CALIFORNIA HYDROGEN BUSINESS COUNCIL

Hydrogen Means Business in California!

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The CHBC is pleased to provide feedback on the request by the California Energy Commission's Research and Development Division to better identify future research needs related to increasing energy storage in California and future research areas would be the most effective in advancing energy storage technologies closer to successful commercial implementation.

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1. For emerging storage technologies, what research support would most bring your technology to commercial viability and which end-use applications are you targeting?

The CHBC would emphasize commercial demonstration support that enables hydrogen and fuel cell technology to demonstrate commercial viability and scalability in the near term, as shown in European Countries today, specifically by making renewable hydrogen and its derivatives as an energy storage option for California utilities.

The most promising way to make renewable hydrogen at high volume is via electrolysis powered by renewable electricity to split water (H_2O) into hydrogen (H_2) and oxygen (O_2).. The produced hydrogen can either be used or stored directly in dedicated facilities (e.g. tanks, caverns, or hydrogen pipelines), in the existing natural gas system, or combined with CO2 to make renewable methane, which can then be injected into the natural gas grid in unlimited quantities to replace fossil natural gas with a low or zero carbon alternative.

Importantly, storing electrolytic hydrogen enables an energy storage pathway that can provide significant scalability and versatility in helping to balance the electric grid in ways not possible with storage technology that has so far been adopted in California. Electrolytic hydrogen and renewable methane derived from electrolytic hydrogen (together, sometimes referred to as “power to gas” is the the only storage solution that can be scaled up to the terawatt hour level, making it especially useful for seasonal and large-scale storage needs. [1]

The growth in renewable energy integration to the grid will drive the demand for long term or seasonal storage systems. This is assured with California’s policy goal to achieve 100% clean electricity with RPS eligible and zero-carbon sources by 2045 (SB 100). The risks to grid stability will necessitate long term energy storage sources that are flexible, scalable and economical. CAISO’s curtailment data further underscores the need for seasonal, large scale storage. More research is needed to specifically address the role of long term/seasonal energy needs for California.

Unlike pumped hydro and compressed air, electrolytic hydrogen solutions carry the flexibility of relative independence from geological or locational constraints. This is because of the modularity and flexible siting requirements of renewable electricity technologies used to power electrolysis, the ubiquitous nature of the gas system and flexibility to site tanks to store and carry the hydrogen, and the potential to establish market mechanisms that would allow electrolyzers to contract with renewable generators or to buy renewable electricity on the wholesale market, so that renewable hydrogen production need not co-locate with renewable generation.

Curtailed energy in California has been growing steadily over the last few years. As the Renewable Portfolio Standard (RPS) and zero carbon electricity requirement climbs to 100% by 2045, one can project that these curtailments will grow even more sharply, yielding significantly less GHG emission reductions than anticipated, and potentially leaving California in a disadvantaged position paying for expensive partial solutions and over-procuring renewable electric resources with diminishing returns. Curtailed energy can be converted into hydrogen via electrolysis, blended with natural gas at acceptable safe limits and stored in the existing natural gas grid infrastructure. The blended fuel can also use for other end use applications including powering and heating homes and businesses.

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[1] https://www.californiahydrogen.org/wp-content/uploads/2018/01/CHBC-Hydrogen-Energy-Storage-White-Paper-FINAL.pdf

More research is needed on safe hydrogen blending levels into the natural gas grid. CEC needs to support an independent research study to demonstrate the compatibility of hydrogen blending limits with the natural gas infrastructure safety and operability and offer a wide range of permissible hydrogen blending limits. The need for such research is backed up by the University of California – Davis, which recently stated that "*blending relative low concentrations of hydrogen with natural gas (<5%–15% H2 by volume) would not significantly increase risks such as potential damage to end-use devices (such as household appliances) or adversely affect the durability and integrity of the existing NG pipeline network or public safety. Although 5-15% hydrogen by volume is often given as a "rule of thumb" value, recent studies stress that the allowable blend concentration may vary significantly between pipeline network systems and natural gas compositions and must therefore be assessed on a case-by-case basis*[2]. ***Another study on admissible hydrogen concentrations in natural gas system states: "natural gas system can tolerate a mixture of up to 10% by volume of hydrogen, depending on the specific local situation"***[3]

Some specific scoping questions that should be considered as part of the research should include the following:

- What level of hydrogen can be safely blended into the natural gas system based on technical and physical requirements?
- What level of hydrogen in the natural gas system will be acceptable to consumers and end-use equipment?
- What new commercial structures, policies, and tariffs will be needed to facilitate pipeline blending (e.g., engineering studies, borrowed gas rates, etc.)
- What new commercial structures, policies, and tariffs will be needed to optimize natural gas infrastructure to capture, store, and transport hydrogen to support the electric grid?
- What new commercial structures, policies, programs, and tariffs should be considered to facilitate greater adoption and use of low/zero-carbon hydrogen supplied by the natural gas system?
- What role can utilities play in piloting hydrogen interconnections with the natural gas system?
- What cost effective low carbon fuels procurement programs should be established at the utilities to accelerate hydrogen market development and energy sector decarbonization?

By investing in further research of hydrogen, California would be joining an international effort that spans from several countries in Europe, Australia, Japan, and beyond. California ought to consider embarking on similar efforts to Equinor in Northern England, which is currently considering converting the entire gas network in the region to hydrogen.[4]

In addition, CEC should support research on optimizing grid management to provide merchant storage facilities with the same access to wholesale power capacity and rates that are available to IOU, MOU and independent power producers. Electrolytic hydrogen project developers need guidance navigating the complex tariff structures of the electricity grid to gain access to excess renewable energy at low

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[2] The Potential to Build Current Natural Gas Infrastructure to Accommodate the Future Conversion to Near-Zero Transportation Technology, Institute of Transportation Studies, UC Davis (March 2017), at 33 (internal endnotes omitted) available at https://steps.ucdavis.edu/wpcontent/uploads/2017/05/2017-UCD-ITS-RR-17-04-1.pdf.

3 Admissible Hydrogen Concentrations in Natural Gas Systems, Gas for Energy (2013), at 10 available at http://www.gerg.eu/public/uploads/files/publications/GERGpapers/SD_gfe_03_13_Report_Altfeld-Pinchbeck.pdf.

[4] https://www.californiahydrogen.org/wp-content/uploads/2017/10/Steinar-Eikaas.pdf

location marginal pricing (LMP). Providing that guidance will help developers site projects that can alleviate grid congestion issues.

CEC should also support research into storage technologies that can help decarbonize other aspects of California's energy economy, for instance vehicle fueling. Power-to-hydrogen technology could be co-located to provide both grid support and hydrogen vehicle fueling supply. Research is needed to identify sites that provide maximum benefit to both the electric grid and the hydrogen vehicle markets. Funding is needed to demonstrate the synergy between energy storage and vehicle fueling systems.

Finally, although the component technologies for hydrogen energy storage are commercially available, next generation concepts such as solid-oxide cells and reversible cells (cells that can operate both as electrolyzers (consume power and make fuel) and fuel cells (consume fuel and make power) need R&D funding support.

What new research grant opportunities would be the most beneficial in supporting these commercial advancements?

We recommend that the CEC look into opportunities to collaborate with CAISO to demonstrate the value of power-to-gas as a grid support technology should be explored. In Canada, Canada's largest natural gas distribution company Enbridge has developed a project in conjunction with Canada's grid operator, IESO, to demonstrate power-to-hydrogen as a storage technology that can provide grid support.[5] CEC should encourage a similar effort in California. Specifically, the CEC should coordinate with CAISO and CPUC to develop research studies that identify constrained locations/pockets based on the current and future CAISO load data and develop strategies to deploy electrolytic hydrogen solutions to mitigate location specific constraints.

CEC should furthermore address large-scale hardware demonstrations needed to show the functionality and value of storage systems with computer simulations and analysis, which are adaptable to the changing needs of the grid as more renewables are deployed. Appropriate simulations of hardware demonstrations under future, high-renewables scenarios will help identify strengths and weaknesses of various technologies.

2. For pre-commercial or near-commercial energy storage technologies, what types of demonstration projects would be most useful to inform the finance industry and end users to consider energy storage procurements in the future.

Utility scale demonstrations that include techno-economic analyses and gathering of operating data to demonstrate reliability and sustained performance.

Which end-use applications are considered the most beneficial for your energy storage technology?

As mentioned earlier, electrolytic hydrogen technology could complement zero emissions hydrogen vehicle refueling, support decarbonization of industrial processes like metal refining and fertilizer production and can store renewable energy and deliver it when needed to any application that uses natural gas, including space heating, water heating, and CNG vehicle fueling. By contrast, batteries can

[5] https://www.energy.gov/sites/prod/files/2015/01/f19/fcto_2014_h2_energy_storage_grid_transportation_svcs_wkshp_teichroeb.pdf.

only store electricity for a short period of time, return energy as electricity, and deliver energy to the same location it was acquired.

While the CEC should support research across the entire range of end-uses for hydrogen and power-to-gas, the highest value involves combining storage capabilities with ZEV fueling applications.

What scale of demonstration project is considered the most valuable to end customers, utilities and project financiers in terms of size and overall cost/value?

- 1 – 10 MW power capacity
- >1 GWh energy storage capacity.
- 10-100hrs charge/discharge duration (ARPA-e has identified the need for long charge/discharge durations of 10-100hrs for its “Duration Addition to electricitY” Storage (DAYS) program. CEC should follow suit.)
- 3 months storage duration (time between when electricity is converted into stored energy and when that stored energy is returned either as electricity or other value product)

3. For all technologies, what other research activities for emerging energy storage technologies would provide the most benefit to the state in meeting the defined future clean energy goals?

California and WECC grid optimization using combinations of short-term and long-term energy storage technologies. California and WECC grid storage siting optimization studies with dispatch modeling.

4. Are there existing planning tools or models that could be expanded or new tools or models that would assist the state in deploying energy storage throughout the state most efficiently and effectively?

We recommend consulting with the National Renewable Energy Lab (NREL) for information on renewables grid integration and Oak Ridge National Lab (ORNL) for information on grid modernization efforts.

Are there existing models that can be used to help define the optimum location, size and time duration for energy storage that will help the state meet future SB100 renewable integration and resulting grid management goals?

H2GRID is being developed by UC Irvine’s Advanced Power and Energy Program (UCI APEP) and will allow analyzing the impact and benefits of deploying power-to-gas across the CAISO grid.

NREL and the Electric Power Research Institute (EPRI) are conducting a study titled “Valuation of Hydrogen the Electric Grid” under the Department of Energy’s (DOE) H2@Scale program.

5. Is there a need for a state-supported independent energy storage testing facility that would accelerate the commercial acceptance of new and emerging energy storage technologies?

Hydrogen energy storage and electrolytic hydrogen do not lend themselves to centralized test facilities. Consider developing and deploying a combination of mobile and remote storage testing systems such as hardware-in-the-loop simulation tools that allow demonstration of grid-integrated functionality.

If so, what level of testing would be needed in terms of system size, rating and duration?

CEC needs to expand its research needs to include technologies across the spectrum of storage size and duration, especially medium and long term, seasonal storage and bulk storage. Therefore, the complete range of system size, rating and duration should be tested. Achieving California's aggressive RPS and zero carbon electricity goals will require a suite of storage technologies from short-term solutions to long-term storage resources like power-to-hydrogen.