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Additional submitted attachment is included below.

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RE: Comments by the California Hydrogen Business Council to Panel 5: Emerging Technologies and Market Opportunities

The following are comments by the California Hydrogen Business Council (CHBC) submitted in response to questions put forth by the Energy Commission to *Panel 5: Emerging Technologies and Market Opportunities* at the June 27 Joint Agency Workshop on Renewable Gas. The CHBC appreciates the opportunity to include hydrogen in the discussion on recommendations on renewable gas. We strongly urge the Commission to consider the broad spectrum of renewable gases, including hydrogen, to keep the intent and language of Senate Bill 1383, which CHBC helped craft last year, and which specifically tasks the "energy commission, in consultation with the state board and the commission, (to) develop recommendations for the development and use of renewable gas." [Sec. 5, Section 39730.8 (b)]. Renewable hydrogen is aligned with the bill's direction to the state board to "Incorporate and prioritize, as appropriate, measures and actions that provide…*(p)otential for new innovation in technology, energy, and resource management practices." (SEC.2 b) 4 (C)*

Note that renewable hydrogen can be produced from biogas, bio-waste, or using renewable electricity via electrolysis that splits water into hydrogen and oxygen, known as "electrolyzed hydrogen" or also knows as a process called power-to-gas (P2G). For the purposes of these comments, we will focus on P2G, since renewable gas produced from biological resources is the focus of questions put to other Panels.

Summary of Key Points

- **Renewable hydrogen has the potential to leverage valuable wind, solar, geothermal, hydro and other in-state valuable renewable electricity sources to reduce greenhouse gas emissions in multiple energy sectors, like transportation fuels, industrial gas end uses, such as fertilizer manufacturers and refineries, and power plants by replacing existing natural gas usage.**

- **Leveraging the greening of the state's electric grid to reduce emissions in other state energy sectors requires different market structures to enable cross-sector participation for technology and energy service providers.**

- **Renewable hydrogen also has the advantage of offering a new option to reduce greenhouse gas (particularly short-lived climate pollutants) for current industrial and transportation sectors that are difficult to decarbonize with electrification only, while leveraging the capacity of our increasingly renewable electric state resources.**

- **Renewable hydrogen can increase electric grid reliability and dramatically increase the integration of renewable energy onto the regional electric grid.**

- **P2G is the only technology capable of providing long-term and seasonal storage at terawatt-hour scale without being limited to certain locations.**

- **P2G, when deployed as energy storage for the electric grid, is more cost-effective and geographically efficient than Li-ion batteries when run at high capacity.**
- **Renewable hydrogen can draw electricity from anywhere on the electric grid or from any power plant and, therefore is more geographically flexible for installation than pumped hydro and compressed air.**

- **Renewable hydrogen is available today for full-scale deployment, although to support more deployment new market rules and expanded markets are needed.**

- **Renewable hydrogen can compete with other forms or renewable energy sources in the future, if new market rules enable commercial scale deployment.**

- **A diverse set of revenue opportunities are needed to ensure economic viability of renewable hydrogen, including a green gas procurement option for gas utilities and industrial customers, fueling purchases for fuel cell transportation providers, and participation in the electric generation, ancillary services, storage, and distribution system balancing markets.**

- **The deployment of renewable hydrogen-based gas produced with P2G systems is expected to reach gigawatt levels in Europe in the next few years and is in the early commercialization phase in Canada; policy and regulatory support is in place and will drive a fully mature market.**

How would you characterize the promise of your fuel/technology and what steps are required to achieve commercial availability?

1. The Promise

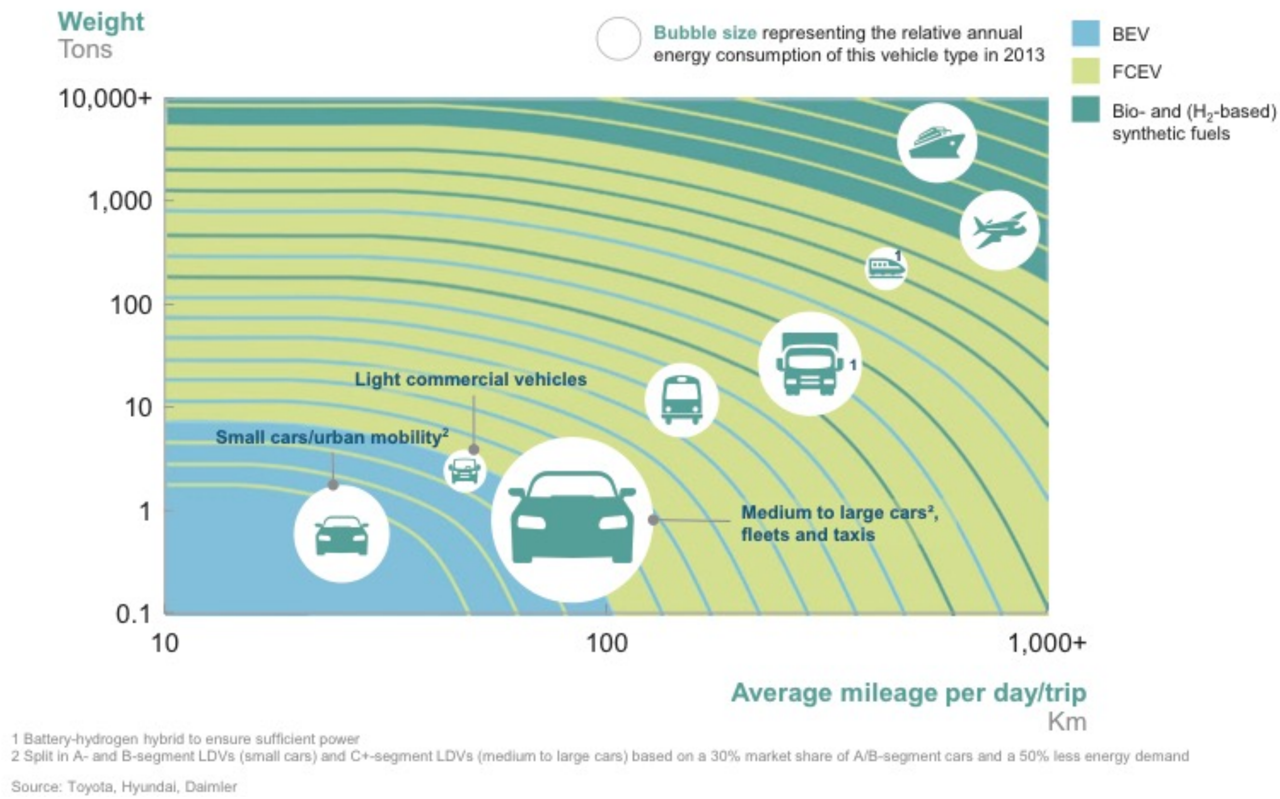
The CHBC believes that renewable hydrogen made with P2G technology can play a critical role in deeply decarbonizing the energy system in multiple ways. For example:

- **It can increase grid reliability and integration of increasing levels of renewables onto the regional electric grid.** Rather than waste excess electricity from over-generation of intermittent renewables, the electricity can be used to power electrolysis to produce hydrogen, which can then be used in a variety of ways or stored for later use.
- **It turns the "duck curve" challenge into an opportunity.** Low or no cost surplus renewable electricity can be repurposed, instead of curtailed, to inexpensively produce renewable hydrogen and enable more renewable electricity to be integrated economically into the grid.
- **P2G provides highly scalable, cost-effective, geographically flexible storage.** It is the only technology capable of providing storage at terawatt-hour scale without location limitations, when the existing gas infrastructure is used. This is particularly important for seasonal storage that will be critical as California reaches high penetrations of variable renewable electricity generation. It is more cost-effective and geographically efficient than Li-ion batteries at high capacity and more

geographically flexible than pumped hydro and compressed air (see Economics of P2G on this docket for further details).[1]

- **Renewable hydrogen can replace fossil- based hydrogen in highly polluting industries such as refining, fertilizer and metals production.**
- **Renewable hydrogen can be distributed to hydrogen stations to fuel zero-emissions vehicles.**
- **Renewable hydrogen also has the advantage of providing a climate protective pathway for energy uses that are difficult to decarbonize with battery electrification only, such as medium and heavy-duty vehicles, shipping, aviation, and certain industrial equipment.** For instance, hydrogen fuel cell electric vehicle technology is better suited to long haul heavy-duty trucks than pure batteries, due to advantages like better performance and quicker fueling times. That said, the two technologies can also complement each other. Fuel cell electric bus equipped with batteries will travel further, be refueled much quicker at a comparable cost, and the hybrid solution prolongs the lifetime of the batteries by maintaining them in an optimal state-of-charge, thus resulting in less chemical battery waste. Another application better suited to hydrogen fuel cells than batteries is forklifts, due to increased productivity and lower operating costs and ultimately reduced carbon footprint.[2] Renewable hydrogen's multiple pathways to "dramatically reduce" greenhouse gas emissions are why it is supported by the US Department of Energy's H2@Scale program.[3]

[1] http://docketpublic.energy.ca.gov/PublicDocuments/17-IEPR-10/TN219923_20170626T180524_Emanuel_Wagner_Comments_Economics_of_Power_to_Gas.pdf
[2] http://www.plugpower.com/wp-content/uploads/2014/12/PlugPower_7ReasonsH2FC_F102116.pdf
[3] https://energy.gov/eere/fuelcells/h2-scale



FCEVs will play an essential role in decarbonizing transport – Projected economic attractiveness [4]

2. Commercial Availability

P2G is already in the early stages of commercialization in North America, where in addition to two demonstration projects, there is a 2MW commercial facility procured by Ontario's TSO (IESO)[5] that will come online in 2017. In Europe, there are more than 30 projects installed or in development of up to 100+ MW in size, with a target for 700 MW by 2025 at one site (see *Economics of P2G* document on this docket for more details).

To advance commercial availability in California, the following steps are needed (see *Economics of P2G* document on this docket for more details):

- **Policy Support -** As specified in response to Question 3 below.
- **Appropriate electricity pricing** - Access to wholesale markets and more aggressive retail rate structures would allow utilities and system operators to fully utilize electrolysis flexibility.
- **Support to enter new markets and maximize revenue opportunities -** e.g. Providing ancillary services, transportation fuels, electricity generation, building end uses, demand response.
- **Support for research and development –** As with any energy technology, R&D helps to improve efficiencies, build understanding of best applications and practices, and test new markets.

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4 http://hydrogencouncil.com/wp-content/uploads/2017/06/Hydrogen-Council-Vision-Document.pdf
5 http://www.sciencedirect.com/science/article/pii/S1464285914702329?via%3Dihub

- **High penetrations of renewable electricity generation –** This will necessitate bulk seasonal storage, for which P2G is favorable because of its flexibility and scalability.

What challenges might interrupt development and commercialization of your fuel/technology for any of the following areas:

a. Technology development

There are no technological challenges for the deployment of the mature electrolysis technology; however, real world data for injecting hydrogen into the pipeline and the effects of higher hydrogen content needs to be collected, see answer 1.c.

b. Project location

A distinct advantage of P2G is its siting flexibility. Whereas other forms of large-scale storage, like pumped hydro and compressed air, have limited feasible locations situated, which often are far from load centers, P2G has many geographic options. It can be co-located with solar or wind facilities to maximize their electricity generation or it can be blended into the vast existing gas system to be transported wherever that system serves. It can also be sited on a small scale at industrial facilities that use hydrogen or near hydrogen vehicle fueling stations.

A challenge for commercialization that must be overcome is how to track and verify the renewable attributes of P2G when it is not co-located with its demand source. There needs to be a mechanism(s) put in place for this, such as a credit system and/or allowing renewable generators to wheel power directly to electrolyzer customers.

c. Pipeline injection

UC Irvine has found that hydrogen can be safely injected into the existing gas pipeline at the same leakage rate as natural gas. UC Irvine determined that up to 10% mixtures of hydrogen with natural gas are possible. This is in line with a variety of technical analyses, which have shown that hydrogen concentrations of at least 6-12% are feasible. California does not yet have a protocol for injecting hydrogen into the gas grid, which is critical to establish for the development of the hydrogen market.

Note that hydrogen can also be synthesized by adding CO2, e.g. from a biogas plant, a chemical processing facility or the atmosphere, to make methane, which can technically be injected in virtually unlimited quantities into the gas grid. This also does not have regulatory framework or protocol.

d. Business models and project financing

Successful business models for renewable hydrogen technology very much rely on the cost parameters, especially the cost of electricity. The June 2017 EU "Study on Early Business Cases for H2 in Energy Storage and More Broadly Power to H2 Applications" determined that power-to-hydrogen projects are already bankable, but require the ability of projects to "stack up several revenues streams from a variety of market applications". It also states that "providing frequency services to the power system (frequency containment and/or restoration reserves) will significantly improve bankability and cut payback times," which should be considered by the appropriate California regulatory agencies. In sum, "*the key challenge today is to identify concrete short-term investment opportunities, based on sound economics and robust business cases. Initial business cases will likely be based on producing green hydrogen and supplying it to industry and mobility.*"[6]

e. Institutional/regulatory

The CPUC currently does not recognize P2G as an eligible storage resource, and it is unclear how P2G can competitively bid into this market if it is not recognized by the State.

Neither CAISO nor a DER market has the rate structure in place for P2G systems to take advantage of low cost or negative electricity rates or to receive compensation for providing grid services.

California's Energy Storage Roadmap[7], developed by the CEC, CPUC and CAISO, does not include renewable hydrogen based solutions, and all involved agencies have been slow to seriously examine these solutions as a low-cost option for greater renewables integration and grid resiliency, despite the clear benefits to the electricity grid as well as to the emerging zero and near emission transportation setting with hydrogen fuel cells and other renewable hydrogen-based transportation fuels.

Lastly, there needs to be a way to test the compliance of power to gas with state goals, such as greenhouse gas reduction. See 2.e. below.

f. Demand and vehicle availability

The demand and vehicle availability of renewable hydrogen in the transport sector is growing, although it still needs policy support to realize its potential to fulfill California's goals. The state has committed to a target of 1.5 million zero-emission vehicles by 2025. Several thousand hydrogen fuel cell electric vehicles are currently operating on California roads, supported by 28 open hydrogen fueling retail stations. According to the *Joint Agency Staff Report on Assembly Bill 8: 2016 Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California*[8], by 2022, 46,300 light-duty FCEVs will be driven on California roads, and most automakers are planning to release a fuel cell version in the next years.

In the medium and heavy-duty transportation sector, numerous companies have announced demonstration, pre-commercial and commercial vehicles, including Toyota, Kenworth, Loop Energy, U.S. Hybrid, and Nikola Motors. Lack of policy support for development and adoption of these vehicles, as well as hydrogen vehicles for public transit, risks interrupting the process of full, economically sustainable commercialization.

Because of renewable hydrogen's multiple uses, the demand for it and its derivative fuels does not revolve only around the transportation market. Demand from numerous other markets also will impact renewable hydrogen development. For example, the higher the requirement for renewable electricity generation, the

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[6] http://www.fch.europa.eu/sites/default/files/P2H_Full_Study_FCHJU.pdf
[7] https://www.caiso.com/Documents/Advancing-MaximizingValueofEnergyStorageTechnology_CaliforniaRoadmap.pdf
[8] http://www.energy.ca.gov/2017publications/CEC-600-2017-002/CEC-600-2017-002.pdf

greater will be the need for large amounts of seasonal storage, as well as the ancillary grid services P2G can provide.

g. Related infrastructure

If utilizing the natural gas grid as a storage resource, there is very limited need to build additional infrastructure, especially when blending the natural gas with hydrogen or when injecting hydrogen that has been synthesized into methane. The repurposing of this existing massive resource for a decarbonized alternative to natural gas is one of the benefits of P2G. If California does not establish permission and protocol for hydrogen to be injected into the existing gas grid, this option would be interrupted. If California does not allow or support P2G in the form of synthesized renewable hydrogen, this would be another inhibiting factor.

Alternatively, hydrogen can also be transported using dedicated hydrogen pipelines, of which 1,600 miles exist in the Unites States today, including 12 miles in California, mostly for oil refining purposes.[9] Additional investment would needed to be made to allow for this option to be realized where appropriate.

With respect to hydrogen fueling infrastructure, as of 2016, according to state reporting, California was half way to its target of 100 hydrogen fueling stations, with a shortfall of fueling stations relative to demand on the horizon in 2020.[10] Therefore, California policy will need to continue to support the development of additional infrastructure to meet the anticipated demand. In order for those stations to achieve the added state goal of economic self-sufficiency, most likely there will need to be multiple revenue streams available to hydrogen providers, as touched upon throughout these comments.

2. What type of government action is required to support development and use of emerging fuels and technologies?

The CHBC believes governmental agencies ought to focus on the following five actions:

a. It is essential that state agencies ensure that hydrogen-based products remains part of the implementation of SB 1383, in which the legislature explicitly directed the Energy Commission to look at "renewable gas" - that both houses of the legislature and the Governor's office understood at the time of the bill's passage to include agency consideration of electrolyzer-produced renewable hydrogen.

b. The CPUC ought to ensure that P2G facilities are eligible for appropriate (wholesale or at least more aggressive retail rate structures) electricity rates, as well as low T&D rates for fuel production and industrial process applications.

c. Gas utilities should be allowed to purchase renewable gas, including hydrogen, along with associated renewable attributes, and work with stakeholders to develop in-state markets of hydrogen and other

[9] https://energy.gov/eere/fuelcells/hydrogen-pipelines
[10] http://www.energy.ca.gov/2017publications/CEC-600-2017-002/CEC-600-2017-002.pdf

renewable gases through procurement policies.

d. Further, the state should allow the gas utilities that procure renewable hydrogen and the corresponding green attributes to monetize (sell) the attribute and return the value of it to their ratepayers, similar to the model authorized by the CARB and CPUC for those electric utilities to provide electricity to EV customers and monetize the LCFS for the benefit of the customer via rebates. By allowing the gas utilities to purchase renewable hydrogen for transportation end users, it dramatically opens up the renewable gas market, facilitates the scalability of the fuel development, and can provide the mechanism to benefit individual customers who may not have the opportunity to participate in the LCFS.

e. The state should also look for opportunities to support gas utility involvement in the fueling station infrastructure, as well as to support in-state renewable hydrogen production. This may include working with electric generation or electric system managers to coordinate access to low-cost renewable electricity available for full capacity electrolyzer hydrogen production, as well as grid management opportunities. Studies show that the higher the capacity factor, the lower the cost of fuel produced, particularly in times where wholesale or negative priced electricity is available.

f. When qualifying renewable hydrogen to participate in a new renewable gas market, the state ought to utilize an emission based metric, similar to that used for electric vehicles in transportation sector or electric batteries in the energy storage markets. Hydrogen produced by splitting water with electricity input has significantly lower GHG emission profile than conventional hydrogen. The state should consider the carbon intensity or similar GHG lifecycle metric.

g. With the new increased renewable energy mandates and a shift in the way electric generation contracts are structured, there is an opportunity to expand electricity storage and re-evaluate the existing CAISO ancillary services market. While doing so, opportunities should be created for renewable hydrogen to provide grid balancing services, storage and new, long-term seasonal storage. Today, the storage market excludes P2G, and the CAISO ancillary services market is limited in scope, as well as short-term (day ahead), which is not a market structure that can be used to finance new investments.

h. The state ought to adopt a method for testing compliance of power to gas with advancing state energy and climate goals. An appropriate test would be along the lines of that which is applied to energy storage in AB 2514:
An "energy storage system" shall be cost effective and either reduce emissions of greenhouse gases, reduce demand for peak electrical generation, defer or substitute for an investment in generation, transmission, or distribution assets, or improve the reliable operation of the electrical transmission or distribution grid.[11]

[11] SEC. 2, Ch. 7.7, Sec. 2835 a)(3) See: http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab_2501-2550/ab_2514_bill_20100929_chaptered.pdf

When an electrolyzer serves a power to gas function, it would not only be cost effective and reduce greenhouse gas emissions, it would also serve as a grid asset.

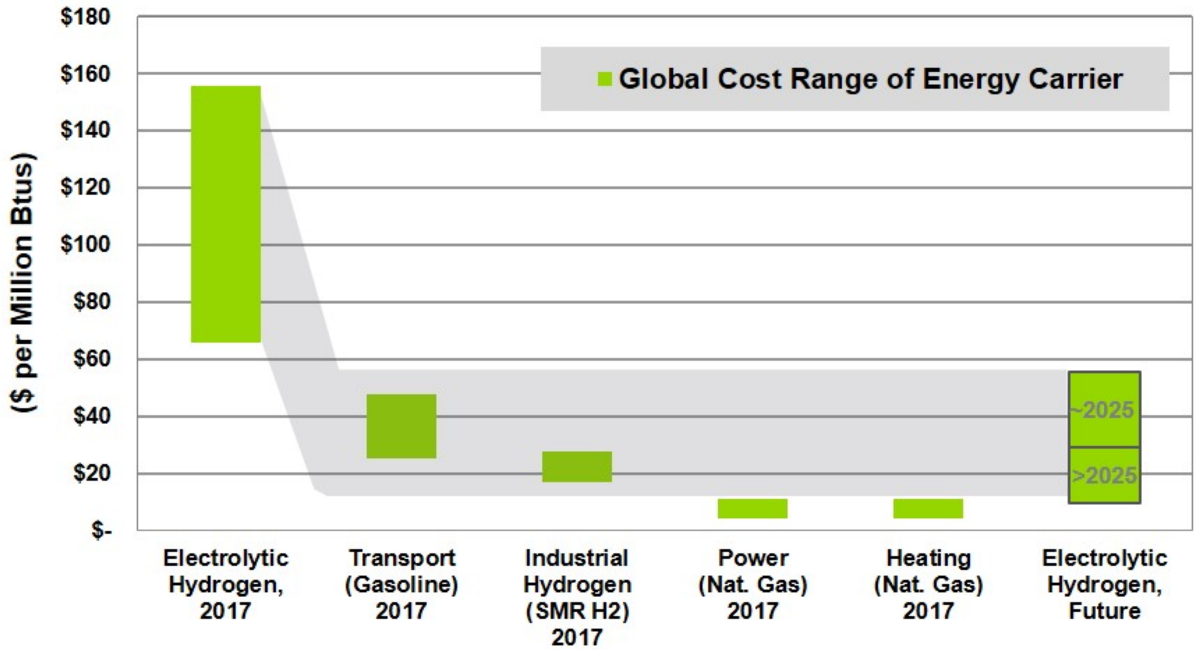
i. State agencies could become more closely aligned with federal agencies on advancing renewable hydrogen. For example, state energy agencies could more formally cooperate and coordinate with the US DOE and its National Renewable Energy Laboratory (NREL) on their programs such as H2@Scale and the P2G pilot project at the NREL campus in Golden, CO.

3. Can cost data be provided to the Energy Commission to support the cost-effectiveness and economic viability of your fuel/technology?

Yes. Please refer to the document titled "Economic of Power-to-Gas (P2G)" that was submitted to this docket on June 26, 2017. Also submitted to the docket is the recently released European Commission supported "Study on Early Business Cases for H2 in Energy Storage and More Broadly Power to H2 Applications" by the Fuel Cells and Hydrogen Joint Undertaking[12].

Finally, Navigant Research just published an article with current and future cost data for hydrogen from electrolysis. In the analysis, the authors state "as *seen in in the following chart, electrolysis remains expensive today. This is because electrolyzer capital costs have not fallen much below $1,000/kW. Renewable electricity costs, while falling dramatically, remain relatively high compared to a very high penetration future. But as those two costs fall, as is projected through 2025 and beyond, the cost of clean hydrogen falls substantially."*

[12] http://www.fch.europa.eu/sites/default/files/P2H_Full_Study_FCHJU.pdf



Hydrogen Cost Comparison with Other Energy Carriers, World Markets: 2017, 2025, and Beyond[13]

13 https://www.navigantresearch.com/blog/a-roadmap-to-the-coming-hydrogen-economy-in-one-chart