of the auto manufacturers, and maybe one or two energy companies. But what we saw last year when we wanted to put this roadmap together was that there was huge interest from a much more diverse cross-section of industries.

So you start to see players like Exelon and Southern Company who are concerned about the grid. You start to see SoCalGas participating because they're interested in natural gas. And you see a lot of the bigger energy companies

starting to participate.

So when people think about the industries impacted by hydrogen, it now is a much broader specter of participants.

If you go to the next slide.

This is a cartoon picture of where hydrogen fits into the energy structures that we've been talking about. We talk a lot about the use of the electric grid to produce hydrogen from electrolysis going from red to blue at the top. We talked about natural gas and other fossil-based feedstocks going through reforming and gasification processes into hydrogen at the bottom. We've also talked about how renewables, wind and solar and also renewable natural gas can feed into both of those networks and produce renewable hydrogen along these pathways.

The important thing about hydrogen and I think Wayne hit this point earlier is its flexibility in how it is produced and how it is used. We tend to focus on the application space. And I think for the context of today, we kind of focus around transportation fuel. So we look at that little circle on the top right and we say this is the area where we are going to implement hydrogen and this is what we're going to focus on.

We tend to lose the bigger picture and that is that hydrogen is then interconnected to these other sectors. And as hydrogen grows as an energy vector, we enable a lot of

these other options to happen.

And one thing that's really important and I think the question that maybe Commissioner Monahan opened the session with and that is how do we -- how do we seed leadership to other regions of the globe? One thing to keep in mind is that the hydrogen solution is very regional. The way we solve problems with hydrogen in California versus the way we might solve them in Texas versus the way we might solve them in the northeast United States, let alone Europe or China can be very different because those feedstocks might be very different, those application spaces might be very different, and the needs to solve specific problems along those different pathways can be very different.

You can go to the next slide.

So this is my last slide. And this is simply to answer the question that we get very often and that is, but is it real? We only see 8,000 cars in California. We see limited penetration. Yet you talk about all of this potential for hydrogen. From an industry perspective and now I'm speaking on behalf of Air Liquide specifically, we back that up with our investments.

So Shane already pointed out the slab of earth where we're putting our new liquefier and hydrogen production facility, a $150 million investment, expected to come online the year after next, for example. Enough to fuel 40,000 fuel

cell electric vehicles in the West Coast market.

And what's really critical for us is that while this on the outside may look like our traditional method of doing industrial production of hydrogen, it's not. It's dedicated specifically to these mobility markets. So the investments that we're making, the contracts that we're assigning, the supply chains that we're aligning are all aimed toward this new mobility market. And that is a huge change for how the businesses manage and what the outcomes will be.

The second investment you may be a little less familiar with because it's not California, is that we've also got a project in Quebec and that's for a 20-megawatt electrolyzer unit using hydropower from Hydro-Quebec and that's to provide renewable hydrogen into our northeast markets. We already have a liquefier there, this electrolyzer unit will then provide about 8 to 10 tons per day of renewable liquid hydrogen into our northeast markets which our next area of penetration. We have a number of stations, a number of opportunities in the northeastern parts of the United States as well.

I'm going to end it with that because I know that the discussion is probably the most important part of the day today. And thank you very much for the opportunity to present.

MS. BERNER: Thanks, Dave.

So now I'm going to turn it over to our virtual dais and to Commissioner Monahan for any questions and comments.

COMMISSIONER MONAHAN: So thank you. This is really fascinating. And I encourage Commissioner Douglas to join and Rhetta if she's still on to join as well.

I do have a number of questions. And I'm sorry, my dog is barking in the background.

I, you know, I keep coming back to this international -- how does California stimulate international investments in hydrogen and fuel cells? And how do we make sure that we're creating a global ecosystem that is investing in the zero-emission technologies and fuel?

And I'm wondering -- this might be a question for Jacob. With the target setting that the countries are making on hydrogen and specifically on fuel cells, do you have a sense of which countries are furthest along? I mean, one would guess Japan and Korea are the two leads. But I'm just curious from your perspective, who would you put in that leadership role together with California?

MR. TETER: I mean, I think some of the policy support mechanisms that California has already put in place have been inspirational to a wide range of regions and countries beyond California.

And from my perspective, those kind of more technology neutral mechanisms like the LCSF and supported by

other more technology forcing, I mean, a portfolio of policies like the LCFS plus the ZEV mandates are things that have not only been adopted by other states but also, you know, considered increasingly by China, adopted by various provinces in Canada. And I think have been always a point of discussion here at the International Energy Agency and the source of inspiration.

I think that those kind of mechanisms are flexible to kind of the uncertainties and technology development that I think are somewhat inevitable and really help businesses that have a clear picture of their particular technology and the potential applications that go along with that technology to stimulate the investments that can then translate into missions, market missions that make sense.

And I think, you know, climate policy will necessarily need to be a part. We saw that the marginal cost of abatement curves that were shown by Xiaoting and I think that, you know, lots of the places where I see a clear need for hydrogen and for, you know, green production of hydrogen, coupling, you know, with a variable renewables and electrolysis, lots of those clearest applications where I don't see any other potential technology to substitute.

Things like either hydrogen fuel cells eventually or initially ICE combustion and ships, eventually fuel cells, perhaps ammonia fuel cell and ships, synthetic fuels --

COMMISSIONER MONAHAN: Jacob, I think my question is different, though. I'm not questioning the need for a diverse set of zero-emissions fuels and technologies. I'm asking which countries are going to be our allies in accelerating deployment of zero-emission fuel cell vehicles.

MR. TETER: Yeah. I think --

COMMISSIONER MONAHAN: And I say that because, you know, I -- like, I look at Japan and I think Japan should be our allies, Japan should be doing this. And they are, but they have three times the vehicle population of California and one-third the number of fuel cell vehicles. Or at least they did when I last checked.

And we need Japan as a big partner in this. Toyota is arguably the number one manufacturer invested in fuel cell. So we have to build this global ecosystem and that is something actually went to China right before the coronavirus as the coronavirus was hitting to China, develop a partnership with Guangzhou, their lead city on renewable hydrogen and fuel cell vehicles.

And Peter, you showed a chart where China had targets and deployment of fuel cell vehicles, arguably because their buses. They're using a lot more energy than our light-duty vehicles are. They may be, I'm not sure, you tell me, the number one hydrogen for vehicles -- hydrogen used vehicles in the world because of the number of buses that they're

fueling.

So China seems to me like a clear potential partner. They really drove down the prices. Battery electric, battery electric vehicles could they do the same on fuel cell electric vehicles is I think a question that weighs on my mind. And I'm just curious, what other countries should we look to to partner? Who are the countries that we really need to activate in addition to China and Japan? To be partners with us here in California to build the fuel cell market.

MR. TETER: Wayne has --

COMMISSIONER MONAHAN: Looks like Wayne has a response.

MR. TETER: I think --

COMMISSIONER MONAHAN: Wayne is raising his hand over there.

MR. TETER: I think mentioned also Germany and France. And indeed Air Liquide just built a -- or just announced that they're going to start building a station here in France. Probably using nuclear but it's a bit unclear with electrolysis for trucks, for long-haul trucks. Fuel long-haul trucks which I think is a discussion point.

But I'll let Wayne also give his opinion on the question.

MR. LEIGHTY: Commissioner, thanks, it's a good

question. And I think from the industry side of things, we certainly are already doing that. I suppose Dave at AirLiquide as well was developing hydrogen in core markets around the world. Those core markets are because they are good places to get started. And as we do that, we create the transferable benefits. So some of what we accomplish in California can transfer to other markets. Some of what we're doing in Germany and China can transfer back over here.

I would observe, then, if you question is about policy partners and kind of moving forward on -- on that front, there are other countries that are now going bigger than California. Bigger in scale and scope. And I would say those are Japan, Korea, China, Germany, and the EU. They're moving forward with larger steps and with kind of the coupling of sectors' broader scope.

I see other places following the very good structures that California has put in place. It's largely Canada the ZEV states, but the structures of low-carbon fuel standard and other things that California has pioneered are now from a policy perspective transferring to markets where we can then go invest.

The last thing I'd say is I think there are aspects that are transferrable. A lot of the progress in equipment and products cost at performance efficiencies are transferrable across markets as long as we do our job on

standardizing the codes and et cetera.

Some things are market specific and Dave talked about this. The infrastructure is specific to the market, develops in California somewhat differently than other places and needs to develop kind of that pace.

Thank you.

COMMISSIONER MONAHAN: Yeah, Dave.

MR. EDWARDS: This is Dave. So I think I would break it down into a couple of different categories. There is the development required for new technologies and new solutions that come out of things like the National Labs and at the, you know, the fundamental research levels, and I think that's going to continue to be a global phenomena. We see that almost everywhere in all the countries that we've mentioned so far that there is technology development occurring.

The thing that's really interesting from the industry perspective is where are the projects, then, being deployed? And we find that that tends to be very regionally specific. We find that Denmark is very much focused on offshore wind to electrolysis to hydrogen for fuel. We find that Japan is very much structured around the societal integration of hydrogen into hydrogen communities, including resiliency and power. And they're also looking with Australia to do this large-scale long distance transport. China, very focused on large vehicles especially around buses.

And the U.S. focused around a number of different things in different regions. In California, it's very much around transportation. In the northeast of the United States, the discussion is much more around grid resiliency. The outcomes from Superstorm Sandy and how do you address that with hydrogen in your ecosystem?

A place like Texas which has all this vested infrastructure and fossil, how do they make a conversion to a renewable future and is there a role for hydrogen to allow them to make that transition? Even within the U.S., very, very different regional structures. But California can learn from all those big projects that are happening in other places and of course everybody's learning from California as we do the big projects here as well.

COMMISSIONER MONAHAN: Great. Thank you.

Rhetta or Commissioner Douglas, do you have questions?

All right, Jane, why don't we turn it over to you for facilitating the discussion.

Thanks, everybody.

MS. BERNER: Great. Thank you. So I thought maybe we would pick up with where I think sort of where Dave just left off about how in California, we've been largely focused on hydrogen for transportation. But then in other places like in the northeast, more for grid resiliency.

We do know we have the debt curve issue in California. Do you see -- what are the opportunities you see for California to focus more on the grid resiliency issue?

And maybe I'll start with you, Dave, since you were sort of talking about it and then we'll go to anyone else.

MR. EDWARDS: Excellent. So grid resiliency and hydrogen storage means two things. It means you need to have electrolysis at scale and you have to have that integrated with either wind or solar in a way that makes sense.

I think Dr. Wang did a good job of outlining, you know, why wind might be better because you get higher utilization and therefore capital utilization and costs are better, for example. But it's not exclusive to wind, for example.

The second thing that you need is large-scale storage and/or an outlet for that hydrogen. And the outlet could be any of those applications. Basically talked about in California, the obvious outlet is transportation fuels today but it could be any of those other industrial sectors, for example, in the future.

But storage becomes an issue and storage in hydrogen generally means a couple of things. It means things like pipelines. There aren't a lot of pipelines in California today. Are we envisioning a future where we have a hydrogen pipeline system that enables large-scale storage? Probably

some decades away from that level of infrastructure, but it's the kind of things we should be planning toward.

And the other kind of storage or the ones that came up earlier in things like geologic storage. So can you have caverns? Can you have EOR applications or other places where hydrogen storage can potentially both from a storage of hydrogen perspective but also the storage from the CO_2 perspective I think -- or for the CO_2 capture side of hydrogen production, for example, become intertwined.

And I think those are aspects that need to be addressed in order to think about large-scale solar. All things that have been demonstrated other places in the world, pieces need to be put together and the economics need to make sense to do it.

MR. BERNER: Wayne.

MR. LEIGHTY: Yeah, if it's okay, Jane, just add at a general level, the future hydrogen society and energy system is I think fairly evident and has been analyzed a lot. Oftentimes the question is what's the next step? How do we start moving in that direction?

My reflection is that the archetypes for electrolysis in California are starting to become evident so that's one conversation. Is that what policy would like to have built because it's starting to becoming evident.

The other is we sure are glad that we got started on

renewable power generation with a renewable portfolio standard and then an investment tax credit. So in some ways, don't worry about getting it exactly right, get started. We sure will be glad a decade from now that we got started with some blending into -- of hydrogen into natural gas and from investment tax credit to start scaling up hydrogen as well.

MS. BERNER: Great. I thought maybe I'd turn to Shane now. You talked about a lot of the private investment that you've attracted to FirstElement Fuel. But I was wondering what the state can do to track more private investment to hydrogen station development and operation from your perspective.

MR. STEPHENS: It's a great question. I think, you know, the -- one quick answer is keep doing what you're doing. Right? Consistent policy signals are really important. I think we have a framework in California of policy that's working. And the private companies are seeing that, right? And they're seeing it as a good ecosystem for investment.

I think one thing that goes actually back to Commissioner Monahan's question, too, is that, you know, right now if you look at globally, different places have their strengths, right? I would say in California, we're probably further along on the real retail hydrogen experience. Right? Having stations open 24/7 with a simple

credit card swipe. The ZEV policy drives a lot of activity at those stations because we do have, you know, a good initial deployment of fuel cell cars here.

You know, the EU for example, is doing I think energy storage through electrolysis more aggressively than we are here. Right? So we have that to learn from them. So I think if we are in a leadership position on that thing or other things, it will unlock more private investment.

The most recent capital raise that we completed was from two Japanese institutions. One is Mitsui and the other one is the Japan Bank for International Cooperation. What's exciting about that is that these are both financial institutions. Right? So you're seeing rather than strategic players, you're seeing financial institutions now coming in and investing in hydrogen.

The other thing that's exciting about that is it's a foreign player putting money here because they want to see the market continue to grow and continue to get learnings from the things that we are doing well here. Right? So I would say, you know, on the one hand, yes, we want, you know, other partners in the world to be shouldering the burden. On the other hand, there are big benefits to being in a leadership position because you're going to see that international investment and those international dollars coming to California and being put to work here to create

jobs, to create an infrastructure to create an industry.

So I think, you know, where there are those other areas that hydrogen infrastructure is expanding, look for policies that can be implemented that are more market-based that encourage the private investment and then, you know, be consistent in terms of the commitment.

MS. BERNER: Great. Thanks.

So I think I wanted to try to ask a sort of bigger question that I think you probably all have thoughts on.

And that is so I think I can safely say you all see hydrogen as being essential to reducing, to decarbonizing the transportation sector and meeting our overall climate change goals. But I think, you know, like we talked about already, there's a lot of different ways to think about the raw hydrogen -- like what's the best role that hydrogen can play? How can it best serve this role?

And if we focus just in transportation that puts a hydrogenous sector and I think, like for instance, Wayne, you talked a little bit about thinking about kind of the use rather than like the duty of the vehicle. But I thought maybe you could expand more on that, how you all think kind of ideally where hydrogen be used more sufficiently in the transportation sector. And then on top of that, how do you plan our infrastructure possess most effectively?

MR. LEIGHTY: Wow, that's a big question. Maybe I

should --

MS. BERNER: And then we're -- everything's solved to then.

MR. LEIGHTY: Well, if we solve that question, then everything is clear. So let's do it. Maybe I'd take the first bit and leave the and then how do we develop toward that as a second topic.

The first bit from our perspective we are a fuel retailer, we think about serving the customer with the best kind of product we can. So the value proposition is strong. I think it's important that we translate from what is often a use case that's articulated in a vehicle class into a customer segment.

So when we talk -- and we heard earlier today, when the natural place for hydrogen is understood is heavy duty. Well, really what I think we're saying is a high output, high utilization vehicle. A place where fast refueling is important. So the strongest demand for fuel cell vehicles at present is in fact in forklifts, material handling. Where it's inside a warehouse so it needs to be zero-emission. And the up time of that asset is so important for that fleet, that business operation. And the total cost of ownership then becomes clear and hydrogen forklifts are expanding greatly.

So then indeed it was said earlier we can think about

the kinds of places on -- in on-road transport where that high output, high utilization exists and it might be in taxicabs and shared mobility in a light-duty vehicle and it might be in Class A trucks hauling beer from one point to another. So, again, it might exist all the way across those vehicle classes.

The last thing to realize, I think, is that there is a customer preference involved as well. There are large and growing customer segments who want that capability. SUVs and pickup trucks are growing segments. A person who's commuting in a pickup truck may not be using that capability but they wanted to purchase it. So we -- as we develop charging and we develop hydrogen, we think about market segments, we think about customers who want a particular level of service. We find that there are people for whom charging works very well and in fact is an improvement to be able to charge instead of refuel. And we find segments for whom charging will not work very well and in fact is a significant difficulty and negative in their utility function and they would love to refuel.

So I think that's our perspective thinking that hydrogen and charging are complementary from a customer and value perspective. Of course there are complementary aspects onboard the vehicle. We don't have OEMs with us right now but, you know, the shared components in electric drive chain,

et cetera. So we see these as very much complementary and therefore develop hydrogen for those customer segments for whom, you know, perform very well.

MS. BERNER: And does anyone else want to add to that or? I think not.

I'll move on, then. I just want to -- let's see, I think next I want to go to Shane to talk a bit about the -- well, we've already talked about it a bit so far is that it's hard to match where the hydrogen is produced with where it's needed for various purposes but including getting it to the refueling stations.

And, you know, we've known, actually that in California we have had some issues with getting supplies and stations and that some stations have been out of fuel at times. So I know at FirstElement you made a big transition from liquid hydrogen as I think a solution, at least one element, one reason is that the solutions help with that issue.

Maybe talk about that and also where you think what else needs to be done in the liquid hydrogen space to enable to do some transportation.

MR. STEPHENS: Yeah. Happy to do so.

So the transition of liquid hydrogen I think we saw, you know, multiple benefits to it. One is you say is to be able to a little more successfully and economically transport

hydrogen from what might be a somewhat stranded, you know, region and get it into urban areas.

Another one is scale. Right? You can move around and store liquid hydrogen at much higher densities. And, you know, today we're doing hydrogen stations with four fueling positions and we're seeing a business case take shape. Right? Well, four fueling positions is tiny for a gasoline station. Right? I mean, you almost never see a gas station that small.

So, you know, once we're able to scale to, you know, doing the kind of volume that a gasoline station does and, you know, we can do that with liquid hydrogen. The economic outlook in the business case and the ability to get price competition with gasoline is even better. Right? So it just looks better over time as we go to bigger volumes.

So I do want to stress, though, that, you know, it's I guess a blessing and a curse. Right? I mean, on the one hand, yeah, you don't want to move hydrogen huge distances. It can be done. You know, there are examples globally of people looking at shipping liquid hydrogen, you know, across the Pacific Ocean. But, you know, we should be I think taking advantage of one of the benefits of hydrogen which is that you can develop more local and regional resources to produce your hydrogen. Right?

So in California one of the big things that we have

is a lot of ag waste and food waste, right, for example. And I would say, maybe this is arguable, but I would say that using hydrogen in transportation is probably the most effective way to put that ag waste and food waste into work for energy, right, and to reduce carbon. So that's absolutely an opportunity that we should be looking at and taking.

But, you know, as I mentioned, Commissioner Douglas brought up in Northern California, you know, potentially offshore wind. With liquid hydrogen production and distribution, I think that's something that we can tap into and actually utilize and do that economically and make it work. So that shift I think was, you know, for several reasons, but it does unlock that possibility, I think, to tap into resources that might be a little bit more remote, a little bit more stranded and get them into Southern California.

I know, you know, it's not the only model that people are using to scale. You know, so there's still different approaches being taken but this is the direction that fuel cell going in. So.

MS. BERNER: And I think I saw that Wayne wanted to add something.

MR. LEIGHTY: Thanks. If I could just build on Shane's good comments by saying this is an area of important

collaboration between policy and industry, the importance of a roadmap, of an idea of where we are headed. Because your second question, Jane, was and so how do we build the right infrastructure? And that depends on where we're headed.

So gaseous and liquid, trucks and pipes, it all kind of depends as we heard from the earlier speakers today on -- in what direction are we headed. And we in industry can certainly make our assessments and investments as best we can, sharing that viewpoint with you and hearing your viewpoint on the policy objectives helps us to navigate in the right direction.

MS. BERNER: And Dave.

MR. EDWARDS: And I'd just like to add to that that as I found out earlier as Wayne has said, flexibility of supply is really important, especially in these earlier stages where there's not a silver bullet that's going to solve every problem for every location at every site or every station, even within the state of California, for example.

We are going to see gaseous deliveries, liquid deliveries, and in the relatively near future we might just see some of these other carriers involved in hydrogen movement within California as well. That is inevitably part of our future of how we think about this energy structure. It's a flexibility of how you move it and therefore how and when you make those investments regionally and with the

technology base that you've got.

MS. BERNER: Great. So we could continue on forever, or at least I could. But I have been told it's our time to move on to questions.

Although -- oh, actually, well, let me turn it over to Jacob real quick. I understand you want to ask a question and then we'll turn it over to the audience Q&A.

MR. TETER: Great. Yeah, I am struck by the fact that California has been really successful in building out this broad network of stations. And indeed anyone knowing owning a Prius can -- or anyone owning a Mirai can go, you know, anywhere across the state.

But I wonder, what would be your plan for trying to build out hydrogen stations beyond California? And what do you see as the challenges in doing so?

MR. STEPHENS: Wayne, you first or me?

MR. LEIGHTY: Go ahead, Shane. Yeah.

MR. STEPHENS: Okay. Great. You know, I think what FirstElement set out to do from the very start was to develop a model that is three things, scalable, right, can create a good business case, and can be exportable to other regions. Right? So I think we're there. I think there does have to be a little bit of a perfect storm of policy incentives to encourage the expansion into other states. I don't think we're that far away from seeing that happen.

And so, you know, I think our model is expandable. I think we like, again, the policy mechanisms California to have some capex funding from the Energy Commission on one hand. And then to have something like the LCFS capacity credit program, not every state has an LCFS program, so it may not be possible. But something like that that's more of a market-based mechanism to encourage, you know, the private investment through a successful long-term operation of a station. I think those two are very good elements that would spur a lot of development.

The last thing that I'll say is, you know, again, if we can show -- are showing and continue to show success on the light-duty side, I think you will see more and more interest snowball on the heavy-duty and transit sectors. There may be an opportunity to leverage some of that infrastructure to help expand, you know, the retail stations to other states as well.

I hesitate a little bit there because I think there -- it's not -- it's the exception rather than the norm for a retail hydrogen station to be coupled with a heavy-duty hydrogen station. Right? I don't think that's viable in most considerations. But if you're looking at more of a connecting network of stations to take you across the region, there may be some opportunities to leverage like a heavy-duty station to put a retail infrastructure there.

So I think I'll conclude with that and Wayne can fill in any gaps that I missed.

MR. LEIGHTY: Well, again, a good question in a big area.

A few additional thoughts. Fundamentally, hydrogen mobility is demand constrained by the number of fuel cell stacks being produced and vehicles coming to market. So what that means is coordination, infrastructure being developed where the vehicles are going. So far that's primarily where the vehicles are pulled by policy, a zero-emission vehicle mandate of some kind like in California or equivalent kind of policies in Asia and Europe.

The second thing is that as Shane alluded to earlier, I think we've learned our lesson in that you develop for the success case. Why would you build infrastructure for the failure case, don't even get started. So in building for the success case, a refueling station that fuels vehicles back to back like gasoline and performs, it necessarily has a low initial utilization. That's true whether it's light-duty vehicles or commercial fleets. We need to understand that simply a commercial fleet does not solve that problem and so it means that there's a bridge. And as Shane said, the HRI pathway and the low-carbon fuel centered in California is one of those example pathways.

It was called policy magic recently in an ARB hearing

because it pulls on two levers at the same time. One is how to get that infrastructure capacity built a little bit ahead of the vehicles. In the chicken and egg question, I think that's been answered that the infrastructure needs to come a bit ahead of the vehicle.

And the second is to decarbonize the supply. The low-carbon fuel standard is not so effective just in its base form for hydrogen because we sell so little hydrogen from the beginning. So as was alluded to today, that pathway in California has sent a very strong signal that everyone has responded to to decarbonize hydrogen from the start. So policy magic.

MR. STEPHENS: Let me --

MS. BERNER: Great. So I think -- oh. Shane, yes.

MR. STEPHENS: I just quickly want to build on one point that Wayne made about, you know, the LCSF program encouraging decarbonization of the hydrogen pathways.

I just -- I think it's so important to note how successful that program is and also at doing it based on the achievable metric. Right? Ultimately what we're trying to do is reduce carbon. And I think -- I'm going to speak a little bit bluntly here. Right?

In the legislature, you get things that are politically more favorable. Right? You get the political flavor of the week. And sometimes that means, you know, the

renewable energy flavor of the week. Right? Like, somebody decides that one renewable energy is better than another one because, I don't know, they're being lobbied or whatever.

So I think it's the job of the agencies. I think the agencies, both CEC and ARB, have done a great job of this. It's the job of the agencies to take a more, you know, level-headed approach and say, no, we need to look at renewables not based on flavor of the week but rather on the desired outcome. Right? Which ultimately is reduced carbon, reduced criteria pollutant emissions.

So the LCFS I think is one great mechanism to do that. CEC has several mechanisms to do that well. And I would just encourage to keep -- keep taking that even-minded approach.

So hopefully I said that well without offending any legislators. But.

MS. BERNER: All right. Well, on that note, we will turn it over to questions for participants.

So Jonathan, I think you're going to post some for us.

MR. BOBADILLA: Do we want to go to hands? I know we've got several hands up.

MS. RAITT: But Jonathan, if you had a couple of Q&A.

MR. BOBADILLA: Yeah, I can get --

MS. RAITT: This is Heather.

MR. BOBADILLA: Yeah, from Q&A?

MS. RAITT: Yeah.

MR. BOBADILLA: All right.

MS. RAITT: We'll do the hands up for the public comment period.

MR. BOBADILLA: Okay.

MS. RAITT: Thanks.

MR. BOBADILLA: All right. And this question isn't directed towards anyone in particular. But from Glenn Rambach, in what way is California engaging the electrical utilities and CAISO in approach to hydrogen as an electricity storage and transport medium?

MS. BERNER: I don't know if any of us is the best person to ask to answer that question. I know there's certainly been a lot of interagency discussions.

Did you -- have your hand raised, Wayne, or were you just moving your hand?

MR. LEIGHTY: I just wanted to say what a great question, and I imagine it's not easy. Amongst the agencies, you all are very busy and operating within your scope to do harmonization across agencies. I image it's difficult. I just echo the person's question, it's an important area to work on.

MR. BOBADILLA: Great. And one question that got touched on but didn't -- it might have been (no audio) stream

was about supply disruptions.

And let me see -- how do we ensure that there's no -- or how -- what is the resiliency of hydrogen on the supply side?

MS. BERNER: Go ahead, Wayne.

MR. LEIGHTY: It's Wayne. I have a thought on that one very briefly which is we finished the launch. I mean, what we observe right now is we're at a delicate place where the adoption is starting to happen but the supply chain is very thin. It's very difficult to have reliability and resiliency in a thin system of any kind. So it's imperative for all of us to succeed that we move on past this nascent phase into a more system with more depth. So let's finish the launch here.

MS. BERNER: And do you want to add to that, Dave?

MR. EDWARDS: Yeah, I would add -- amplify exactly what Wayne said and that is in the early days of an energy transition, you know, we're faced both with economic, technical, and operational challenges in making this transition. And, you know, the events of last summer that caused some of the interruptions are really indicative of those early stage developments.

But with a stable market that's growing with investments and the investments some of the ones that we announced from Air Liquide and a lot of the ones from other

companies as well are directly going to address that. Robustness comes with size but it also comes with planning and investments specific into this market.

Keep in mind that most of the hydrogen that goes into a fuel cell vehicle today is relying on infrastructure that was put in place for other applications. It was put in place for industrial supply or for refinery applications. And we're peeling some of that off and generating renewables and putting it into this new market but still relying on that infrastructure that wasn't optimized for it.

Going forward, all the investments that we're making now are specific to this mobility market. Meaning, you know, resiliency, the reliability, the redundancy, are now meeting the targets of individual consumers driving cars very different than industrial supply managing a contract, for example.

MR. STEPHENS: And, yeah, if I can weigh in a little bit too. You know, one of the slides I think was titled that, you know, the supply of hydrogen has to be dedicated and more robust. Right? So I think Wayne and Dave already hit on some of those points. We're relying on byproduct hydrogen, you know, and a supply chain that was not necessarily robust enough.

FirstElement, I think we realized this, you know, back in 2015, right around the time we were opening our very

first stations. Right? We saw weaknesses in the supply chain. We saw that demand was going to be bigger. But I think there were two challenges. Right? One is that it took a while to convince people of that because everybody thought oh, it's FirstElement, it's just those idealistic, optimistic guys, you know.

And I think the second challenge is that, you know, when you recognize the issue and start making investments in infrastructure, it takes time for infrastructure. Right? It's not, you know, developing a new app, right, or a new smart phone. Infrastructure developments just take more time to materialize.

So I think, you know, as Dave says, some of those announcements have been made and are public. I can assure you that there are a lot of other investments being made. So, you know, I think we feel much more comfortable with the outlook than what we knew in the past. Unfortunately, I can't talk very specifically about a lot of the stuff that's happening because it's competitive information, it's stuff that's not been publically announced.

But, yeah, I think the challenges of the past were well kind of articulated here and I think, you know, we recognize what the future needs. You know, it's some redundancy and robustness but also just dedicated supply for this marketplace. And those things are happening and

investments are being made, and the outlook is much better.

MS. BERNER: Great. So I think we have reached the time limit on our panel. I want to thank all of our panelists, it's been a great discussion.

And, Heather, I think you might want to introduce the public comment period.

MS. RAITT: Right. Thank you, Jane. This is Heather Raitt.

Thank you, Jane. And thank you so much to our panelists. Super helpful discussion.

So we do need to move on to the public comment period.

And RoseMary Avalos will be -- is from our Public Advisor's Office here to help us with that. And I'll just remind folks to go ahead and use the raise hand function if you'd like to make a comment.

And for folks on the phone, press star 9 to raise your hand to let us know you'd like to make a comment.

And, RoseMary, go ahead, please. Thank you.

MS. AVALOS: Thank you, Heather.

Yes, I'm RoseMary Avalos with the Public Advisor's Office.

And I'll first call on attendees using the raised hand feature on Zoom. Please state your name and affiliation for the record. Also spell your first and last name after

you are unmuted and before commenting. And do not use the speaker phone feature when talking because we won't be able to hear you clearly.

Okay. I'm going to call on Bernard Berrier. Go ahead. You'll need to unmute yourself. There you go.

MR. BERRIER: Thank you very much. I'm Bernard Berrier, aka Barney. And I'm with the Biomass Biochar Cooperative. And also helping out NuFuels, a biomass to hydrogen conversion technology using gasification in Fischer-Tropsch.

My question is how -- what role do you see? Obviously my interests intersect in reduction of the overburden of biomass both in the forest and in the fields and the production of hydrogen fuel cell.

And by the way, my name was stolen, I had a company called First Element Power Systems, hydrogen fuel cell integration company in 2000. But -- so it's a great name and I'm glad that it's being used today for fueling stations.

Thank you for your receiving my question. What role do you see?

Yes. B-E-R-N-A-R-D, B-E-R-R-I-E-R.

MS. AVALOS: Okay. We will move on to the next public comment.

Ray Pingle, go ahead, your line is open.

MR. PINGLE: Good morning, this is Ray Pingle from

Sierra Club California, and this is really just an excellent workshop.

You know, clearly, one of the most important objectives we have in doing all this is to have -- use carbon-free fuel. And I would like to make a recommendation to the Energy Commission that's got some excellent reports on its website on tracking progress. And there's a tracking progress report for zero-emission vehicles. And it does have a section where it talks about hydrogen fueling stations but it makes little mention about the renewable content of the hydrogen fuel.

And so I would like to recommend that going forward, the CEC specifically maybe have a graph or something that documents what is the percentage renewable content of all the hydrogen fuel utilized in the state by year. And with the goal, obviously, to increasing it to 100 percent. I know right now there's a law requiring 33 percent, it exceeds that. But I think that would be very helpful for us to track that.

Having said that, I would just like to ask the question to anybody that has a sense of what percentage of renewable fuel might we have by say 2030? I'm encouraged by the partnership between Air Liquide and FirstElement to build a large 100 percent renewable hydrogen plant in Nevada. But is that a trend within the industry? So I appreciate any

comments on that.

Thank you very much.

MS. AVALOS: Thank you, Mr. Pringle.

This is RoseMary with the Public Advisor's Office. And I just want to remind those that are going to provide public comment that this is solely for public comment. You can ask questions, but it's not -- you will not be receiving a response. You can ask your questions within the docket system and staff will review. But during this period, it's for public comments only.

And also I want to remind you to spell your first and last name and your affiliation.

Okay. We'll take on the next public comment.

Kate, go ahead. You'll need to unmute yourself, Kate.

Okay. We'll go on to David Uselton. We'll go ahead unmute Dave. I think we're having a problem with Kate. Go ahead, Dave.

MR. USELTON: Hi. Thank you.

My name is David Uselton, I'll spell that last name for you, U-S-E-L-T-O-N. I have no affiliation other than being a fuel cell driver for now our third generation. We started with a Tucson from Hyundai, third one to come in the U.S. Went to a Mirai, now in an Excel.

A couple of quick things. One, I'm hoping that maybe

we can rethink the way we subsidize the fuel. Over the past seven years my wife and I have seen so many people who seem to be in it for the free fuel. And we're not. We're in it because we believe it's the right future for our children.

I'd like to thank all the participants here that are in it for that reason which I believe most of you are. Right? That this is a long-term gain to help our global ecosystem and our children to have a better future.

And so maybe there's some ways to rethink the free fuel. Maybe it's a subsidy to standard cost of fossil fuels, maybe it's something else. I get it. Some people say it's a way to offset the cost of the vehicle. But there must be other ways to do that including maybe lifting the restriction on three vehicles in a row getting some subsidy in the cost of the vehicle and then pay for more of the fuel just to get people in it for the right reasons. Right? Otherwise, they just get mad. When they can't fuel, they get mad, they post all over Facebook, they give it a bad reputation and all they were looking for was free fuel.

And we got in this when my son was (indiscernible). And we bought him a model from Hammacher Schlemmer and he put it together and said why isn't every car like this, dad? I said, well, do the math of a (no audio). He did. In fact, he got quite a good grade from his teacher for having done the math. And at the time it wasn't viable. And we had the

discussion that someday it will be. And this is the right answer.

So I urge everybody to take a long hard look at are there other ways to be subsidized in the adoption that doesn't just necessarily give people free fuel. Maybe it's open corridors to more places. Or I hate to say it but people that have a little more wealth that do invest in this because they believe in the green but we don't quite have the transportation corridors to get there like Palm Springs and so forth.

But again, that puts it on high wealth people and that's probably not our objectives with tax dollars. But maybe some way to rethink that.

I have one minute left. I would just like to A, thank True Zero and Shell, both you two build fantastic stations. Right? And the fact that we're now going to see more adoption to infrastructure by people, we thank you for that commitment as well. I forget the name of the company that does the stuff -- that's building the new plant. All of you guys do great work.

I hope someone will go scrutinize Iwatani. They've been an embarrassment at that San Juan station for a year and a half now, or maybe it's just over a year. But I hope someone's in there looking at them real hard and saying hey, if you want any more tax dollars from us, make this station

work.

That's it. Again, just the last point. Love it. We really support it for the long term and what it does for our families and our futures. And we thank everyone that's putting a great effort into reality.

MS. AVALOS: Okay. Thank you, Mr. Uselton.

The next public comment is from Tim Sasseen.

Go ahead, Mr. Sasseen.

MR. SASSEEN: Hi, this is Tim Sasseen from Ballard Power Systems. My name's spelled, T-I-M; last name, S-A-S-S-E-E-N.

Thank you for this great workshop. Really appreciate the Energy Commission listening to the hydrogen industry and reaching out to get the most up-to-date and informative information. Excellent.

Really want to thank Commissioner Monahan in particular and comment on one thing that she raised which is the efficiency question. This is something that's brought up for hydrogen quite often.

And on the hydrogen side, you know, we try to be transparent about how our losses are on fuel cells for electrolyzers. On the battery side it's not always as apparent and it's not just the round trip efficiency of a battery, you have to take into account transmission losses on the order of 4 percent, distribution losses than can be about

the same. Chargers which can be 10 percent or some of the 100 kilowatt-ish chargers, that can go up to 30 percent for some of the DC fast chargers.

And then as we talk about capturing renewables for the sake of transportation, you're going to -- if you look at an all battery solution, storing that energy in large battery systems can also be surprisingly inefficient. I worked for a time at (indiscernible) for sustainable energy on the SCHIP program and we had found, see it in recent reports that round trip efficiency for stationary batteries are just somewhere between 20 to 30 percent loss from HVAC systems and for self discharge.

So that's in addition to the 5 percent loss in charging, 5 percent loss in discharging. So that doesn't bring parity to fuel cells with battery efficiency but it certainly does change the numbers and it changes the economics. So I would suggest that you look very carefully at that.

And beyond that, it really is a question beyond round trip efficiency. You have to look at how the energy carrier performs the job. For intermittent usage, for low-energy density, batteries do a phenomenal job. But when you put them towards high utilization application as Wayne Leighty was talking about, systems get very expensive, very heavy, very cumbersome, and you have to double up, triple the

resources in order to the do the job. And that's where hydrogen starts to look very, very effective.

So it's more than just round trip efficiency. You know, please do look deeply into those numbers and all the cost components that are required for that effort but also look at the applicability by segment. I think all of this starts to guide California towards a more comprehensive regional if not statewide approach at how the energy system develops and at making big bold moves which can get past a lot of the cost curves that so many countries now are seeing and are really an effective way to get to true carbon -- decarbonization through using hydrogen.

Thank you again for this excellent panel. Fantastic speakers, you really did do a good job in picking the right people to talk to day.

Thank you very much.

MS. AVALOS: Thank you, Mr. Sasseen.

Now we go on to Deanna Haines. And please spell your first and last name and your affiliation.

And you're unmuted. Thank you.

Deanna Haines.

Okay. We'll move on to William Zobel.

MS. HAINES: Can you hear me?

MS. AVALOS: Just one moment.

Okay. We can hear you now, Deanna.

MS. HAINES: Sorry about that. Deanna Haines; D-E-A-N-N-A; Haines, H-A-I-N-E-S, with SoCalGas.

I just wanted to point out one of things that Wayne had mentioned about the ability to blend hydrogen into the natural gas system. You know, the natural gas system throughout California is a very integrated expansive network with -- in Southern California, over 100,000 miles of pipe alone. And we have, you know, storage facilities that are pretty large and that can store large amounts of gas.

And recently the Lawrence Livermore National Laboratory released a study called "Getting to Neutral" that talked about the biomass conversion into hydrogen and having the system, the natural gas system be an offtake for that hydrogen to help build that scale that some of the speakers talked about to bring those costs down.

I'd like to just remind folks that that is a really good way of doing it, plus it's a carbon negative solution and that can help bring the cost down overall for hydrogen, decarbonize the gas in the system, and really have synergies with, you know, creating some value out of the, you know, the fuel from agriculture in forest waste, especially with our dead trees. We have I know over 130 million dead trees. So that biomass and the reduction of that fuel source could also be a synergy. So there's a lot of synergies here with an integrated look at this and not just looking at it from a

transportation sector.

Thank you.

MS. AVALOS: Thank you, Ms. Haines.

And I'm going to go ahead and make an announcement that we're going to shorten the public comment period because we have more people in the queue and to give everyone an opportunity, we'll have to shorten the time to one minute.

So William Zobel, go ahead. And your line is open.

William, you will need to unmute yourself on your line.

MR. ZOBEL: Oh, there it is. Sorry about that. That popped up a little late.

Good morning, my name is Bill Zobel; B-I-L-L; Z-O-B-E-L. Since I have a minute, I'll move quickly. I'm the executive director of the California Hydrogen Business Council.

We heard a lot of speakers today, they were all very good, appreciate their comments. In particular, we heard a call for regulatory certainty to facilitate investment. Both Dr. Leighty and Dr. Stephens mentioned the business case for investment. The council recognizes this is absolutely necessary for more private capital to make its way into this market to achieve the scale necessary to unlock the full economic potential of hydrogen that was outlined by Dr. Wang in her remarks.

A good example of this supportive policy being played out is being played out in the European Union, EU, specifically Germany where governments and private industry have committed to spending over 9 billion Euros on research on investment in hydrogen. This is a very recent and compelling example where clear and consistent policy signals support the business case and spur investment which allow markets to grow and mature.

One example close to home are the HRI credits which have succeeded in allowing for expanded capacity but they don't give the OEMs enough forward looking certainty in our view. The Energy Commission can and should do more to facilitate this with positive signals coming from both new and existing programs. The AB-8 funds do that. CARB recognizes the importance of extending AB-8 beyond the 2023 sunset date in the recent SB498 report.

This recommendation is in line with holding to the goals at executive order which have been given funding by the legislature. We urge the CEC to join this call for the extension of the AB-8 funds.

And quickly, on the production side, we also need clear and consistent policies to increase the supply and encourage producers to invest. Particularly we need policies to accelerate decarbonized hydrogen as Dr. Edwards pointed to the investment his company is making on the production side.

But he also pointed to the fact that regulatory certainty is required and will need investment to meet these goals.

With that, I think I'm probably close to my time so I will conclude my remarks. And I just thank you for the opportunity to participate.

Thank you.

MS. AVALOS: Thank you, Mr. Zobel.

We'll go onto David Park. Your line is unmuted.

David Park.

MR. PARK: Hi, this is David Park with the California Fuel Cell Partnership. That's D-A-V-I-D, P-A-R-K.

Commissioner Monahan, Commissioner Douglas, Advisor DeMesa, thank you for summon such a holistic and knowledgeable panel today and for all this IEPR proceedings.

We at the partnership are grateful for the ZEV neutral spirit of these proceedings and are hopeful that this spirit will be reflected in the policy recommendations that flow out of these hearings.

To emphasize Jacob's comments, California is the world's crucible for development of environmental and energy policy which is possibly the greatest export from our state. Whole country has followed California's lead. Our partnership, government industry, and academia are developing a new energy economy that would pay back dividends to California for the next three decades.

We emphasize the road to achieve the ZEV tipping point reference by Wayne will be difficult to climb. The state and world would be wise to enable all mechanisms to lower this hurdle across the ZEV platforms.

To emphasize the theme of consistent policy signals and perhaps providing a look into today's afternoon sessions, we point to Governor Brown's executive order to achieve 200 fueling stations by 2025, and 5 million ZEV by 2030.

This -- I'll cut my comment short for this afternoon but we look forward to our continued partnership.

Thanks very much.

MS. AVALOS: Thank you, Mr. Park.

The next speaker comment is Andrew Martinez.

Go ahead, Andrew, you may speak. Spell your first and last name, please.

MR. MARTINEZ: Hi this is Andrew Martinez; A-N-D-R-E-W; M-A-R-T-I-N-E-Z. Staff air pollution specialist with California Air Resources Board.

Just want to make a couple quick comments just to clarify for members of the public because I've heard some questions that I believe members of the public probably would benefit from being pointed towards some information resources.

Obviously, thank you to everybody who is providing comments on what kind of information you'd like to see and

where you'd like to see it. I'd just like to point out that both the Energy Commission and the ARB do provide semiannual reports with updates that include a lot of the information I've heard discussed today in terms of the questions that the public is seeking. Just point members of the public to a website arb.ca.gov\hydrogen. And I know that the -- I believe that the reports for -- from the Energy Commission, the joint agency staff reports aren't individual webpages so perhaps that's something that the Energy Commission staff can provide later.

And just one really quick clarification, I heard that possibly there's confusion about the fueling payment subsidies and I just want to clarify that that is not state provided, that is provided by the auto manufacturers.

Thank you.

MS. AVALOS: Thank you, Mr. Martinez.

We'll move on to Travis Andren -- Andren, I'm sorry. Go ahead, your line is unmuted.

MR. ANDREN: Thank you very much. That's Travis, T-R-A-V-I-S; A-N-D-R-E-N, Andren, representing D3 Designs, Inc., a social benefit corporation.

My comment today is twofold. First, I'd like to understand in Dr. Wang's presentation if there is any inclusion of nuclear and hydrogen coproduction as is being researched by the U.S. Department of Energy? Albeit not a

renewable source, it is a clean energy source that has the capacity to produce large volumes of hydrogen.

Secondary, looking at vehicle to grid resilience having seen the track record from power utilities such as PG&E's outages over the past two years as well as other national electrical grid concerns in cooperation with increasing natural disasters from climate change, is there an interest from the CEC and the hydrogen industry from both the vehicle application of vehicle to grid integration as well as from the Energy Commission's grid integration from a distributed network of electricity producing vehicles?

Thank you very much and I appreciate the conference.

MS. AVALOS: Thank you, Travis.

We'll go onto Robert Perry. Your line is unmuted.

Go ahead and unmute (indiscernible).

MR. PERRY: My name's Perry. Can you hear me?

MS. AVALOS: Yes.

MR. PERRY: Okay. Yeah, my name's Robert Perry, I'm an independent energy consultant. I just wanted to follow up on the number -- prior comments concerning the incredible opportunities presented by biomass, particularly in the Sierra Nevada mountain range, the 130 million dead trees. And I would direct people to look at what's being done with the Sierra Resource Conservation District. They started a pilot project converting trees into biomass which are now

being -- the syngas is being used to run a reciprocating engine. But this is clearly a resource that could be converted to hydrogen. It eliminates an existential climate threat while converting it into a high value storage medium.

So I urge everybody to seriously consider that avenue because that is California's climate challenge.

Thank you.

MS. AVALOS: Thank you. Thank you, Robert.

We'll move on to Robert DuBois. Your line is unmuted.

Okay. Mr. DuBois.

MR. DUBOIS: Yes.

MS. AVALOS: Unmute your line. There you go.

MR. DUBOIS: Robert DuBois, D-U-B-O-I-S. I'm with NuFuels. And we -- N-U-F-U-E-L-S. We have a conversion system, a non-combustion conversion system, high efficiency conversion system.

Just loved -- I've loved to hear in on this meeting. It's -- I love the fact that they're working from a micro and a macro level simultaneously and it's very, very hopeful from where we sit and also the planet sits.

My comment is as a baby boomer, I've noticed my children and grandchildren are different culturally than we were. In other words, they view the world quite differently and it particularly affects the private automobile. I'm not

saying private automobiles are going anywhere soon, but the emphasis I heard one commentator saying a more efficient use of hydrogen and transportation might be -- in early stages might be directed at mass transit, urban mass transit where there'd be also an environmental effect as well, more of an environmental effect.

So that's my comment and thank you very much for letting me make it.

MS. AVALOS: Thank you, Mr. DuBois.

The next commenter is Mike. Go ahead, your line is unmuted. Mike? Hello? You need to --

MR. SKVARLA: Hi.

MS. AVALOS: There you go.

MR. SKVARLA: Yeah. All right. My name is Mikhael Skvarla, not Mike. I'm here on behalf of the California Hydrogen Coalition. And that's Mikhael, M-I-K-H-A-E-L; Skvarla is S-K-V-A-R-L-A.

Quickly, we appreciate the opportunity to have a hydrogen focused worked today. With deference to the time, I'll shorten the comments and follow up with written comments.

Quickly, we encourage California to continue its leadership on hydrogen and fuel cells. We look forward to seeing how much can be achieved with the awards in the recent CEC GFO and continued support of the LCFS HRI program to

build 200 light-duty fueling stations by 2025.

We further look forward to working with the state to achieve 1,000 light-duty stations by 2030 which will cover 94 percent of California, 97 percent of disadvantaged communities.

With regards to the questions about batteries versus fuel cells, I wanted to note that Mr. Sasseen from Ballard did a great job at highlighting some of these issues. I'll further follow-up in our comments with some study from Germany to discuss (indiscernible) coalitions which discuss both energy and vehicle production and the carbon penalties that are associated with some pathways.

In closing, hydrogen and fuel cells are poised for a great opportunity for leadership in California in helping to achieve its climate goals while adding to Californians' lives.

Thank you.

MS. AVALOS: Thank you for your comment.

That concludes our public comments. I'll move over -- hand it over to Heather.

MS. RAITT: Thank you, RoseMary.

Commissioners, did you have any conclusion remarks you'd like to make?

COMMISSIONER MONAHAN: No. Just want to thank the panelists and all the folks that have participated remotely,

asked questions, provided public comment, really appreciate all the input.

MS. RAITT: Great. So I'll just add this is Heather Raitt. This afternoon we have Part 2 of this workshop and it has a separate Zoom webinar ID so please go ahead and join us and use that webinar ID that's listed here.

(Thereupon, the Hearing was adjourned at 12:00 p.m.)

--oOo--

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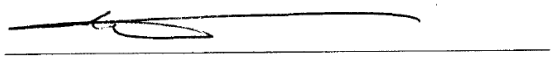

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