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Subject: Request for Information (RFI): DE-FOA-0001626—Hydrogen Infrastructure Research, Development, and Demonstration: Identifying project priorities to address deployment barriers

Prepared for: U.S. Department of Energy's (DOE) Fuel Cell Technologies Office (FCTO)

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Description:

DOE's FCTO issued an input request for "priority areas that will advance deployment of hydrogen fueling stations and delivery infrastructure and input on barriers and activities to pursue in both the near and longer-term," on July 27, 2016. This document provides a response to this request for information. Cavendish Energy suggests multiple important areas of exploration that can significantly advance the mission of the FCTO and this particular request for information.

Background:

Although hydrogen has been a promising option for FCEVs and other energy uses to replace fossil fuels for many years, it has yet to overcome some significant economic and technical barriers to make it meaningfully useful or competitive. We applaud the activity of the DOE and its programs to continue the work of lending support to helping this energy source become more viable. Central to the history of this support has been a narrowing of the methods for the underlying production of the hydrogen. The current focus now seems limited to hydrocarbon reforming techniques and electrolysis. Each of these has shown progress over the last two decades, but they still lack the proper take-off speed for viability in any commercial sense. It is to DOE's credit that it is seeking to address some of these core difficulties by generating this input request as itemized under topics I-VII of the RFI.

The underlying capacity to produce hydrogen on-site in an economically viable manner as a fueling station business opportunity currently eludes the reforming and electrolysis providers. Decreased costs associated with massive demand increases and general availability to the public is still in the unknown distant future with no clear roadmap. Fueling station system design and integration, component manufacturing issues, modularity, combined heat and power (CHP) applications to reduce overall costs, as well as numerous other barriers need to be overcome before progress beyond limited pilots can be achieved.

Innovation is required, especially disruptive innovation to reconfigure the hydrogen markets in a manner that will provide abundant, reliable, sustainable supply at a price that will permit FCEVs to compete on a cost basis, and to facilitate hydrogen as the energy-carrier in other applications. Such innovation should address more than just the current two incumbent technologies for the answers.

Substantial resources have been expended by industry stakeholders, federal labs, academia, government agencies, and others in positioning small-scale hydrocarbon reformation and electrolysis as the imagined solutions. Meaningful progress has been made as a result of this two-pronged focus. However, Cavendish Energy suggests that there may also be nearly insurmountable obstacles associated with such an exclusively two-pronged approach. These include, but are not limited to, storage and transportation costs, hazardous materials concerns, regulatory requirements, and the lack of energy sustainability.

Cavendish Energy has developed a novel third mechanism for producing hydrogen at the requisite volumes, purity, reliability, sustainability, and economic viability. The underlying technology has been tested and demonstrated repeatedly with our advanced engineering partner the Gas Technology Institute. Cavendish Energy's process has been developed under significant secrecy to protect the intellectual property and is now ready for commercial development. The science behind the process is well understood and the research is well along, and Cavendish is ready to finalize the development and demonstrate the innovative approach.

The Cavendish process provides clean, sustainable, affordable, and reliable hydrogen from domestic resources, and contributes to increased U.S. energy security, reduced criteria pollutants, and reduced greenhouse gas emissions. In particular, it solves some of the major problems currently faced by hydrogen fueling stations: Renewable hydrogen fuel costs, station and equipment costs, and station reliability and performance. The Cavendish Process can provide on-site scalable volumes of sustainable, cost-competitive, environmentally benign hydrogen and can thus facilitate lower station costs and increase the overall utilization of hydrogen in the market. Each of the following barriers can be improved upon by the Cavendish Process. For example:

- <u>Station and equipment cost.</u> A Cavendish fueling station can be constructed for one-third to one-half the costs of current, conventional hydrogen fueling stations.
- <u>Station footprint.</u> The footprint of a Cavendish station will be relatively small compared to current alternatives.
- <u>Station reliability and performance.</u> Cavendish can produce hydrogen reliably at the volumes required, in either continuous or batch process.
- <u>Station availability.</u> Cavendish fueling stations can be established at a wide variety of locations, including current gas stations, car dealerships, universities, fleet locations, industrial sites, etc. – including indoor sites.
- <u>Lack of a domestic supply chain for equipment parts.</u> The Cavendish system is modular and produces hydrogen on-site, and is thus not overly dependent on a domestic supply chain for equipment parts.

- Lack of real-world business cases for FCEVs and hydrogen stations. Cavendish fueling stations will be cost-competitive for fleets and for general FCEVs. Of the seven topics listed in the RFI, Cavendish thus addresses at least five:

I. Hydrogen fueling station system design and integration

The footprint required for hydrogen stations constrains their ability to be sited, and this is of special concern for siting in dense urban areas where first adoption is expected. Sandia National Laboratories indicates that only 20% – 40% of existing gasoline stations in regions in California have enough space to accommodate the inclusion of hydrogen fueling. The Cavendish system lowers station costs and reduces the station footprint by eliminating or reducing the need to inventory liquid or high pressure gaseous hydrogen at the site. In addition, Cavendish on-demand generation of hydrogen can reduce the amount of buffering of high pressure gas required for dispensing.

II. Hydrogen infrastructure component manufacturing

The Cavendish system is relatively simple and uncomplicated, and it produces hydrogen at relatively low pressures and temperatures, thus reducing the need for unique, exotic, or complex components requiring specialized manufacturing processes. The utilization of the Cavendish Process does not introduce the need for any uncommon components or materials. The best way to reduce the challenges associated with infrastructure component manufacturing is to eliminate the need for components for which there is not a mature domestic supply chain to rely on.

IV. Business case analysis for FCEV fleets

Cavendish represents an innovative technical and business model that is essential to reducing the levelized cost of hydrogen fuel and to reducing the risk of investing in station infrastructure. The underlying challenge with making a sustainable business case for infrastructure investments is the high capital and operating cost of getting the hydrogen to the station site. DOE research and demonstration investments in technologies, such as The Cavendish Process, which can reduce the overall cost of delivered hydrogen by eliminating the cost of transporting high pressure gas or cryogenic liquid to each fueling location is the best way to improve the business case for hydrogen fuel cell vehicle use.

V. Co-location of hydrogen production with CHP generation systems

DOE may wish to consider technologies that can simultaneously produce hydrogen, heat, and power, not necessarily technologies that can benefit from some other wasteful process. The Cavendish system can simultaneously produce hydrogen, heat, and power and thus constitutes a CHP generation system.

VI. Delivery of hydrogen from stranded renewables

The Cavendish system can produce anywhere from very small (single kgs/day) to large volumes (100s kg/day) of cost-effective hydrogen on-site, and the major input is recycled aluminum. As such, the Cavendish process qualifies for California's low carbon fuel credits and counts toward the state's renewable energy mandates. Future research and demonstrations should broaden the definition of what sources of renewable feedstocks are available to the hydrogen industry, and by doing so, innovative technologies may benefit and advance more rapidly.