## **BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA**

Order Instituting Rulemaking to Develop an Electricity Integrated Resource Planning Framework and to Coordinate and Refine Long-Term Procurement Planning Requirements.

Rulemaking 16-02-007 (Filed February 11, 2016)

## REPLY COMMENTS OF CALIFORNIA HYDROGEN BUSINESS COUNCIL ON THE ADMINISTRATIVE LAW JUDGE'S RULING SEEKING COMMENT ON PROPOSED SCENARIOS FOR THE 2019-2020 REFERENCE SYSTEM PORTFOLIO

Emanuel Wagner Deputy Director **California Hydrogen Business Council** 18847 Via Sereno Yorba Linda, CA 92866 310-455-6095 ewagner@californiahydrogen.org

Dated: March 15, 2019

## **BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA**

Order Instituting Rulemaking to Develop an Electricity Integrated Resource Planning Framework and to Coordinate and Refine Long-Term Procurement Planning Requirements.

Rulemaking 16-02-007 (Filed February 11, 2016)

## REPLY COMMENTS OF CALIFORNIA HYDROGEN BUSINESS COUNCIL ON THE ADMINISTRATIVE LAW JUDGE'S RULING SEEKING COMMENT ON PROPOSED SCENARIOS FOR THE 2019-2020 REFERENCE SYSTEM PORTFOLIO

California Hydrogen Business Council (CHBC)<sup>1</sup> respectfully submits the following reply

comments pursuant to the Administrative Law Judge's (ALJ) Ruling Seeking Comments on

Proposed Scenarios for the 2019-2020 Reference System Portfolio, dated February 11, 2019

(ALJ Ruling).

<sup>&</sup>lt;sup>1</sup> The views expressed in these comments are those of the CHBC, and do not necessarily reflect the views of all of the individual CHBC member companies. Members of the CHBC include Advanced Power and Energy Program at UCI, Air Liquide Advanced Technologies U.S., Alameda-Contra Costa Transit District (AC Transit), American Honda Motor Company, Anaerobe Systems, Andreas Hofer GmbH, Arriba Energy, Ballard Power Systems, Bay Area Air Quality Management District, Beijing SinoHytec, Black & Veatch, BMW of North America, BSHARK, California Air Resources Board, California Fuel Cell Partnership, California Performance Engineering, CALSTART, Cambridge LCF Group, Center for Transportation and the Environment (CTE), Charm Industrial, Chiyoda Corporation, Coalition for Clean Air, Community Environmental Services, CP Industries, DasH2energy, Dominion Energy, Eco Energy International, ElDorado National - California, Energy Independence Now (EIN), EPC - Engineering, Procurement & Construction, Ergostech Renewal Energy Solution, EWII Fuel Cells, FIBA Technologies, Inc., First Element Fuel, FuelCell Energy, GenCell, General Motors, Geoffrey Budd G&SB Consulting Ltd, Giner ELX, Gladstein, Neandross & Associates, Greenlight Innovation, GTA, GTM Technologies, H2B2, H2Safe, Hexagon Lincoln, LLC, Hitachi Zosen Inova ETOGAS GmbH, HODPros, Horizon Fuel Cells, Hydrogenics, Hydrogenious Technologies, Hydrogen Law, HydrogenXT, HyET - Hydrogen Efficiency Technologies, Hyundai Motor Company, ITM Power, Ivys, Iwatani Corporation of America, Johnson Matthey Fuel Cells, Kontak, KORE Infrastructure, Kraft Powercon, Life Cycle Associates, Linde North America, Longitude 122 West, Loop Energy, Magnum Energy, Millennium Reign Energy, Montreux Energy, Motive Energy Telecommunications, MPL Consulting, Natural Gas Fueling Solutions - NGFS, Natural Hydrogen Energy, Nel Hydrogen, Neo-H2, New Flyer of America, Next Hydrogen, Noyes Law Corporation, Nuvera Fuel Cells, Pacific Gas and Electric Company - PG&E, PDC Machines, Planet Hydrogen, Plug Power, Politecnico Di Torino, Port of Long Beach, Powertech Labs, Primidea Building Solutions, RG Associates, Rio Hondo College, Rix Industries, Sacramento Municipal Utility District (SMUD), SAFCell, Schatz Energy Research Center (SERC), Sheldon Research and Consulting, South Coast Air Quality Management District, Southern California Gas Company, Strategic Analysis, Sumitomo Corporation of Americas, Sumitomo Electric, Sunline Transit Agency, T2M Global, Tatsuno North America, The Leighty Foundation, TLM Petro Labor Force, Toyota Motor Sales, Trillium, True Zero, United Hydrogen Group, US Hybrid, Verde, Vinjamuri Innovations, Winkelmann Flowform Technology, WireTough Cylinders, Zero Carbon Energy Solutions.

## Contents

I.	]	<b>REPLY COMMENTS TO SELECTED COMMENTS FROM PARTIES 4</b>
A.	. (	Comments of CESA 4
B.		Comments of Southern California Gas Company (SoCalGas) 4
C.	. (	Comments of Protect Our Communities Foundation 4
	1. 10	Hydrogen is key to decarbonizing the energy system in California and beyond and 0% renewable hydrogen is possible across sectors with the right policy support
	2.	POC's information on the efficiency of electrolytic hydrogen is misleading
	3.	Electrolytic hydrogen storage can be cost competitive with batteries at high capacity 11
	4. du	Electrolytic hydrogen and methanated electrolytic hydrogen serve needs for long ration and seasonal storage that batteries cannot
	5. pol	Hydrogen fuel cell technology for transportation is an established part of California licy and necessary to decarbonize this sector
II.	(	CONCLUSION 24

## **Table of Figures**

Figure 1 - Storage System Capital Cost of P2G2P vs Li-Ion Batteries13
Figure 2 – Fuel Cell Cost Improvements over the Last Decade at Low and High Volumes 15
Figure 3 – Storage Capacity of Different Energy Storage Technologies in Terms of Power and
Duration
Figure 4 - Residual Load Resulting from Simulations of a 100% Renewable California Electric
Grid, Hourly Matching Demand with Available Solar and Wind Resources
Figure 5 – FCEV, BEV and ICE CO2 Emissions over Entire Lifecycle
Figure 6 – Comparison of the Cumulative Investment of Supply Infrastructures (BEV & FCEV)

### I. REPLY COMMENTS TO SELECTED COMMENTS FROM PARTIES

#### A. Comments of CESA

The CHBC supports CESA's comment that the High Hydrogen Scenario ought not be "limited to looking at how an increased level of FCEVs and fewer battery electric vehicles can support carbon mitigation"<sup>2</sup> and that it instead ought to include hydrogen storage capabilities. We also agree that improvements to models may "be needed in future IRP cycles to incorporate multi-day and seasonal storage capabilities,"<sup>3</sup> in order to capture the value of hydrogen as an energy storage resource.

### B. Comments of Southern California Gas Company (SoCalGas)

CHBC broadly agrees with SoCalGas' comments regarding hydrogen and that hydrogen, with its many beneficial uses "*can play a critical role as part of an optimal, risk-mitigated balanced energy portfolio mix in California as part of this cross functional energy interaction and integration across multiple economic sectors*" and that "*(t)his is an especially important consideration under deep decarbonization scenarios.*<sup>4</sup>

#### C. Comments of Protect Our Communities Foundation

In their comments, Protect Our Communities Foundation (POC) makes a number of statements about hydrogen that are inaccurate and do not reflect the current state of the industry or

<sup>&</sup>lt;sup>2</sup> CESA Comments on Proposed Scenarios for 2019-2020 Reference System Portfolio, p. 4 <u>http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M272/K339/272339531.PDF</u>

<sup>&</sup>lt;sup>3</sup> CESA Comments on Proposed Scenarios for 2019-2020 Reference System Portfolio, p. 5

<sup>&</sup>lt;sup>4</sup> So Cal Gas Comments on Proposed Scenarios for 2019-2020 Reference System Portfolio, p.2

its forecasted technology development and cost reduction.<sup>5</sup> POC comments that hydrogen is "expensive compared to solar and batteries ... emits significant amounts of CO2 and is inefficient" and that a No Hydrogen "Scenario represents the only way to eliminate greenhouse gas ("GHG") emissions entirely and thus comes the closest to achieving carbon neutrality."<sup>6</sup> POC further states that the "low production costs of (hydrogen production) technologies utilizing fossil fuels compared to the relatively high costs of renewable alternatives suggests that this trend (of producing hydrogen with fossil fuels) will not change in the foreseeable future."<sup>7</sup> Each of these assertions is flawed, as explained below.

## 1. Hydrogen is key to decarbonizing the energy system in California and beyond and 100% renewable hydrogen is possible across sectors with the right policy support

Hydrogen does not contain or emit CO2. When produced with renewable feedstock, it does not emit <u>any</u> greenhouse gas over its lifecycle. POC argues that California should not pursue hydrogen development because most global hydrogen production uses fossil fuels as feedstock.<sup>8</sup> While it is true that most hydrogen production around the world still uses traditional steam methane reforming fueled by natural gas<sup>9</sup>, the industry both in California and globally is, much like the electricity industry, transitioning toward renewable sources. Just as we would not

<sup>&</sup>lt;sup>5</sup> POC Comments on Proposed Scenarios for 2019-2020 Reference System Portfolio

http://docs.cpuc.ca.gov/SearchRes.aspx?DocFormat=ALL&DocID=266859657

<sup>&</sup>lt;sup>6</sup> POC Comments on Proposed Scenarios for 2019-2020 Reference System Portfolio, p. 2

<sup>&</sup>lt;sup>7</sup> POC's statements are based on a study published by the International Journal of Hydrogen Energy 42.1 titled: Methane

Cracking As A Bridge Technology to the Hydrogen Economy, Weger, Lindsey, et.al., 2017, pp.721-722.

<sup>&</sup>lt;sup>8</sup> POC Comments on Proposed Scenarios for 2019-2020 Reference System Portfolio

<sup>&</sup>lt;sup>9</sup> Hydrogen is overwhelmingly used in oil refining, chemical, fertilizer and food production, which are not subject to renewable hydrogen mandates or incentives.

want to stop deploying battery technologies for storage, vehicles, and other useful applications simply because most global electricity is generated from fossil fuels, <sup>10</sup> we should also not discontinue hydrogen energy technology alongside renewable and zero carbon electricity generation, as it is a complementary solution that is needed to achieve full decarbonization across sectors.

One method of making decarbonized hydrogen is to use organic feedstocks, such as using biomethane in steam methane reforming. There are also emerging technologies, such as producing hydrogen directly with solar energy.<sup>11</sup> The most scalable pathway is to use electrolysis, a mature technology that splits water into hydrogen and oxygen that when powered by renewable electricity, creates renewable hydrogen that is GHG-free from well to wheel in any use case. As California's electricity grid transitions to 100% renewable and zero carbon sources by 2045, pursuant to the mandate in SB 100, hydrogen can also become 100% decarbonized with the right policy and regulatory support in place.

Supporting decarbonized hydrogen production and distribution is a foundational and integral part of California's climate, renewable energy, and clean air policy. Before policy direction on any other transportation fuel, SB 1505 (2006) required renewable hydrogen to make up at least a third of hydrogen for transportation fueling in California<sup>12</sup>, a target that the hydrogen industry has already surpassed.<sup>13</sup> In 2018, California adopted SB 1369<sup>14</sup> requiring "the PUC, State Air Resources Board, and Energy Commission to consider green electrolytic

<sup>&</sup>lt;sup>10</sup> For 2017 global renewable electricity generation statistics, see: <u>http://www.ren21.net/gsr-</u> 2018/chapters/chapter 01/chapter 01/#sub 4

<sup>&</sup>lt;sup>11</sup> https://cleantechnica.com/2019/03/03/belgian-scientists-announce-new-solar-panel-that-makes-hydrogen/
<sup>12</sup> https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill\_id=200520060SB1505

<sup>&</sup>lt;sup>13</sup> According to ARB's AB8 report, between 37%-42% of hydrogen for transportation are renewable in California.

<sup>&</sup>lt;sup>14</sup> https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill\_id=201720180SB1369

hydrogen an eligible form of energy storage, and to consider other potential uses of green *electrolytic hydrogen.*<sup>15</sup> The first generation of in-state renewable hydrogen production facilities are under development, including a 100% renewable hydrogen production facility in Moreno Valley, Riverside County, due to come online in 2020 and funded by the Energy Commission, which will use dedicated renewable generation to power a 2.5 MW electrolyzer to produce hydrogen.<sup>16</sup> Additional projects by H2B2 and FuelCell Energy will bring to total in state renewable hydrogen production to over 2,600 tons annually.<sup>17,18</sup> Moreover, SB 1383, which was adopted in 2017, requires the Public Utilities Commission, along with other state agencies, "to consider and, as appropriate, adopt policies and incentives to significantly increase the sustainable production and use of renewable gas."<sup>19</sup> The CHBC worked closely with the author of the bill to ensure that the law explicitly does not limit the scope of the agencies' consideration to biomethane and biogas when deciding upon solutions to mitigating short lived climate pollutants, but instead to broaden it to "renewable gas," so that renewable hydrogen is included in all relevant deliberations. The Energy Commission's 2017 Integrated Energy Policy Report reinforces this in its recommendations on implementing SB 1383, explicitly calling for inclusion of hydrogen produced via electrolysis and synthetic methane derived from this process in the suite of solutions California deploys to mitigate short lived climate pollutants.<sup>20</sup> Such developments in California point out that the state is clearly trending toward renewable hydrogen, contrary to what POC asserts. Hydrogen production is furthermore assured to 100%

<sup>&</sup>lt;sup>15</sup> https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill\_id=201720180SB1369

<sup>&</sup>lt;sup>16</sup> This project is being developed by Hydrogenics and Stratosfuel with funding from the Energy Commission.

<sup>&</sup>lt;sup>17</sup> https://www.energy.ca.gov/2018publications/CEC-600-2018-004/CEC-600-2018-004.pdf

<sup>&</sup>lt;sup>18</sup> <u>https://www.forbes.com/sites/alanohnsman/2017/11/30/toyota-to-turn-cow-manure-into-hydrogen-to-back-its-fuel-cell-vehicle-push/#751f73ec4589</u>

<sup>&</sup>lt;sup>19</sup> SB 1383 text: <u>https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill\_id=201520160SB1383</u>

<sup>&</sup>lt;sup>20</sup> See 2017 IEPR pp. 285-286. Note the IEPR uses the term "power to gas," which is hydrogen produced via electrolysis using grid electricity or dedicated renewable generation, or this hydrogen synthesized into methane.

decarbonize along with California's electricity grid, if there are additional policy and regulatory measures in place to support this, such as access to wholesale or low retail electricity rates and low transmission and distribution charges for electrolysis, standards and protocols for hydrogen pipeline injection, and rate structures that capture the ramping ancillary services value of electrolysis (e.g., VAR support, frequency regulation).

Decarbonizing hydrogen is also the direction that the global hydrogen industry and policymakers around the world are pursuing. At the September 2018 Global Climate Action Summit in San Francisco, the Hydrogen Council - a coalition of over 50 CEOs from the hydrogen industry - announced a target of transitioning to 100% decarbonized hydrogen in the transportation sector by 2030, with other sectors following if supportive policies are enacted. The CHBC supports this goal.<sup>21</sup> In California, Southern California Gas Company just announced that it will blend 20% renewable gas into its gas delivery system by 2030<sup>22</sup>, and offer renewable natural gas to residential customers.<sup>23</sup> The CHBC also applauded this commitment.<sup>24</sup> The European electricity industry has moreover concluded that renewable hydrogen is integral to achieving deep decarbonization and electrification.<sup>25</sup> In the UK, the H21 project is aiming to convert North of England's gas grid to hydrogen as part of the nation's deep decarbonization program, with a view toward switching at least 3.7 million homes from natural gas to hydrogen and transitioning the sources of hydrogen to zero carbon feedstocks as the project progresses.<sup>26</sup> Keele University is also exploring blending up

<sup>&</sup>lt;sup>21</sup> https://www.californiahydrogen.org/2018/12/20/chbc-endorses-full-decarbonization-goal-of-hydrogen-in-transportation-by-2030/

<sup>&</sup>lt;sup>22</sup> <u>https://www.sempra.com/socalgas-announces-vision-be-cleanest-natural-gas-utility-north-america</u>

<sup>&</sup>lt;sup>23</sup> https://www.sempra.com/socalgas-seeks-offer-renewable-natural-gas-customers

<sup>&</sup>lt;sup>24</sup> <u>https://www.californiahydrogen.org/2019/03/11/chbc-supports-socalgas-decarbonization-commitment-and-encourages-hydrogen-to-play-a-major-role/</u>

<sup>&</sup>lt;sup>25</sup> <u>https://cdn.eurelectric.org/media/3172/decarbonisation-pathways-electrificatino-part-study-results-h-AD171CCC.pdf</u>

<sup>&</sup>lt;sup>26</sup> https://www.northerngasnetworks.co.uk/wp-content/uploads/2018/11/H21-Meeting-UK-Climate-Change-Obligations.pdf

to 20% electrolytic hydrogen into its private gas network beginning in Summer 2019 to reduce carbon emissions from heating in buildings, in what is known as the HyDeploy Project.<sup>27</sup> Blending hydrogen with natural gas across the U.K. is estimated to reduce 6 million tons of carbon annually, the equivalent of taking 2.5 million cars off the roads. The German government has concluded that electrolytic hydrogen and its derivatives will be an "essential component" to the nation achieving near carbon neutrality<sup>28</sup> and is committed to full commercialization of these technologies by 2022.<sup>29</sup> France also sees decarbonized hydrogen as potentially "one of the pillars of the carbon neutral model" and is investing 100 million euros to reach a target of 40% decarbonized hydrogen for industrial use by 2028, along with plans to develop hydrogen for energy storage and transportation.<sup>30</sup> Similar decarbonized hydrogen ambitions are underway elsewhere in Europe, as well as in Australia, Canada, and Asia. Such facts negate POC's claim that decarbonized hydrogen will not develop for the foreseeable future and instead prove that the industry is in fact currently trending toward decarbonization at increasing speed and scale.

In Japan, under the leadership of the Ministry of Economy, Trade and Industry and the Cabinet Office, efforts are underway to develop hydrogen as one of the nation's core energies. It marks the first step toward realizing a CO2-free hydrogen society, a key strategy set last December at the second meeting of Japan's Ministerial Council on Renewable Energy, Hydrogen and Related Issues.<sup>31</sup> Electrolytic hydrogen is a key to decarbonization in part because it is particularly equipped to meet the need for round-the-clock load following generation that is needed in high renewable electricity scenarios. California, with a substantial and increasing deployment of

- <sup>28</sup> https://www.umweltbundesamt.de/en/press/pressinformation/a-greenhouse-gas-neutral-germany-is-almost-possible
   <sup>29</sup> http://www.powertogas.info/fileadmin/content/Downloads/Brosch%C3%BCren/dena\_PowertoGas\_2015\_engl.pdf

<sup>31</sup> https://www.businesswire.com/news/home/20180125005516/en/MHPS-Successfully-Tests-Large-Scale-High-Efficiency%C2%A0Gas-Turbine-Fueled

<sup>&</sup>lt;sup>27</sup> https://hvdeploy.co.uk/app/uploads/2017/11/13647 KEELE HYDEPLOY FAO BOOKLET A5 WEB.pdf

<sup>&</sup>lt;sup>30</sup> https://renewablesnow.com/news/france-unveils-hydrogen-ambitions-615072/

intermittent and diurnal varying renewables with low capacity factors is experiencing challenging grid stability issues and gaps in power generation that will increase if California is unable to recognize a portfolio approach to cross sector energy integration, as the state progresses toward SB 100's goals of 100% renewable and zero carbon electricity generation. The use of short-duration energy storage technologies (mostly lithium ion battery systems) to address these gaps has resulted in increased emissions on the California grid.<sup>32</sup> Reversible fuel cells or electrolyzers can serve as a controllable load that correspondingly helps the grid manage instances of overproduction from renewable resources to produce a renewable hydrogen fuel for storage and later electricity production or for fuel cell vehicles. Zero Carbon emission hydrogen fueled utility scale combustion turbines are technically feasible today with generation equipment projected to be similar to installed costs of combined cycle gas turbine generators. While battery energy storage is necessary, the inclusion of clean, 24/7 load-following generation is also required for a successful conversion to 100% clean energy.<sup>33</sup>

## 2. POC's information on the efficiency of electrolytic hydrogen is misleading

POC cites a source from 2006 that states the "*hydrogen via the electrolysis process is only 20-25% efficient*,"<sup>34</sup> as an argument for why hydrogen is unfavorable as a form of electricity storage, as if efficiency is the only metric by which to evaluate energy storage technologies. In actuality, policy makers will need to look at the abatement cost for greenhouse

<sup>&</sup>lt;sup>32</sup> Itron, Energy + Environmental Economics (E3), 2017 SGIP Advanced Energy Storage Impact Evaluation, available on-line at: http://www.cpuc.ca.gov/uploadedFiles/CPUC\_Public\_Website/Content/Utilities\_and\_Industries/Energy/Energy\_Programs/Dema\_nd\_Side\_Management/Customer\_Gen\_and\_Storage/2017\_SGIP\_AES\_Impact\_Evaluation.pdf

 <sup>&</sup>lt;sup>33</sup> Davis, et. al., Net-Zero Emissions Energy Systems, Science 360, 1419 (2018) 29 June 2018.
 <sup>34</sup> POC Comments on Proposed Scenarios for 2019-2020 Reference System Portfolio, p. 13

<sup>10</sup> 

gas reduction while consumers will look for total cost of ownership. Efficiency is part of that calculation, but not in itself the metric to use. As for the POC citation, the source refers to hydrogen for transportation, not as an electricity storage carrier, and thus does not apply. Electricity-to-hydrogen conversion efficiency is comparable to the efficiency of batteries in real-life operation in grid applications. Efficiency is often considered the ultimate use in comparing electrolytic hydrogen to batteries, but efficiency of the ultimate use of the returned energy is not attributed in battery use cases, and it is apples-to-oranges to do so for electrolytic hydrogen. At the end of the day, comparison between batteries and electrolytic hydrogen fuel, electrolysis will generally play well. Reversible electrochemical cells are currently under development and have the potential to exceed 60% round trip efficiency. Coupled with its low cost of storage duration, hydrogen energy storage has outstanding prospects to become the technology of choice for long-duration storage.

# 3. Electrolytic hydrogen storage can be cost competitive with batteries at high capacity

Regarding the cost effectiveness of hydrogen compared to batteries, electrolytic hydrogen as a storage resource becomes more cost effective as the storage capacity increases due to the low incremental cost of each additional unit of energy stored. All storage technologies are composed of two main elements: a Power Conversion System (PCS) and an Energy Storage System (ESS) [source: Lazard]. Electro-hydrogen can use a dedicated hydrogen storage medium such as a tank or liquid carrier as its ESS or can employ geological storage, and can also leverage the existing, installed natural gas infrastructure to serve as the ESS. When comparing capital costs in terms of the PCS only, electro-hydrogen currently has significantly lower costs, in

11

the range of \$522-\$1,000/kW<sup>35,36</sup>, when compared to Li-Ion batteries, which are in the range of \$1,328-\$2,935/kW.<sup>37</sup> Both of these ranges of cost are for widespread deployment of the technology (i.e., electrolyzers and Li-ion batteries). Note that battery systems can provide two-way power conversion, whereas the electro-hydrogen case can use existing equipment (e.g., Natural Gas Combined Cycle [NGCC] plants) to reconvert the stored energy to electric form. Notably, gas turbines that can be retrofitted into NGCC plants to take up to 30% hydrogen blends are currently on the market, with 100% hydrogen turbines expected to be commercially available soon, and fuel cells have been commercially available for decades.<sup>38</sup>

When comparing installed cost in terms energy storage capacity, the discharge duration must be considered. Battery storage costs per kWh stored are constant, i.e., for each additional kWh of storage capacity, an additional unit of storage must be added at a fixed capital cost. However, when electro-hydrogen relies on the massive capacity of the installed natural gas grid to serve as the ESS, the installed storage cost per kWh of an electrolytic hydrogen system decreases as the capacity increases. The figure below shows the capital cost<sup>39,40</sup>, adjusted for conversion losses, for a lithium-ion battery system and an electrolyzer system injecting hydrogen onto the gas grid for later use in an existing combined-cycle power plant for charging durations up to 72 hours. The latter electrolyzer case is dubbed Power-to-Gas-to-Power (P2G2P). See Figure 1 below. Note that power-to-gas in this case refers to electrolytic hydrogen. Power-to-gas

<sup>37</sup> DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA (SAND2015-1002)

<sup>&</sup>lt;sup>35</sup> McKinsey & Company, "Commercialisation of Energy Storage in Europe," Fuel Cell and Hydrogen Joint Undertaking, European Commission, March, 2015.

<sup>&</sup>lt;sup>36</sup> Nel ASA, Press Release / OSE-Filing, "Nel ASA enters into exclusive NOK 450 million industrial-scale power-to-gas framework agreement with H2V PRODUCT," Oslo, Norway, June 13, 2017.

<sup>&</sup>lt;sup>38</sup> <u>https://www.mhps.com/special/hydrogen/article\_1/index.html</u>

<sup>&</sup>lt;sup>39</sup> U.S. Department of Energy, H2A Production Case Studies for Current (and Future) Central Hydrogen Production from Solid Oxide and PEM Electrolysis (Version 3.0)

<sup>&</sup>lt;sup>40</sup> DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA, Sandia National Laboratory, 2015.

can also refer to methanated electrolytic hydrogen. POC's comment that power-to-gas is necessarily methanated electrolytic hydrogen is incorrect.<sup>41</sup>

The cost ranges shown in Figure 1 identify the relative potential for each of these technologies for reducing storage costs. The chart shows that P2G2P could reach cost parity with a battery system with a storage duration of less than 5 hours. For storage duration of greater than about 50 hours, P2G2P is forecast to provide storage less expensively than batteries even when comparing current P2G2P costs to forecast future costs for batteries.



Figure 1 - Storage System Capital Cost of P2G2P vs Li-Ion Batteries

<sup>&</sup>lt;sup>41</sup> POC Comments on Proposed Scenarios for 2019-2020 Reference System Portfolio, p. 15

A more accurate way to compare storage technologies, however, is to calculate levelized cost of storage (LCOS), i.e. the cost, over the life of the project, of storing a kWh of electricity and returning it to the electric grid for later use. While LCOS studies of battery technologies are common (see Lazard), few researchers have analyzed the LCOS of electrolytic hydrogen in comparison to battery storage technologies. Researchers at UC Irvine are developing a model to make an accurate comparison. In order to maintain consistency across many energy production scenarios, the model does not consider the cost of the electricity used to charge the storage system. Under highly curtailed renewable scenarios, excess solar power can be obtained for very low prices. Initial results from the model, using a capacity factor of 50%, or 12 hours of charging time per day, suggest an LCOS for batteries of 10-22 ¢/kWh compared to electrolytic hydrogen of 11-40 ¢/kWh, depending upon the technologies and pathways considered. Under future systems cost and efficiency forecasts, the model suggests an LCOS of batteries of 5-15  $\phi$ /kWh compared to electrolytic hydrogen of 8-21 ¢/kWh. Electrolytic hydrogen can be cost competitive with batteries and promises to serve an important role fulfilling the need for energy storage in California.

The National Renewable Energy Laboratory (NREL) agrees and also has found that "(*i*)*nitial cost analysis indicates that hydrogen systems could be competitive with battery systems for energy storage and could be a viable alternative to pumped storage hydro and CAES at locations where these latter two technologies are not favorable.*"<sup>42</sup> Similarly, a World Energy Resources Report on E-storage<sup>43</sup> provides a cost comparison of multiple energy storage

<sup>&</sup>lt;sup>42</sup> <u>http://www.nrel.gov/docs/fy16osti/64764.pdf</u>

<sup>&</sup>lt;sup>43</sup> https://www.worldenergy.org/wp-content/uploads/2016/03/Resources-E-storage-report-2016.02.04.pdf

technologies including electrolytic hydrogen and shows that the cost economics by 2030 is comparable with battery technologies, including Redox Flow (Redox) and Li-Ion (Li) batteries.

The U.S. Department of Energy is showing a 60% cost reduction of fuel cells in the last 10 years, with \$50/kW costs at volume production of 100,000 units/year, see Figure 2.

## **Fuel Cell Cost Improvements**



† SA Inc., bottom-up analysis of model system based on commercially available FCEVs

https://www.hydrogen.energy.gov/pdfs/17007\_fuel\_cell\_system\_cost\_2017.pdf

U.S. DEPARTMENT OF ENERGY OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY FUEL CELL TECHNOLOGIES OFFICE

Figure 2 – Fuel Cell Cost Improvements over the Last Decade at Low and High Volumes<sup>44</sup>

<sup>&</sup>lt;sup>44</sup> <u>https://www.hydrogen.energy.gov/pdfs/review18/fc01\_papageorgopoulos\_2018\_o.pdf</u>

Hydrogen production based on wind power can already be commercially viable today based on the market conditions in Germany and Texas, according to economists at the Technical University of Munich (TUM). Flexible electrolytic hydrogen could make this technology a key component in the transition of the energy system.<sup>45</sup>

## 4. Electrolytic hydrogen and methanated electrolytic hydrogen serve needs for long duration and seasonal storage that batteries cannot

It should also be noted that electrolytic hydrogen and P2G2P can store massive amounts of energy and can shift such energy over very long periods of time, spanning weeks to months, and seasons, which is difficult or impossible for Li-ion batteries, despite their advantage in roundtrip efficiency. Electrolytic hydrogen and methanated electrolytic hydrogen are possibly the only solution for storage up to the terawatt-hour scale, which will be essential for long duration and seasonal storage as California transitions to a 100% renewable, zero carbon electricity supply. Figure 3 shows the capacity that hydrogen storage offers compared to other energy storage technologies. <sup>46</sup>

Figure 4 shows residual load resulting from simulations of a 100% renewable California electric grid, hourly matching demand with available solar and wind resources. Two cases are considered: (1) wind dominant, and (2) solar dominant. While the amount of electric energy produced is slightly greater than the demand, it is clear that massive and seasonal energy storage

<sup>&</sup>lt;sup>45</sup> https://www.tum.de/en/about-tum/news/press-releases/detail/article/35259/

<sup>&</sup>lt;sup>46</sup> http://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf, p. 58

Exhibit 21: Hydrogen can be stored for months without losing much of its power



Technology overview in power and time



is required. Options for storage technologies are also presented in Figure 4 showing that both the power and energy capacity of hydrogen energy storage in current gas infrastructure (pipelines and storage facilities) is the only option that can technically balance renewable power and energy with load on an annual basis. The magnitude of hydrogen energy storage compared to existing pumped hydro and to lithium-ion batteries (from complete electrification of the light and medium duty fleet of 21 million vehicles) makes hydrogen energy storage the only technology able to balance hourly and seasonally load and generation sufficiently. This fact, together with the lack of self-discharge or evaporation, and separate power and energy scaling that enables cost effective seasonal storage, make hydrogen essential for achieving our zeroemission goals. While seasonal storage appears more clearly required for the wind dominant case



(Figure 4 (a)), similar amounts of seasonal storage and more daily storage are required for the solar dominant case (Figure 4 (b)).<sup>47</sup>

*Figure 4 - Residual Load Resulting from Simulations of a 100% Renewable California Electric Grid, Hourly Matching Demand with Available Solar and Wind Resources.*<sup>48</sup>

<sup>&</sup>lt;sup>47</sup> Saeedmanesh, A., Mac Kinnon, M. and Brouwer, J. *Hydrogen is Essential for Sustainability*, Elsevier Science, 22 November 2018. <u>https://doi.org/10.1016/j.coelec.2018.11.009</u>

<sup>&</sup>lt;sup>48</sup> 1-year hourly simulation of the load and power generation dynamics of a 100% renewable grid in California, and the capacity of different storage technologies for (a) wind dominant case (37 GW solar capacity and 80 GW wind capacity installed) and (b) solar dominant case (162 GW solar capacity, 5.6 GW wind capacity installed).

In 2018, the National Fuel Cell Research Center calculated that in order to meet the total world electricity demand with solar and wind and batteries alone, over 157,000 TWh of electricity would be consumed, requiring 20,000 TWh of storage. To meet that storage demand with batteries alone, 3,144 Mt of Lithium and 25,815 Mt of Cobalt would be required, which is more than currently in existence on the planet.<sup>49</sup>

Electrolytic hydrogen storage additionally has more continuous capacity in less space than Li-ion batteries. This is particularly important when there is a need to absorb continuous power generation or to provide time shifting of load over long periods. For example, a **1.2 MW** Li-ion battery installation in Quebec uses a **53 ft.** container and has a storage limit of only **1.2 MWh at a time**.<sup>50</sup> By comparison, a **1.5 MW** capacity electrolyzer project in Hamburg uses a **40 ft**. container and can store up to **36 MWh**/**day**, as long as it is connected to the gas grid, and electricity generation to power the electrolyzer is continuous.<sup>51</sup>

To be clear, CHBC fully supports advancement of battery technology for storage and other applications as a critical element of decarbonizing the energy system and optimizing renewable electricity deployment. We strongly believe that hydrogen storage solutions and batteries are complementary and that opting for one over the other will impede successful realization of California's deep decarbonization targets.

<sup>&</sup>lt;sup>49</sup> https://www.californiahydrogen.org/wp-content/uploads/2018/11/20181106-ESNA-CHBC-HES-Workshop\_Brouwer.pdf

<sup>&</sup>lt;sup>50</sup> http://news.hydroquebec.com/en/press-releases/799/a-first-prototype-for-esstalion-technologies-inc/

<sup>&</sup>lt;sup>51</sup> https://www.hydrogenics.com/2015/10/15/e-on-inaugurates-energy-storage-facility-using-hydrogenics-pem-technology/

# 5. Hydrogen fuel cell technology for transportation is an established part of California policy and necessary to decarbonize this sector

While POC pits hydrogen fuel cell and battery technology against each other, since 2009, California legislation and executive orders have prioritized both battery electric and hydrogen fuel cell electric vehicles in its zero emissions transportation strategy. We strongly support this approach over adopting the battery-only strategy. The U.S. federal government also embraces both types of technology, evidenced most recently in an announcement earlier this month by the US Department of Energy in which both types of technology along with relevant infrastructure projects are included in a \$51.1 million grant solicitation.<sup>52</sup>

Lifecycle analysis show that hydrogen fuel cell electric vehicles can provide significant GHG emission improvements, even over BEVs, see Figure 5.<sup>53</sup>

<sup>&</sup>lt;sup>52</sup> <u>https://www.energy.gov/articles/department-energy-announces-50-million-commercial-truck-road-vehicle-and-gaseous-fuels</u>

<sup>&</sup>lt;sup>53</sup> http://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf



## Exhibit 13: FCEVs can achieve very low CO, emissions if the whole lifecycle is considered

#### Figure 5 – FCEV, BEV and ICE CO2 Emissions over Entire Lifecycle

SOURCE: EPA; A Portfolio of Powertrains for Europe (2010); Toyota Mirai LCA; IVL; Enerdata; expert interviews

Battery and fuel cell electric transportation technologies are more and less appropriate for certain applications and situations, and in fact complimentary both in the ecosystem of zero emissions transportation and even sometimes within vehicles that use a combination of plug in and fuel cell electric technologies. Fuel cell bus manufacturers include New Flyer, ElDorado National California, BAE Systems, American Fuel Cell Bus, Van Hool, and the total cost per mile is comparable to CNG buses we have in service, according to SunLine Transit <sup>54</sup>. Medium duty fuel cell trucks are used by FedEx and UPS<sup>55</sup>, heavy duty trucks are in being developed and tested by

<sup>&</sup>lt;sup>54</sup> <u>https://www.sustainable-bus.com/fuel-cell/el-dorado-national-fuel-cell-bus-ballard-completed-successfully-testing/</u>

<sup>&</sup>lt;sup>55</sup> https://spectrum.ieee.org/green-tech/fuel-cells/ups-to-deploy-fuel-cellbattery-hybrids-as-zeroemission-delivery-trucks

Toyota, Kenworth, Nikola Motor, Loop Energy. Light duty fuel cell electric cars include Toyota Mirai, Honda Clarity, Hyundai Nexo<sup>56</sup>, and Mercedes-Benz GLC F-Cell. Germany has introduced hydrogen-powered rail as another application<sup>57</sup>, and the UK is planning to do so by 2022.<sup>58</sup> The shipping industry is also developing hydrogen-powered projects, including the Bay Area Red and White Fleet's fuel cell "Water-Go-Round" ferry<sup>59</sup>, and cruise ships for Royal Caribbean Cruise Line and Viking Ocean Cruises.<sup>60</sup> In aviation, fuel cell planes have been tested since 2015<sup>61</sup> and electrolytic hydrogen based synthetic fuels are being researched internationally as a high volume pathway to decarbonized aviation.<sup>62</sup>

Hydrogen fuel cell electric technology is the most promising choice over battery electric for transportation application where there is need for its attributes of long range, rapid fueling time, low weight, and also where there is lack of access to electrical charging infrastructure. Light duty passenger FCEVs have achieved a 380 mile range, surpassing battery electric options, an advantage that is amplified in adverse weather conditions.<sup>63</sup> FCEVs can also make more sense for those without access to easy charging at home and/or who need to drive long distances and do not want to have long wait times to recharge. In the medium and heavy duty sectors, FCEVs have similar advantages, along with lighter payloads due to the heavy weight of batteries compared to hydrogen fuel cells that make them more economical than battery electric options.

<sup>&</sup>lt;sup>56</sup> The Hyundai Nexo has received a five star rating in the Euro NCAP test, and the highest occupant protection score of any zeroemission vehicle: https://www.euroncap.com/en/results/hyundai/nexo/33731 <sup>57</sup> https://www.cnbc.com/2018/09/17/worlds-first-hydrogen-powered-train-enters-into-service.html

 <sup>&</sup>lt;sup>58</sup> https://www.telegraph.co.uk/cars/news/hydrogen-fuel-cell-trains-run-british-railways-2022/
 <sup>59</sup> https://www.sfchronicle.com/bayarea/article/Bay-Area-to-build-first-hydrogen-fuel-cell-ferry-13376358.php

<sup>60</sup> http://www.cruisington.com/cruise-lines-looking-to-pioneer-fuel-cells-as-green-power-source/

<sup>61</sup> https://www.aerospace-technology.com/projects/hy4-aircraft/

<sup>&</sup>lt;sup>62</sup> https://www.icao.int/environmental-protection/GFAAF/Pages/Project.aspx?ProjectID=46

<sup>&</sup>lt;sup>63</sup> The Hyundai Nexo has an EPA rated range of 380 miles, <u>https://www.hyundaiusa.com/nexo/index.aspx</u>. The highest battery electric range listed is in the Tesla S is 335. https://www.tesla.com/models

Infrastructure for FCEVs remains an issue, as the upfront cost tends to be higher compared to other zero emission technologies. However, a "Comparative Analysis of Infrastructures: Hydrogen Fueling and Electric Charging of Vehicles" by the German Institute of Electrochemical Process Engineering (IEK-3) at the Research Center Jülich showed that for Germany, once electrification of vehicles exceeds 20 million, FCEV infrastructure becomes cheaper than BEV infrastructure, as shown in Figure 6.<sup>64</sup>



*Figure 6 – Comparison of the Cumulative Investment of Supply Infrastructures (BEV & FCEV)* 

In addition, the study showed "mobility costs per kilometer are roughly equal in the high market penetration scenario at 4.5€ct/km for electric charging and 4.6€ct/km for hydrogen fueling. Because hydrogen permits the use of otherwise unusable renewable electricity by means of on-site electrolysis, the lower efficiency of the hydrogen pathway is offset by lower surplus electricity costs."

<sup>&</sup>lt;sup>64</sup> https://www.californiahydrogen.org/wp-content/uploads/2017/10/Energie\_Umwelt\_408\_NEU.pdf

In a 2017 KPMG survey, 78% of Global Automotive Executives absolutely or partly agree that FCEVs will be the real breakthrough for electric mobility.<sup>65</sup> Furthermore, in the 2018 survey, fuel cell electric vehicles replaced battery electric vehicles as this year's #1 key trend until 2025.<sup>66</sup> While infrastructure for FCEVs remains a hurdle, the 6,000+ FCEVs in California alone show that the technology is mature and holds promise to be cost competitive at scale. Toyota announced that their goal is to be offer FCEV models in 2025 at the same cost as their hybrid vehicles<sup>67</sup>, with offering ranges of 400-650 miles per fill.<sup>68</sup>

#### П. **CONCLUSION**

CHBC appreciates the Commission's consideration of these reply comments and looks forward to continuing to collaborate with the Commission to accurately understand and advance hydrogen as an energy resource in the IRP process.

Respectfully submitted. have

Emanuel Wagner **Deputy Director California Hydrogen Business Council** 18847 Via Sereno Yorba Linda, CA 92866 310-455-6095 ewagner@californiahydrogen.org

Dated: March 15, 2019

 <sup>&</sup>lt;sup>65</sup> <u>https://assets.kpmg/content/dam/kpmg/xx/pdf/2017/01/global-automotive-executive-survey-2017.pdf;</u> p. 14
 <sup>66</sup> <u>https://automotive-institute.kpmg.de/2018/brain.html#automotive-key-trends</u>

<sup>67</sup> https://www.autocar.co.uk/car-news/industry/hydrogen-cars-cost-same-hybrids-2025-say-toyota

<sup>&</sup>lt;sup>68</sup> https://www.reuters.com/article/us-toyota-hydrogen/toyota-plans-to-expand-production-shrink-cost-of-hydrogen-fuel-cellvehicles-idUSKBN1KG0Y0