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

CALIFORNIA ENERGY COMMISSION

(This is a Request for Information only - Complete Pages 1 and 2 for each initiative)

Title of Proposed Initiative: Massive Energy Storage for High Renewable Use

Investment Areas (Check one or more) – *For definitions, see First Triennial Investment Plan, page 12*:

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

Electricity System Value Chain (**Check only one**): *See CPUC Decision 12-05-037, Ordering Paragraph 12.a. http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF.*

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

Issues and Barriers:

California's electricity system will need to undergo significant changes due to the increasing amount of variable renewable energy sources that are being integrated into the electric power system. With increasing amount of uncontrollable, intermittent and dynamic renewable energy sources that are being integrated into these systems, renewable energy sources (RES) could have significant negative impacts on grid operation in different time scales, including those that affect regulation, load following, and scheduling. Introducing energy storage technology is a promising technology option to manage and complement renewable intermittency since energy storage technologies allow direct control to retrieve, store and dispatch additional power at various time scales. The main barriers that are impeding full market adoption of the massive energy storage technologies are 1) lack of information on system integration and 2) the cost.

Initiative Description and Purpose:

The proposed initiative will focus upon the enabling massive energy storage technologies that offer independent sizing of energy conversion and energy storage, to fully integrate the increasing amount of renewable sources into California's electric power system. Massive energy storage technologies (e.g., hydrogen fuel cell/electrolysis, flow batteries, pumped hydro, and compressed gas energy storage) have the potential for mass storage at lower cost due to separate energy conversion and storage components that allow for independent sizing. In the proposed initiative, the system integration of such energy storage systems will be evaluated and advanced.
Recommended minimum funding level = $300,000/project; Recommended maximum funding level = $1,500,000/project.

Stakeholders:

Major utilities (e.g., Edison, Sempra Energy Utilities); Renewable energy industry; Universities

Background and the State-of-the-Art:

- There are many different energy storage technologies currently available. Hydrogen energy storage, pumped hydro, compressed air energy storage, various types of battery systems, flywheels, super capacitors, and thermal energy storage are all either being used or investigated for energy storage to provide frequency regulation, alleviate transmission congestion, defer costs of new construction, provide load shifting, and reduce "time of use" and demand charges[1].
- While each of these technologies could be designed for storage of large amounts of energy, the primary technologies that can cost effectively store large amounts of energy are compressed air energy storage, pumped-hydro and hydrogen energy storage system with fuel cells and electrolysis[2]. These technologies are cost effective for massive energy storage primarily because the energy storage components and equipment of the system are independent of the energy conversion components and equipment. This is a fundamental and profound difference that creates significant competitive advantages for these technologies as integrated into the electric power system.
- Pumped hydro energy storage is the oldest, most efficient, cost effective and most widely used method of energy storage, accounting for over 99% of energy storage worldwide. But only locations with a suitable elevation gradient to provide the gravitational potential energy, and the land area and geographic features for storage of a large amount of storage media (water) are amenable to large scale pumped hydro energy storage.
- Worldwide there are currently two compressed air energy storage facilities in operation, Huntorf, Germany, and McIntosh, Alabama. To release the stored energy the compressed air is routed to a gas turbine fueled by natural gas that produces electricity. One of the challenges that have plagued recent compressed air energy storage is associated with the high pressure combustion[3].
- Hydrogen energy storage has been demonstrated by NREL and Xcel Energy, with the wind-to-hydrogen demonstration project in Boulder, Colorado. In the most recent demonstration, low temperature electrolysis was applied in a PEM Fuel Cell to split the water into hydrogen. The PEM electrolyzer achieved system efficiency of 57% [4]. Electrochemical energy conversion technologies are promising for massive energy storage and hydrogen production from intermittent renewable power sources, and also have the potential for mass storage at lower cost than batteries due to separate energy conversion and storage components that allow for independent sizing.

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[1] Diaz-Gonzalez, F., et al., *A review of energy storage technologies for wind power applications.* Renewable & Sustainable Energy Reviews, 2012. **16**(4): p. 2154-2171.
[2] Steward, D., et al., *Lifecycle Cost Analysis of Hydrogen Versus Other Technologies for Electrical Energy Storage*. 2009, National Renewable Energy Laboratory: Golden, Colorado.
[3] Marean, J. Compressed Air Energy Storage Engineering and Economic Study. in New York State Energy Research and Development Authority. 2009. Albany, NY.
[4] Harrison, K., et al., *The Wind-to-Hydrogen Project: Operational Experience, Performance Testing, and Systems Integration*. 2009, National Renewable Energy Laboratory: Golden, Colorado.

Justification:

Describe how this technology or strategy will provide California IOU electric ratepayer benefits and provide any estimates of quantified annual savings/benefits in California, including:

- Quantifiable performance improvements for the proposed technology/strategy: The anticipated performance metrics: 1) sufficient dynamic capability to meet renewable power variability, 2) ability to use 100% of the available renewable resource, and 3) overall system efficiency of greater than 50%
- Number of direct jobs created in California: 1,000 to 5,000 new and sustainable jobs.
- Why this research is appropriate for public funding: The research is aimed to utilize more 'green' and renewable energy, which is required by law in California, and it also contributes significantly to environmental benefits (air quality, and greenhouse gas reduction) for the public.

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

☐ Promote greater reliability

☒ Potential energy and cost savings

☐ Increased safety

☒ Societal benefits

☒ Environmental benefits: less GHG and criteria pollutant emissions

☐ GHG emissions mitigation/adaptation in the electricity sector at the lowest possible cost

☒ Low emission vehicles/transportation

☐ Waste reduction

☐ Economic development

Describe specific benefits (qualitative and quantitative) of the proposed initiative

Public Utilities Code Sections 740.1 and 8360:

Please describe how this technology or strategy addresses the principles articulated in California Public Utilities Code Sections 740.1 and 8360. The California Public Utilities Code is available online at www.leginfo.ca.gov/cgi-bin/calawquery?codesection=puc.

(Address California Public Utilities Code Sections 740.1)

The proposed initiative offers a reasonable probability of providing benefits to ratepayers by integrating more renewable energy sources to the electric grid and lower the GHG emissions. The organization (Advanced Power and Energy Program, UCI) has a long-standing record of performing similar R&D tasks of similar risk and complexity, and a proven track record of working with teaming partners. The proposed initiative, to our best knowledge, is novel and not duplicate research currently undertaken. The projects under the initiative will support 1) Environmental improvement, 2) Conservation by efficient resource use, 3) Development of new resources and processes, particularly renewable resources and processes which further supply technologies, and 4) Improve operating efficiency and reliability.

(Address California Public Utilities Code Sections 8360)
California's transmission system will need to undergo significant changes due to the increasing amount of variable renewable energy sources that are being integrated into the electric power system. The proposed initiative is aimed to enabling the massive energy storage technologies to be fully integrated into the current transmission and distribution system. Under the California Public Utilities Code Sections 8360, the proposed effort is aimed to identify and address barriers to the interconnection of distributed renewable energy sources coupled with energy storage, to strengthen the transmission system and to improve the reliability when higher renewable penetration is achieved. The proposed initiative will also advance 1) the deployment and integration of cost-effective distributed renewable resources and generation, 2) the deployment and integration of cost-effective advanced electricity storage and peak-shaving technologies, and 3) the identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.