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Additional submitted attachment is included below.

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CHBC Comments on Docket: 17-IEPR-07 - Integrated Resource Planning

July 21, 2017

The California Hydrogen Business Council (CHBC) appreciates the opportunity to submit follow-up comments to the comments submitted to this docket on the May 25. With today's comments, the CHBC continues to highlight the need to recognize hydrogen and fuel cell technologies as key energy resources in integrated resource planning. Hydrogen can play a critical role in supporting grid reliability, integrating increasing levels of renewables onto California's electricity grid, and in decarbonizing the energy system in multiple ways across sectors, including transportation and industrial uses.

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 other IEPR related discussions.

The following is a summary of key concepts we wish to put forth for your consideration in refining the policy framework for integrated resource planning.

Summary of Key Points

1. **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.**

2. **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.**

3. **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.**

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

5. **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.**

MAIN ATTRIBUTES OF RENEWABLE HYDROGEN TO CONSIDER

Below is a more in-depth discussion of some of the main attributes of renewable hydrogen.

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. Beyond the storage function of converting electricity to gaseous fuel for later use, these systems can cycle up and down rapidly providing multiple services including voltage and frequency regulation, rapid demand response and spinning reserves across multiple grid domains. With fast response times, electrolyzers provide operational flexibility and can modulate hydrogen output to participate in energy management[1] and ancillary services markets on a utility scale and at end user facilities, all while producing hydrogen.[2]

It turns the "duck curve" challenge into an opportunity.

[1] Electrolyzers provide operational flexibility to participate in multiple energy markets including Regulation, Load Following or Fast Energy Markets, Spinning Reserves, Non-Spinning Reserves and Replacement/Supplemental Reserves.
[2] Novel Electrolyzer Applications: Providing More Than Just Hydrogen, NREL, 2014, www.nrel.gov/docs/fy14osti/61758.pdf

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.

Renewable hydrogen is bankable today, although it needs multiple revenue opportunities to ensure economic viability.

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

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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.*"[3]

Renewable hydrogen can replace fossil- based hydrogen in highly polluting industries such as refining, fertilizer and metals production.

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

Renewable hydrogen, which emits zero greenhouse gas, can decarbonize refineries and current hydrogen production, which according to CARB, represent the state's largest individual industrial greenhouse gas source, contributing 31% of the sector's total emissions.[4]

Renewable hydrogen can be distributed to hydrogen stations to fuel zero-emissions vehicles.

Another benefit of renewable hydrogen is that it provides useful, zero emissions transportation fuel, turning the challenge of integrating high penetrations of renewables into the power grid into a greenhouse gas free transportation solution.

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.[5] 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.[6]

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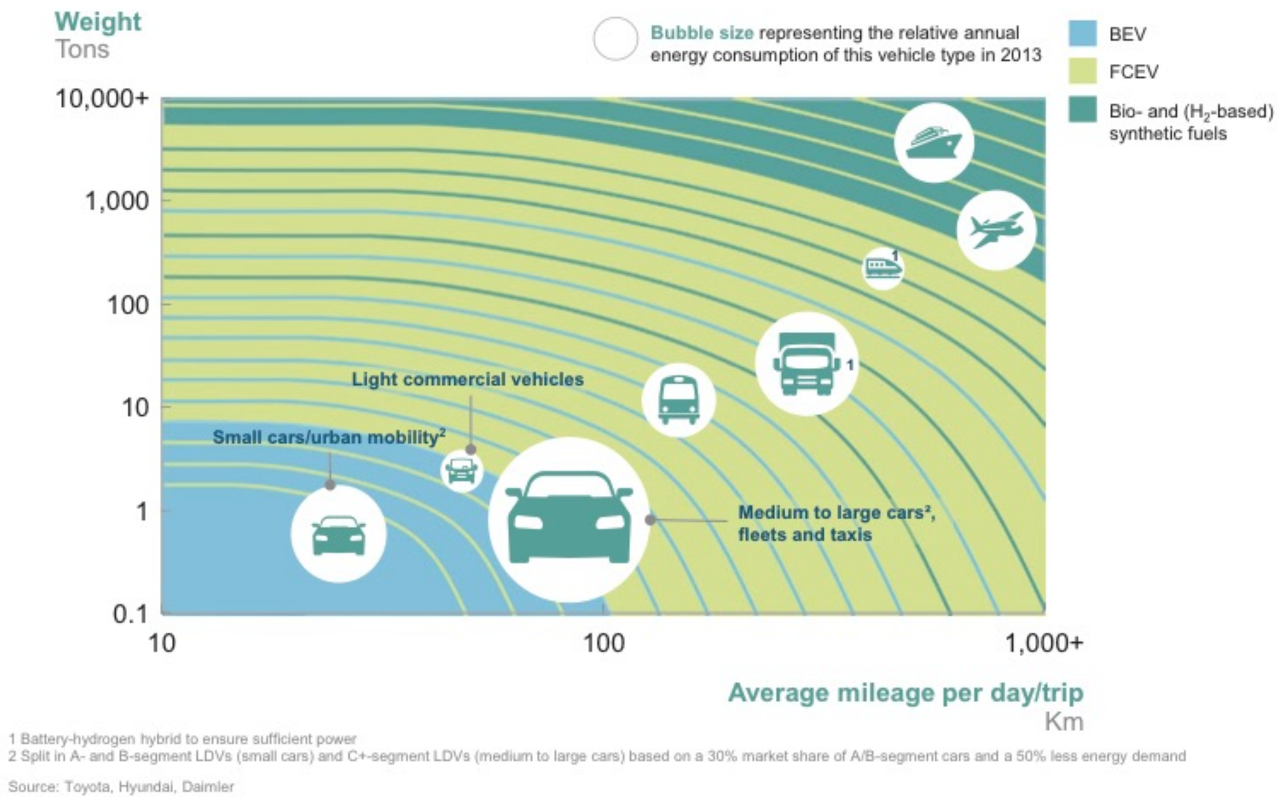
[4] *2016 Edition, California GHG Emission Inventory,* CARB, p. 7
https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2014/ghg_inventory_trends_00-14_20160617.pdf

[5] http://www.plugpower.com/wp-content/uploads/2014/12/PlugPower_7ReasonsH2FC_F102116.pdf
[6] https://energy.gov/eere/fuelcells/h2-scale



FCEVs will play an essential role in decarbonizing transport – Projected economic attractiveness [7]

More flexible as a large scale storage source than pumped hydro or compressed air.

Power-to-Gas (P2G) is a technology that can be similar in scale to pumped hydro and compressed air, but is much more modular and flexible in siting and size (kilowatt to multi-megawatt scale and gigawatt-hours of storage capacity). Unusual about hydrogen is that it is a technology tha itt:

- may store electrical energy and may return (use) the energy in a form other than electric energy,
- may store energy from the grid at one location and may return it to the grid or otherwise use the energy at another location,
- can store energy for long durations (e.g., seasonally, or annually), and
- can transport and distribute renewable energy throughout society at lower cost than electric transmission and distribution, and with inherent storage capacity.

Like customer-side solutions that may never return stored energy to the grid, all storage solutions that provide energy services and benefits to the grid should be properly accommodated in the state's regulatory and market frameworks.

[7] http://hydrogencouncil.com/wp-content/uploads/2017/06/Hydrogen-Council-Vision-Document.pdf

STAGE OF COMMERCIALIZATION

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)[8] 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.

The opportunity of hydrogen and power-to-gas cannot be understated. In Europe, P2G is expected to reach gigawatt levels in the next few years and is in the early commercialization phase in North America, where policy and regulatory support are key to achieving a fully mature market.

The CHBC would specifically like to reference examples from Germany, which has proceeded to build dozens of Power-to-Gas facilities in the last years. Germany is focused on regional grid cooperation as a top priority for the near term, and similar to the CAISO, German TSOs believe this is likely the most cost-effective solution for integrating renewable electricity generation up to 60-70% penetration into the power grid.[9] In addition, Germany continues to focus significantly on P2G development. As stated by the German Federal Economic Development Agency, "Hydrogen and power-to-gas technologies occupy a prominent place in the long-term energy storage plans and future mobility and fuel strategy of the German government."[10]

This is echoed in policy positions throughout the national government, such as the German Energy Agency's Power-to-Gas Roadmap and Strategy Platform that targets 2020-2025 for one GW installed and full commercialization of P2G[11] and the German Federal Environment Agency's approach to achieving near carbon neutrality. This was summed up by the former agency leader (now State Secretary at the Ministry for Energy and Economics), Jochen Flasbarth, as follows:

"The essential component in the transition to a society that is almost completely greenhouse gas-neutral is to convert the power which will be produced entirely from renewables into hydrogen, methane and long-chain hydrocarbons."[12]

In keeping with this view, last year Rainer Baake, State Secretary at the Federal Ministry for Economic Affairs and Energy called for P2G as necessary for decarbonizing existing and potentially a limited number of additional gas power plants to achieve 2050 greenhouse gas targets.[13]

In reflection of federal policy, Germany has become home to several dozen P2G projects, and its energy and environment agencies continue to focus on research and development, as well as policy implementation of power-to-gas and power-to-liquid, e.g. renewable hydrogen produced by electrolysis used to make gas

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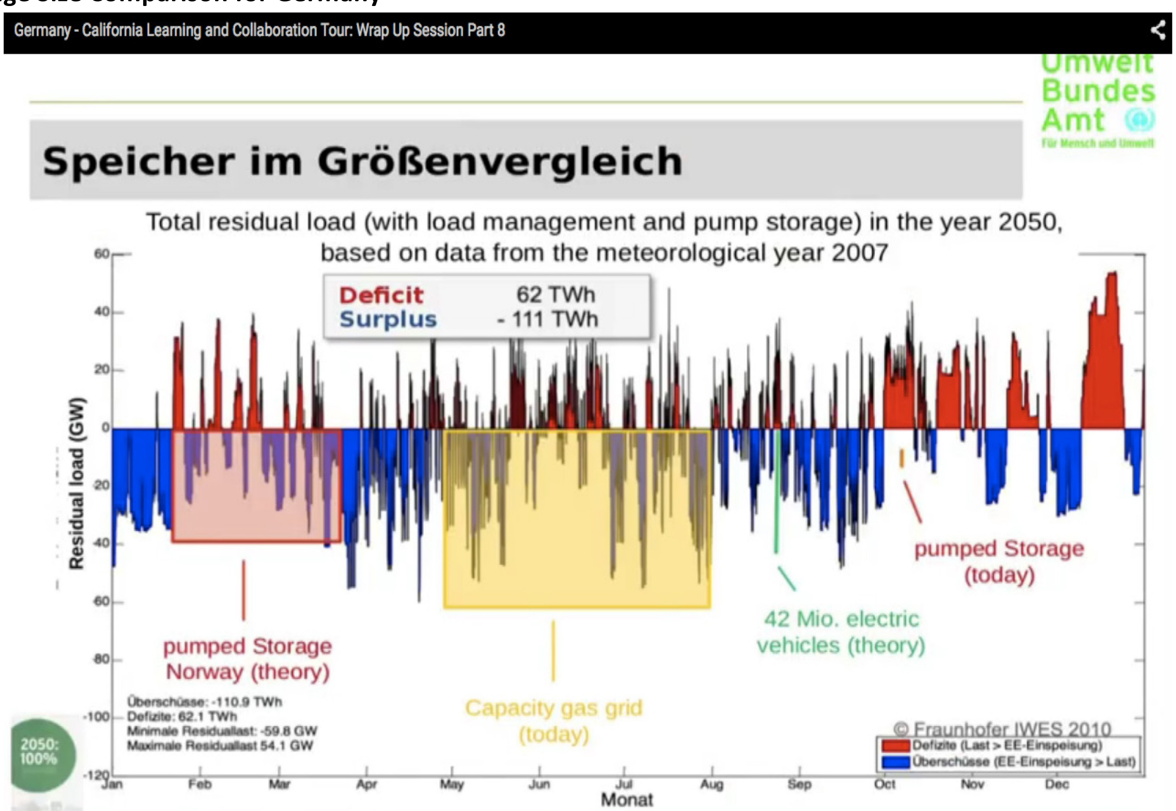
[8] http://www.sciencedirect.com/science/article/pii/S1464285914702329?via%3Dihub
[9] Source: Presentations by 50Hertz CEO Boris Schucht and TenneT COO Ben Voorhorst at 2015 Stakeholder CAISO
[10] 2017/2018 Fact Sheet on The Energy Storage Market in Germany, GTAI
https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Fact-sheets/Energy-environmental/fact- sheet-energy-storage-market-germany-en.pdf?v=9
[11] See: http://www.powertogas.info/english/roadmap-power-to-gas/
[12] https://www.umweltbundesamt.de/en/press/pressinformation/a-greenhouse-gas-neutral-germany-is-almost-possible
[13] https://www.cleanenergywire.org/news/phasing-out-conventional-cars-close-call-rwe

(hydrogen or synthetic methane) and synthetic liquid fuel. In the last year, the German Federal Environment Agency issued two in-depth analytical position papers on these topics.[14]

With regard to battery storage development in Germany, large-scale installations are modest compared to California – 200 MW of large scale battery storage is expected by the end of 2017 – with more activity in the small-scale residential sector.[15] Government support has been limited, and there are currently no plans for that to significantly change. The Federal Ministry of Energy and the Economy gives this restrained view on its website: "*Currently available electrochemical storage facilities do not deliver the necessary technological and commercial conditions for both uses (transportation and storage).*"[16]

Germany's energy system is also interconnected with ten countries with a total transfer capacity of more than 20 GW of hydropower. *Despite this,* the German government is still intent on supporting additional P2G development because, as the figure below illustrates, modeling has shown that the capacity of P2G for integrating high penetrations of renewable power up to 100% in Germany exceeds that of "out of country" (namely Norway) hydropower, thereby providing an even larger storage resource.

Storage Size Comparison for Germany



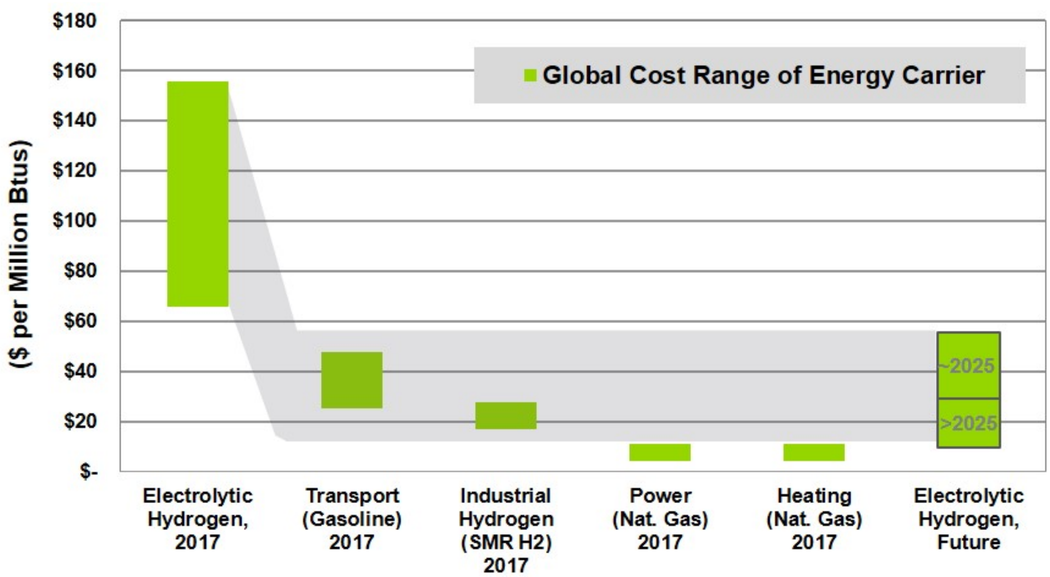
[14] https://www.umweltbundesamt.de/publikationen/integration-of-power-to-gas-power-to-liquids-into; http://www.lbst.de/ressources/docs2016/161005_uba_hintergrund_ptl_barrierrefrei.pdf

[15] https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Fact-sheets/Energy-environmental/fact-sheet-energy-storage-market-germany-en.pdf?v=9

[16] http://www.bmwi.de/Redaktion/EN/Artikel/Energy/research-priorities-energy-storage.html

Moreover, a study conducted by McKinsey & Company found that converting renewable power into hydrogen by P2G followed by salt cavern hydrogen storage and use of combined cycle power plant conversion back to electricity (called Power-to-Power, P2P) was cheaper than pumped hydro storage. The findings showed that P2P with a round trip efficiency of 40% and capital costs of $1,000/kW has a lower levelized cost of electricity than pumped hydro storage, the current lowest cost energy storage solution.[17]

Navigant Research just published an article with current and future cost data for hydrogen from electrolysis. In the analysis, the authors state "a*s 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."*



HYDROGEN COST COMPARISON WITH OTHER ENERGY CARRIERS, WORLD MARKETS: 2017, 2025, AND BEYOND[18]

The CHBC submitted a document titled "Economic of Power-to-Gas (P2G)" to the Renewable Gas docket on June 26, 2017. Also submitted to that 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[19]. The June 2017 Report for the Fuel Cells and Hydrogen 2 Joint Undertaking, states that "*within the portfolio of storage technologies, hydrogen is widely recognized as a promising option for storing large quantities of renewable electricity over longer periods*."[20] One conclusion of the comprehensive report is that power-to-hydrogen is bankable already today, but needs to be allowed to

[17] McKinsey & Company, "Commercialisation of Energy Storage in Europe," Fuel Cell and Hydrogen Joint Undertaking, European Commission, March, 2015.
[18] https://www.navigantresearch.com/blog/a-roadmap-to-the-coming-hydrogen-economy-in-one-chart
[19] http://www.fch.europa.eu/sites/default/files/P2H_Full_Study_FCHJU.pdf
[20] http://www.fch.europa.eu/sites/default/files/P2H_Full_Study_FCHJU.pdf

stack up several revenue streams from a variety of market applications. With that, revenues from providing frequency services to the power system (frequency containment and/or restoration reserves) will significantly improve bankability and cut payback times.

Hydrogen also allows for a cross-silo approach of energy resources by creating a zero-emission fuel for all forms of transportation applications. Today, several thousand hydrogen fuel cell electric vehicles are already 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*[21], 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, U.S. Hybrid, Loop Energy, Kenworth, TransPower, and Nikola Motors.

Applications in goods movement (forklift trucks) are commercial, and demonstrations in rail, airplane and drone applications are being conducted.

Hydrogen's multiple uses allows for the demand for it and its derivative fuels to be broad and not only revolve around one energy sector. Demand from numerous other markets also will impact (renewable) hydrogen development. For example, the higher the requirement for renewable electricity generation, the greater will be the need for large amounts of seasonal storage, as well as the ancillary grid services P2G can provide.

RECOMMENDATIONS FOR GOVERNMENT ACTION

The CHBC believes governmental agencies ought to focus on the following actions:[22]:

- **State agencies need to 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.
- **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. 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.

[21] http://www.energy.ca.gov/2017publications/CEC-600-2017-002/CEC-600-2017-002.pdf
[22] http://docketpublic.energy.ca.gov/PublicDocuments/17-IEPR-10/TN219923_20170626T180524_Emanuel_Wagner_Comments_Economics_of_Power_to_Gas.pdf

- **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 renewable gases through procurement policies.
- The **CAISO ought to examine the ancillary services market for opportunities for P2G**.
- **Pursue high penetrations of renewable electricity generation,** which will necessitate bulk seasonal storage, for which P2G is favorable because of its flexibility and scalability.
- **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.
- 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.[23] 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.

Thank you for your consideration.

Sincerely,

Emanuel Wagner
Assistant Director
California Hydrogen Business Council

[23] 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