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Electric Program Investment Charge (EPIC) 4 Investment Plan: California Energy Commission (CEC) Staff's Proposed Draft Initiatives

7/29/2021

Accelerate Cost Reductions for Renewable Generation Technologies

1. **Floating Offshore Wind Energy Technologies.** Advance offshore wind as a key clean supply resource for Senate Bill (SB) 100 (De León) buildout and a complement to solar. Technology advancements may include (1) optimizing component design (e.g., blades, towers, support structures) for cost, durability, and operational efficiency; (2) developing standardized processes for manufacturing, assembly, and installation; (3) grid integration innovations and port infrastructure readiness strategies; (4) environmental impact assessment and minimization.
2. **Advancing Geothermal Energy and Mineral Recovery Technologies.** Expand geothermal as a firm and flexible resource that complements intermittent renewables and catalyze low-impact production of in-state lithium (Li) for use in batteries. Technology advancements may include (1) improving drilling technologies and well-targeting; addressing corrosion and scaling; advancing flexible operations; improving the cost of small-scale systems to utilize additional geothermal resources (e.g., repurposing oil and gas wells); and (2) demonstrating recovery methods for Li and other brine co-products.
3. **Emerging Solar Energy Technologies.** Improve solar generation efficiency, cost, and output to support solar's central role in the SB 100 buildout. Technology advancements may include (1) improving performance and lowering costs for thin-film solar (perovskites, bifacial thin film, tandem PV); and (2) demonstrating technologies that enable increased solar output (bifacial PV, trackers).

Achieve Reliability and Create a Nimble Grid Responsive to Intermittent Renewable Generation

4. **Short Duration Energy Storage Technology Demonstrations to Support Grid Reliability.** Initiative includes (1) Improvements to Li-ion batteries to address reduced capital and life cycle cost, round trip efficiency (RTE), depth of discharge and cycling issues, degradation over time, thermal run-away, fire safety, form factor improvements, and overcoming barriers to scale; (2) Demonstration of non-Li-ion chemistries for reduced cost (capital and life cycle), better lifetime performance, access to greater depth of discharge, reduced degradation over time, better RTE, and improved supply chain diversity over Li-ion battery systems.
5. **Long Duration Energy Storage Technology Demonstrations to Support Grid Reliability.** Development and demonstration of technologies better suited to long duration energy storage (8 hours or more) such as, but not limited to flow batteries, advanced battery chemistries, flywheels, compressed air, liquid air systems, molten salt, molten sulphur, and chemical storage of green hydrogen and green methane to achieve life cycle cost effectiveness.

6. **Energy Storage Use Case Demonstrations to Support Grid Reliability**. Develop and demonstrate energy storage use cases to support grid reliability on the customer and utility sides of the meter. Demonstrate applications such as (1) dynamic charge reservation to enable back-up batteries to provide time-critical grid support when called upon; (2) deferral of new transmission and distribution lines by providing non-wire alternatives; (3) improvement of vehicle-to-grid capabilities when integrated with energy storage; (4) microgrid islanding during demand response and emergency interruption events; (5) energy storage discharge response to the CPUC's Unified Universal Dynamic Economic Signal. Create clear definitions for storage durations (micro-short term, short term, long term, seasonal, etc.) based on customer and grid needs. Formulate protocols for short-term predictive applications and advanced energy storage discharge protocols that can (1) respond to distribution constraints in real time, (2) allow an increased amount of energy storage that can be interconnected to support the resiliency needs of the customer and grid, and (3) accommodate the projected eight-fold increase in the fielding of energy storage defined in the SB 100 Joint Agency Report. Current processes for interconnection limit energy storage interconnection, are costly and time consuming, and severely hamper achievement of SB 100 goals. This initiative supports CPUC proceedings to improve the interconnection process while maintaining safety.
7. **Green Hydrogen Roadmap Implementation to Support Grid Reliability.** This initiative provides next steps to implement the Interim EPIC Plan's Green Hydrogen Roadmap and Strategic Plan. This would focus on the Hydrogen for Grid Reliability use case(s) developed in the Roadmap and Strategic Plan. It would provide an update of the roadmap before EPIC 5 based on new technology developments, industry progress over time, and new research results obtained during the implementation of all of EPIC 4 initiatives.
8. **Infrastructure, Market Analysis, and Technology Demonstrations to Support Firm Dispatchable Decarbonized Generation.** Formulation of a general framework to evaluate cost, performance, and technology attributes among various forms of firm dispatchable decarbonized generation and long duration energy storage in front of the meter to achieve SB 100 goals while optimizing ratepayer cost and benefit (i.e., how solutions such as green hydrogen and green methane compare in cost, capacity, performance, and impact with other long duration energy storage solutions or other grid firm dispatchable technologies). The framework would guide priority demonstration projects including the infrastructure and supply chain provisions to optimize firm dispatchable decarbonized generation while at the same time reducing greenhouse gases (GHGs) and criterion pollutants.
9. **Advancing Clean, Dispatchable Generation.** Advance performance and cost competitiveness of clean, dispatchable generation technologies to reduce dependence on fossil-based peaker power plants, complement intermittent renewables, and support SB 100 implementation. Technology advancements may include hydrogen fuel cells; combustion systems (gas turbines and reciprocating engines) that use high blends of green hydrogen; and bioenergy conversion technologies (digesters and gasification) for electric applications. This initiative would focus on advancing specific generation plant types, complementing the evaluation framework, infrastructure, and supply chain focus of initiative #9 above.
10. **Technology Demonstrations to Address Grid Congestion Resulting from 3X Generation Growth on the Path to a Decarbonized California.** Demonstrate technologies, such as

power flow control technologies and enhanced use of reactive power systems, that can change the impedance of T&D lines to effectively re-route power to relieve congestion as well as smart reconductoring to increase the line ampacity with no increase in weight or other relevant factors to retain existing utility towers. Achieve a nimbler grid to carry more power on the same rights-of-way supporting Garamendi Principles, with use cases to alleviate congestion, improve regional intertie capacity, reduce renewable energy curtailments, improve interconnection capacity, reduce line losses, and reduce wildfire ignition risk. Identify the optimal mix of technologies for use cases and ratepayer benefit. This initiative would be coordinated with electric utilities to ensure there is no duplication

11. **Demonstrate Technologies to Maintain Reliability and Power Quality in the Inverter-Centric Grid of the Future Associated with High Levels of Renewables.** Complete targeted development and demonstration of emerging technologies to address power quality factors such as harmonics, power factor, and rotational inertia, which are essential to maintaining a reliable grid. Technologies such as grid forming inverters, harmonics filters, and power factor correction devices (e.g., synchronizing condensers, dynamic volt-ampere reactive systems, and capacitor banks) as well as other emerging technologies are being developed and improved continuously to help address power quality challenges with integrating renewables into the grid. Additional research is needed to: demonstrate the feasibility of these emerging technologies, identify clear functional requirements and standards, and facilitate market adoption of the technologies for bulk power system application.
12. **Furthering Cybersecurity with Highly Modulatable Grid Resources.** As more modulatable technologies are connected to the grid, cybersecurity must be considered. This initiative would identify and develop protocols and best practices that should be required of CEC-funded distributed energy resource (DER) technologies to ensure they are addressing cybersecurity issues in their product development. This would build on cybersecurity protocols developed under the CEC Public Interest Energy Research Program as well as initiatives developed by the investor-owned utilities, Electric Power Research Institute, Department of Defense, Department of Homeland Security, and other organizations that are addressing the issues surrounding cybersecurity and its impact on grid resiliency. Examples of project topics may range from applying or further developing cybersecurity protocols for aggregation of DERs and related communications for modulatable resources in front of the meter as appropriate. This initiative would be managed with a sensitivity to what data needs to be maintained confidentially and what is publicly available.

Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid

13. **Improving Forecasts of Behind-the-Meter Solar and Storage.** Improve accuracy of methods for forecasting behind-the-meter (BTM) solar PV and storage to limit reserve resource requirements and realize associated cost benefits. Research advancements may include (1) developing new models to strengthen forecasts of solar irradiance; and (2) improving methods for load forecasting by better accounting for energy flows from BTM solar PV and storage under different conditions.
14. **Direct Current Systems for Efficient Power Delivery.** Improve efficiency in power delivery by utilizing DC systems, generating cost savings for customers and reducing demand on the

grid. Technology advancements may include developing and deploying low-cost, modular, and replicable BTM DC power systems that enable efficient, clean, and reliable power for electric vehicles (EVs) and other DC end-uses such as solid-state lighting and motor-driven loads.

15. **Behind-the-Meter Renewable Back-up Power Technologies.** Develop and demonstrate low-cost BTM renewable energy technologies that enable customer resilience to grid outages. Technology advancements may include (1) developing modular power electronics that enable BTM renewable generation systems (e.g., rooftop solar) to provide back-up power at reduced cost; (2) reducing hardware costs of back-up power electronics; making battery storage an optional addition to back-up systems rather than required; and increasing standardization of solutions to promote replicability.
16. **Design-Build Competition.** Community-scale deployments of integrated DER technologies continue to be challenging as they typically involve disparate stakeholders, customers, and locations. Scale up requires not only coordinating and integrating technology deployments across these groups, but also innovative financing and business models. This initiative seeks to implement the next design-build competition for EPIC – building off the efforts of the Advanced Energy Communities Program and the Mixed-use Development Design-Build Competition. This initiative would continue the previously implemented two-phase model and focus on a different building sector.
17. **Efficient Transportation Electrification and Charging Technologies.** Conduct applied research, development, and technology demonstrations of new high efficiency charging devices and systems that reduce electric losses and costs of EV charging. This initiative would span all vehicle classes and power levels, including efficient electrification of challenging transportation sectors. Technology advancements may include advanced on-board charger design, prototyping, and performance validation; next generation power electronics for high-efficiency, high-power charging systems (e.g., wide bandgap materials); and enabling efficient electrification of agricultural and other off-road vehicles.
18. **Enabling Plug-in Electric Vehicles as Distributed Energy Resources.** Advance technologies and demonstrate plug-in electric vehicle (PEV) charging and discharging that is flexible, safe, reliable, and coordinated with grid needs. Technology advancements may include developing grid-interactive inverters in bi-directional charging equipment; advancing software for integrating PEV charging with building management systems; and demonstrating high-accuracy, low-cost submeters for PEV chargers to avoid separate service requirements.
19. **Integrating Distributed Energy Resources for Grid-Supportive Vehicle Charging.** Integrate DERs (e.g., distributed solar, storage, etc.) with transportation electrification to mitigate the grid impacts and GHG emissions associated with EV charging. Technology advancements may include: developing, testing, and validating hardware and software solutions to advance load management capabilities and reduce installation and operating costs; conducting pilot demonstrations of promising use cases to scale up deployment; and developing and expanding tools for quantifying the benefits of pairing EV infrastructure with other DERs to address grid constraints.
20. **Lithium-ion Battery Reuse and Recycling Technologies.** Improve, scale up, and demonstrate innovative reuse and recycling technologies for end-of-life Li-ion batteries to conserve

critical materials, promote material sustainability, and reduce the cost of new storage products by lowering material costs. Technology advancements may include battery design to facilitate repurposing and recycling; demonstrating the performance of recovered materials in new batteries; and developing flexible approaches for efficient battery collection, sorting, and diagnostic testing.

21. **Enabling Grid Resilience with Load Flexibility in the Industrial, Agricultural, and Water (IAW) Sectors.** Few viable control strategies and technology solutions exist for owners and operators of IAW facilities to implement. Participation in existing demand response (DR) programs has been limited because incentives and rate structures are not sufficiently attractive. This initiative would establish the *California Industrial, Agricultural, and Water Flexible Load Research and Deployment Hub* to conduct research to (1) increase the use and market adoption of advanced, interoperable, and flexible demand management technologies and strategies as electric grid resources; and (2) develop and advance flexible load technologies, tools, and models to facilitate and increase grid resiliency and DR participation in the IAW sectors.
22. **Virtual Power Plants Autonomous and Predictive Controls.** Continuously changing DR market conditions make it difficult for consumers to feel confident making the investments required to participate in flexible load programs. Community Choice Aggregators (CCAs) and others can become hubs for promoting demand flexibility and creating revenues from the wholesale market. This initiative would use the virtual power plant (VPP) concept, which includes networking and managing a portfolio consisting of distributed, consumer-owned renewable generation and flexible power consumers (e.g., heating, ventilation, and air conditioning [HVAC], water heaters, smart appliances, EVs, batteries) to respond to changes in electricity market incentives. This initiative would (1) develop and demonstrate open source data and management controls to help aggregate customer loads, (e.g., use of telemetry, measurement, and verification; real-time data collection and analysis practices; and various hardware and software systems); and (2) assist CCAs and others in following grid signals and participating in wholesale energy markets by coordinating consumption and dispatch.
23. **Increasing Reliability and Interoperability of Load Flexible Technologies.** Research is needed to overcome some of the technical and market barriers that hinder deployment of load flexible technologies and their ability to provide deeper and more reliable load impacts during times of need. This initiative would (1) develop and test new technologies and strategies that are not part of the CalFlexHub scope to increase understanding of how flexible loads perform and are accounted for in the California energy markets and (2) implement large-scale field demonstrations of technologies developed through the CalFlexHub to evaluate and verify the value proposition to customers and the grid. The goal is to increase technology interoperability and integration improvements that increase the capability, availability, reliability, ease of use, and cost-effectiveness of load flexible technologies.

Improve the Customer Value Proposition of End-use Efficiency and Electrification Technologies

24. **Technology Prize Competition for Advanced Electric Stovetops.** This initiative would provide funding for a prize competition for contestants to develop an advanced electric stovetop that can overcome consumer and industry acceptance barriers. Two prizes would

be awarded from this competition – one for the best technology for residential kitchens and another for commercial kitchens and restaurants who have a higher production need.

25. **Low-Carbon / High-Temperature Industrial Heating**. The industrial sector produces over 20 percent of California's GHG emissions, representing the second largest source of emissions in California. A large portion of industrial emissions is due to process heating, which accounts for approximately 70 percent of the total industrial energy use. This initiative would help decarbonize industrial high-temperature process heating through (1) use of high-temperature heat pumps, (2) use of direct electrification technologies (microwave, radiofrequency, infrared, ohmic, etc.), and (3) use of green hydrogen as an alternative to direct electrification to use renewable electric power.
26. **Energy Efficiency and Decarbonization in the Cement Industry.** California's cement industry consumes 65 million therms of natural gas and 1,320 million kWh of electricity (estimated values for 2016) and is a major contributor to carbon dioxide (CO_2) emissions, with eight cement plants subject to Cap-and-Trade Program producing approximately 8 million metric tons CO_2 equivalent annually. Approximately 60 percent of emissions from cement production are process-related, primarily from the conversion of limestone to clinker, while 40 percent comes from fuel and electricity consumption. This initiative would advance (1) electrically driven carbon capture and utilization to increase the energy efficiency of carbon capture and utilization processes to reduce GHG emissions, (2) alternative raw materials, chemistries, and processes for the production of Ordinary Portland Cement and substitutes that enable electrification of cement production, and (3) fuel switching from fossil fuels to electricity.
27. **Energy Efficient Separation Processes.** Approximately 10-15 percent of the total energy used in the United States is for chemical separations and is done via distillation, drying, and evaporation of liquids (e.g., milk), gases (e.g., oxygen/hydrogen), and solids (e.g., wastewater). There are opportunities to switch to non-thermal separations driven by electricity. This initiative would (1) develop and demonstrate new equipment that replaces thermal separation with alternative, non-thermal electricity-driven separation processes and (2) improve electrical efficiency of existing separation processes that have not been widely adopted due to unfavorable economics. Targeted markets include food processing, chemicals, water desalination, wastewater treatment, carbon capture (including direct air capture), and others. The goal is to advance energy-efficient separation processes generic to the industrial and water sectors and improve economics.
28. **Domestic Hot Water (DHW) Heat Pumps Using Low-Global Warming Potential (Low-GWP) Refrigerants.** Heat pump water heaters (HPWHs) would continue to use high-GWP refrigerants, typically HFC-134a with a GWP of 1,410. These refrigerants are potent GHG emitters and their impact on global warming can be hundreds to thousands of times greater than that of CO_2 per unit of mass. This initiative would develop, test, and demonstrate high-efficiency 120V HPWH and 240V HPWH that use low-GWP refrigerants. The goal is to use refrigerants with less than 150 GWP.
29. **Innovative Solutions for Improving the Value Proposition for Building Envelope Upgrades.** As more homes decarbonize with electric HVAC heat pumps, it becomes critical that building envelopes in existing buildings become more tightly sealed and insulated to minimize heat loss from buildings during the winter and heat gain in the summer. This initiative would (1)

develop new envelope technologies and manufacturing processes to reduce cost, (2) develop and test thermal storage materials to enable building envelopes to actively store and release thermal energy with an emphasis on lower cost, and (3) develop, demonstrate, and validate the accuracy of affordable non-intrusive home performance assessment and diagnostic tools to determine air leaks, moisture infiltration, presence of asbestos or lead, R-value of existing insulation in buildings, and other parameters. The goal of this initiative is to improve the value proposition of building envelope retrofits.

30. **Combination Heat Pump for DHW and Space Conditioning.** Currently, separate space and hot water heat pumps do not fully utilize the waste heating or cooling produced from these units. Combining space and hot water heat pumps into one unit could reduce overall electrical demand compared to having separate pieces of equipment. This initiative would develop and demonstrate a system that combines both hot water and space conditioning into a packaged, modular unit using a single compressor. This initiative would apply next generation heat pumps in new applications to reduce demand, reduce installation and operation complexity/cost, reduce climate impacts by using low-GWP refrigerants, and increase market adoption. The goal is to use less energy to accomplish the same output as two pieces of equipment at an affordable cost with minimal engineering , integration, and operational complexity and potentially avoid the need to upgrade the electrical infrastructure.
31. **Roof Top Unit Nano-Grid Demonstration.** The solar and energy storage revolution presents an economic opportunity for many ratepayers, but disadvantaged communities, low/middle income, dense urban commercial buildings, and rental customers are generally being left behind and relying on grid services. This initiative would develop and test a modular package that includes solar PV, battery storage, and an electric heat pump to serve HVAC load. The heat pump would directly use DC from on-site solar arrays and energy storage systems to avoid efficiency losses through inverters and transformers. When solar power is unavailable, the heat pump would run on electricity from the grid. The goal is to develop and demonstrate the value proposition of a roof top nano-grid that would reduce electrical cost of heat pump operations, be cost-competitive, and capitalize on efficiency by using DC energy directly, while not exporting to the main grid, requiring an interconnection agreement, or using grid services during critical peak hours.
32. **Smart Energy Management Systems (SEMs) for Homes.** A recent CPUC report found that nearly one-fifth (19 percent) of heat pump adopters had to undertake an electrical panel upgrade**.** The costs of these upgrades range $3,000 to $10,000. SEMs, such as smart electrical panels, home energy monitoring systems, smart circuit splitters and sharing, and programmable subpanels could reduce upfront costs of electrification by overcoming the limitations of panel amperage capacity by utilizing active load management. This initiative would demonstrate (1) the effectiveness and potential of SEMs to reliably and cost-effectively adjust load to prevent low-priority loads from operating when there is not enough existing electric panel capacity to serve them; and (2) the potential of providing DR capability. The goal is for the SEMs to cost less than upgrading electrical panels and infrastructure and to provide real-time energy-use information and control.
33. **HVAC Decarbonization for Large Buildings.** Natural gas-fired boilers constitute most space heating systems in large commercial buildings. Boilers are often oversized for worse case

design temperatures or duplicated to provide redundancy in case of maintenance. This initiative would (1) develop and test hybrid, low-GWP electric heat pump systems that can operate during low-load conditions with boilers and chillers used during the high-load situations, (2) develop and test advanced, large air source and water source heat pumps that use low-GWP refrigerants with coefficients of performance greater than 3 and at a competitive price, (3) develop, test, and demonstrate other HVAC technologies, such as non-vapor compression cooling, solid-state cooling, and ground-source heat pumps. The overall goal is to determine the technical and economic potential of non-gas alternatives for heating large commercial buildings.

Enable Successful Clean Energy Entrepreneurship Across California

34. **Bringing Rapid Innovation Development to Green Energy (BRIDGE).** This initiative would continue the funding mechanism that provides follow-on funding for promising innovations that come out of EPIC or federal grant programs.
35. **Realizing Accelerated manufacturing and Production for Clean Energy Technologies (RAMP).** This initiative supports clean energy companies transitioning clean energy technologies from one-off prototype production into low-rate initial production.
36. **Provide Support for Entrepreneurs to Test, Verify, and Validate Their Innovations.** This initiative would continue the CalTestBed Program, which provides entrepreneurs access to testing laboratories and facilities across the state to facilitate third-party testing and validation of promising clean energy technologies.
37. **Mobilizing Significant Private Capital for Scaling Clean Energy Technologies.** This initiative seeks to increase the "bankability" of clean energy technologies and increase the use of traditional (non-Venture Capital), large institutional financiers to deploy technologies at scale. Strategies supported may include conducting technical/financial due diligence of clean energy technologies to lower deployment risk and deploying financial backstops to overcome perceived risk from institutional lenders.
38. **Tech Transfer Hub.** While research institutions have established technology transfer offices, the share of clean energy related intellectual property (IP) that is licensed for commercialization is much lower than other sectors such as healthcare or IT. This initiative seeks to facilitate the accelerated transfer of energy technology related IP from institutions, such as universities and laboratories, to private entities focused on commercialization.
39. **Advanced Battery Manufacturing.** This initiative seeks to support the scale up of advanced battery manufacturing in California focusing on advanced technologies such as Li-metal batteries at the component, cell, and battery pack levels. Funding could support strategies such as accelerated testing of battery packs and/or components; development of innovative manufacturing techniques; and workforce development for battery manufacturing.

Inform California's Transition to an Equitable, Zero-Carbon Energy System that is Climate Resilient and Meets Environmental Goals

40. **Evaluating Air Quality, Health, and Equity in Clean Energy Solutions.** Conduct research that supports an equitable distribution of benefits from clean energy solutions. Research advancements may include examining the air quality, health, and equity implications of clean energy deployment strategies; evaluating the benefits of early demonstrations;

improving energy affordability in under-resourced communities; and developing associated analytical approaches, modeling tools, data, and metrics.

41. **Integrating Climate Resilience in Electricity System Planning.** Develop tools and strategies to support a climate-resilient transition to a zero-carbon electricity system. Research advancements may include evaluating climate impacts on electricity demand, supply, and distribution to support electricity planning and operations; quantifying the benefits of strategies to ensure grid reliability and community energy resilience; and informing energy resilience investments that address the needs of California's Disadvantaged and Vulnerable Communities.
42. **Advancing the Environmental Sustainability of Energy Deployments.** Ensure that the anticipated rapid growth of clean energy deployments to achieve SB 100 targets meets other environmental and sustainability objectives. Research advancements may include: developing tools and methods to assess land and sea use changes associated with resource buildout scenarios; assessing environmental risk (e.g., for sensitive species and habitats) from specific technologies at the project level; developing and validating mitigation techniques and technologies to minimize impacts; developing new monitoring technologies and validating them for use in energy projects.

Cross-Cutting Initiatives

43. **Cost Share.** This initiative would provide a means to provide cost share to promising EPIC related projects and attract federal, private, or non-profit foundation funding opportunities to California
44. **Events and Outreach Support.** This initiative would fund support for CEC staff to carry out activities such as the EPIC Symposium, technology forums, innovation tours, as well as manage online platforms such as Energize Innovation and Empower Innovation.