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Grid balancing in California through renewable hydrogen production

Additional submitted attachment is included below.

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The Energy Commission is currently soliciting ideas and stakeholder input for the 2018 – 2020 EPIC Triennial Investment Plan. For those that would like to submit an idea for consideration in the 2018-2020 EPIC Triennial Plan, we ask that you complete the form below. Submittals are due by **5:00 p.m. on February 10, 2017.**

Part 1. Initiative Description and Purpose:

1. Please provide a brief description of the proposed initiative:

The proposal outlines ways for EPIC to support and help pioneer the construction and operation of a pilot plant at-scale to produce renewable electricity-based hydrogen fuel.

Using renewable electricity to produce hydrogen fuel will help reduce curtailment of fluctuating renewable electricity in the grid, thus enabling the ability to manage the integration of more renewables on the grid, whilst providing zero-emission fuel for the transportation sector.

The initiative could be a joint project between relevant stakeholder in both the energy and hy-drogen transportation sectors. These stakeholders could develop a pilot project at sufficient scale with the aim of developing and demonstration an archetype for a viable business model for economically-competitive, renewable hydrogen production.

This could catalyze a future rapid expansion of commercial hydrogen plants to meet the growing demand for renewable hydrogen fuel in California, arising from the ongoing market introduction of Fuel Cell Electric Vehicles (FCEVs).

2. What technical and/or market barriers would the proposed initiative help overcome? For scientific analysis and tools, what knowledge gaps would the proposed initiative help fill?

An EPIC-supported pilot project on renewable hydrogen production could help both to overcome financial barriers during early years, as well as create a stakeholder platform for developing an archetype business model for the integration of renewables, power grid, and hydrogen produc-tion.

A pilot project would assemble all relevant stakeholders in both the energy sector (utilities, re-newable generators, and energy companies) and the hydrogen transportation sector (hydrogen equipment providers, oil companies, and hydrogen station operators). These stakeholders are needed to develop the optimal model for connecting hydrogen with renewable power genera-tion and the grid. This optimal model reduces electricity costs for the hydrogen production whilst increasing the gains for the power grid in the balancing of fluctuating, intermittent renewable electricity.

Additionally, this model includes investigation on the application of Net Energy Metering 2.0 to hydrogen production that is directly connected to renewable generation, and/or “wheeling” renewable electricity via the major transmission lines to the hydrogen production plant whilst providing load demand-response services to the grid.

For the case of hydrogen fuel production, EPIC support for the electrolyser plant investment would enable the achievement of both scale and a competitive hydrogen fuel price faster than would be possible if purely dependent on market demand. FCEV market deployment is in the ear-ly-growth phase, which is not yet sufficient to build a large-scale hydrogen production plant that can provide fuel at price parity to gasoline or diesel. However, a shortfall of hydrogen fuel capac-ity—both renewable and non-renewable—is projected around 2020, therefore it is necessary to initiate projects that will be able to support the similarly-projected market deployment by that time. EPIC support for the investment would allow for an earlier plant construction at appropri-ate scale, that will be utilized sufficiently to provide hydrogen at competitive price levels.

Part 2. Benefits and Impacts

3. If this initiative is successful, either fully or partially, what would be the expected impact? Who are the primary users and/or beneficiaries?

Integrating hydrogen production with renewable electricity would provide benefits to both ener-gy and transportation sectors, particularly in enabling a business case for a continued increase in California and US renewables, and reduced greenhouse gas (GHG) emissions and criteria pollu-tants.

For the energy sector, hydrogen production will both utilize and integrate an increasing share of renewables in the power grid, whilst reducing the risk of curtailment and providing a cushion below the electricity rates achievable for renewable generators.

An electricity price at $50/MWh is sufficient to enable hydrogen fuel at a pump price competitive to gasoline. For a renewable energy generators providing electricity for hydrogen production, this price level is significantly above what may be achieved under typical Power Purchase Agree-ments (PPAs) when delivering to the power grid – thereby supporting a continued expansion of renewable generation.

For the power grid, hydrogen production is a highly responsive power demand that can be turned on/off depending on the power available in the grid. E.g., during day time where there is a high risk of solar power curtailment, hydrogen production can be "ramped up" – whereas during high power demand periods in the afternoon and evening, hydrogen production can be "ramped down." At scale, such hydrogen production could enable integrating a higher share of renewa-bles in the grid due to this dynamic power offtake.

According to the Air Resource Board (AB8 Staff report Dec. 2015 - http://www.energy.ca.gov/2015publications/CEC-600-2015-016/CEC-600-2015-016.pdf), the demand for hydrogen fuel in California may reach 155 tons per day by 2025, which corresponds to a daily electricity demand of 9GWh for hydrogen production with a total installed electrolysis capacity of 300MW. Beyond 2025, the power demand and installed hydrogen production capaci-ty would increase very rapidly due to FCEVs entering the growth phase (100 thousands of vehicles sold per year).

For the transport sector, renewable-based hydrogen production could enable a pump price com-petitive with gasoline, which is a perquisite in enabling a continued and accelerating market share of FCEVs in California. FCEVs are zero-emission vehicles, and—when based on renewable hydrogen, they are zero-emission at both the tailpipe and on a Well-To-Wheel basis – thus re-newable electricity connected with hydrogen production could enable a long term transition to a fully zero-emission (GHG and criteria pollutants) transportation sector.

4. Describe what quantitative or qualitative metrics or indicators would be used to evaluate the impacts of the proposed initiative:

An initial or pilot project on renewable hydrogen production could be evaluated based on the following metrics:

• Project consortia consists of the required stakeholders to address all relevant aspects on the business case and model development for renewable hydrogen production. Energy companies, renewable generators and utilities will be needed to develop optimal con-nection models between both the renewables, grid and hydrogen production. Also con-siderations are relevant on aspects such as grid fees, Renewable Energy Credit (REC) generation, PPAs and load demand-response services. Gasoline/station operators and hydrogen equipment providers are needed to address aspects of hydrogen production, distribution, and offtake for hydrogen fueling stations.

• Project should demonstrate an electrolyser hydrogen production plant of sufficient initial capacity (e.g. 2MW or 1,000kg/day) and with the ability to scale as demand grows (e.g. minimum to 10MW or 5,000 kg/day). Sufficient capacity size will be required to pilot var-ious aspects of the integration with renewables and interface to the grid (e.g. load-balancing services). Also, scale is required to enable a feasible business case and model in the long term.

• Project budget should be cost competitive e.g. in the range of $3-5 million for a 2MW electrolyser plant, with a substantial private financing component, reducing the required EPIC funds (e.g. 50/50 split).

• Pilot project candidates could be chosen based on competitive tender rounds, that would allow consortia to form and specific in detail the project scope and tasks. In that respect inclusion of renewable hydrogen production in the EPIC Investment Plan should be kept on an overall level, to allow different consortia approaches to be proposed.

• Cost-Benefit metric, e.g., reduction of GHG emissions per dollar of public funding, and/or GHG emission reductions per total dollars (public and private capital) invested in the project – e.g. using the Air Resources Board Low-Carbon Fuel Standard pathways for various fuel pathways including hydrogen and their related CI value as a metric, as this represent the achieved GHG emission reductions.

5. Please provide a list of peer-reviewed references that support the responses for questions 3 and 4. Proposed initiatives that include peer-reviewed references will be given stronger consideration.

Novel Electrolyzer Applications: Providing More than Just Hydrogen, NREL, Sept 2014
http://www.nrel.gov/docs/fy14osti/61758.pdf

Economic Assessment of Hydrogen Technologies Participating in California Electricity Markets, NREL, Feb 2016: http://www.nrel.gov/docs/fy16osti/65856.pdf

H2 at Scale: Deeply Decarbonizing Our Energy System, Department of Energy / NREL:
http://www.nrel.gov/docs/fy16osti/66246.pdf (report)
https://energy.gov/eere/fuelcells/downloads/h2-scale-workshop (work shop presentations)

Summary of Market Opportunities for Electric Vehicles and Dispatchable Load in Electrolyzers, NREL:
http://www.nrel.gov/docs/fy15osti/64172.pdf

Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart, NREL:
http://www.nrel.gov/docs/fy16osti/65023.pdf

Study on Hydrogen from Renewable Resources in the EU, European Fuel Cell & Hydrogen Joint Undertaking:
http://fch.europa.eu/sites/default/files/GHyP-Final-Report_2015-07-08_5%20%28ID%202849171%29.pdf

Commercialisation of Energy Storage in Europe, European Fuel Cell & Hydrogen Joint Undertak-ing:
http://www.fch.europa.eu/sites/default/files/CommercializationofEnergyStorageFinal_3.pdf

Assessment on a widespread Hydrogen Refueling Station network for grid balancing of renewa-ble electricity in Denmark 2035 and 2050:
http://brintbiler.dk/wp-content/uploads/2016/01/MegaBalance-project-report-2015.pdf

6. (For technologies only) What competitive advantages does the proposed technology solution have over current benchmark technologies? If the technology is beyond the prototype stage, what strategies do you suggest to bring to scale?

Integrating hydrogen production with otherwise-curtailed renewables can provide competitive flexibility, scale and cost-effective grid balancing services.

Electrolysers for hydrogen production can ramp from 0-100% power load in less than a few sec-onds, substantially faster than e.g. conventional power plants, thereby providing an exceptional response time for instantly required grid balancing needs.

Hydrogen fuel demand will grow rapidly with FCEV vehicle deployment, and—in the long term—the scale will be at a substantial, with thousands of MW electrolysers in operation that can pro-vide a significant and flexible load demand response to the grid, helping to integrate high shares of renewables into the grid.

Whereas investments in other grid-balancing technologies are based solely on the revenue from providing grid balancing, hydrogen production would not rely on this model. Conversely, invest-ments in hydrogen production would be solely based on providing fuel to the transportation sec-tor, whilst connecting renewables with the grid would only be to reduce the electricity costs that will enable a gasoline-competitive fuel price. Thus, vehicle fuel customers would indirectly con-tribute for the hydrogen production investments, whereas the grid would benefit from the bal-ancing services provided from this electrolyser facility. Overall, this will make hydrogen produc-tion a very competitive balancing technology in the long term, compared to other technologies who rely on revenue from grid services.

Part 3. Connection to Energy Commission's EPIC Framework
Energy Commission staff have developed a draft strategic framework to guide the CEC's planning and implementation of EPIC across triennial investment cycles. One of the objectives of the draft strategic framework is to communicate a consistent set of priorities for organizing current and future EPIC investments.

7. Please indicate which of the following strategic framework themes you feel the proposed initiative best fits within:
    - Advance Technology Solutions for Deep Energy Savings in Building and Facilities
    - Accelerate Widespread Customer Adoption of Distributed Energy Resources
    - Increase System Flexibility from Low-Carbon Resources
    - Increase the Cost-Competiveness of Renewable Generation
    - Create a Statewide Ecosystem for Incubating New Energy Innovations
    - Maximize Synergies in the Water-Energy-Food Nexus
    - Develop Tools and Analysis to Inform Energy Policy and Planning Decisions
    - Catalyze Clean Energy Investments in California's Underrepresented and Disadvantaged Communities

If Other, Please Specify