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BEFORE THE

CALIFORNIA ENERGY COMMISSION

In the matter of,	)	
	)	Docket No. 21-IEPR-05
	)	
2021 Integrated Energy Policy	)	Re: Hydrogen in
Report (2021 IEPR)	)	California's Clean
	)	Energy Transition

IEPR COMMISSIONER WORKSHOP ON

CURRENT AND EMERGING TECHNOLOGIES

REMOTE ACCESS ONLY

FRIDAY, JULY 28, 2021

2:00 P.M.

Session 2: Current and Emerging Technologies

Reported By:
Elise Hicks

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P R O C E E D I N G S

JULY 28, 2021 2:00 P.M.

MS. RAITT: All right. Well, good afternoon everybody, welcome to the second session of this 2021 IEPR Commissioner Workshop on Hydrogen to Support California's Clean Energy Transition.

I'm Heather Raitt, the Program Manager for the Integrated Energy Policy Report, or the IEPR for short.

This workshop is being held remotely consistent with Executive Order N-08-21 to continue to help California respond to, recover from, and mitigate the impacts of the COVID-19 pandemic. The public can participate in the workshop consistent with the direction in the Executive Order.

This is the afternoon and final session of this workshop. To follow along with today's discussions, the schedule and presentations are available on the CEC's website.

All IEPR workshops are recorded and a recording will be linked to the Energy Commission's workshop -- excuse me, website -- shortly following the workshop. And a written transcript will be available in about a month.

Attendees have the opportunity to participate today by asking questions or up-voting questions submitted by others through Zoom, using the Q&A feature. Or, you may make comments during the public comment period at the end of the afternoon. Or, you may submit written comments by following the instructions in the meeting notice. And written comments are due on August 11th.

At this time, I'll pass it over to Commissioner Andrew McAllister, the Commissioner for the 2021 IEPR. Thank you.

COMMISSIONER MCALLISTER: Thank you, Heather. And really, just nicely done and congratulations to you and the whole staff on a great session this morning. We got a lot of really good themes beginning to be developed by our various speakers and there's a lot of the substance to work with now as we elaborate the IEPR and, you know, build on those interactions going forward. So, that was great.

This afternoon we're going to focus -- this morning we focused on kind of the industry structure, looking at some pilots, some policy-related research that's happening, items looking at the hydrogen economy relatively broadly I'd say, and starting to think about some of those planning issues.

We're going to focus on technologies this afternoon. And so, wanted to just say how excited I am about this afternoon session as well. There's just so much potential here. And we're walking forward, trying to sort of knit this tapestry together across the various sectors of our energy economy from power sector, storage, transportation, critically, and industrial, thermal and even some retail applications potentially.

And then, also just linking it as Matthew, you said this morning, to some of the bio resources, the molecule, really, aspect of it in terms of the transition of the gas system.

And so I think, really, this is a tapestry that really covers a lot of the state, so potentially at least, and that's kind of the challenge we have before us is figuring out what that can look like and how we can optimize investment in the various pieces, with the most potential.

So, with that I will -- I'm Andrew McAllister, the Lead Commissioner on this year's Integrated Energy Policy Report. And I'm joined on the dais this afternoon, so far, with Commissioner Darcie Houck from the California Public Utilities Commission, and Matt Baker from the California Resources Agency. So, thank you both for being here.

We may be joined by Commissioner Douglas, who's the Lead Commissioner on siting issues and much of the large infrastructure, and whose staff really helped organized this day today.

And, let's see, I think that's about it. I'm not sure if we're expecting anyone else, any other Commissioners on the dais.

But with that I will pass the microphone to Commissioner Houck from the CPUC. Thanks for being with us this afternoon, as well.

COMMISSIONER HOUCK: Thank you, Commissioner McAllister. And I concur with all of your comments about this morning's workshop. And again, thank everyone that was involved with putting this together, the panelists, CEC staff, and appreciate being able to participate and hear from everyone today, and look forward to this afternoon's session. And I will turn it over to Deputy Secretary Baker.

DEPUTY SECRETARY BAKER: Thank you. I just want to echo what everyone else has said. It was a great morning. I'm looking forward to the afternoon. And let's get started, I guess.

Back to you, Commissioner McAllister.

COMMISSIONER MCALLISTER: Thanks for being with us, Deputy Secretary Baker, really appreciate it. And for your leadership generally on this and related issues, really appreciate that.

So, with that I think I'll pass the mic back to Heather to get us kicked off on this afternoon's session.

MS. RAITT: Great, thanks. So, we'll start the panel this afternoon on Current and Emerging Technologies. And it is being moderated by Jack Brouwer. Jack Brouwer is a Professor of Mechanical and Aerospace Engineering at the University of California, Irvine. He is also the Director of the National Fuel Cell Research Center and Advanced Power and Energy Program at UC Irvine.

So, go ahead Jack. Thanks for being here.

MR. BROUWER: Thank you so much Commissioner McAllister and other distinguished leaders here in the State of California for taking on this important subject of how hydrogen can support California's clean energy transition.

I'm happy to be here today, both to moderate the session and to provide a few comments to introduce this topic. Because I think hydrogen -- well, I don't think, I know hydrogen is essential for us to achieve our zero emissions goals.

The next slide, please. And while I usually have nice animations, I was told I could only do this by PDF to show some of the results that we have obtained through a couple of decades of research in this topic area.

And what you see in this particular slide is the fact that once we achieve very high renewable percentage, this is a 100 percent renewable grid in the State of California. And it's a wind dominant case in which you can see certain 15-minute periods of the year in which there are deficits. Those are the red data. And certain periods of the year that we have surpluses of the wind and solar power. And all we need to do is move it around in society, store it for periods of time to make a 100 percent grid, renewable grid work.

And the fact of the matter is we need lots of batteries to do this. We also need our pumped hydro system to do this. But even if you add all the batteries that we could possibly put, and all the pumped hydro, and even more pumped hydro resources in the state none of them are sufficient without also transforming the gas system to enable massive energy storage in the underground storage facilities that we currently use today for this purpose.

Underground storage facilities of gaseous fuels are what enable us to adopt renewable electricity in high magnitudes. Okay. This is the only known solution that can get us this huge a magnitude of energy storage.

And that's what I'm showing in this orange box that shows hydrogen storage. If we try to do it with just battery, solar, and wind, we're never going to get there. If we try to do it with just battery, solar, wind and pumped hydro, we still don't get there. You need the gas system to do this.

The next slide, please. And our research suggests that an immediate adoption of a renewable hydrogen injection standard is really quite important for this. The gas system not only has the massive storage capabilities that are going to be required for long duration and seasonal storage, but it also has reliable transmission and distribution.

As a matter fact, the GTI study that I'm referencing here, in 2018, showed more than five 9s availability of the gas system throughout the United States.

And why should we adopt a renewable hydrogen injection standard immediately? For two main reasons. WE need to begin the transformation of that gas system to a zero emission system and you can't begin it without at least trying some hydrogen injection.

And secondly, it will serve as an immediate off take for the additional investment in solar and wind resources in this state, which are going to become more and more difficult to make economically viable unless there is a very large ability to accept renewable power when it's not wanted on the grid.

And this is why even just a 5 percent hydrogen injection into the natural gas system is desirable today because it would offer this additional off take and additional investment value in sun and wind power.

The next slide, please. And we looked at this gas system transformation also to 100 percent renewable hydrogen. And this is an example of just closing off the valves at the California/Arizona border, and putting solar into that square area that you see there. Now, it's a pretty big square area. It's 20 miles by 20 miles.

But just transforming the gas system without adding any additional transmission and distribution, and putting solar in that one space that you see here, the next slide please, would engender a 40 point increase in the renewable content in the State of California.

What do I mean by that? We don't have to invest in transmission and distribution. We can use the existing pipelines. Of course, you have to invest in their transformation to handle pure hydrogen, but they could handle the pressure dynamics as I'm showing in this chart. And the resources on the downstream for both storage and for reconversion to electricity are all accounted for adding 40 points of additional renewable content.

So, we can go from about 40 percent, which we are at today, to 80 percent with this one project. And it’s because of this massive resources that the gas system contains that we’re enabled to do something like this.

The next slide, please. And this resilience has been proven by underground delivery of the gas system and fuel cell systems, which also have zero criteria pollutant emissions, and which also can operate on renewable hydrogen in the end to enable both greenhouse gas emissions reductions and reliable zero emissions, including criteria pollutant emissions, power generation at the end points.

The next slide, please. And I’m not the only one that’s saying this. I was fortunate to work with a whole bunch of really awesome scientists and engineers led by my colleague, Steve Davis, who you see as the lead author here, that show us that unless you try to include something like hydrogen and its features, and its derivatives, there’s no way that you can decarbonize the entirety of society.

As you can see, things like ammonia and

fertilizer production, cement and steel plants. You can see aviation and long duration, long haul trucking, and these kinds of things that need hydrogen and its derivatives to make them zero emissions.

The next slide, please. And so, anything that requires, on the transportation side, rapid fueling, or long range, or heavy payload will prefer hydrogen to, and engender zero emissions, to batteries, okay.

Now, we need lots of battery vehicles, too. Lots of battery transport. Lots of battery boats and planes. But when it gets to a really big payload, that's when hydrogen is preferred as a zero emission vector.

Next, please. And there are some industries that will require heat that only a fuel can deliver. Or a feedstock, like the hydrogen itself is the molecule. Or, even a reducing gas, okay, which hydrogen can serve as, that won't be made zero emissions without something like hydrogen and its derivatives. The steel, cement, plastics, pharmaceuticals, computer chip manufacturing, ammonia and fertilizer production, these kinds of things need a hydrogen input in order to make them zero emissions.

Next, please. And I'm not able to tell you all of the features of hydrogen, but I was fortunate to work with an awesome graduate student and post-doctoral research to write this paper that's called Hydrogen is Essential for Sustainability. And it offers 11 features, I've talked only about four or five of them in this presentation, that I think will be required for zero carbon and pollutant emissions in our sustainable future.

So, I encourage you to look this up, Hydrogen is Essential for Sustainability, published in a Journal of Current Opinion on Electrochemistry.

Next, please. So, I'm happy to introduce the next speaker, a person that can well speak to commercially available technology today in proton exchange membrane and alkaline electrolysis.

This next speaker is Steve Szymanski. That's who I think we have on next. Oh, shoot, the backup slides are here. Go to Steve's presentation next, that's the only -- if we need to go to the backup slides as the dais has questions, I'd be happy to go to that. But Heather, can you go to the next presenter's slides, please?

MS. RAITT: Yeah, we'll get there. Here it comes, thanks.

MR. BROUWER: So, I'm happy to introduce the first speaker, Steve Szymanski from Nel Hydrogen.

MR. SZYMANSKI: Thank you, Jack.

MS. RAITT: Thanks for your patience as we're having a little trouble.

(Audio discussion)

MR. BROUWER: I could also just say next slide 20 more times and get rid of those backups. That looks good. Thank you.

MR. SZYMANSKI: All right, great. Thank you. Thank you, Jack and I appreciate the opportunity to, you know, provide some comments and some material for this workshop.

The next slide, please. Just very quickly, I'll just say that, you know, Nel Hydrogen, for folks who are not familiar with us, we are -- you know, we like to consider a pure play hydrogen company that, you know, provides both electrolyzer solutions as Jack mentioned, as well as hydrogen refueling equipment solutions.

I'm not going to spend a lot of time talking about the hydrogen fueling equipment solutions, other than to say that we do have a subsidiary in California that provides, you know, both light-duty and heavy-duty fueling stations for fuel cell vehicles.

But I represent the electrolyzer side of our business and so I'm going to be focusing my remarks on electrolyzer technology.

The next slide, please. Again, just kind of a snapshot of who we are. We're a publicly traded company on the Oslo Stock Exchange. Our corporate headquarters are in Norway. But I sit at the head of the electrolyzer business unit here in Connecticut, where I have been for more than 20 years now.

Our other major operating centers, which I have another slide on, are in Norway and Denmark. And I'll talk more about the Norway manufacturing operation in more detail.

The next slide, please. So, just kind of, you know, just where we kind of see ourselves in the green hydrogen value chain, you know, if you look kind of electricity production on the front end and some, you know, end use cases such as mobility, and Power-to-X on the back end, you know, we kind of sit in the production space, the production of green hydrogen through our electrolyzer technology. And then, as I mentioned, we do have kind of hydrogen processing technology through our fueling division.

And so, we think we play an important role in the propagation of green hydrogen in the market.

The next slide, please. You know, again to just kind of summarize, you know, we kind of have two separate divisions. Our Alkaline and PEM Electrolyzer

Division that I work for. I'm not going to get into a lot of detail in the differences between alkaline and PEM electrolyzers, you know, other than to say that they have kind of their own kind of advantages, you know, and kind of operational characteristics that lend themselves to kind of, you know, one solution set versus another.

And so, you know, the good thing is that we can -- we offer kind of a range of products in both technology sectors.

The next slide, please. Just again, to kind of -- what I want to talk about with this slide here is kind of capacity. You know, a lot of people ask us kind of what is the capacity of electrolyzer manufacturers today and kind of where is it going? You know, here at our PEM electrolyzer plant in Connecticut, you know, right now through kind of a one shift operation we can do, you know, a little better than 50 megawatts per year of stack production. And so, you know, nominally I say that, you know, with a two shift operation, you know, we could do 100 megawatts per year at this facility with no upgrades to our facility system.

Our alkaline electrolyzer factor is in the middle of an expansion this year. By the end of 2021 we'll have a production capacity of about 500 megawatts per year of electrodes at this facility in Heroya. And we will -- we have plans for incrementally increasing that in 500-megawatt-per-year increments to about, you know, 2 gigawatts per year capacity at that single facility. So, we'll talk a little bit more about that expansion activity.

And then, in Herning, Denmark, where we do our HRS systems, we can do about 300 fueling systems per year in that facility.

The next slide, please. Okay, well next I'm going to get into kind of the hydrogen opportunity, you know, why we think there's just a tremendous opportunity for green hydrogen, as Dr. Brouwer just discussed.

The next slide, please. So, you know, we have been serving kind of the existing applications in use cases for hydrogen for, you know, decades now. And, you know, clustered on the left there is kind of the industrial application, you know, kind of portfolio. And, you know, I like to say we've kept the lights on here at our facility here in Connecticut for, you know, more than two decades selling into these industrial applications.

But really, the opportunity for green hydrogen is really focused on, you know, a couple of emerging sectors. You know, kind of Power-to-X, you know, converting renewable energy into hydrogen for a variety of use cases. And then mobility. I mean we think that there's some unique aspects to the mobility sector that, you know, we can kind of differentiate it from some of the other green hydrogen use cases. So, this is really where we see the opportunities growing because the areas of application are growing at a very large scale.

The next slide, please. So, you know, in terms of the existing market for hydrogen, you know, this kind of pie chart just kind of says, look, you know, we're at about 70 million tons per year of hydrogen in a handful of industrial kind of uses today. And, you know, this pie chart is colored gray because, you know, frankly it's all gray hydrogen. Less than 1 percent of the hydrogen being used to satisfy these markets is coming from electrolysis. So, this all gray hydrogen coming primarily from natural gas here in the U.S.

The next slide, please. So, when we look at kind of the hydrogen markets, you know, we are suggesting that they're going to grow by, you know, more than a factor of 8 in the next 30 years. And a lot of this is going to be new uses for hydrogen. Not just, you know, the existing feedstock is going to grow as well, but really a lot of this 8X growth is going to be coming from new uses for hydrogen. You know, many of them kind of energy related uses for hydrogen. And, you know, this is really where we see a lot of the excitement around the opportunities for green hydrogen.

The next slide, please. So, you know, one of the things that's really making green hydrogen a real opportunity, a real commercial opportunity is the cost of wind and solar dropping so significantly. And green hydrogen, the cost of green hydrogen is being driven by that extremely low LCOE for wind and solar because, you know, 70 to 80 percent of the cost of making green hydrogen is the electricity feedstock.

So, as we get down to some of these low, you know, kind of auction prices for wind and solar that is really helping to drive the opportunity for producing low cost, you know, competitive green hydrogen for these new use cases.

The next slide, please. So, we announced kind of a cost target or a, you know, kind of a production target for green hydrogen of $1.50 per kilogram by 2025. And you can read some of the fine print there in terms of what's baked into that.

But this is, you know, quite a bit earlier than I think a lot of people have been assuming or projecting. And I'm going to get into it a little bit more as to why we think we can get there.

The next slide, please. So, when we kind of look at, you know, one of the things that's really helping to drive cost reduction is the scale. I mean as we see these kind of grid scale applications for green hydrogen emerging, you know, we are looking at capturing, you know, economies of scale through, you know, simply kind of scaling up our core technology. And, you know, I'm going to get into kind of a little bit of a breakdown on this. But, you know, fundamentally we've got an alkaline electrolyzer stack. It's a one ton per day, one metric ton per day stack that's rated at about 2.2 megawatts of input power. And we use that as the repeating unit for kind of aggregating larger plants.

And, you know, I can tell you that, you know, 100-megawatt plants are becoming kind of commonplace in the pipeline of opportunities we're looking at. And so, you know, we have very detailed designs for these larger plants.

The next slide, please. So, you know, the capacity expansion at Heroya is really going to make -- it's a real game changer in terms of the production costs of hydrogen. We are -- you know, we're building a plant that is using, you know, advanced manufacturing techniques, a lot of automation and robotics, and things like that. And, you know, this is the kind of thing that really offers a significant cost reduction opportunity when you start taking advantage of, you know, those kinds of techniques.

The next slide, please. So, you know, our first production line, as I mentioned, is being installed right now. We're actually testing kind of individual, you know, aspects of the production line. And this is going to be, you know, replicated in increments in this factory to go from that 500 megawatt per year capacity to the 2 gigawatt capacity that's capable at that facility.

The next slide, please. So, you know, when we talk about kind of the electrode production cost, this is the variable cost including direct labor, compared to where we are -- where we were last year in terms of production cost, when we get this first production line at Heroya up and fully validated, you know, we're going to be taking that cost down by about half. So, we're going to cut that production cost in about half.

And furthermore, when we get the second line on, we believe we can cut it in half again. So, you know, this is really a really big deal in terms of our ability to hit that $1.50 per kilogram target that we're advertising.

The next slide, please. And, you know, in addition we are working on a number of enhancements to design that will enable us to realize an energy consumption reduction by about, you know, 5 to 10 percent. And that doesn't sound quite as dramatic as some of the CAPEX reductions, but remember that, you know, the biggest cost contributor to the production of hydrogen through electrolysis is the cost of the feedstock. So, anything you can do to take out a kilowatt hour to make a kilogram of hydrogen is a direct cost reduction opportunity.

The next slide, please. So, just a couple quick visuals. Again, we are taking, you know, historical experience with large plants. You know, this picture on the left is nominally about a 135 megawatt plant from the early 20th Century, at a facility in Norway. And we're taking -- we're directly translating our experience with plants like into kind of modern variants of these large plants.

The next slide, please. And also, you know, one of the things that we're doing as well is we're looking at scaled up stack design. You know, today a 20 megawatt plant, you know, might require 8 cell stacks. A future 20 megawatt plant using stacks that are scaled up by roughly a factor of 4 would only require 2 stacks. So, this is an important way that you cut cost as well by consolidating stacks, as well.

The next slide, please. So, just a couple more slides. The next slide. You know, when we talk about how are we going to hit this $1.50 target based on a kind of a TCO analysis, you know, the Heroya expansion is going to have about a 40 percent cost reduction in the total system cost.

But there's this whole EPC piece that really is a significant contributor. And so, one of the things we're doing is standardizing designs. You know, design once, build often is kind of the way -- is kind of the mantra for this.

And when you come up with reproducible standardized designs, you really can take a significant part of that EPC cost out because, frankly, these really are like design build projects. When you're talking about building a big plant like this, that's the way you need to treat it. And so, we're spending a lot of time focusing on that, on that EPC reduction.

The next slide, please. So again, you know, just again kind of another rendering. This is a 100 megawatt plant. You know, again, we've got some dimensions there.

Just I know my time is up. I think I just have one or two more slides I just wanted to touch on, if that’s okay.

The next slide, please. We can skip over this one. This is kind of a containerized PEM. This is a larger 20 megawatt plant design we’re delivering to Spain.

I just want to touch on these last two slides here because these are kind of the important ones. In terms of CAPEX, you know, alkaline is starting at a lower starting parts based on today’s cost. But PEM has a steeper curve and we see both costs on a $1.00 per kilowatt basis converging over the next couple of decades.

And then the last slide, please. And, you know, this is kind of where I just want to conclude, you know, where when we look at kind of renewable hydrogen and how it compares to blue hydrogen which is, you know, hydrogen from SMR with carbon capture, and gray hydrogen which is kind of, you know, todays’ kind of primary hydrogen source, you know we really believe that we can be cost competitive even as soon as the end of the decade with both blue and gray hydrogen. So, this is something we feel strongly about and we believe we have the pathway to getting there.

So, thank you for allowing me to speak and I apologize for running over.

MR. BROUWER: Thank you very much, Steve, and appreciate that perspective.

Next, we have Dr. Venkat Venkataraman from Bloom Energy.

MR. VENKATARAMAN: Okay, can you hear me okay? I'm not able to start my video, so somebody help me out.

MR. BROUWER: You were earlier so, hopefully, we can --

MR. VENKATARAMAN: Yeah, it says the host doesn't allow me to do it, that it should be done by somebody else.

All right, good. Thank you. Can you see me okay?

All right, thanks very much for giving this opportunity. Thanks Commissioner, as well as David to invite me. And Jack, thanks for the moderation.

So, the way I'm going to present it is how does Bloom think about the decarbonization, particularly we talk about hydrogen. I can't beat what Jack said in terms of the need for hydrogen in the decarbonization world.

If we go to the next slide? I'm going to use this picture that is given by US DoE. It's a pretty apt way of looking at the hydrogen going from the source to the use. Just bear in mind the hydrogen is not a molecule that you get out of it, even though I hear there’s something called white hydrogen which is -- can be, but in general you do need a source, which is the energy source to produce hydrogen.

And then, on the end of it, on the other side of it to decarbonization hydrogen can be used for power generation, but it has got a whole range of uses as Jack pointed out. Including transportation, mobility, injecting into the pipeline are making into distilled chemicals. So, this is the whole story.

Now, the very fitting Bloom question is actually fits both sides of it. We can be a hydrogen source using Bloom electrolyzer. On the downstream of it, it can also be using the Bloom systems for using the hydrogen to produce power. So, we fit in both categories.

The vision right now we have is we want to introduce the source part of electrolyzer, Bloom electrolyzer this year. And we have been running on the fuel cell mode producing power.

In addition to that, there are other applications that we do. We have developed a use basis.

Let’s go to the next slide. I just want to quickly go through the build up of our systems. I think many of you might know about the solid blocks and fuels as part of it. The secret sauce is the electrolyte, which when you heat it up to 800 degrees C it has got a very unique property of transporting oxygen ion through the electrolyzer.

In the process of doing it, it actually releases electrons, so this is a direct conversion of chemical energy into electric energy.

So, the way we build our systems is we go through module by module. So, we start with the fuel cell and then we put in the stack, and then the stack goes into columns, then they go into server, and server the power plant. So, this is how we do it.

The advantage is several fold. Obviously, the manufacturing technologies can be cloned and you can easily go from 300 kilowatt to megawatt in this production. Fuel cell (indiscernible) -- are demonstrated.

Secondly, in terms of reliability part of it, when you go in to apply the units, because of the modularity (indiscernible) --

So, the reaction that we are showing here is actually a methane molecule, which is natural gas on the -- as the input. We have modified it to run it on hydrogen, too. So, you can run it on natural gas, you can run it on biogas, you can run it on hydrogen. And all the combinations are possible with this system today.

So, if we go to the next slide. The overall solution that we are going -- are looking at is the combination of what a system can do and also combining with hydrogen on the right-hand side.

So, one important feature of the Bloom system is it can build resilient microgrids. It can be coexistent with different distributed energy resources in the same place. And it can off-grid or it can be parallel with the grid. There are many flexibilities that exist with the system. That gives you the microgrid solution which is for high availability --

Another side of it is, obviously, (indiscernible) hydrogen. That is we can go produce hydrogen (indiscernible) -- use hydrogen for power production.

In addition to that, some of the initiatives we have are for carbon capture. Well, I will kind of touch upon that a little bit. And also, since we can run on biogas, either it can be run on directed biogas, which is nothing but the methane molecule, or it can be onsite power generation using biogas where we call it some (indiscernible) -- so, we kind of cover the whole decarbonization solution.

If you go to the next slide, so this is one important aspect of it which allows us to go from both hydrogen production as well as power production. So, the solid oxide fuel cell can be reversed to become an electrolyzer.

So, on one hand you can put the hydrogen as a feedstock and produce electricity in the fuel cell or you can practically reverse it so if you apply the potential of a cell, you can break the water out of steam molecule to produce hydrogen. So, this reversibility is important in many ways.

Number one, we introduced the electrolyzer only this year, but the basic technology of building the stack existed for solid oxygen fuel cells, so we can use exactly the same technology. We have to Optimize-- electrodes, but I think that is a lot easier part. So, from a production perspective, we are already ready --

The second one is that in terms of modularity and scale up we can easily do it once we have proven the technology to do the electrolyzer.

The third part of it, because of thermodynamics -- it helps a lot. I think we can build a very highly efficient electrolyzer. So, this helps in a big way in terms of decarbonization.

If you go to the next slide. This is kind of a vision we have today. So, I'll go through carefully. So, first and foremost there are different colors of hydrogen. It really can be color agnostic at the end of it. We have produced hydrogen for decarbonization perspective and reduced the greenhouse gas emissions. So, some people get emotional about the color of hydrogen, but in general it's actually can be called as green.

On the left-hand side is our current fuel cell, right. You got your fossil fuel, natural gas, and then that produces power. We are working on a carbon capture, so which can be added as a module to the existing fuel cell. That you see the carbon capture, in doing that we can produce power, also. You can produce hydrogen also as a commodity. So, that's a very unique thing that we are trying to do now.

The middle one is nuclear. Actually, we can use the energy that is curtailed today, the nuclear energy, and produce hydrogen. So, we have significant opportunity here because a lot of the nuclear power plants are not running full capacity, primarily because of the fact of insertion of renewables, and they have to slow down. This helps the nuclear industry. We want to make them produce hydrogen as a commodity and create revenue.

And you go to the renewable side of it, I talked about the biogas side. The biogas side, also you can do the carbon capture and produce hydrogen. We kind of call it the gold hydrogen because it does come with the carbon capture, just like blue, but because we are starting with the carbon neutrality you can go to negative carbon. So, we call it the gold hydrogen.

And we can also use the electrolyzer with the renewable energy to produce the so-called green hydrogen. So, that can be used for power also.

One interesting thing is that if you onto the transportation side, this is more on the stationary side. On the transportation side, the nice thing is we can produce electricity and that can be used for charging. Or, the hydrogen that is produced, regardless of the color, can be used in the vehicle for mobility applications. So, that also gives you a big advantage.

In addition to that, we are actually working on some of the marine application where you can put the fuel cell in the ship. And tomorrow, we can actually do the same way with hydrogen.

So, we actually want to expand both spectrum to producing hydrogen and also using for power generation. One other thing is we all realize, right, when you go into producing hydrogen we definitely need to partner with many people. Where we can do generation of hydrogen, we can actually use that hydrogen for power production, those are big. But in between there's a lot of things that need to happen.

In terms of storing it, as Jack pointed out, this can easily potentially be for batteries, for which we need to have partners.

The inside of it also use, we need to have use cases demonstrated. So, that's why we got (indiscernible) for all the renewables. We signed a deal with them to do the demonstration. We're working with (indiscernible) for nuclear power plants. We are working with SoCalGas for injection into the pipeline. And last, we have a few opportunities for using the hydrogen in percolator plants, and steel industry, too. So, we are covering all of them as use cases.

From a production perspective we use electrolyzers here. So, we're going to recognize it with some use cases. And wrap up of the production will be happening next year.

However, since we already have a factory producing (indiscernible) fuel cell, as the technology matures we can kind of switch between one another.

So, if you go to the next slide. This is an interesting way of looking at power generation. So, we actually do want to get away from fossil fuel. But the recent study for U.S. Energy Information Administration clearly shows that the natural gas may continue for a longer period of time.

But if you want to go focus more on decarbonization, this gives you a unique way. So, you can go and take that same thing, natural gas, you can produce blue hydrogen with carbon capture. So, the technology is available.

We talked about the renewables and producing green hydrogen. We also talked about the nuclear power plants producing pink hydrogen, too.

In reality, I think what Bloom is looking at is partner with each one of them to play a big role in producing blue, green, pink or whatever the color of hydrogen may be that reduces the carbon emission, as well as creating the overall industry to get to zero carbon.

So, if you go to the next one. So, this is about more on the fuel cell side. As I said, natural gas today we can do natural gas, biogas, and mix of natural gas and hydrogen, as well as hydrogen. And so, we have covered all the things today and in addition to the carbon capture.

So, the vision for Bloom is be a player here.

And again, I want to repeat that we can't do everything on our own. We do need to collaborate with the different people to make the thing work, make the hydrogen economy work in California. We are most ready for that.

So, I'll stop here. Thank you.

MR. BROUWER: Thank you very much, Venkat.

And next we have Eric Guter from Air Liquide.

MR. GUTER: Hi. Thank you, Jack. And just a correction --

MR. BROUWER: Just a correct, yes, of course. Eric, you're not from Air Liquide. That's like your main competitor. That's the worst mistake I could make.

MR. GUTER: Jack, I'm going to come visit you very soon.

MR. BROUWER: Air Products.

(Laughter)

MR. GUTER: Hello and good afternoon.

MR. BROUWER: Sorry.

MR. GUTER: It's my pleasure to be here and I would like to thank California Energy Commission for the opportunity to speak on behalf of Air Products.

This is certainly an exciting time and I look forward to sharing some information about how hydrogen can play a role in California's energy future.

The next slide, please. Air Products, by way of background, is the only US-based gas company and is headquartered in Allentown, Pennsylvania. We've been in hydrogen production for over 60 of our 80-year history and have been involved in hydrogen for mobility applications for about the last 30 years.

We are organized around three major growth platforms, gasification, carbon capture and storage, and hydrogen for mobility, all of which support our corporate sustainability goals on the journey to zero emissions.

I lead our hydrogen for mobility business and I'm based in Southern California where I've been for my entire 26-year tenure with Air Products. And in mobility we see renewable power and hydrogen as being complementary sources of energy to facilitate decarbonization of the transportation sector with power being able to rapidly decarbonize light-duty applications, and hydrogen being best utilized in heavy-duty applications due to the vehicle weight and duty cycle requirements of the vehicle.

However, there is no one-size-fits-all solution, either, in terms of technology or energy source. It will take an all-of-the-above strategy to meet our ambitious goals.

The next slide, please. Air Products has over 110 hydrogen production facilities around the globe with over 8,000 metric tons a day of capacity. We have also announced over 1,600 tons per day of new capacity, which will be coming on stream over the next five years to meet industrial and mobility needs around the world.

We produce all types of hydrogen, from gray, to blue, to green. I like to focus on carbon intensity rather than colors because that's the end goal we're trying to achieve, and each one of these has a distinct role to play. But in that space, our Port Arthur facility, which we commissioned in 2013 with retrofitting it with carbon capture and sequestration, that sequesters about a million tons of CO2 annually.

And we have also recently announced a $1 billion net zero hydrogen facility in Alberta, Canada, using natural gas as the feedstock with carbon capture and sequestration, and hydrogen turbines for power.

And also, our $5 billion green hydrogen project in Saudi Arabia, NEOM, which will produce 650 tons a day of hydrogen from renewable wind and solar power.

In addition to this last investment, we have also committed $2 billion of downstream infrastructure investment to facilitate the energy transition around the globe, focused on geographies like California which are leading the way.

As a world leader in hydrogen production, Air Products has continually developed new and decarbonized sources of hydrogen to meet the needs of the energy transition and aggressively combat climate change.

The next slide, please. We distribute hydrogen from our facilities using a wide range of technologies dependent upon customer needs, starting with pipelines. Highlight by our over 700-mile pipeline in the U.S. Gulf Coast, and our over 30-mile pipeline in the L.A. Basin supporting industrial and mobility customers today.

We also distribute hydrogen in liquid form, which provides low cost, long range distribution and storage for supply chain resiliency.

Hydrogen is also distributed as a bulk gas in trailers and mobile fuelers for mobility demonstration projects. We have invested significantly in this area to assist customers in trialing hydrogen as a transportation fuel, which replicates the experience and performance of fossil-based fuels.

Additionally, with the announcement of our NEOM project, we see ammonia as having a significant role to play in the energy transition as it is moved around the globe today in large quantities, primarily for fertilizer production is an efficiency -- it is an efficient energy carrier and can be used directly as a replacement fuel in sectors like shipping which, according to Bloomberg, will require more than 500 million metric tons of ammonia to decarbonize it, representing over a twofold increase relative to current production levels.

The next slide, please. Globally, there are about 70 million metric tons of annual dedicated hydrogen production, with about 10 million tons being produced in the U.S. California shares about 10 percent of that production.

Air Products has demonstrated experience in all forms of hydrogen production with the predominant method being steam methane reforming, which most commonly uses natural gas because of its low cost, as the feedstock, resulting in carbon dioxide emissions.

Fertilizer production and oil refining are the main uses of this hydrogen which -- with approximately an equal share of the market.

And although gray hydrogen production results in CO2 emissions, it’s important to note that switching to gray hydrogen as a transportation fuel still results in a 30 to 50 percent emissions reduction when compared to traditional transportation fuels.

With this, speed is one of the most important elements, perhaps the most important factor in the energy transition.

Pairing carbon capture with steam methane reforming, or auto thermal reforming, such as we've done or will be doing in Alberta, Canada, can significantly reduce CO2 emissions or even result in negative emissions when paired with advanced feedstocks.

And finally, hydrogen sourced via electrolysis using renewable power provides zero carbon hydrogen, which is a promising energy source not only for mobility, but also other hard-to-abate industrial sectors like power production, steel, cement, and fertilizer production.

Like California, we've tried to take a technology agnostic approach to these production methods and are focused on developing low and no carbon sources to meet our collective ambitious emissions reduction goals.

The next slide, please. The key to decarbonization begins with policy and we appreciate and applaud California's leadership in developing policies that set the example globally. The right policy signals incent the right behavior and California is well on its way to meeting its emissions reductions targets.

We think the most effective policies are technology agnostic in focusing on developing low and zero emission energy sources and end-use markets. With these two elements, rapid transition to carbon neutrality can occur, but it requires careful planning to ensure the reliability and resiliency of new, low/no carbon supply chains.

Policy must also incent world scale investment which is required to rapidly replace our dependency on traditional fossil fuels production and distribution infrastructure, which has been built up over decades.

At Air Products, we have taken the first steps in building world scale investments in decarbonized hydrogen, but much more work needs to be done to build up low and zero emissions infrastructure in a timeline to meet California's objectives.

The next slide, please. Through effective policy, renewable power and hydrogen, as I mentioned earlier, are complementary sources of energy supporting energy transition. And mobility, although hydrogen can be used in any application, is most useful in the heavy-duty sector due to the weight of the battery and due to stakeholder requirements of the vehicle.

Through California's policy OEMs, we're already developing and testing new buses and heavy-duty hydrogen fuel cell trucks to replace legacy fossil fuel vehicles.

Companies like Air Products are developing and support the fueling infrastructure to facilitate this transition.

In heavy industry, as I mentioned earlier, hydrogen and ammonia have a significant role to play in decarbonization as one of the only viable energy sources identified to decarbonize these important sectors.

Hydrogen also has a role to play in long-term energy storage to address the intermittency of renewable power as we transition to zero emissions power grids.

The next slide, please. How do we accelerate the energy transition? Building upon California's leadership in leveraging lessons learned in the early demonstration phase of hydrogen usage, we think it's important to build upon our already strong policy.

As I mentioned earlier, transitioning to hydrogen as a fuel source, even gray hydrogen results in a 30 to 50 percent decrease in emissions. Therefore, nothing is more important than making the transition and doing so rapidly.

To facilitate this, we believe significant policy should be focused on developing new sources of hydrogen production and hydrogen hubs needed to meet the anticipated demand in mobility in heavy industry, which is on the order of a fourfold or more increase over what's currently produced in California today.

For hydrogen, there is no one-size-fits-all solution. We'll need gray, blue and green projects to serve the growing market needs and to continue decarbonizing the molecule as the market grows.

In addition to policy accelerating the transition, we believe energy production should be the primary focus for grants and incentives to ensure a robust and decarbonized fuel source. Policy enhancements can also include easier to access pore space for CO2 sequestration which independent bodies, like Lawrence Livermore National Labs, suggest must be a part of California's energy transition strategy.

Continued emphasis on an accelerated adoption of zero emission vehicles will develop commercial scale technologies and markets for energy producers, infrastructure providers, and vehicle manufacturers.

Last, while it might be a cliché, but the best way to leverage private investment is to create market certainty. Air Products is committed to investing, but need to know the market will be there. That's where long-term certainty on incentives, HRI credits, regulations, and contracts for difference come in. We recommend the CEC consider how it uses its one plus billion dollars in infrastructure incentives to help create this market certainty moving forward, and especially as the state increasingly focuses on zero emissions, heavy-duty transportation, and heavy industry conversion.

With that, I want to again thank the CEC and everyone for participating in this discussion and supporting California's dream to become the first zero emission state in the United States. Thank you very much.

MR. BROUWER: Thank you very much Eric Guter from Air Products.

And last, but not least, I want to welcome Laura Nelson from the Green Hydrogen Coalition to present next.

MS. NELSON: Hi. Thank you, Jack. I want to make sure you all can hear me okay.

MR. BROUWER: Yes, we can. Thank you very much.

MS. NELSON: You bet. And I have my video on, but I don't see myself so I think that --

MR. BROUWER: But we can see you now, though. Those who are watching can see you, so that's great, thank you for turning it on.

MS. NELSON: Okay, wonderful. You bet.

Well, Jack, Dr. Brouwer, it's always great to be with you. Thank you for moderating today. And I want to say, of course, also thank you to the California Energy Commission. To Commissioner McAllister for his leadership today, and Commissioner Douglas to you and your team for organizing this conversation. And, of course, Commissioner Houck we appreciate your work and partnership with the Public Utilities Commission, as well. So, thank you all for creating this opportunity. And a special thanks to you, Commissioner McAllister, for your engagement on some of our Western Initiatives, which I'll talk about here in just a moment.

So, if you want to go ahead and move to the next slide, that would be great. So, the Green Hydrogen Coalition is a nonprofit 501(c)(3) and we are unique in this way. We are an educational organization really focused on facilitating the policies and practices that will advance production and use of green hydrogen in all sectors where it will accelerate a carbon-free energy future.

And I think our approach is very unique. We focus on large, scalable projects where we can simultaneously leverage that supply and the demand across multiple sectors so that we can scale, and realize many of the economies that you've heard discussed here today so that we create a cost competitive opportunity for green hydrogen across many sectors.

So, the next slide, please. So, just to give you insight into what we're talking about when we look at scale, we focus on initiatives that will help us to build this scale.

Our core effort began with the Intermountain Power Project, which is a project located in Delta, Utah, and Utah happens to be my home state, with off take in California. And this plant is being converted from a coal facility today to a combined cycle combustion turbine that will in fact use green hydrogen on day one of operation in 2025. I'll talk about that a little bit more in a minute.

We also view the importance of regional collaboration to achieve our goals. How do we come together to create strategic planning initiatives, roadmaps if you will around these best policies and practices so that we can create a very effective ecosystem for green hydrogen production and use at scale.

So, with this in mind we partnered with the Western Interstate Energy Board and the National Association of Energy Officials, NASEO, to create a state led initiative to create this policy toolkit for the ecosystem of green hydrogen in the west. And I'll talk, again, a little bit more about that through this presentation.

And then, our next initiative is what we call HyDeal North America, where we're looking to bring together production and off take in a hub area, so that we can leverage all of the elements, commercial contracts, infrastructure, production, off take in a single setting to drive that scaled production and use of green hydrogen.

And HyDeal North America is focusing first on L.A., again talk about this more in a minute, does have a target of $1.50 a kilogram of delivered green hydrogen by 2028. So, beyond just production of green hydrogen, it's looking at that delivery as well.

So, next slide, please. So, one question we often get asked is will the hydrogen economy finally be here? It seems like it's been on the hype curve for a while and, certainly, you've heard through Eric's presentation that we do use hydrogen today. There are many applications. Air Products, of course as a U.S. company, has been great in providing us with many of those resources that we need across multiple applications.

But we're seeing this new momentum today and you've heard this, I think, through all of the presentations today that there are significant projects in the pipe today taking us from a slightly below, I believe about 100 megawatts of green hydrogen production today, to over 50 gigawatts of green hydrogen production in the next decade or less.

So, this is just an example of what we're seeing in the news around the growing economy for green hydrogen production and demand where you see off take and production coming together to create these real opportunities for green hydrogen.

So, big news. And I think we are finally at the point, the tipping point if you will, for the green hydrogen economy.

So, next slide, please. So, you also heard that green hydrogen is a very small percentage of the hydrogen that's produced today. It's actually less than 1 percent, maybe approaching 1 percent. But the majority of it is in fact produced from natural gas, or gray hydrogen, or brown hydrogen through coal. There is some carbon capture and sequestration, or blue hydrogen. But a very small amount is produced from renewable resources.

So, what we see just in the process of producing hydrogen even though, as Eric mentioned, in its final utilization zero carbon, which is awesome. And we totally support reducing those carbon intensities across these many applications. We need to really consider how we produce hydrogen and reduce that carbon intensity. Because global hydrogen production today accounts for emissions, CO_2 emissions that actually are greater than those of Germany.

So, it is an imperative, we believe, to reduce the carbon emissions occurring from the actual production of hydrogen.

So, next slide, please. So, just to give you, just kind of reiterating those colors. If we talk about these colors, we're really looking at what is the primary feedstock. Is it a fossil-based resource or a non fossil-based resource?

So, when we look at green hydrogen what we're really talking about is a non fossil-based resource approach to producing hydrogen. And we see many technology streams to do that. Of course, electrolysis is an important part of that stream, but we also see biomass, or biogas opportunities existing as well to get us to that really lower carbon intensity in terms of production. And then, getting the win/win of lower production CO_2 with hydrogen, as well as lower utilization CO_2 with use of hydrogen.

So, next slide, please. So, this is just a nice picture, I think, of what you've heard is hydrogen really can be used across many sectors. We see it used today in the refining space for example, in other transportation, particularly in passenger vehicles today, as well as other industrial applications.

But there are huge opportunities for hydrogen today to create clean energy economies, and also to drive local job growth, which we think is a very important part of this overall conversation.

You heard Jack talk about the use of hydrogen in our natural gas systems to lower the carbon intensity there. We think that's a great and an important application.

We also see increased applications for mining, for hard-to-abate sectors in transportation, like fleets, and maritime, and also air travel.

Energy storage, an important part of the decarbonization effort underway today. And that brings really to the power sector where there is tremendous opportunity to provide for decarbonized energy that is dispatchable and reliable.

So, next slide, please. So, I won't spend a ton of time on this, but just another note that in fact green hydrogen is commercially viable now, and it is on trajectory for lowest costs, as Steve talked about this in his presentation.

This is from IRENA, the International Renewable Energy Agency, which really, I think, provides for conservative estimates. And what they're saying is that in the next decade we can expect, in fact, with just these decreases in the levelized costs of wind and solar that green hydrogen is going to be cost competitive, certainly with blue hydrogen as a competitive option for off take.

So, the next slide, please. And so, why is green hydrogen important right now for California? Well, this is, I think, really just a snapshot of why it's important for California and really for the region. And appreciate all that you all are doing and the work that you're taking on to really plan for how we can meet some of these challenges we see, specifically in the case of this slide showing up in California, but I think are increasingly becoming regionally significant as we see an increased penetration of renewable energy resources on our grid to support or clean energy goals and as those costs of those renewable resources come down and really out bid fossil-based alternatives.

What happens though, of course, is this challenge of wind, those resources come online when they're available based on the fuel supply. So, you can see on the right side of this slide here that when we have tremendous amount of renewables we use, to a 100 percent renewable energy scenario in California, that we're going to have overproduction in certain hours and under production in other hours. So, we really need to do that shifting.

And when we have weather challenges or even fire challenges, et cetera, that impact operation of our grid this resource can be very important in shifting loads and resources not just within the day, but across days, even weeks.

And I think very importantly, because I think this gets to the economics, we can avoid curtailments. In March of this year, March of 2021, wind and solar curtailments hit a record high. And those are really uneconomic and send, I think, distorted signals to the market about the important of those resources because those resources can be in fact dispatched in other ways to provide for grid reliability and balancing.

So, next slide, please. So, you also heard mentioned that geologic storage of hydrogen can really be a cost competitive solution. And we, at the Green Hydrogen Coalition, are supportive of all types of storage. Each type of storage really has a role to play. What we're talking about is looking at that long duration piece where you really need that several hours, specifically if you go beyond 12 hours lithium ion batteries are going to compete. You have limited opportunities for compressed air storage. You even heard discussion Steve, I believe it was, around pump storage and limitations there.

And so, hydrogen really shows up as an opportunity to meet that significant storage that's going to be required to continue to integrate increased renewable energy resources.

So, next slide, please. And just as an example, and this is information that was provided to us by Mitsubishi Power Americas, again with the lithium ion batteries are very important resources. Combining those with renewable energy projects is an important way to shift load and resource in the day, looking at 4-hour storage or even 8-hour storage. Lithium ion on a levelized cost basis is the cost-competitive alternative when compared to green hydrogen, in this case specifically stored in salt dome formations, or in a geologic formation. But really, it's about, and it's not shown on this particular graph, but once you hit about this 12 hour mark, you're really looking at lithium ion batteries become more costly and not the cost-effective option when compared to green hydrogen.

So, next slide, please. So, green hydrogen. I'll mention the Intermountain Power Project is converting from a coal-fired facility, 1,800 megawatts today, to about an 840 megawatt gas-fired facility in 2025 that will utilize 30 percent green hydrogen on day one with a scale up of 100 percent green hydrogen in less than 20 years.

We understand from Mitsubishi, who is providing the combustion turbine for this particular project, that it isn't a matter of capacity or capability, I should say, for the combustion turbine to utilize 100 percent hydrogen. It really is a matter of getting the production to scale.

And so, this product envisions significant electrolytic hydrogen production that can be done on site, with existing water rights, and then stored in salt domes that are also co-located on the site, using existing transmission lines. The onsite labor force that's there today, skills can be repurposed so those jobs are going to be really important to create this unique opportunity to deliver clean, dispatchable energy with significant scale ups over the coming, I think, less than two decades, which is happening I think faster than any of us would have imagined just 12 or 18 months ago.

So, we believe that this is really a part of an affordable and responsible transition. And as I always like to say, creating this clean energy economy that really is going to provide us with that resiliency, reliability, and affordability that's given us the quality of life we have. So, we think this is a great example.

And interestingly, we're starting to see announcements from, you know, NextEra in Florida, from Long Island about using green hydrogen to reduce carbon intensity of combined cycle plants today. So, we think this has been a leader in causing much change in the power space.

So, the next slide, please. So, green hydrogen absolutely is a dispatchable, zero carbon fuel that can reduce the need for fossil fuels and gas plants, as we just heard. But I did want to emphasize that this is also about creating jobs.

The Intermountain Power Plant, specifically, is in a rural community where those jobs are very, very important. Those individuals can be really disadvantaged in terms of their economic access. And we understand that power plants can often be co-located with communities that are disproportionally impacted by how we produce and use energy.

And so, we really want to share with you that clean hydrogen, green hydrogen can also be a part of what we considered to be an important solution for disadvantaged communities for providing not just jobs, but cleaner energy outcomes locally.

So, next slide, please. So, I want to talk just quickly about our other two initiatives I mentioned. First, the Western Green Hydrogen Initiative, which is really building that regional collaboration to help policymakers to evaluate and understand the potential of hydrogen in achieving energy resilience, and creating economic development opportunities in the west.

And so as you see here, we have 11 western states. Three additional states that are really interested because they think what we're creating here is quite unique, and then we also have the participation of two Canadian provinces.

So, if you think about it, it's really the western interconnect that's involved in this. But this is beyond power sector considerations, it's really looking at the full scope of production and use of green hydrogen.

So, next slide, please. And this is a state-led initiative. I mentioned we partnered with two other associations. But we really look to the states to provide guidance to help inform what matters for their economies, what matters for their energy policies.

So, Dan Lloyd from Montana, along with David Bobzien from Nevada are the chairs for this initiative. Commissioner McAllister, thank you again, Vice-Chair, along with John Chatburn, the second Vice-Chair for this initiative. And we appreciate the great leadership that these states are providing. And we think that the partnership and roles that the states can provide is particularly unique.

And what the California Energy Commission is doing in terms of planning and determining how we can better build our system is very informative to the work that the states are doing now.

So, next slide, please. So, the last initiative I want to talk about is our HyDeal North America. I mentioned that we're starting in L.A. HyDeal LA is really focused on establishing this first green hydrogen industrial hub at scale. And we are really bringing together all of the different partners and advisors to help to create momentum for green hydrogen very, very quickly so that we can realize that buck 50 delivered cost, achieve 100 percent renewable electricity that's affordable and reliable, decarbonize many sectors including the refining sector, and moving towards renewable fuels. Providing for that green ammonia solution for maritime goods and movement. And demonstrating green hydrogen fuel cell passenger flight.

In fact, we do have a member, a sponsor of the Green Hydrogen Coalition that is working on this today. And that we can, in fact, look for those export opportunities again driving, I think, economic and global solutions for green hydrogen at scale.

So, the next slide, please. And we have many partners that are supporting us and really dedicated across contracting, and planning, funding, policy, and regulatory, and project management.

So, the next slide, please. And we appreciate that we have a multitude of advisors, including environmental groups, National Labs, utilities. Jack, I see your picture there. As well as helping us, really, to create something that is a sustainable solution for L.A. And we believe that we can replicate this model in other locations.

So, next slide, please. So, our first part, we are going to do this in phases, but we want to leverage existing infrastructure, including transmission infrastructure. We want to look at how we can utilize the green hydrogen in the natural gas pipeline, and really create this locally diverse resources that can provide the solutions that I've mentioned.

So, I'm going to wrap up here because, Jack, I think I'm at time.

So, the next slide, please. So, we are creating a regulatory and policy roadmap that will help us to resolve these issues. And I'm going to -- you have these slides, so I'm not going to spend a considerable amount of time here because I really would like to get to my next slide. Which should be, you know, we appreciate all of the work that the California Energy Commission does. We look forward to working with you to advance these goals.

So, if you can just go ahead and progress to the next slide, that would be great. We think that there is an absolute important role for you all to play in helping with the modeling about optimal portfolios across gas and power sectors to help us study how we can accelerate transformation of existing assets, and create skilled jobs, including repurposing natural gas pipelines, accelerating hydrogen industrial hub development. Helping to clarify that green hydrogen used in a fuel cell in turbines can quality for RPS, and an RPS guidebook we think would be very important.

Help to create a alignment with key stakeholders including labor and environmental justice groups.

And then, finally, RD&D is critical. We've got to continue to expand and build our portfolios so we understand all of the opportunities, applications, and other considerations around use and production of green hydrogen.

So, with that you can go to my next slide, which I think should be my last slide, which is we want to be in touch. We want to work with you and so we continue to produce materials that will to inform you all. And I look forward to your questions. So, thank you so much.

MR. BROUWER: Thank you very much, Dr. Nelson.

And now, I believe, we want to open it up for the dais to ask us any questions you'd like or have us follow up. I'd like to have, yes, everyone from the panel to turn your video on, if you may, and I'll turn it over to Commissioner McAllister, please.

COMMISSIONER MCALLISTER: Great. Yeah, can you hear me? I think I'm unmuted. Yes?

MR. BROUWER: Yes.

COMMISSIONER MCALLISTER: Great. Well, thanks for a great panel, this is really excellent. And, you know, some of the themes sort of carried over from this morning, but this was very pragmatic and I think very targeted in the right way, you know, around the technologies.

So, but I think I would -- so, we have a lot of folks on the dais. Thanks everyone for joining. And I think I'll invite Commissioner Douglas to take the lead on the questions and then we can poll the rest of the dais, Commissioner Houck, Monahan, and Deputy Secretary Baker.

COMMISSIONER DOUGLAS: Thank you, Commissioner McAllister. And I'll ask -- sorry -- I'll ask a few questions and then I may come back and have a few more.

But a question for Steve, you know, from Nel Hydrogen is just in terms of the production target of $1.5 a kilogram by 2025, if I understood correctly, can you maybe help me understand again how you see the market getting to that number?

MR. SZYMANSKI: Yeah. I mean I think, you know, the inputs to the TCO model that we used to kind of arrive at that figure are -- you know, there's certain parameters that are out of our control. Certainly, we are in control of, you know, kind of the capital cost of the electrolyzer equipment. We have some amount of control in terms of the efficiency, the electrical efficiency of the electrolyzer equipment.

You know, but certainly other inputs, you know, such as the cost of the electricity feedstock is somewhat out of our control. But, you know, we are using kind of market information that says, you know, gee, if we can get to $20 a megawatt hour of energy input cost at, you know, some kind of capacity factor, you know, we can get there.

And so, you know, I think that kind of the things that, you know, we need to happen to enable $1.50 per kilogram hydrogen are -- you know, they're pretty basic. I think we need to see, you know, real commercial projects where you can, you know, get electricity, green electricity at a certain cost and at a certain capacity factor and, you know, that really kind of enables the pathway to getting there.

COMMISSIONER DOUGLAS: Thank you. Just another question, this one for Venkat, if I could. Just I was intrigued by the discussion of the reversal cell that can be reversed and become an electrolyzer. I just wanted to understand a little bit. If you could discuss any of the opportunities or applications of this technology, as you see it, that would be helpful.

MR. VENKATARAMAN: Yeah, I think we are actually trying out a few of them, even we have one application with the DOE in general, and we did that. So, the main thing is that people always talk about reversibility. The advantage you have is we can run, if you have excess power from this hydrogen storage, and then take the hydrogen and release it back power, the time and production of hydrogen and as well as the power, and using hydrogen as storage is the perfect applications where we can use it.

So, then you come into a question of what would be the efficiency of it, kind of the (indiscernible) -- kind of a company who has batteries. But what we have proven is that it may be a little bit less efficient in terms of the benefits and overall efficiency. However, from a storage and cases it actually perfectly makes sense.

There are two attempts made. One is can you put everything in one box, can you run it in two different directions? People have looked at it. But that makes it a little bit cumbersome because you will like -- sometimes you want to produce hydrogen and you want to, well, produce power, and this is in case conflict.

So, what the philosophy we are following is that there are a few applications there. Keep electrolyzers separately because that's where you can optimize the cost so that you can get to the one and a half dollars per kilogram, I think if you have a couple of cost and then the energy you're putting in is cheap, then you can probably choose. So, keep that separately.

And use the fuel cell, and the same thing cost optimized, they can coexist in the same place. So, we have a few program like that, that we are going to be running next year. One is with the DOE. So, that's the place where hydrogen is used through storage and you can see when you want to produce hydrogen when the excess power is there, and when you want to produce more or less hydrogen as storage.

COMMISSIONER DOUGLAS: Interesting. I just had one more question and then I'll open this up for others. And that was for Eric, just really briefly.

You know, you talked about the need for policy to accelerate the transition to hydrogen in a general way, but do you have any specific recommendations you'd like to put before us?

MR. GUTER: I think, you know, greater education around the state as to where the state sees hydrogen playing a role would be helpful. As I think about the ICT, as an example, Innovative Clean Transit, right, we've spent -- we've had every trans agency up and down the state trying to figure out do I go with battery electric, do I go with hydrogen, and each one of them performing a study. Probably one of the most inefficient means of, you know, using resources and capital to figure out whether we want to use battery electric or hydrogen as a fuel source.

And so, areas like that where we can help clarify for industry or by policy where we see hydrogen playing a distinct role, versus battery electric, I think would be hugely helpful.

COMMISSIONER DOUGLAS: Uh-hum, that makes sense. I think that's it for me right now. Thank you. Other questions?

DEPUTY SECRETARY BAKER: Yeah, this is Matt. I just wanted to ask kind of a little bit of a sharper follow up on your question, Commissioner Douglas, and maybe turn this around.

You know, what do you see as the barriers to, you know, moving this technology forward in California. And in particular barriers that might be able to be addressed by policy? And, you know, for the whole panel, if you could just be quick, though.

MR. GUTER: Certainly, I think there's -- from my perspective it's around price uncertainty and net conversion, right. Everyone is waiting, there's all talk about getting to $1.50 by a certain time frame, so no one wants to be a first mover because everyone wants to wait for $1.50.

I think there are ways to commercially address that, but what's most important is developing the production infrastructure and end-use markets, and rapidly transitioning as we collectively drive down that cost over time.

MR. BROUWER: There are some policies that are currently in the works. For example, like at the CPUC, that would engender microgrid technology that are very important for these kinds of energy conversions, these electrochemical energy conversions. They haven't moved that quickly through the CPUC, yet, to engender this sort of end use. Right. That would engender reliable use of fuel cells, plus solar, plus batteries in microgrids to help the state. That's an example of policy that's moving, but not yet approved.

Another one is access to some of the markets. So, for example if wholesale market access could be granted to electrolysis wherever it was in the grid, even if it was in the distribution system, like some other energy storage technologies, but since it's not -- doesn't necessarily return electricity back to the grid, they're not able to access that same sort of aggregated battery energy storage access to wholesale markets.

So, this is one of the ways in which you could, you know, help engender more widespread use of that curtailed electricity and even cheap electricity at the wholesale markets whenever it's available, and usually that's renewable electricity. That would be a very nice policy to adopt.

There could be additional policies, too, that would support things like the fueling infrastructure, which the Energy Commission and the state has been very well supporting. But if it could be engendered towards these communities that need it the most, right, those that don't have access to the battery electric vehicle charging, and to heavy duty, and things like this, this would be pretty nice for engendering hydrogen adoption where it's most needed. There might be others.

MR. VENKATARAMAN: I think definitely microgrid is a big one because we've been in the thick of it, right, in terms of creating a dispatchable situation, right. And certainly that will help a lot locally from introducing the technology.

In terms of hydrogen itself, there -- if you go to two different aspects of it. One is injection into the pipeline. We definitely need to get to a point where people are comfortable with it. We definitely need some more --

MR. BROUWER: I forgot, I can't believe I forgot that one. Yeah, that's very important. And it's very important not because of the immediate decarbonization impact, but because of this technology evolution and eventually being able to transform to 100 percent.

Yeah, that's very important. And adopting renewables. Yes, very good. Thank you.

MR. VENKATARAMAN: Yeah, that one is big. In terms of mobility this is another thing, right. If you look at other countries where they are falling pretty quickly into changing over from EV charging to hydrogen, also we definitely need to push hard on that.

Because if you imagine, you can go and take your car and fill the hydrogen, and run for long. It's a huge, huge benefit. So, we definitely need some kind of a push for policy to push on the mobility. Because otherwise what will happen is you still will be caught in the paradigm of using EV chargers and batteries.

The last one, I think going back to the injection, when you go into a downstream in using your appliances or anything like that, people worry about how the actual transition is to the hydrogen. Because even if you have a conduit of hydrogen going through to the end point, people have to prepare for it. So, we definitely need some more initiatives to push it. As we look at globally, that's going to be an important point to completely decarbonize, right.

MS. NELSON: Hey, Jack, this is Laura. I just wanted a general comment. Because there's so much discussion around the cost I think that we overlook the benefits. And I think that we really have to think about how we are going to value those benefits. And certainly, I think that comes into planning, and also pricing, and how we're going to do tariff design.

And so, I think that we have to look across the board at both regulatory effort of legislative activity. We've been working on designing green hydrogen, really having a sense about how that can drive decarbonization and highlighting the benefits of that particular resource. And so, then I think that that plays in to how we capture that in tariff design, and also in our planning efforts.

MR. SZYMANSKI: This is Steve. I'll say that, you know, I spent a lot of time talking about green ammonia as a hydrogen carrier and how, you know, it really can propagate hydrogen, you know, over large spans of the globe. And, you know, one of the important aspects of kind of creating a -- you know, kind of a premium for green ammonia based on the kinds of benefits that are being discussed is certification.

And so, we're spending a lot of time trying to create a model of certification for green ammonia because, you know, you need to be able to assure that, you know, if a customer really does value the premium that you get out of a commodity that you properly can track and, you know, certify that value.

So, I think that is the kind of thing that we need to kind of get to eventually because, you know, right now I think there are customers that are willing to pay a premium for these kinds of benefits, but there's no easy way to kind of discern, you know, how you're assuring that value.

COMMISSIONER MCALLISTER: Thanks for that. So, I want to invite either Commissioner Houck or Commissioner Monahan, you can -- assuming both of you have questions, maybe one of you can volunteer to go first.

COMMISSIONER HOUCK: And I can go first. I'll make it kind of quick because you've already started to answer it. Just following along the lines of the last question. As has been discussed today the Energy Commission's been doing a lot of really great work in this area. And as this technology is moving forward where do you see the PUC's role or what areas do you think the PUC should be looking at as we're examining the potential for green hydrogen to be a part of our clean energy future?

MR. BROUWER: So, I mentioned a couple of things associated with the PUC previously. One of them is the microgrid proceeding. But there are many others, too.

there was the renewable gas injection proceeding. I think that might be over now. But it didn't consider the injection of renewable hydrogen and, yet, this is a very important aspect of enabling this transformation that we know we must engender in the future.

So, adopting a renewable hydrogen injection standard for the gas utilities is a very, very important thing. And I don't know if that will require a new proceeding or what will engender that at the PUC.

There are some additional things, too. In the reliability there is, I think, an open proceeding on the reliability of the electric grid. And I think that including something like the potential for delivery of renewable hydrogen via gas pipeline to existing gas plants would be remarkably effective at doing this.

So, for example, when we had the PSPS events and wildfires here in Southern California, LADWP was able to keep the lights on by running the coastal power plants. Now, we don't want to keep doing combustion there in the long term because we'd like to have fuel cells there, instead, which would have zero carbon and zero criteria pollutant emissions. But in the short term, if we could decarbonize them with directed hydrogen, I think that would be a remarkable achievement. And it would show the world how we can reliably move towards 100 percent zero carbon.

MS. NELSON: Hey Jack, this is Laura. I wanted to bring up one other thing that you mentioned earlier, I think in your opening remarks, was around tariff design and specifically looking at how we can use -- you know, we can create a tariff for electrolytically produced hydrogen. Because electrolyzers can really be used as a flexible load source.

So, I think that's something that we could continue to provide education and inform on, and consider going forward. So, I think there may be things that aren't underway right now, but certainly could be in the mix that I think would support electrolytic production in this case of green hydrogen.

And I don't know, you mentioned it earlier Jack, and I don't know if you want to add anything to that.

MR. BROUWER: Yeah, I guess if access to wholesale markets could be given to hydrogen production that uses electricity in ways that supports increased renewables on the grid. So, this is very important. So, if they get dispatched in a way that supports adding more and more renewables on the grid, then wholesale access could be granted as a result of that kind of dynamic performance.

And this is very much the same as battery energy storage has been engendered by CPUC policies and implementation over the years.

But again, it's a different thing. Now what you are doing, instead of storing electricity and giving electricity back, you're making green hydrogen and then it gets to be used to displace petroleum or something like that in its end use.

So, sometimes it's hard to cross sectors like this. I know that the implementation of SB 350 was supposed to allow some of this cross-jurisdictional things, hopefully things like that could be engendered as well.

MR. VENKATARAMAN: Yeah, one thing I do want to point out, the green hydrogen part of it, as I say, in the stored one, the energy that is stored or you've got the hydrogen is not necessarily to go in terms of grid -- in the grid. It has a multitude of things. Jack, that's what you're alluding to. The user stored hydrogen can be multiple to the decarbonization, not necessary going into bulk pricing. So, that's an advantage you have, unlike going into battery storage you have only one limited use which is essentially getting the power back. It's not necessarily the only use for hydrogen, you can use it for any purposes, right. For chemical industry or chemical, you can do it. There's a whole range of applications you can do. That's the power of hydrogen compared to just using batteries.

MR. BROUWER: Yeah.

COMMISSIONER MCALLISTER: I want to keep our -- I just want to keep our eyes on the clock. So, we're -- the schedule says that we have until 3:40 for this. I'd ask Heather and her team whether we have a lot of public comment or that we seen to, because we have until 4:30 overall. But I want to make time for some Q&A from the Zoom participants and public, and then for some wrap up comments. But we have some time, just want to keep it moving along.

And I see that Commissioner Monahan has a question.

COMMISSIONER MONAHAN: I do. I'm curious, you know, the statement that green hydrogen should be cheaper than gray or brown hydrogen. How much controversy is there around that presumption?

MR. BROUWER: So, these are -- okay, so we have done independent analyses that also include scientific methods that are proven to be accurate with regard to their predictions and their back casting of solar and battery energy costs. Okay, battery system costs. And these are the exact same methods that apply a learning rate, and a market size are applied to the electrolyzers and the fuel cells. And since they scale in a similar way to solar and batteries, with the surface area that you're able to produce in an individual cell, I'm quite confident that these -- that with the appropriate policy and incentives on the front end we will very, very quickly move down that cost curve. Just like people were kind of surprised happened with solar, okay, and with batteries.

And it's a very similar cost curve and market projection that I'm quite sure will move us down to making green hydrogen cheaper than even the fossil that we have today.

COMMISSIONER MONAHAN: And Jack, is it around 2 cents per kilowatt hour, is that the magic electricity price?

MR. BROUWER: Yeah, so I agree with Steve Szymanski who in the end says the most important factor is actually the cheap electricity. Because eventually when you get to a reasonably high capacity factor and you have cheap electricity that's what matters the most. Because the cost of the electrolyzer is a last important fact then in the end. Yeah.

MR. VENKATARAMAN: On thing you need to calibrate: Today we use hydrogen all over as in our fuel cells, right. We pay in the neighborhood of anywhere between $8 to $10 of kg today. So, even though the SMR, whatever the source you have, people claim that it can be produced at dollar 50, but end consumer like us, we pay more in dollars. So, I want to put that in context. So, even though we are challenged to produce hydrogen and there are, but the thing that we --

COMMISSIONER MONAHAN: Yeah. Well, I was saying this morning, actually, that at the pump it's more like $15 to $18.

MR. VENKATARAMAN: Exactly.

COMMISSIONER MONAHAN: There you go.

MR. VENKATARAMAN: We can put a (indiscernible) requirement on the green hydrogen when it actually benefits the environment. But it's also you've got to put a reality spin on it because even the current one, what are the gray areas you produce -- and this is not cost effective, either, from a consumer perspective. Maybe the source is low, but it's not the case when you use it. Otherwise, we'll be running a whole range of fuel cells of hydrogen today since we have a --

COMMISSIONER MCALLISTER: Yeah, so I want to sort of maybe extend this. So, Jack, I appreciate your sort of bringing in the learning curve literature and I think that makes a lot of sense here.

I guess I am wondering if there are any particular points in the fuels -- in the hydrogen ecosystem, say with fuel cells, electrolyzers, or any other components that might be unique in terms of, you know, what might inject a little hiccup into that learning curve and make it not so smooth.

And maybe there's, for instance, you know, some of the resources that are needed, like rarer or some things like that. I wonder if there's, you know, in particular bottlenecks that you want to raise the flag on that might need a policy response?

MR. BROUWER: A very nice question. Our analyses, associated with both the fuel cells and electrolyzers, suggest that the -- that -- okay, first of all, only some types of electrolyzers have the need for precious metals. In particular, proton exchange membrane fuel cells require precious metals.

If you look at the alkaline electrolyzers and the solid oxide electrolyzers, they don't require the precious metals. Now, they do require some metals that are pretty expensive, like some of the stainless steels that are used and things, but they aren't precious metals. And even if you look at the precious metals that are required in proton exchange membrane fuel cells and electrolyzers, these are in very, very small quantities. That's the first point. And they are highly recoverable and recycled at the end of life.

And so, what ends up happening is that it's very different than the limitations that you see for lithium ion batteries, which are hard to recycle and hard to recover, and you need to use massive amounts of those kinds of materials. You use very small amounts.

And so, it's of course a very good question and we need to be concerned about end of life, and recycling, and everything, too. But I don't see a fundamental limitation that would be a hiccup into the learning rate, as you asked.

MR. VENKATARAMAN: Yeah, I think for us, actually, that's a good question. We have looked at what we are using in the solid oxide fuel cell is exactly the same type of material we use for the electrolyzer. And we don't really have any supply problem because it's not precious metal. And there's enough of (indiscernible) available. And also, if we go with electrolyzer.

For us, I think, that's not been a challenge. Even if you go to gigawatt worth of electrolyzers, it shouldn't be a big problem --

COMMISSIONER MCALLISTER: I had one more question, but go ahead Commissioner Monahan.

COMMISSIONER MONAHAN: Oh, I was going to build on what you just said, Commissioner McAllister, just in terms -- I mean, if the primary issue is really around electricity price, do you see anything that we can do in the R&D space to remove any other roadblocks?

MR. BROUWER: There's a whole bunch of R&D questions that I think are important. And a lot of them are associated with safety. So, for example, if you could engender the safe transformation of pipeline infrastructure, or the safe transformation of underground storage facilities, which we don't know exactly how to do that, yet. Okay, so research and development in those kind of things.

Safety and end use capability with hydrogen and natural gas mixtures. So, things like, you know, the residential stoves, and heaters, water heaters, and space heaters and things like this, could they be transformed into something that is hydrogen-based and things like that.

So, there's a whole bunch of research questions that go along the way of the vision that I suggested. As a matter of fact my backup slides, which you have now before you, suggest a number of RD&D topics that you could consider. I didn't have time to present those. I wasn't planning on presenting them, I was just having them available for you.

And those aren't the only ones, those are just some of the ones that came out of our research program here.

COMMISSIONER MCALLISTER: Great. I want to just get one more question out really quickly. And so a couple of you, I think, and maybe this morning it also came up in terms of the -- some sort of, you know, hydrogen injection standard or, you know, sort of the certification issue has come up. And I guess I want to just invite a little more discussion about that because I think it's likely that something along these lines, a discussion along these lines might occur at the Legislature at some point.

And so, a clean gas standard, you know broadly speaking, perhaps in that context, you know, are you suggesting that hydrogen should just be part of that, or it should get a carve out, or there's some particular policy on the gas side that's unique to hydrogen as opposed to some of the other forms of non-fossil gas.

MR. VENKATARAMAN: So, I think we have to come to some conclusion on the injection centers. I can tell you that the amount of hydrogen that we can inject into the pipeline in a safe manner have been discussed quite heavily in the literature. It can go anywhere between

25 percent to almost like 29 percent by volume is not a problem. So, even the existing infrastructure will handle it.

So, many countries are actually trying to come up with standards on it. And people worry about if the hydrogen content goes higher than that, it is going to be a problem. It's always a common fear, right. But we do have to come up with some standards which is globally that can be used either in California or U.S. This is important.

The research, we have done it. I think even we have done -- some of the testing we have done and 30 percent is not a problem, but people have to get comfortable with it, right. So, I think any policy stance you have will help a lot.

And then, there are also questions about embrittlement, somebody's asking it. Yes, it is something that needs to be looked out, but there are a variety of choice on the fuel that we can easily deal with the problem with it. So, I think others can answer that, but it is solvable. It's not a major issue.

MR. BROUWER: And it's a phenomenon that is slow and then there are so many mitigation ideas, you know, things that would coat those or put a pipe just in the same right of way, or put a pipe inside of a pipe or all kinds of things that are relatively low investment means of transforming. But those still also could use some RD&D investment, at least the demonstration part, from a lot of companies that are developing these kinds of solutions.

And we can learn a lot also from other jurisdictions that have already adopted injection standards, and already adopted a certain limit that they allow. And even like I said before, a small limit in the beginning and involving the utilities which know that, hey, we have primarily plastic in this region, okay. And we can inject right here and we know it's not going to be an embrittlement problem. But here, we have to check for this, you know, and these kinds of things.

I think enabling the utilities to work with researchers to start doing it and investigating the challenges that result is very, very important.

COMMISSIONER MCALLISTER: Great, thanks to all of you very much, super helpful. And obviously, there's a lot to dig into there going forward. We're not going to answer all of these questions today but really important to get, hopefully, a collective direction to be able to build something if, indeed, that conversation does happen, you know, say around a clean gas standard.

Let's see, I guess we're over time, but I don't think it’s a problem because we don’t have a huge number of questions from the audience. But I do want to move to Zoom questions, now, and would pass it off to the IEPR team to help moderate that.

MR. ERNE: So, Commissioner McAllister this is David Erne. I’ll be moderating any questions.

COMMISSIONER MCALLISTER: Oh, hey David.

MR. ERNE: Yeah. And folks have been -- folks on the panel have been responding to some of the questions and answering them as time goes on, so we’re really down to two; the most recent one on embrittlement, which was discussed.

So, of the two remaining questions, one question is: In the context of grid scale electricity, I understand the benefits of green hydrogen to be clean dispatchable energy and long duration energy storage. Am I missing anything?

So, if folks want to talk about other benefits they see to grid scale electricity for hydrogen, please chime in.

MR. BROUWER: Well, I can speak to that. Certainly, those two features are engendered by introducing green hydrogen to support the electric grid. But there’s a lot of other things that have to go along with it, right, like that underground geologic storage.

That's actually proven to be viable and work well, okay, in salt cavern underground storage.

As a matter of fact, Air Products and other companies are operating salt caverns with hydrogen storage right now very successfully, with very low leakage rates, and the like.

So, but we don't know for sure if we can transform the depleted oil and gas field underground storage, geological storage facilities that are currently in operation in the State of California.

So, you know, there are some things that we need to invest in to determine if we can actually provide that sort of long-duration storage.

When it comes to grid scale electricity, they can also, once you build these facilities, provide short-duration storage services as well. We have shown that the dynamics of the fuel cells that can be coupled to these hydrogen energy storage facilities can be very, very quick and offer short-duration and long-duration storage capabilities. And also, including things like spinning reserve, and N+1 FERC capacity requirements can be met by these kinds of facilities. So, there's a whole bunch of other grid services that could be provided by these kinds of entities. Fuel cells and electrolyzers operating on renewable hydrogen in the grid context.

It also can provide voltage support, frequency support. Sorry, I don't need to name all the ancillary services.

MR. VENKATARAMAN: By the one, one of the concepts that we have from a reversible perspective exactly fits in this. Right, if you do our way of producing hydrogen there are applications that we can do, which in a microgrid part of it, in a campus level that we are actually trying to put together for next year, does help in a bigger way. Right. And it gives you the versatility that we're looking for.

So, the research we are doing with NREL and with ID, Idaho National Lab, and DOE is a good one to go and test it out. It does give you the resilience as hydrogen is used as a storage unit. So, there are more things we can do.

MR. ERNE: Any more responses?

All right, move to the next question: Could more details be provided to explain how battery storage for longer periods of time becomes expensive? For example, does this mean that a Tesla power wall stored energy to be used as a (indiscernible) -- this is in comparison to the long-duration storage, the inexpensive aspects of long-duration storage using hydrogen.

MR. BROUWER: I believe that it was the presentation of Dr. Nelson of the Green Hydrogen Coalition that presented that information.

But we have done similar analyses and it's primarily because of separate power and energy scaling that is enabled by the hydrogen energy storage systems that batteries cannot provide. Every battery comes with a fixed amount of kilowatts and a fixed amount of kilowatt hours. Okay. So, if you need more kilowatt hours, you have to buy more batteries. If you need more kilowatts, you have to buy more batteries.

Hydrogen, on the other hand, if you need a certain kilowatt rating and you need a massive number of energy kilowatt hours rating, you just build the tank a little bit larger. And use the same electrolyzer in the same fuel cell.

And so, what ends up happening is there's always a crossover point where hydrogen energy storage becomes cheaper than battery energy storage. It's that separate power energy scaling feature of hydrogen.

A second thing to note is that for long duration storage self-discharge of something like a power wall, okay, will occur. So, if you charge it one day and you leave it for a week and then you discharge it, you only have order of magnitude 90 or 95 percent of it left. If you leave it for six months, you may have nothing left. Because self-discharge always occurs with battery energy storage that has the chemicals immediately in contact with the electrodes.

Hydrogen is separate. You put it in the tank, it's over there. Here are the electrodes from the electrolyzer and the fuel cell. And so that's why it doesn't have that self-discharge problem, also.

MR. ERNE: Thank you, Jack.

And we'll just go through the last question here quickly, which is: As California is subject to severe droughts, do you see problems with supplying sufficient quantities of water and a large scale production?

MR. BROUWER: So, the answer is unequivocal, no. It's not to say that water isn't a challenge, but in the hydrogen economy analysis that almost every jurisdiction, it's not just me that's saying, Japan is saying this, the UK is saying this, Germany is saying this, the amount of water use economy wide will go down when we introduce this renewable hydrogen economy using water to make renewable hydrogen.

Why is that? It's because on the power plant end of things, like Bloom Energy servers, they hardly use any water. As a matter of fact, they can make water. As opposed to the current use of water in power plants today.

So, overall there will be less overall water use. Now, maybe we'll have to use it in different places than we used it before and that's going to be a challenge, because we've got to move the water around in society a little bit differently in the hydrogen economy. But less water overall is going to be used in a hydrogen economy that uses water for making renewable electricity than we currently use for our society. So, this is a very important aspect to think about.

The other thing to think about is it's a virtuous cycle. You use water, okay, when you make the renewable hydrogen. But when you convert it back to electricity, it makes the water back. And the earth is able to move that water around, you know, on the order of seasons, okay, to return it back to you in that same location.

So, it's something that I'm sure we can sustainable do forever, if we want to.

MR. ERNE: Thank you, Jack.

Heather, I turn it back over to you.

MS. RAITT: Great, thank you. Thanks so much. So, thanks to our panelists, that was really wonderful.

And so, we will move on to our last presenter, Mike Petouhoff who spoke this morning is back. And he's a Manager, again, over -- just repeating that he works in the Energy Commission's Research and Development Division.

So, go ahead, Mike.

MR. PETOUHOFF: Thank you, Heather. I was asked just to make a few comments about the process for the EPIC Investment Plan.

The next slide, please. So, even though this is an IEPR workshop and comments will certainly support the IEPR report, but you can also make comments that may feed into EPIC for some of the research things, so we want to share what those are.

We're essentially looking under EPIC this cycle about four themes, decarbonization, resilience and reliability, entrepreneurship, and affordability, and the overarching theme of equity.

The next slide, please. There's been a series of public workshops from May until July. One of them was July 1st, which was the EPIC Hydrogen Workshop. And then, now that those workshops have come to closure, on August 4th there's going to be a workshop that is an opportunity to prepare or present the overall proposed EPIC Plan.

And then, sometime in September there will be a business meeting where the plan will be considered for approval, and then submitted to CPUC around October 1st. And again, these are tentative dates subject to discussion between CEC and CPUC. In this tentative scheme, we think that CPUC would provide an approval sometime around spring of 2022 and we would start the solicitations in the fall.

So, the next slide, please. So, the areas that you can comment on, if you feel like some of the research issues that have come up today are important or are for EPIC, we certainly have the project that we talked about, which is the Role of Green Hydrogen in a Decarbonized California, a Roadmap and Strategic Plan.

And then, several other hydrogen technology and development and demonstration projects that are being done by all the different offices in the Energy Research and Development Department.

So, there's also ongoing Natural Gas Research Program and there's some funding before the California Legislature. Some has been granted already, and some is still under consideration that would help further research as well.

So, if you have comments and you make them, they can go into any of these different areas.

The very last slide that will be presented under closing comments describes how to submit comments under the IEPR. And if you submit comments under IEPR that are relevant to research, they'll be routed to us under EPIC. Or, if you want to go to the August 4th EPIC workshop, you can submit comments there as well.

So, that's really it. We wanted just to bring to your attention this parallel process, especially since the EPIC submission is getting ready to come to closure in the next several weeks and that will essentially map out the next four years of research for us. Thank you.

Back to you for public comments.

MS. RAITT: Great. Actually, Raquel, could you move to the 1.5 minute timer, please.

And Dorothy Murimi is -- this Heather. And Dorothy Murimi is going to moderate the public comments for us. She's from the Public Advisor's Office. So, go ahead, Dorothy.

MS. MURIMI: Thank you, Heather.

So, just a few instructions for folks. If you're on Zoom, use the raise hand feature. It looks like a tripod. And if you're on the phone, press *9 to raise your hand. We'll be having commenters -- apologies here.

One person per organization may comment and comments are limited to 3 minutes per speaker, but the time may be reduced to make room for all who want to speak.

So, I'm going to start with folks on Zoom. Apologies, comments are one and a half minutes per speaker.

So, we're going to start with V John White. Again, that's V John White. You may unmute and begin commenting.

MR. WHITE: Thank you very much. Can you hear me?

MS. MURIMI: Yes, I can.

MR. WHITE: I'm John White from the Center for Efficiency and Renewable Technologies. I wish I had a little longer, but I'll do my best to be short.

I want to stress the need for independent definitive feedstock lifecycle costs and end-use emission analysis. There's a lot of claims being made and we need somebody to help us understand what's true and what's wished for. And that includes tracking and reporting.

I think there's going to be a lot of claims made about green hydrogen that are going to need to be verified. Also, ARB needs to tighten up their definition of eligible renewable natural gas so that we don't give the same credit to the out-of-state landfill projects that we've been doing under cap and trade.

I also think -- I have 50,000 miles of personal experience driving light-duty hydrogen vehicles. And I think we need to do a much better job of not just expanding stations, but the reliability of the supply. I think the out-of-state suppliers are much less reliable than they should be, and I think we should be looking to expand distributed electrolytic hydrogen production.

Also, I think we need to understand that the SMR hydrogen from out-of-state is really not the platform we want to build on.

Also need to look at hydrogen leakage in transport and production. I would also be cautious about the expanded reliance on the natural gas pipeline system and the hydrogen blending because we don't want to lock in the existing natural gas distribution and pipeline system when we're trying to phase out the use of natural gas in California.

Aliso Canyon, for example, needs to have half the industrial demand or half the demand for gas in Southern California to be reduced if we're going to be able to close it. So, we need to connect all these dots.

I appreciate the Commission's fine work in this area and we'll be making written comments.

MS. MURIMI: Thank you, John White.

Next, we'll have Bruce Applegate. Bruce Applegate, you may unmute and state your comments.

MR. APPLEGATE: Thank you. This is Bruce Applegate. I'm the Associate Director at Scripps Institution of Oceanography at the University of California, San Diego.

I'd like to focus everybody's attention, now, offshore of California's coasts to the deep blue sea and share some exciting news. And that the final 2021-2022 state budget included $35 million for the UC San Diego Scripps Institution of Oceanography to design and build a first of its kind hydrogen hybrid research vessel.

This is based on a conceptual design that's the outcome of about four years' of feasibility studies that we did in partnership with Sandia National Labs, and others. And our concept is for a hydrogen fuel cell system to be integrated with a conventional diesel electric propulsion system on an operational research vessel.

And our goal is to carry enough hydrogen so that we can conduct 75 percent of all the ship's missions entirely as a zero emission ship. The ship that we're aiming to replace is our smallest vessel, Robert Gordon

Sproul, which focuses its work in the bays' and coastlines' nearshore areas in San Diego, Southern and Central California.

So, this is a vessel that has a very high visibility. We carry hundreds of students and researchers from across the University of California every year. Furthermore, Scripps, as a world leader in oceanography is recognized for its leadership in ocean research vessels. This will be a very visible platform and a great way to demonstrate maritime hydrogen.

Thank you very much.

MS. MURIMI: Thank you, Bruce.

Next, we have Karin Sung. Apologies if I misstated your name. Please unmute and state your name, and give your comments.

MS. SUNG: Hi. Thank you, everyone. My name is Karin Sung with the CPUC. I would just like to make a small correction to what was stated earlier. The CPUC does have a proceeding that's open that is considering hydrogen injection into natural gas pipelines. It's the same proceeding that is considering biomethane. It's scoped into phase 4. So, phase 4-A is SB 1440 biomethane procurement and phase 4-B is hydrogen blending into our pipelines.

Additionally, SoCalGas had originally submitted an application to pilot hydrogen injection into a small test run. That application has been dismissed, only because there was insufficient detail and they have been instructed to reapply.

And so, there are efforts being made at the CPUC to provide hydrogen transportation through existing infrastructure. That's all. Thank you very much.

MS. MURIMI: Thank you, Karin.

Next we have Yuri Freedman. That's Yuri Freedman. Yuri, you may unmute your line, state your name and give your comments.

MR. FREEDMAN: Hi. Good afternoon, this is Yuri Freedman at SoCalGas. Can you all hear me?

MS. MURIMI: Yes, we can.

MR. FREEDMAN: Thank you. So, first I'd like to thank all the panelists for their exciting and real informative presentations. And I want to say we do appreciate the efforts that the Commission has taken exploring the potential of green hydrogen in California.

We at SoCalGas share the view that hydrogen is well-positioned to enable decarbonization due to it is complementary with renewables, as so well articulated by Professor Brouwer, and the potential of its broad deployment across the range of end uses, as laid out by distinguished panelists Dr. Nelson, Venkat, Eric and

Stephan.

Many participants of today's workshop discussed pathways to lowering costs of clean hydrogen production. I'd like to say it's really important to recognize the current cost of transporting hydrogen to its end use is a large and often larger part of overall cost to the customer.

And with that in mind, work on reducing these costs and developing cost effective and scalable hydrogen transportation solutions to proceed in parallel with efforts when reducing hydrogen production costs if we are to achieve rapid and broad hydrogen adoption.

As just one illustration of the potential in this area is the recently issued European Hydrogen Backbone Report, which I have placed in the chat box, where they concluded that almost 70 percent of the content-wide hydrogen network could be built by using repurposed gas pipelines.

So, we think it's really, really important to advance in this area, to do more demonstration projects.

As Karin mentioned, we are going to work on resubmitting our application in a more robust way. Very much looking to go over it with the Energy Commission in this area. Thank you for the opportunity.

MS. MURIMI: Apologies, Yuri. Oh, thank you, Yuri.

Next, we have Issam Najm. Apologies if I've stated your name wrong. Please restate your name and you may begin your comment.

MR. NAJM: Thank you. My name is Issam Najm and I am a resident of Porter Ranch, which is in the City of Los Angeles. And we are the community that has been dealing with the Aliso Canyon Gas Storage Facility.

And listening to Dr. Brouwer and others, there's this idea that we should convert the methane storage infrastructure to hydrogen, as we just also heard from the gentleman from SoCalGas.

I ask the CEC to recognize that storing hydrogen in existing gas storage facilities located in urban areas does nothing to relieve the surrounding communities from the dangerous health effects of these facilities.

Because the issue is not what gas is stored in it, but rather the crude oil that comes out with it, whenever it's pulled out of the field.

So, while we wish these were salt caverns, they are not. And the crude oil is the problem, it is not the gas. Thank you.

MS. MURIMI: Thank you for your comment, Mr. Najm.

Next we have William Zobel. William Zobel, your line is unmuted. You may state your name and begin your comment.

MR. ZOBEL: Yes, good afternoon. Hopefully, you can hear me.

MS. MURIMI: Yes, we can.

MR. ZOBEL: My name is Bill Zobel. I'm the Executive Director of the California Hydrogen Business Council representing over 120 members involved in the commercialization of hydrogen and fuel cell technology.

Thanks for the opportunity to comment this afternoon. Excellent panel today, or this afternoon I should say. We participated in this morning's panel as well, where our comments focused on the carbon intensity of various hydrogen production pathways as a way to characterize that hydrogen produced versus the color wheel, which has been described by so many panelists today.

This afternoon I wanted to talk a bit more about some of the comments that were made by Dr. Brouwer and others relative to wholesale market access for electrolytic hydrogen producers.

As we know, in California the jurisdictions are focused on the production and use of green electrolytic hydrogen through these carbon emissions and improve air quality.

As we heard today the number one cost, the number one cost of producing this form of hydrogen is the cost of electricity. The CHBC would recommend that policymakers strongly consider allowing electrolytic hydrogen producers access to the wholesale electric markets, as was recommended by Dr. Brouwer and others on the panel today.

Policymakers should understand that this access for electrolyzers is not a handout. This comes at no cost to the state, at no cost to ratepayers. Cost causal tariff design will ensure this. Done right, it creates a commercially workable production pathway for low cost green hydrogen. Putting this in place will also make better use of renewable resources, reduce renewable power curtailment, support grid operations as Dr. Brouwer opined on, and provide project developers additional certainty required to make these investments.

Our time is limited, so I won't go on. But we do have some language to share with policymakers and we'll work on setting that up, some briefings with those on the dais today in the future. So, thank you very much.

MS. MURIMI: Thank you, William.

Next we have David Park. David Park, your line is unmuted, you may state your name and begin your comments.

MR. PARK: Good afternoon and thank you very much. And my name's David Park. I am the -- I'm with the California Fuel Cell Partnership. My function there is as the industry representative or industry coordinator for our members.

And good afternoon Commissioners and distinguished panel. I commend the holistic coverage of hydrogen production and the economy development this morning and this afternoon.

I just wanted to point out one detail and fact on the retail cost of hydrogen. And I just want to inform the panel that the retail price of hydrogen is on a downward trend. In fact yesterday, I was fueling at the Fountain Valley Station, which is one of the newest high capacity liquid hydrogen storage stations in the network. It has four fueling positions and about 1,200 kilograms per day storage. And, therefore, the price of hydrogen is at $13.05 as of yesterday.

The different in price across the network is due to the capital cost of development and then the operating costs that the developers have to make up. And so, we do indeed see a broad span of costs across the state on the retail price. But indeed, the price, the retail price of hydrogen is coming down.

I would invite the Commissioners and our colleagues to come visit the stations. As the California Fuel Cell Partnership, we'd be happy to facilitate the tour. And we do work in partnership with the Governor's Office of Economic Development and AIR.

Thanks very much and appreciate your time.

MS. MURIMI: Thank you, David.

Next we have Mikhael "Mik" Skvarla. Your line is unmute. Apologies if I misstated your name. Please state your name, unmute and begin your comment.

MR. SKVARLA: No problem. Mikhael Skvarla, here on behalf of the California Hydrogen Coalition. I just wanted to thank the Commissioners and staff for hosting this workshop. I think it's been a long time coming and this has been great to have a dedicated multi-session discussion about hydrogen and the hydrogen end uses.

The broad conversation today was about enabling policies and we'll follow up with written comments. I just want to reflect the comments made by Bill Zobel, the access to wholesale markets are absolutely vital for us to achieve pricing in and around what the Department of Energy's Earthshot is. You know, the Energy Commission and CPUC can help us work through those policy things and if legislation's needed, we're absolutely standing ready to move that and would be partners with whoever wants to take that step.

I just wanted to also talk real quick about another enabling policy that would go a long ways, obviously pipeline injection.

But then today we have commercial end uses that are readily available being made by two of the largest car manufacturers with regards to sales in the State of California. Combined with a third, they represent over a third of all vehicle sales in the State of California. And they've brought fuel cell electric vehicles to market that are readily available today.

The need to expand and dedicate an effort to building out the full market to self-sufficiency is absolutely vital and important. This needs dedicated funds that are keyed for hydrogen, and not technology neutral, as that's not an investible signal to our station developers or the investors of those companies.

So, to the extent that as we look at the AB 8 reauthorization that we can dedicate funds again towards hydrogen medium-, light- and heavy-duty to build an entire statewide network to self-sufficiency, that would be appreciated. Thank you.

MS. MURIMI: Thank you, Mikhael.

Just a quick announcement. Again, for people that are on the phone line only, you may press *9 to indicate --

MR. SKVARLA: Five seconds over.

MS. MURIMI: Again, for folks that are on the phone line, you may press *9 to indicate that you'd like to make a comment. And anyone else that is on Zoom, use the raise hand feature to raise your hand. We'll give that one more moment.

Seeing no other commenters, Commissioner McAllister, I'll hand the virtual mic back to you.

COMMISSIONER MCALLISTER: Thank you, Dorothy. And thanks for all the commenters who were here today. And thanks to everyone who's remaining. We still have 150 or so people, so kudos to those who stuck it out to the end of the day.

We saw a lot of great speakers today and heard a lot of great ideas, so really, really heartening to have this relatively deep discussion.

Let's see, we still have -- oh, there, we still have great presence on the dais. Let's see, Heather, should we go to just wrap up comments from each Commissioner?

MS. RAITT: Yeah. Yeah, we ought to do that, thanks.

COMMISSIONER MCALLISTER: Okay, great. Well, I guess I just will go very, very briefly. I just -- I think there's a chicken and egg problem that we all sort of expressed, that all the speakers kind of expressed in one way or another. And I think as we do that cycle and keep building, we'll see really how large this ecosystem and how targeted on the things we're talking about it can be.

And, you know, giving it some rigor along the way and helping it with policy, but also expecting accountability. I think that was kind of the tenor, I think, and a fair amount of optimism around those points.

In particular, you know, SB 100 modeling does need, as I think Le-Quyen said on Commissioner Gunda's behalf at the very beginning, you know, it does need clean firm power, and hydrogen is obviously a contender for that. And so, really fleshing that out and what that might look like was sort of implicitly a lot of the conversation today.

Really looking forward to collaboration across agencies on this issue. Commissioner Houck, thank you for being here for the whole day.

And one big venue for collaboration between our two Commissioners is the EPIC Program and I think that's a huge just gem of a program for the state. It's really that the team, Laurie ten Hope's team and the whole EPIC team, I just want to call them out for a lot of the R&D that they're already funding.

But one skill set that I think we've developed very well is being able to understand which are the really key topics that need a good look for the state, and some funding and some support for all the different pieces of our clean energy transition.

And so, I think there's much more to come here, particularly if and when the Legislature pushes some funding towards this.

And then also, just finally, I want to just call out by name David Erne, and then the whole team at EAD for putting this workshop together. And Commissioner Douglas and your office, and all the team in EPIC and EAD both. Thanks for putting together a great day, it's been very interesting. I agree.

And with that, I'll push it over to Commissioner Douglas for some wrap-up comments.

COMMISSIONER DOUGLAS: Thank you, Commissioner McAllister. And I'll be very brief. I thought it was a really great and a really informative workshop. And you can see just there's so much going on the space, and so much to learn, and incorporate in our thinking. And it is a very fast moving and cutting edge field.

And so, I learned a lot today. I really appreciate the speakers and, of course, everyone who worked hard to pull this workshop together. And I look forward to continuing to move forward on this and continuing to learn more. And as you said, Commissioner McAllister, you know, build our knowledge that feeds into the SB 100 Report, and any number of other areas as well.

So, I think with that I'll pass this on.

COMMISSIONER MCALLISTER: How about we go to Commissioner Monahan, and then Commissioner Houck, and then Matt Baker. Does that sound good? All right.

COMMISSIONER MONAHAN: Yeah, I really learned a lot today. It was a very exciting conversation. I think, you know, as we started the day like we looked upon hydrogen in kind of this narrow band of activities, and now it's this whole expansive ecosystem that we're learning about. And, you know, we're behind the EU in some aspects, we're ahead in other aspects. And so, you know, California, we want to be at the lead, we want to always be at the cutting edge. So, this was a really important grounding discussion for helping accelerate our investments in hydrogen.

And one last thing, I mean I don't see how we reach 2050 targets without it. We just will need a diversity of low and zero carbon fuels to be able to do it. And hydrogen is part of that portfolio, and especially some of these very hard-to-decarbonize sectors that seem really optimal for hydrogen.

COMMISSIONER MCALLISTER: Okay.

COMMISSIONER HOUCK: Okay, I wasn't sure.

COMMISSIONER MCALLISTER: Sorry. Sorry.

COMMISSIONER HOUCK: But today was very informative. I appreciate being able to participate in this event and want to thank all of the Energy Commissioners, the staff, and the EPIC team and those that put the workshop together, the panelists and the participants.

I'm looking forward to learning more about hydrogen and how it fits in to where we're going with our clean energy future and what we at the CPUC can do to help do across agency work with the CEC and the Resource Agency on these issues.

So, again thank you and I look forward to continuing this discussion with everyone.

DEPUTY SECRETARY BAKER: Yeah, I want to thank everyone who helped put this together. And I want to thank all the panelists and all the participants. I think this was a really -- I learned a great deal today.

And I will just add that, you know, onto something Commissioner Monahan said which is, you know, California has been a leader in so many areas, I look forward to us being a leader in clean hydrogen, both in the production and the deployment of it to serve our low carbon needs.

Thanks everyone.

COMMISSIONER MCALLISTER: Well, thanks to all of you, really, for your leadership in your respective areas. And it's nice to see sort of cross-cutting theme that lets us have these conversations together because I think it actually really is stimulating to hear the sort of subject matter expertise of each of the Commissioner officers and all the principals here as well. So, I think having these public conversations, we don't get to do it enough, really, so it is a great platform for that as well. So, happy to be a part of it.

With that, I think we are done. I'll pass it back to Heather to maybe put up that slide. There we go. How to submit your e-comments to the docket. We would like to have this by August 11th. And please, there's so much content here, so looking forward to everybody's insights on particularly what the state can do to address any particular barriers, or particularly policies that might help really push this enterprise forward.

So, and thanks to David Erne, and Mike Petouhoff, and the whole team across the two divisions again.

Okay, Heather, are we finished?

MS. RAITT: We are, thank you.

COMMISSIONER MCALLISTER: All right. Well, thank you and your team as well. A really great day, appreciate that.

MS. RAITT: Have a good night, everybody.

COMMISSIONER MCALLISTER: Okay, take care everyone.

(Thereupon, the Workshop was adjourned at 4:25 p.m.)

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I do hereby certify that the testimony in the foregoing hearing was taken at the time and place therein stated; that the testimony of said witnesses were reported by me, a certified electronic court reporter and a disinterested person, and was under my supervision thereafter transcribed into typewriting.

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