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Research Initiative for DC Power Distribution in Buildings

Additional submitted attachment is included below.

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The Energy Commission is currently soliciting ideas and stakeholder input for the 2018 – 2020 EPIC Triennial Investment Plan. For those that would like to submit an idea for consideration in the 2018-2020 EPIC Triennial Plan, we ask that you complete the form below. Submittals are due by **5:00 p.m. on February 10, 2017.**

Part 1. Initiative Description and Purpose:

1. Please provide a brief description of the proposed initiative:

Initiative: Direct DC Power Distribution in Buildings
Direct distribution of DC power in buildings offers energy, reliability, and other benefits over AC power, but we lack sufficient experience and commercial products for wide deployment of this technology. To overcome these barriers, several research activities are needed:
1) Side-by-side, carefully controlled tests of DC vs. AC in buildings to quantify cost, energy and operational savings, along with non-energy benefits such as power quality and resilience, covering all building end-uses with and without battery storage;
2) Field demonstrations of DC power distribution in new construction and retrofit for both Zero Net Energy (ZNE) buildings and ZNE-ready buildings, to determine practical barriers to deployment and energy savings under actual usage conditions;
3) Development and standardization of key interoperability features that will make DC a plug-n-play option in buildings (particularly at voltages >48 VDC). Standards should be international standards where possible, drawing on the rapid penetration of off-grid DC solar systems in the developing world. Areas to standardize include: voltages, connectors, and communication protocols for power control;
4) Development and testing of DC electrical components that are missing or not widely available today, including: DC electrical protection devices, such as circuit breakers and switches, Dual input DC and AC appliances, Power converters such as bi-directional AC/DC converters, DC EV chargers, and DC battery chargers, and turnkey solutions for directly connecting PV systems to battery storage;
5) Field and lab tests for using existing buildings DC retrofit using AC wires in buildings for DC systems;
6) Develop a DC resource center with updated retrofit and new construction templates, guidelines, database and other support;
7) Demonstrate DC microgrids for community-scale solar systems and multifamily buildings, particularly in disadvantaged communities;
8) Develop a DC "power hub" for distribution and storage of power from small-scale solar systems directly to DC loads such as consumer electronics, especially in small occupied spaces such as apartments.

2. What technical and/or market barriers would the proposed initiative help overcome? For scientific analysis and tools, what knowledge gaps would the proposed initiative help fill?

There are significant technological and market barriers that inhibit market adoption of DC distribution in buildings, including the following:
• A lack of cost-competitive, market-ready DC-ready appliances and power system components, including DC system protection schemes.
• A lack of mature and DC-explicit standards and guidelines (e.g., for electrical protection, physical connectors, etc).
• Limited awareness of DC systems and their potential benefits among potential specifiers and purchasers.
• The universal availability of legacy AC systems, which present a particularly large barrier for retrofit applications, due to high capital costs for "switching" to DC or adding DC infrastructure in parallel with AC.

Part 2. Benefits and Impacts

3. If this initiative is successful, either fully or partially, what would be the expected impact? Who are the primary users and/or beneficiaries?

The primary impact of this initiative is energy savings due to avoided AC-DC power conversions. The scale of energy savings from DC distribution in buildings varies, depending on the type of building and the equipment present in the building, but can average 5-10% of the baseline electricity consumption for the end-uses converted to DC (potentially up to 3/4 of typical building loads). The presence of on-site battery storage and EVs, which are native DC assets, push the savings toward the higher end of that range. For a building designed to be ZNE but having to invest significant capital in "extreme" efficiency measures to reach the ZNE threshold, these savings from DC distribution can be enough to make the building net-zero on an annual basis. In addition, more efficient power distribution in the building can allow capital savings on smaller PV inverters (since less of the PV output has to be converted to AC) and smaller battery installations (since more of the stored energy is actually delivered to the end-use load rather than wasted in power conversions).

4. Describe what quantitative or qualitative metrics or indicators would be used to evaluate the impacts of the proposed initiative:

For the lab and field testing and demonstrations, the metrics for evaluating success would focus on how well the DC systems actually deliver the purported benefits, such as energy savings, reliability, and power quality improvements. The creation of international standards for DC power voltage and connectors would be another indicator of success. Another metric would be the number of test deployments of DC power in buildings that were informed by the results of this initiative. In the longer run, the metrics of success focus on how well the market barriers are being overcome, such as the number of DC-ready products that are commercially available, the market share of DC-ready products, and the number of DC-ready buildings constructed each year.

5. Please provide a list of peer-reviewed references that support the responses for questions 3 and 4. Proposed initiatives that include peer-reviewed references will be given stronger consideration.

Glasgo, Brock, Inês Lima Azevedo, and Chris Hendrickson. 2016. "How Much Electricity Can We Save by Using Direct Current Circuits in Homes? Understanding the Potential for Electricity Savings and Assessing Feasibility of a Transition towards DC Powered Buildings." Applied Energy 180 (October): 66–75. doi:10.1016/j.apenergy.2016.07.036.

Vossos, Vagelis, Karina Garbesi, and Hongxia Shen. 2014. "Energy Savings from Direct-DC in U.S. Residential Buildings." Energy and Buildings 68, Part A (January): 223–31. doi:10.1016/j.enbuild.2013.09.009.

Thomas, Brinda A., Inês L. Azevedo, and Granger Morgan. 2012. "Edison Revisited: Should We Use DC Circuits for Lighting in Commercial Buildings?" Energy Policy 45 (June): 399–411. doi:10.1016/j.enpol.2012.02.048.

6. (For technologies only) What competitive advantages does the proposed technology solution have over current benchmark technologies? If the technology is beyond the prototype stage, what strategies do you suggest to bring to scale?

A key advantage of DC power distribution over AC distribution is energy savings from avoided power conversions, as discussed in question 3 above. In addition, according to several studies, DC power distribution in buildings has important non-energy benefits compared to AC power. DC systems allow for easier integration of power, communications, and controls with certain DC standards (Power over Ethernet and USB). Distribution of power at lower voltages (<50V) in occupied spaces is safer because of reduced electrocution risk and allows greater convenience in reconfiguring hardwired equipment. Expanded use of renewables also reduces greenhouse gas emissions, extending the energy savings of DC power in this critical dimension. In addition, existing research in DC data centers has demonstrated that the elimination of certain power system components in DC systems can significantly increase system reliability. Furthermore, the ability of DC systems to seamlessly act as microgrids (i.e., to be islanded from the grid) can improve resiliency, an increasingly valuable characteristic for high reliability loads and disaster mitigation. Furthermore, DC microgrids are effectively de-coupled from the AC grid (even when not completely islanded from the grid), which makes the end-use equipment on the DC microgrid less susceptible to frequency and voltage disturbances on the grid. Although such benefits are widely discussed in the literature, they have not been thoroughly investigated, substantiated, or quantified.

Part 3. Connection to Energy Commission's EPIC Framework
Energy Commission staff have developed a draft strategic framework to guide the CEC's planning and implementation of EPIC across triennial investment cycles. One of the objectives of the draft strategic framework is to communicate a consistent set of priorities for organizing current and future EPIC investments.

7. Please indicate which of the following strategic framework themes you feel the proposed initiative best fits within:
    - Advance Technology Solutions for Deep Energy Savings in Building and Facilities
    - Accelerate Widespread Customer Adoption of Distributed Energy Resources
    - Increase System Flexibility from Low-Carbon Resources
    - Increase the Cost-Competiveness of Renewable Generation
    - Create a Statewide Ecosystem for Incubating New Energy Innovations
    - Maximize Synergies in the Water-Energy-Food Nexus
    - Develop Tools and Analysis to Inform Energy Policy and Planning Decisions
    - Catalyze Clean Energy Investments in California's Underrepresented and Disadvantaged Communities

If Other, Please Specify

Accelerate Widespread Customer Adoption of Distributed Energy Resources