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R&D for a New Generation of Right Size-New Boxes Residential Sector Decarbonization Technologies

Additional submitted attachment is included below.

EPIC 5 Research Concept Proposal

Title

R&D for a New Generation of Right Size-New Boxes Residential Sector Decarbonization Technologies

1. Please provide the name, email, and phone number of the best person to contact should the CEC have additional questions regarding the research concept:

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3. Please provide a brief description of the proposed concept that you would like the CEC to consider as part of the EPIC 5 Investment Plan. What is the purpose of the concept, and what would it seek to do? Why are EPIC funds needed to support the concept?

New EPIC investments are needed to close critical knowledge gaps and launch **new technology R&D initiatives** that can remove significant barriers and accelerate the pace and scale of decarbonization in the **residential sector**. In California, there are about 13 million households/housing units, and realizing state legislative policy goals for rapid decarbonization translates into fairly rapid conversion to electricity from natural gas for heating, cooking and hot water heating in most of these. The vast majority of change must come from choices made by those 13 million households—**paid for with their own money**.

Almost all of those households are now routinely paying a utility bill surcharge to fund EPIC programs. While all ratepayers certainly benefit indirectly from R&D investments at the system level (e.g., related to improvements in renewable resources, transmission systems, wildfire control, safe energy storage, etc.), the residential sector and seemingly mundane residential end-use technologies have received much less attention in prior EPIC investment rounds. This may be due to constraints passed along with the funding. But it is hoped that with the urgency of large-scale decarbonization at the scale of years and not decades, and with heightened concern for consumer equity and energy costs, some attention and investment might be directed to the residential sector in EPIC 5 planning.

Strategic EPIC R&D can make technology choices easier and more effective for consumers by addressing a number of current technology limitations and barriers. Existing HVAC, water heating, cooking technologies are often a poor fit in terms of size, cost, architecture, lifestyle, and institutional constraints. This is particularly true for multifamily units, renter-occupied housing, small older single-family units, and across the board for moderate and lower-income households. What is needed are **right size** technologies made a**vailable in** and **developed through new boxes**. By "new boxes," I mean **both** new, more appropriate **form factors with better fit** to consumer needs, and also through new **outside-the-box multidisciplinary ways of thinking** about technologies, designs, impacts, and everyday end-users to help come up with those solutions. We can use the shorthand of RS/NB (right size/new boxes) to refer this new class of more broadly user-appropriate technologies.

The problem of residential electrification is daunting.

Make no mistake. The barriers to decarbonization at any scale in the residential sector are many. It is first important to first take a sober look at the scale of residential decarbonization challenge in California. An estimated 80% of California housing units are now heated with natural gas, and 98% of those also use gas for water heating. Currently, only about 5% of all households use electricity for both space and water heating—the ultimate profile of a decarbonized residential sector. And the use of heat pumps as the primary space heating technology (much more efficient than electric resistance heating) can be found in only 3% of California households.

(These statistics are from the Commission's 2019 *Residential Appliance Saturation Survey* [RASS]. Online queries of the RASS database can be performed at https://rass.dnv.com. Another excellent data source on residential energy use and technology is the DOE/EIA 2020 *Residential Energy Consumption Survey*, which includes a large subsample of 1,152 California households. https://www.eia.gov/consumption/residential/data/2020/)

We need to drill down though. Social scientists have long warned about how misleading aggregates and averages can be when talking about residential energy use and conservation actions (Lutzenhiser 1992). So, analysis of the RASS and RECS data also show **considerable variation** in housing, technologies and energy use (and carbon emissions and decarbonization potentials) across different **consumer subgroups** and demographic categories: single family and multifamily units; owner and renter occupied; high incomes and low incomes; singles, couples, small families, and large families. It is reasonable to infer, then, that one-size-fits-all policies and technologies that ignore the variegated in realities of on-the-ground conditions will do little to advance decarbonization goals.

4. In accordance with Senate Bill 96i, please describe how the proposed concept will "lead to technological advancement and breakthroughs to overcome barriers that prevent the achievement of the state's statutory energy goals." For example, what technical and/or market barriers or customer pain points would the proposed concept address that would lead to increased adoption of clean energy technology or innovation? . . .

Consumer Barriers and Technology Limitations

Many consumer barriers are well known from decades of experience with energy efficiency technologies and policies. They include limited knowledge and resources, lack of incentives, and uncertain benefits, along with high dollar costs, concerns about risk and performance, hassles and poor product availability. In some of our earlier research, these barriers have been summarized as falling under the categories of "concerns, capacities and conditions" (Lutzenhiser et al. 2003); and they have often been an explicit focus of earlier energy efficiency program design and evaluation. (For an overview and history of energy efficiency policy, see Lutzenhiser 2014).

However, with the success of efficiency codes and standards, along with improved market offerings of improved appliances and HVAC systems (and focus on the growth of utility-scale renewable energy supplies), policy interest in promoting energy efficiency with consumers has declined. And the learnings from the efficiency experience are hardly being applied in the case of energy end-use transition.

More important, there are other significant barriers that have only been considered superficially in energy efficiency. And there are important technology limitations that are scarcely recognized in the efficiency world or decarbonization/system transition discussions (for sobering analyses of the challenges of energy transitions see Smil 2016; Sovacool 2016).

Some of the most important of these social and institutional barriers include:

(1) The recognized fact that household technology **supply chains** and technology delivery systems (e.g., for HVAC, hot water heating, induction cooking, solar PV, storage, grid communications, EV charging), in the light of their own histories and internal logics, work well enough. However, they are **disconnected, disjointed, and dysfunctional** for energy transitions and consumer choice. They are fraught with risk and uncertainty for households.

(2) Household energy-using **technologies are shaped** by firms and their considerations of costs, production realities, market experiences, design choices, standards and regulations—all opaque processes that are conducted by a shrinking number of global competitors and a fairly homogeneous set of product offerings. The multitude of "models" and product "series" reported in Energy Star databases and manufacturer websites seem endless. But on closer inspection those offerings tend to vary little from one another in important ways.

(3) While the “target market” for the bulk of HVAC, water heating and related gas vs. electric residential technologies is often a buyer with resources and a single family owner-occupied home, that market doesn’t include a very large portion of the California residential households who have limited funds, are renters who don’t own their systems and appliances, owners who live in multifamily housing or older small detached units with little flexibility to accommodate the larger, feature-rich standard industry/supply chain offerings. In short, there is **often a poor fit between technologies and circumstances**.

(4) A range of **intermediaries** stand between many occupants and transition to new non-fossil fuel technologies. For renters, there are property owners (mom and pop to REITs to NGOs) and managers (on-site to distant). For condo owners (and some single-family developments), there are management companies, HOA boards, and governing documents. For both, there may be supplier relationships and long-standing commitments to product lines and manufacturers.

(5) A host of **non-energy** and **non-climate** factors—both perceived costs and risks—override energy and climate concerns. This was well established knowledge in the energy efficiency era, when focus on comfort, convenience, cultural norms, social status, and the like had often trumped energy benefits. This knowledge may need to be revived in the decarbonization energy transitions period.

Research and development priorities

R&D is needed for a set of new technologies that are “right-sized” in terms of having a good fit with consumer and housing realities—and that also come in new boxes (appropriate form factors) and through new thinking outside of conventional boxes and technology-shaping processes currently delivering market menus of household technologies. All, or at least most, of these will confront challenges from barriers and limitations outlined in items 1-5 above. In the next section, I offer some investment program designs and principles that can help to address these hurdles and result in RS/NB (right size/new boxes) technologies.

Here is a very partial and not well-developed list of technology R&D ideas. All would have their detractors and nay-sayers, and some may be unrealistic in the end. But all would benefit from new thinking, innovative experiments and field testing. And some are well developed and being newly developed in other countries and cultural contexts, including Europe and Asia. This means that we do not have to start from scratch, but can learn from others’ successes and differences that may not apply in here.

Technology Examples

- Down-sized heat pump water heating and innovations in small split systems
- Deal with the HPHW heat-stealing and noise problems in small living spaces
- Other non-HP water heating alternatives (solar thermal, PV, cogeneration)

- Easily installed point of use and demand water heaters
- 120v alternatives to 240v
- DIY options

- Higher efficiency PTACs and new PTHP replacement designs
- 120v alternatives to 240v for PTHPs and mini-splits
- Plug-and-play furnace replacements
- Shell insulation and retrofit innovations
- Low-cost high-efficiency window upgrades/replacement
- DIY options

- Low-cost service panel upgrades
- Panel load management
- Working within the limits of existing wiring; DIY options
- Repurposing gas lines as electrical conduits

- Low-cost, easy-install gas range replacements for multifamily and other small spaces
- Attractive and functional counter-top induction and convection appliances
- 120v alternatives to 240v
- DIY options

- Load management solutions for EV charging in infrastructure constrained multi-family housing (e.g., 120v shared carport circuits)
- Mini-solar (e.g., German model of balcony solar + storage)
- Right-sized apartment and MF building and/or multi-house emergency storage
- Lower-cost and easily installed and integrated storage batteries
- Innovations in Grid interactivity (at least grid information/communications) for the small “not-smart-home” majority of the market
- DIY options

Design principals and strategies across all of these possibilities (and more)

– Right size and develop new, varied and consumer-focused form factors

– Simplify designs and drive down production costs

– Reduce consumer prices and increase access to devices/support

– Take DIY options seriously

– Focus on tailored rental apartment solutions

– Explore solutions for condo complexes and condo owners

– Explore innovative renter solutions (portability of technologies)

Specific Initiatives to Organize an RS/NB EPIC Research Program
These could be structured in a variety of ways. But new thinking and innovation is needed, with an emphasis on solutions for consumer/citizen groups and circumstances that are otherwise likely to be left behind in decarbonization. Technology is more than devices, and the research on technological change has shown that transitions are the result of complex interactions between physical, engineering, economic, social, and institutional elements of socio-technical systems (e.g., Geels 2006; Sovacool et al. 2015).

So, encouraging change in such systems (e.g., the fossil fuel-dominated residential end-use sector in California) will require drawing together insights from across disciplines and social sectors. And, while commercial entities can produce incredible products, technology markets on their own cannot be expected to produce residential decarbonization in California. Public sector and ratepayer investment is necessary to stimulate work that will result in benefits for consumer segments that are not profitable in the near term. Unfortunately, that may be more than 50% of California households.

Academic centers are natural places to locate such public interest R&D. They already bring together many disciplines and increasingly foster interdisciplinary collaboration in teaching and research. They are also ripe with new/young ideas and energies, and they have a strong track record in successful EPIC research—including multidisciplinary technology R&D. And many bring strong collaborations with industry and communities to the table. The relationship between technology R&D and market transformation is not well developed. I draw on work with Sy Goldstone (long-time Chief Economist of the Energy Commission) and Carl Blumstein (founding Director of the UC Institute for Energy and Environment) that argues for an established place for real-time feedback from ongoing market transformation research, in addition to more conventional disconnected 2-4 year parallel studies and/or narrowly focused program evaluations (Blumstein, Goldstone and Lutzenhiser 2000).

I would propose **two thrusts for an RS/NB research program**. The **first** would be a ***Technology Observatory*** that would gather for public and researcher access information on all of the target residential technologies in the U.S. and elsewhere in the world. The Observatory would also engage with and convene academic, industry, NGO, and community partners and experts to identify industry choke points, consumer and supply chain pain points, histories of innovations that have either succeeded or failed to cross the “valley of death” between laboratory R&D and the marketplace, and to generally offer a living sketch of the residential technology landscape to inform research design, technology entrepreneurship, and industry cutting edge R&D. The Observatory would also be a focal point for data on real-world technology performance and could sponsor or contribute to third-party evaluation of technologies developed on the second side of the program.

That **second** element would be an ***RS/NB Technology Incubator*** that would identify, mentor, foster, support, and facilitate industry funding for innovative RS/NB residential technologies. Inventors, community groups, small businesses, industry R&D, national laboratory scientists, academic faculty, and students would all be engaged without prejudice. RS/NB technology R&D would take place with active multidisciplinary conversations and open collaboration. Prototypes would be developed in appropriate facilities, and intellectual property rights claimed in line with contributions and existing institutional IP arrangements (e.g., for EPIC projects, UC, CSU, Cal Poly, Community Colleges, and business/community partners). Field testing would be conducted in California community settings with multidisciplinary guidance and rigorous evaluation protocols.

The *Technology Observatory* findings would inform the RS/NB Incubator activities, priorities and allocation of resources. The *Incubator* trials and testing would feed information into the *Observatory's* databases. And *Observatory*-involved evaluations would inform the Incubator's assessments of field tests and conversations with manufacturers and commercialization channels

5. Please describe the anticipated outcomes if this research concept is successful, either fully or partially. For example, to what extent would the research reduce technology or ratepayer costs and/or increase performance to improve the overall value proposition of the technology? What is the potential of the innovation at scale? How will the innovation lead to ratepayer benefits in alignment with EPIC's guiding principles to improve safety,[ii] reliability,[iii] affordability,[iv] environmental sustainability,[v] and equity?[vi]

The work would focus on immediate and short-term **benefits/value proposition** along with longer-term climate change mitigation benefits. Those benefits to customers include: air quality improvement; better health and safety; ability to maintain communications and critical necessities during natural disasters and/or utility power shutoffs; and utility cost savings immediately, plus buffering the impacts from expected continuous future energy price increases.

The RS/NB focus on **user-appropriate technologies** will improve the fit between devices, capabilities, usability, cost, and end-users needs, practices, understandings, and resources.

In line with research on socio-technical transitions, the R&D would be on the lookout for **unexpected** and **unintended** risks and impacts, but also benefits, advantages, rewards that might well otherwise go unnoticed and unexamined in decarbonization policies and programs.

The RS/NB project would also broaden current frameworks to allow **unimagined possibilities** to appear and be explored. The approach would consult and involve actual users. Centers would recruit young and innovative minds who have not yet been told which boxes or silos they have to work inside of, as well as fostering multidisciplinary and cross industry thinking and collaboration. The approach should also realistically be prepared for failure as well as success, and disappointment as well as gratification—thinking like a venture capitalist and not always playing it safe (there is precedence for this in prior EPIC **small grant high risk/high reward programs**).

6. Describe what quantitative or qualitative metrics or indicators would be used to evaluate the impacts of the proposed research concept.

The RS/NB approach ensures a data-rich environment and data-informed discussions. There are many imaginable metrics, ranging from device testing performance and field-testing results, to industry uptake, consumer interest, rates of commercialization, product offerings, units produced and shipped, retailer interest, consumer responses and evaluations.

7. Please provide references to any information provided in the form that supports the research concept's merits. This can include references to cost targets, technical potential, market barriers, equity benefits, etc.

The relevant literatures are voluminous and include estimates of detailed metrics for impacts, rates of diffusion, costs, etc. It would be selective and misleading (and too time-consuming to review them here. However, the following references from the discussions above should be mentioned their citation.

References

Blumstein, C., S. Goldstone and L. Lutzenhiser. 2000. "A theory-based approach to market transformation." *Energy Policy.* 28(2):137-144.

Lutzenhiser, L. 1992. "A cultural model of household energy consumption." *Energy.* 17:47-60.

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Geels, F.W. 2005. "Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective." *Technological Forecasting and Social Change.* 72(6):681-696.

Smil, V. 2016. E*nergy Transitions: Global and National Perspectives. 2nd Edition*. Praeger.

Sovacool, B.K., S.E. Ryan, P.C. Stern, K. Janda, G. Rochlin, D. Spreng, M.J. Pasqualetti, H. Wilhite, L. Lutzenhiser. 2015. "Integrating social science in energy research." *Energy Research & Social Science.* 6:95-99.

Sovacool, B.K. 2016 "How long will it take? Conceptualizing the temporal dynamics of energy transitions." *Energy Research & Social Science.* 13:202-215.

8. The EPIC 5 Investment Plan must support at least one of five Strategic Goals:
Transportation Electrification
Distributed Energy Resource Integration
Building Decarbonization
Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas
Climate Adaptation
Please describe in as much detail as possible how your proposed concept would support these goals.

The entire detailed discussion above supports all of the EPIC 5 Strategic Goals. In particular, technologies mentioned in the section titled **Technology Examples** (pp. 4-5) directly apply to the transportation, building decarbonization, net-zero, and climate adaptation goals. In all cases, successful RS/NB R&D would help to accelerate technology uptake, satisfaction, efficient use, and decarbonization outcomes.