February 13, 2014

To whom it may concern,

Attached is my response to the questionnaire released by the Energy Commission in regards to the development of the 2nd Triennial EPIC Investment Plan. Thank you for your consideration.

Sincerely,

Randall Benson
Senior Nuclear Engineer and Senior Reactor Operator
San Onofre Nuclear Generating Station
Southern California Edison
Randall.Benson@sce.com

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Title of Proposed Initiative: Closing the Nuclear Fuel Cycle with GenIV Reactors

Investment Areas:

☒ Applied Research and Development

☒ Technology Demonstration & Deployment

☐ Market Facilitation

Electricity System Value Chain:

☐ Grid Operations/Market Design

☒ Generation

☐ Transmission

☐ Distribution

☐ Demand-Side Management

Issues and Barriers:
Since 1976, the development of new nuclear (fission) power in the state of California has been prohibited by PRC § 25524.2, until the CEC finds that the NRC "has approved and there exists a demonstrated technology or means for the disposal of high-level nuclear waste." Because of decisions by the Obama administration, plans for the development a permanent geologic repository for spent nuclear fuel (SNF) have been delayed indefinitely. The lack of a waste solution will prevent the development of nuclear power, an energy resource with extremely low lifecycle GHG emissions.

Initiative Description and Purpose:
The purpose of this funding initiative is to support the development of a closed nuclear fuel cycle that minimizes the quantity and radiotoxic longevity of SNF generated by nuclear power. The basic principle to accomplish this lies in the proven concept of a breeder reactor, which is defined as a reactor capable of generating more fissile material than it consumes. Light water reactors (LWR) currently in operation in the United States only generate about 60% as much fissile material as they consume. As a result, SNF must be discarded (A) for lack of isufficient fissile material is available to sustain the reaction and (B) due to the accumulation of fission products in the fuel, which are neutron poisons. The fuel is considered "spent" despite retaining in excess of 99% of its original energy content. By contrast, breeder reactors generate fissile material sufficient to continue the reaction so long as fertile material is present. Complete burnup of nuclear fuel would extract all of its energy and destroy all of the actinides, which are the heavy metals with long half-lives that drive the million-year considerations of storing SNF. The only waste product of a closed fuel cycle would be fission products, whose radioxicity falls below that of natural uranium in a matter of 300 years. In addition the quantity of nuclear waste (per unit energy output) would be dramatically reduced.

As breeder reactors have been demonstrated and commercially operated in many countries, the technology is well beyond the proof-of-concept stage. However, specific advances are required to establish their commercial viability in the United States, where previous R&D efforts were abandoned under the assumption that geological storage would solve the waste problem, cheap prices of fresh uranium, and as a result of the same regulatory and political climate that halted the construction of new LWRs. Remaining research needs include:

- Driving down cost of proliferation-resistant reprocessing methods (i.e. alternatives to PUREX that do not isolate plutonium) to remove fission products, ensuring 100% actinide burnup
- Validating design features to enable competitive economics of breeder reactors, such as modularity, passive safety, online-refueling, and Brayton cycle power conversion

Funding of projects under this initiative could be combined with other initiatives that more specifically target issues like economics, safety, and flexible load-following capability. However, the goals of this initiative would be considered primary, as a solution to the waste problem is a pre-requisite to the return of new nuclear power to California, per PRC § 25524.2. A minimum funding amount that should be committed to such a project would be on the order of $5 million. A possible maximum for a single project could be $25 million. Match funding would be expect to account for a large portion of total project costs, as this funding initiative would be expected to complement funding by DOE, other states, and private sources.

Stakeholders:

Stakeholders who would be likely to support this funding initiative include:

- the IOUs, which remain responsible for managing SNF until a solution is implemented, and might consider building new nuclear power plants, if the ban were lifted
- The California Council on Science and Technology, which has advocated nuclear power in California's future power mix
- The UC Berkeley Department of Nuclear Engineering
- Lawrence Livermore National Laboratory, whose energy R&D portfolio includes advanced reactor design and nuclear fuels, and other national labs
- General Atomics, headquartered in San Diego, which is developing a gas-cooled fast reactor would be a strong candidate for funding under this initiative
- Any concerned California resident who wishes to see a safer, cheaper, and quicker resolution the nuclear waste issue

Background and the State-of-the-Art:

The world's first breeder reactor, Experimental Breeder Reactor 1 (EBR-I), was a 200kWe reactor demonstrated at Idaho National Lab (INL) in 1951. It successfully demonstrated the principle that a power reactor could generate more fissile material than it consumed. EBR-I was succeeded by the 20MWe EBR-II in 1965, which provided the majority of the lab's electricity and heat overs its 30 years of operation. EBR-II successfully demonstrated the principle of passive safety through experiments in which the cooling systems were shut off manually (simulating a loss of coolant accident, such as those that occurred in Three Mile Island and Fukushima). Reactor power dropped to near zero within 5 minutes and the reactor safely shed decay heat without requiring any human intervention or the operation of an active safety system.

The first commercial breeder reactor was Shippingport, originally designed as a burner when it opened in 1957. During its 3rd fuel cycle, from 1977 to 1982, it bred U-233 from Th-232. Larger scale breeder reactors in the United States built upon the prototypes demonstrated at INL. These include the Clinch River Breeder Reactor (CRBR), a joint private-federal venture, and the Integral Fast Reactor (IFR), a DOE project. Both were halted by votes of the U.S. Congress to deny further funding because of escalating cost and proliferation concerns in 1983 and 1994, respectively. Drawing on the lessons learned from this experience, a consortium of General Electric and Hitachi have developed a GenIV reactor based on the IFR under the name PRISM.

Outside of the U.S., breeder reactors have been demonstrated in the U.K., France, Germany, Japan, and the former Soviet Union. R&D is currently on-going in many other countries, particularly those which are members of the GenIV International Forum.

Justification:

The persistence of the nuclear waste problem has two negative impacts on California IOU ratepayers:

1. SNF continues to pile up at Diablo Canyon at a rate of 48 metric tons per year, while over 2,000 metric tons remain on site at California's retired nuclear power plants. While federal courts have recently ordered DOE to cease collecting the waste storage fee and California utilities have received some compensation to cover past waste storage costs, it appears certain that California IOU ratepayers will face large burdens associated with indefinite onsite storage of SNF. At SONGS alone, the cost of transferring and packaging the SNF currently residing in wet storage to dry storage is estimated by EPRI at approximately $122 million and the cost of maintenance and monitoring, on the order of millions of dollars annually, will continue until a waste solution is found.
2. By statute, new nuclear power plants will be excluded from helping to achieve California's AB 32 goals. The repercussions of the closure of SONGS illustrate the enormously underappreciated benefits that it provided for SCE and SDG&E ratepayers. In 2012, GHG emissions in California's electric power sector rose by an estimated 6.75 million metric tons of CO2e as a result of the outage. Further, the difficulties of planning for and ensuring local reliability in Southern California reveal the limits on siting utility-scale renewable generation in close proximity to load. The current goal among California regulatory agencies is to replace a mere 50% of SONGS with "preferred resources" (while the remainder will be replaced by increased natural gas generation). This underscores the infeasibility of an exclusively renewable electricity system. Instead, a mix of nuclear and renewables should be pursued, so that the diminishing marginal benefits and increasing marginal costs of very high penetrations of intermittent renewables do not burden California IOU ratepayers in pursuit of AB 32 goals.

Ratepayer Benefit:

☒ Promote greater reliability

☒ Potential energy and cost savings

☒ Increased safety

☐ Societal benefits

☒ Environmental Benefits – less land use compared to renewables + sustainable nuclear fuel use

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

☒ Low emission vehicles/transportation

☒ Waste reduction

☒ Economic development

Nuclear power provides reliability and capacity value that intermittent renewables cannot provide, except with the use of storage (which remains very expensive), demand response (which cannot conceivably shave peak demand by more than 20%), or back-up generation (which is currently natural gas). Nuclear power has historically provided zero-emissions electricity to California IOU ratepayers at significantly lower cost than non-hydro renewables; innovation in reactor design will drive these costs even lower. GenIV plants will be safer and produce substantially less waste than currently operating plants. The use of nuclear power will avoid the land use and habitat impacts created by utility-scale renewable energy development. In addition to generating electricity, nuclear power can also desalinate water, generate alternative transportation fuels, and provide industrial process heat.

Public Utilities Code Sections 740.1 and 8360:

§740.1: This funding initiative targets nuclear technologies that provide (a) environmental improvement, (b) promote public and worker safety, (c) conserve the nuclear fuel supply through efficient use, (d) develop new resources and processes, and (e) improve operating efficiency and reliability and otherwise reduce costs.

§8360: This funding initiative promotes the (c) deployment and integration of cost-effective generation and (j) lowers unreasonable or unnecessary barriers (i.e. PRC §25524.2) to the adoption of smart grid technologies.