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Additional submitted attachment is included below.

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Comments of California Hydrogen Business Council to the Roadmap for the Commercialization of Microgrids in California

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Introduction

The California Hydrogen Business Council (CHBC) respectfully submits these comments to the Roadmap for the Commercialization of Microgrids in California (October 2017), which focuses on the key issues and identifies strategic actions to assist in the commercialization of microgrids in California.

The CHBC is comprised of over 100 organizations involved in the business of hydrogen and fuel cells.[1] The organization's mission is to advance the commercialization of hydrogen in the energy sector, including transportation, goods movement, and stationary power systems to reduce emissions and dependence on oil. The vision of the CHBC is to reinforce California's position as the most advanced clean energy state in the nation, expanding the sustainable use of its precious natural and renewable resources and providing clean air to its citizens, by adopting hydrogen and fuel cell technologies in transportation, power and goods movement markets.

Power to Gas (P2G) can play a major role in implementing the state's policy goals

The CHBC is pleased to see the important cross-agency effort between CEC, CAISO and CPUC to develop a roadmap for commercialization of microgrids in California through the EPIC funding program, which is pivotal to the safety, reliability and resiliency of microgrids. We are concerned, however, that inadequate attention has been paid to technologies and use cases that span energy forms

[1] The views expressed in these comments are those of the CHBC, and do not necessarily reflect the views of all the individual CHBC member companies. A complete list of members can be found at www.californiahydrogen.org

(electrical, chemical, thermal) and applications (power, transportation fuel, and heat) for a microgrid setting. Hydrogen solutions such as Power-to-Gas (P2G), which can play an important role in implementing the state's policy goals, have been essentially excluded from the state's storage roadmap development, policy and regulatory frameworks.

The CHBC believes that hydrogen can play important energy storage, delivery, and conversion roles in microgrid applications, supporting critical loads within a community that includes grid resiliency, redundancy and security services that are provided to the electrical distribution system. P2G has the potential to offer local grid control and smoothing of intermittent renewables, thus allowing higher overall penetration of renewables in the electric grid.

Hydrogen solutions such as Power-to-Gas (P2G) can be deployed to support continued operations of critical loads across multiple microgrid market segments, including institutions like universities, commercial and industrial entities, local communities, military installations, and off-grid or remote island locations.

As discussed in the draft roadmap on the CAISO challenges with the "duck curve" on steep ramping needs and overgeneration risks, it makes it even more critical for microgrids to play a unique role during these challenges. Renewable hydrogen produced from excess renewable electricity via electrolysis can be used as a dispatchable load-balancing resource (complementing the renewable intermittency) and as an energy storage medium in microgrids with high levels of renewable power generation. Hydrogen can be dynamically produced during peak renewable electricity production times (when the price of renewable power is low or even negative) and can be converted back into electricity through fuel cells when solar or wind energy is not available. In this way, hydrogen supports increased deployment of intermittent, renewable power production assets into microgrids and the utility grid network. Hydrogen is an especially attractive energy storage solution that is cheaper than battery energy storage when massive amounts of energy storage or long durations of energy storage are required (for example as required for seasonal shifting of renewable energy).[2] The existing natural gas grid can also act as storage medium. A recent study from the UC Davis Institute of Transportation Studies[3] indicates that relatively low concentrations (between 5 and 15% of hydrogen by volume) is feasible for blending with natural

[2] CHBC White Paper "Power-To-Gas: The Case For Hydrogen" https://californiahydrogen.org/sites/default/files/CHBC%20Hydrogen%20Energy%20Storage%20White%20Paper%20FINA_L.pdf

[3] The Potential to Build Current Natural Gas Infrastructure to Accommodate the Future Conversion to Near-Zero Transportation Technology (UC Davis, 2017)

gas and would not adversely impact the durability, integrity of the existing natural gas pipeline network or public safety. The UC Davis Study also highlights the potential benefits of GHG reductions with natural gas with renewable hydrogen blending in the pipeline. The stored chemical energy can be also used to generate electricity via a fuel cell or other generation equipment, used as transportation fuel, or for any other purpose for which hydrogen or methane is used.

Power to Gas (P2G) is part of the 21st century "smart" energy technology

P2G fits strategically as part of the 21st century "smart" and modernized electric grid, offering multiple grid and off grid services. P2G provides operational flexibility to support grid balancing services when requested including rapid and accurate response to an energy need, rapid change in ramp directions on demand, sustaining upward or downward ramp for extended periods of time, provide multiple start and stop cycles, and start with short notice from a zero or low-electricity operating levels.

Electrolysis is a mature technology that converts electricity into hydrogen (and oxygen) by splitting water. Beyond the storage function of converting electricity into gaseous fuel for later use, these systems can cycle up and down rapidly providing multiple services including voltage and frequency regulation, spinning reserves, ramping services, and capacity across multiple grid domains. Electrolyzers are connected to the grid via inverters (in the same manner as batteries) which have very fast response times, allowing them to provide operational flexibility and they can modulate hydrogen output to provide energy management and ancillary services to the microgrid system, as well as participation in energy markets on the utility grid at network scale, all while producing hydrogen.

Universities and other institutions across the US are taking steps to develop microgrids, for knowledge-building, industry and technology collaboration, and improving energy resiliency. At the University of California, San Diego (UCSD), the campus microgrid supplies electricity, heating and cooling for the 450-hectare campus supported by several key resources including solar photovoltaic systems, a cogeneration plant, and fuel cells using biogas feedstock and technology that can generate hydrogen, electricity and heat through the process.[4]

[4] UC San Diego: https://sustainability.ucsd.edu/highlights/microgrids.html

P2G is part of the microgrid at the University of California, Irvine

The University of California, Irvine (UCI) campus microgrid is comprised of over 4 MW of solar photovoltaics (PV), a 4.5-million-gallon thermal energy storage (TES) system with district heating and cooling, a 19 MW natural gas combined cycle (NGCC) cogenerating plant, and a 2 MW/0.5 MWh lithium ion battery energy storage system serving a community of more than 30,000 people and encompassing a wide array of building types, and transportation options.

The newest addition to the UCI campus microgrid is a 60-kW power-to-gas (P2G) system that uses a polymer electrolyte membrane (PEM)[4] electrolyzer to convert excess renewable power into hydrogen gas. The hydrogen gas is injected into the campus pipeline system where it is blended with natural gas. The hydrogen/natural gas blend is then used to power the onsite NGCC system. The UCI system demonstrates several of the value propositions (e.g., dispatchable load, capturing otherwise curtailed intermittent renewable power, using the natural gas system for storage) that P2G technology can provide for microgrids. A simulation of the UCI microgrid conducted by researchers at the Advanced Power and Energy Program (APEP) showed that a hypothetical 27 MW P2G system could allow UCI to deploy significantly more solar PV capacity and increase the renewable energy consumed on campus from 3.5% of total consumption to 35% of total consumption, an increase of 10 times.[5]

Researchers at APEP also connected a PEM electrolyzer directly to a roof mounted PV array and showed that the electrolyzer could easily conform to the dynamics of PV power production even on cloudy days with highly intermittent solar production (Figure 1). These tests demonstrate that the rapid response characteristics of electrolyzers can assist in providing many ancillary services, including rapid ramping, frequency and voltage regulation to support microgrid power quality and resiliency.[6]

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[5] Additional Information on the UCI Microgrid is available at: http://www.energy.ca.gov/research/notices/2015-09-30_workshop/presentations/03_UC_Irvine_Deployment_and_Integration_of_Renewables_at_UCI_9-30- 15_Lynwood.pdf

[6] PEM electrolysis is a hydrogen-production technology that can enable a zero-carbon footprint when used with renewable resources. More information:https://energy.gov/eere/fuelcells/downloads/hydrogen-production-polymer- electrolyte-membrane-pem-electrolysis-spotlight

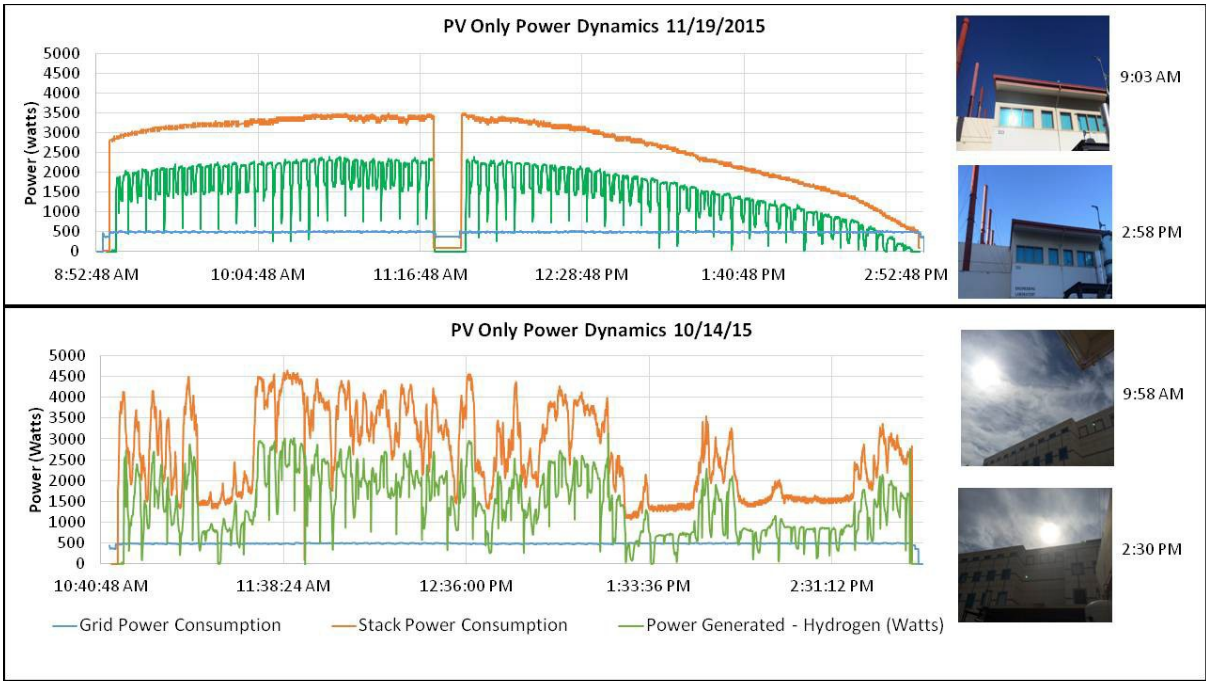

FIGURE 1 - POWER CONSUMPTION OF THE ELECTROLYZER WITH RESULTANT HYDROGEN PRODUCTION FOR TWO DIRECT DC-CONNECTED 'PV ONLY' TESTS CARRIED OUT IN THE FALL SEASON.

P2G can help microgrid operators like UCI reduce their carbon footprint by using the stored excess renewable energy and thereby reducing the amount of traditional power that must be generated on the microgrid, or imported from the grid at large. P2G can also help reduce the carbon intensity of transportation systems supported by the microgrid. Renewable hydrogen produced during peak renewable power production periods can also be used to power hydrogen fuel cell electric vehicles (FCEVs) like the fuel cell electric bus being tested and demonstrated on the UCI campus as part of the "Anteater Express" shuttle service. The "multiple use application" aspects of P2G provide greater flexibility to integrate renewables beyond power applications into transportation.

Economics of P2G

P2G can be cost competitive with batteries and promises to serve an important role fulfilling the need for energy storage in California. Electrolytic hydrogen and methane produced using renewable electricity compare favorably to lithium ion batteries, pumped hydro, and compressed air energy storage (CAES), particularly at continuous capacity – which is foreseen as the state seeks to integrate larger shares of renewable generation.

- Power-to-Gas-to-Power (P2G2P), that is power-to-gas-systems used to return energy in the form of electricity generation via a power plant, 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.

- Initial results from University of California, Irvine modeling, using a capacity factor of 50%, or 12 hours of charging time per day, suggest a levelized cost of storage (LCOS) for batteries of 10-22 ¢/kWh compared to P2G 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 ¢/kWh compared to P2G of 8-21 ¢/kWh. In other words, P2G can be cost competitive with batteries and promises to serve an important role fulfilling the need for energy storage in California.
- Additional 2016 analysis by PwC suggests that worldwide, the LCOS for electrolytic hydrogen used as energy storage will be competitive with lithium ion batteries by 2030.[7]

CHBC agrees with the draft roadmap that standby charges and departing load charges can make microgrid technologies less cost-competitive as these costs are transferred to the end users. To foster the adoption of zero carbon technologies like P2G, CHBC is in alignment with the roadmap assessment that the nature and amount of the standby and departing load charges need to be reevaluated by the appropriate regulatory agencies. CHBC believes that microgrids should receive the same treatment as a stand-alone storage facility, where its energy consumption that supports supply of energy to the grid is considered wholesale consumption, whereas its station power is considered retail.

CHBC also believes that P2G technologies deployed in a micro-grid environment has a strong potential to participate in the CAISO markets for energy and ancillary services, including regulation and reserves.

CHBC supports the draft roadmap recommendation that contractual arrangements between utilities and microgrid operators as part of resource procurement will need to be developed to address the above discussed issues.

CHBC commends the recommended action items developed in the draft roadmap to foster greater market adoption of microgrids in California. CHBC agrees that it is critical to develop market relevant information that defines the value of a microgrid to end users and to the grid operator. CHBC would

[7] https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_E-storage_2016.pdf

recommend that the California Energy Commission take steps to include all technologies including P2G as part of market outreach efforts. CHBC is looking forward to supporting the California Energy Commission in developing market relevant information to highlight the role of P2G as part of market outreach efforts.

Conclusion

California is faced with an increasingly urgent need to deploy energy storage solutions to support intermittent renewable power generation. CAISO reports that over 300 GWh of solar and wind electricity were curtailed in 2016, and that number is likely to increase. California can expect anywhere between 4,000 and 10,000 GWh of curtailment by 2030 based on the 2025 California Demand Response Potential Study (Lawrence Berkley Laboratory).[8] P2G enables flexible conversion and storage of intermittent or curtailed renewables. Being modular and flexible in siting and size (kilowatt scale to multi-megawatt scale and gigawatt-hours of storage capacity), P2G can play a critical role in supporting smaller community based microgrids or large utility scale energy storage solutions in California cost-effectively. Investing in advancing the commercialization of P2G now will help accelerate its adoption and can pave the way for a more resilient, more energy efficient, more renewable and sustainable communities in California.

[8] http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442452698