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Advantages of Power-to-gas in LDES

Additional submitted attachment is included below.

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April 26, 2022

California Energy Commission
715 P Street
Sacramento, California 95814

Re: Docket No. 19-ERDD-01

Electrochaea Corporation appreciates the opportunity to provide comments on the Workshop on Advancing Non-Lithium-Ion Long-Duration Energy Storage Technologies. Electrochaea Corporation is a subsidiary of Electrochaea GmbH, a growth-stage company that has developed a solution for the production of clean, synthetic methane. Synthetic methane is a low carbon intensity (CI) replacement for fossil-based natural gas.

These remarks provided by Electrochaea are on the importance of a technology called power-to-gas as a long-duration energy storage solution. Power-to-gas is a means to store renewable energy while providing renewable gas for any current use of natural gas including firm power renewable energy generation. This comment includes a description of power-to-gas methanation and its benefits that were not mentioned in the Workshop.

I. What is power-to-gas?

Power-to-gas is a technology in which the energy of a power source is stored in a gas. When power-to-gas is combined with methanation, a clean synthetic methane, is produced from CO_2 and hydrogen, which is a renewable and clean drop-in replacement for fossil natural gas.

Power-to-gas methanation has many advantages, including efficient use of power that would otherwise be curtailed, long-term and high capacity (TWh) energy storage, and production of low carbon intensity fuel. This long-duration energy storage (weeks to months) cannot be accomplished with traditional batteries. This renewable energy provides a cost-effective resource for integrated resource planning, large capacity storage in existing infrastructure, and doubling production of renewable gas from biogas sites.

As an example, Electrochaea has developed a grid-scale power-to-gas solution that stores renewable energy in grid-quality synthetic methane. CO_2 and clean hydrogen are combined by a microorganism called Archaea to produce clean, synthetic methane. Clean, synthetic methane has a CI that is significantly lower than fossil natural gas and it fully functions to replace all uses of fossil natural gas. Thus, use of low CI synthetic methane significantly reduces GHG emissions, utilizes investment in existing gas distribution and storage infrastructure, and contributes to the transition to a clean energy economy. Electrochaea's two-step power-to-gas biomethanation process is illustrated below in Figure 1.

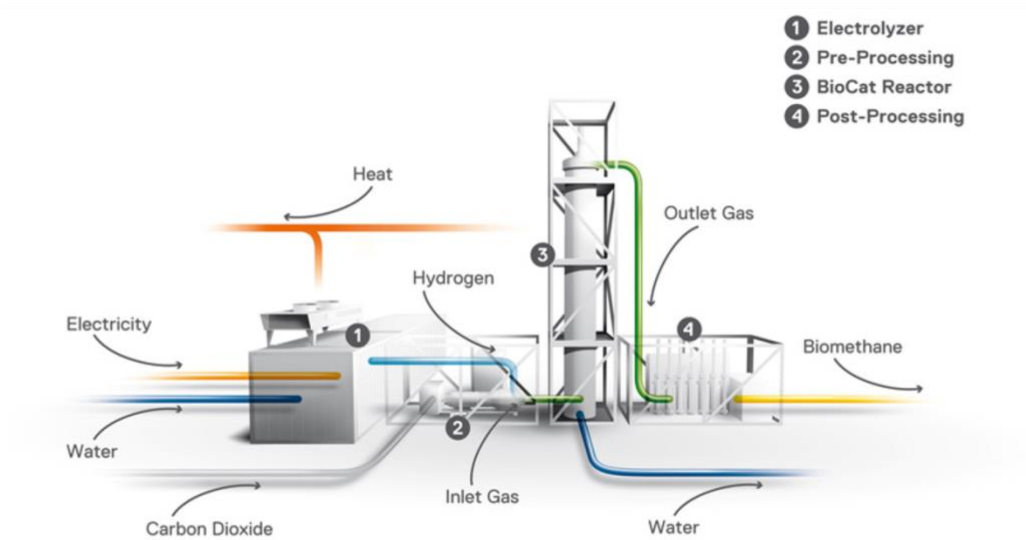

Figure 1. (1) Renewable energy is used to produce clean hydrogen by electrolysis, (2) hydrogen and carbon dioxide are delivered to the reactor (3) in which clean, synthetic methane is synthesized by the archaea. (4) Clean, synthetic methane (biomethane) is prepared for grid injection or use.

The Electrochaea story started in the year 2006 with basic research and four years of proof-of-concept work in Prof. Laurens Mets' laboratory at the University of Chicago. De-risking of the process for commercialization began in 2011, using raw biogas to produce methane at a brewery digester in St. Louis, MO, and continued with field trials in 2013 in Foulum, Denmark. In 2016, an industrial scale plant was commissioned in Avedore, Denmark at a wastewater treatment plant. The power-to-gas methanation plant, in intermittent operation for 3.5 years, obtained 4,500 total operating hours. Grid quality synthetic methane (>97% methane) is produced by the self-sustaining biocatalyst, and has been injected onto the Danish gas grid. A second-generation plant, with automated remote operation, was commissioned in 2019 in Switzerland, and was injecting high quality methane onto the gas grid within 96 hours of startup. Both plants have demonstrated flexible operation with rapid recovery after different periods of shutdown. This flexibility is important to accept intermittent renewable power when it is available. Load factor tests have shown that the Electrochaea power-to-gas biomethanation system can be operated at 0-100% capacity.

II. Solutions driven by power-to-gas technologies

The power-to-gas methanation process produces clean, synthetic methane that can replace any use of natural gas, including renewable electricity production. When one volume of synthetic methane is used, one volume of fossil natural gas need not be removed from the fossil vaults. In this case the energy from one volume of renewable uses our existing infrastructure, with existing markets and replaces the same volume of fossil gas without a net increase in the release of greenhouse gases from a fossil energy source.

Storage of power that would be otherwise curtailed. Electrochaea's technology makes it possible to store renewable energy and recycle CO_2 in a cost-effective way. This technology eliminates the temporal link between energy supply and demand, allowing efficient energy storage in methane. When renewable power is available but cannot be used immediately, the power must be curtailed. If this otherwise curtailed power is available for the production of synthetic methane, the energy will not be lost and can be stored in the gas infrastructure. This enables full use of renewable energy production, even in the absence of available consumers, thus enabling continued growth of the market for renewable electric power, while providing an expanding source of renewable gas. In addition, clean methane produced using power-to-gas processes is capable of providing very-long-duration energy storage and can play a significant role in addressing the seasonal mismatch in supply and demand that makes it difficult to achieve 100% renewable electricity[1]. The more intermittent renewable energy generated, the more valuable power-to-gas methanation technology becomes.

Long-duration energy storage which cannot be achieved with traditional batteries. Power-to-gas adds a critical and additional advantage to renewable energy generation by providing seasonal storage of renewable energy. Analogous in many ways to pumped hydro or other forms of gravity-based storage, Electrochaea's technology is able to convert wasted power generation into synthetic methane for much later future use. In this way, the existing gas grid and connected storage facilities become the largest battery in the US, storing renewable energy for use later in the day, month, or even year. The US has the design capacity to store ~4,690 billion cubic feet of natural gas[2], which is equivalent to 1.37 billion MW. ~6,000 MW of battery storage capacity was planned for 2021[3]. Thus, there is as much as 23,000 times the amount of storage in the natural gas infrastructure as in the 2021 battery storage capabilities. Unlike traditional battery technologies, the 'state of charge' of the gas grid is effectively insensitive to a charge/discharge cycle. The gas infrastructure would essentially never be full of renewable energy and would not degrade its state of charge during storage. Unlike the owner of a lithium-ion battery, the gas grid operator would never be compelled to discharge at the first anticipated best time to empty the battery to prepare for its next economic charge cycle.

Integrated resource planning. Low CI methane, when stored in the existing natural gas reservoirs, can provide reliability benefits to the power grid, while providing renewable electricity. A renewable gas reserve would enable continued use of current electricity generation assets to produce low CI electricity, maintaining jobs and existing infrastructure with known reliability and performance metrics. Developing a renewable gas transmission system for power ramping needs is critical. For example, the recently projected load ramps in

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[1] Denholm et al. 2021. The challenges of achieving a 100% renewable electricity system in the United States. Joule 5: 1331-1352
[2] https://www.eia.gov/todayinenergy/detail.php?id=30632
[3] https://www.eia.gov/todayinenergy/detail.php?id=49236

California, in excess of 25,000 MW by 2030, are unlikely to be met by solar and wind alone and cannot respond on demand. Increasing the intermittent renewable resources on the grid will exacerbate not only the ramping needs in the afternoon, but also the intermittency and curtailment issues seen throughout the day. The loss of renewable production for even short periods of time, due to weather conditions alone, could jeopardize the power grid in the absence of reliable, proven gas generations assets.

It is likely that a synergy exists in the coupling of the renewable power sector with renewable gas production. As intermittent renewable electricity generation increases in CA and the US, there will necessarily be greater curtailment of electricity generation. The power that is being curtailed could be stored in the hydrogen molecule using power-to-gas processes. By providing a buyer for economically curtailed power, production of low-cost renewable gas would be enabled and lost revenues for the renewable power producers would be recovered. In addition, clean fuels produced using power-to-gas processes are capable of providing very-long-duration storage and can play a significant role in addressing the seasonal mismatch in supply and demand that makes it difficult to achieve 100% renewable electricity[4]. The power-to-gas process can provide a perpetually sustainable fuel and stabilize economic returns for the developers of renewable power, while reducing the risk of the development of additional renewable generation assets.

Storage in existing infrastructure. Using existing infrastructure reduces capital investment, technology risk and land use concerns. Application of power-to-gas methanation produces clean methane which can be used for power generation in combined cycle gas turbine baseload and gas turbine peaker plants and prevents purchasing of traditional batteries for energy storage.

Doubling the production of renewable gas from biogas sites. The use of biogenic CO_2 in the power-to-gas methanation process can double the amount of clean methane produced from biogas sites. The biomethanation process is compatible with any anaerobic digestion gas, including the anaerobic digestion gas from projects focused on organic waste diversion from landfills. The renewable gas produced by power-to-gas and other technologies will initially cost more than our current natural gas. Like wind and solar and other nascent technologies, the cost of assets and the gas product will decrease with scale of production and market growth. In the interim, the higher value of this fuel will provide additional impetus to eliminate leaks from the gas grid and improve stewardship over the current gas to power infrastructure to meet climate goals and prevent economic losses to rate paying customers.

Advantages over hydrogen storage. Hydrogen is more difficult and expensive to store and transport than natural gas. Alternatively, hydrogen can be used to produce a natural gas replacement that can be easily stored and transported in the existing gas infrastructure. When hydrogen is converted to methane, the existing gas infrastructure can be used for storage and

[4] Denholm et al. 2021. The challenges of achieving a 100% renewable electricity system in the United States. Joule 5: 1331-1352

distribution. The production of methane from hydrogen is an efficient means to store hydrogen and the energy contained in the hydrogen molecule. When hydrogen is produced by electrolysis using renewable energy, the energy is stored in the clean hydrogen molecule (<2kg $CO_2e/kg\ H_2$). When 4 moles of hydrogen are combusted with 2 moles of oxygen, 949 kJ/4 moles of hydrogen is released. When 1 mole of methane is combusted with 2 moles of oxygen, 818 kJ/mole of CH_4 is released. Thus, the methane molecule retains most of the combustion energy of hydrogen[5], making it an ideal molecule for storage in the existing infrastructure.

Thank you for the opportunity to participate in this Workshop.

Submitted by,

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[5] *Thauer et al. 2010. Hydrogenases from Methanogenic Archaea, Nickel, a Novel Cofactor and H_2 Storage. Annual Review of Biochemistry 77:509-536*).