STATE OF CALIFORNIA

EPIC TRIENNIAL INVESTMENT PLAN 2015-17
Proposed Energy Research Initiative Questionnaire

CALIFORNIA ENERGY COMMISSION

Title of Proposed Initiative: Solid Acid Fuel Cell Residential NG Power Unit

Investment Areas:

☒ Applied Research and Development
☒ Technology Demonstration and Deployment
☐ Market Facilitation

Electricity System Value Chain:

☐ Grid operations/market design
☒ Generation
☐ Transmission
☐ Distribution
☐ Demand-side management

Issues and Barriers:

Main issue to adoption of solid acid fuel cell (SAFC) power units in DG applications is cost and scale-up of SAFC stacks. Currently, only 1 kW level SAFC stacks have been demonstrated at a cost of almost $6000/kW. The power output for SAFC stacks needs to be increased by 5x for residential distributed power applications, while the stack cost needs to decrease by at least 6x to $1000/kW. At these lower stack cost values and with the system level cost savings allowed by SAFCs, it becomes possible to achieve an overall system installed cost of $2000/kW, which is required for massive adoption of residential fuel cell power.

Initiative Description and Purpose:

Here we propose an intermediate temperature fuel cell approach based on the use of solid acid electrolytes (solid acid fuel cell, or SAFC), specifically CsH_2PO_4. SAFCs operate at intermediate temperatures (~250°C), are inherently impermeable to gases, and transport "bare" protons through a solid electrolyte. These properties give SAFCs advantages over other fuel cell technologies in cost, durability, start/stop cycling, fuel flexibility, and simplified system design. To date, SAFCs have demonstrated power densities over 330 mW/cm2 on hydrogen/air with lifetimes of thousands of hours, and assembled into kilo-watt level stacks. SAFCs also have very high tolerances to typical anode catalyst poisons such as carbon monoxide (e.g., 20% CO), ammonia (e.g., 100ppm NH_3), and hydrogen sulfide (e.g., 200 ppm H_2S), largely due to their operation at intermediate temperatures. Thus, SAFCs run effectively on a wide range of reformed fuels without thermal issues that otherwise limit stability and increase stack/system costs. Even with these advantages, significant hurdles must be overcome to commercialize SAFC systems for DG applications. The present proposal, led by SAFCell, is targeted towards four ambitious goals: 1) reduce PGM material costs by 5x, 2) increasing SAFC power densities by 2x and lifetimes by 10x, 3) demonstrating novel low cost, cell and stack mass manufacturing techniques, 4) optimizing fuel flexible reforming for thermal integration with SAFC stacks.

Recommended Funding Level: $1-10MM

Stakeholders:

Stakeholders who support initiative include: SAFCell, Inc. (Pasadena, CA), Sempra Utilities (Monterey Park, CA), Southern California Edison (Rosemead, CA), The California Institute of Technology (Pasadena, CA), CALSTART (Pasadena, CA), Fuel Cell Energy (Danbury, CT), The Gas Technology Institute (Des Plaines, IL), Lawrence Livermore National Laboratory (Livermore, CA), the National Renewable Energy Laboratory (Boulder, CO), InnovaTek (Richland, WA), UltraCell, LLC (Livermore, CA), and the Los Angeles Cleantech Incubator (Los Angeles, CA).

Background and the State-of-the-Art:

Fuel cells remain the most efficient means of converting chemical to electrical energy. Yet, current fuel cell technologies are not commercially viable for small (< 100kW) distributed power applications. Low temperature PEMFCs are largely limited to hydrogen as a fuel, whereas fuel flexible technologies (e.g. PAFCs, HTPEM and SOFCs) remain too costly. Here we propose an intermediate temperature fuel cell approach based on the use of solid acid electrolytes (solid acid fuel cell, or SAFC), specifically CsH2PO4. SAFCs operate at intermediate temperatures (~250°C), are inherently impermeable to gases, and transport "bare" protons through a solid electrolyte. These properties give SAFCs advantages over other fuel cell technologies in cost, durability, start/stop cycling, fuel flexibility, and simplified system design. SAFCell, Inc. develops scalable SAFC stacks for applications requiring tens of watts to tens of kilowatts. SAFCell is partnering with targeted system integrators to enter first portable, and then stationary power markets. Over the last four years, SAFCell has scaled its SAFC stacks from watts to kilowatts, while simultaneously increasing cell active area, performance and longevity, and decreasing the stack price per kilowatt by an order of magnitude.

Compared to mature fuel cell technologies, SAFC systems will most closely resemble PAFC systems due to their similar operating temperatures and electrochemistry. PAFCs and HTPEMs (e.g. PBI-based membranes) operate at temperatures ~ 160-200 °C, and therefore offer some of the temperature-based advantages of SAFCs. For this reason, PAFCs were the first fuel cell technology to be commercialized, even though their performance metrics are much lower than PEMFCs or SOFCs. However, the highly acidic and liquid nature of the phosphoric acid electrolyte leads to many challenges which drive up stack and system costs. The result is an installed cost of around $4,000/kW for large (> 100kW) PAFC systems, and limited commercial adoption of the technology. The solid state nature and slightly elevated temperatures of SAFCs eliminate the main cost increasing limitations of PAFCs. As such, system installed costs for SAFCs will be significantly lower than those for PAFCs, once the technology is matured. This cost reduction will enable commercial adoption in portable, auxiliary, and stationary power applications.

It should also be noted that a commercially viable solid acid electrolyte technology is multi-purpose, that is, not only applicable to fuel cells, but also liquid fuel production from hydrocarbons, hydrogen separation and compression, and a candidate for FC-FC hybrids. This broad range of applications are a result of the intermediate operational temperature of SAFCs, and high impurity tolerances that come with it. It is for this reason that ARPA-E has put out a funding opportunity announcement on intermediate temperature fuel cells and electrochemical devices called “Reliable Electricity Based on ELectrochemical Systems” (REBELS), which seeks to disrupt traditional learning curves for distributed stationary power generation by introducing new technologies that can significantly lower cost and increase performance compared to current distributed generation technologies. This program has a proposed funding level of $30MM over a maximum of three years.

Justification:

Our primary focus will be on the development and deployment of residential power units. Accordingly, the technology will initially provide measurable benefits to the self-generation residential sector. Based on the California Energy Commission Report titled "*California Energy Demand 2014-2024 Final Forecast, Volume 1: Statewide Electricity Demand, End-User Natural Gas Demand, and Energy Efficiency*," date January 2014, the California Energy Demand (CED) for residential consumption was 90,651 GWh for 2012. Moreover the projected Mid Energy Demand for the residential sector in 2015 and 2024 are 93,452 GWh and 110,910 GWh, respectively, with an average annual growth of 1.7% between 2012-2024. The report also forecasted the electricity mid demand for non-photovoltaic self-generation is 14,480 GWh in 2024 with the growth in non-PV self-generation coming mainly from recent increases in the application of fuel cell projected forward and from commercial combine heat and power (CHP). Our technology, if afforded the opportunity to be matured by 2024 with public funding facilitation, would play an important role in addressing the CED of the residential market. With such market potential, we expect to generate thousands of direct jobs in California in the form of research and development, manufacturing, installation, and servicing.

Ratepayer Benefits (Check one or more)**:**

☒ Promote greater reliability
☒ Potential energy and cost savings
☒ Increased safety
☒ Societal benefits
☒ Environmental benefits – lower total emissions due to higher fuel conversion efficiencies
☒ GHG emissions mitigation/adaptation in the electricity sector at the lowest possible cost
☐ Low emission vehicles/transportation
☐ Waste reduction
☒ Economic development

As mentioned in the background discussion, fuel cell systems exhibit high electrical efficiency with overall efficiencies greater than 80% are possible in CHP operations. Overall, the system will be more efficient with high quality waste heat of higher value and would provide appreciable potential energy and cost savings to ratepayers. Fuel cell power generators have relatively few number of moving parts and would have the benefit of low mean time between failure rates. Broader deployment of wind and solar energy generators will require flexible and fast responding back-up power to cover their intermittency. When coupled with photovoltaic systems, fuel cell (FC) generators would provide redundancy of power generation and greatly increase system power reliability and availability. Fuel cell system emission and noise are near zero (CARB certified) and would allow operation near demand even in densely populated area including isolated small communities.

Public Utilities Code Sections 740.1 and 8360:

SAFC technology addresses many of the principles summarized in CPUC Sections 740.1 and 8360. Specifically, SAFC is rapidly accelerating its technology readiness level and thus, if deployed, would offer reasonable probability of providing immediate benefit to ratepayers. The proposed project is well aligned with SAFCell's business and resource plan. The project supports environmental improvement owing to the technology's low system emission and noise. Owing to its reliability, affordability, versatility, and convenience, SAFC self-generation power units would provide public safety via a stable distributed power source with improved operating efficiency.