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Industrial Heat Pumps

Additional submitted attachment is included below.

CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

Electric Program Investment Charge 2026–2030 (EPIC 5) Research Concept Proposal Form

The California Energy Commission (CEC) is currently soliciting research concept ideas and other input for the Electric Program Investment Charge 2026–2030 (EPIC 5) Investment Plan. For those who would like to submit an idea for consideration, please complete this form and submit it to the CEC by **August 8, 2025**. More information about EPIC 5 is available below.

To submit the form, please visit the e-commenting link: https://efiling.energy.ca.gov/EComment/ECommentSelectProceeding.aspx and select the Docket **25-EPIC-01**. Enter your contact information and then use the "choose file" button at the bottom of the page to upload and submit the completed form. Thank you in advance for your input.

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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2. Please provide the name of the contact person's organization or affiliation:

Electric Power Research Institute, Inc. (EPRI)

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?

EPRI seeks to advance innovations in the design and integration of low-cost, electricity-driven heat pumps for industrial applications requiring heat sink

temperatures > 300˚F, while simultaneously incorporating strategies to provide "on-demand heat" independent of the availability and cost of using electrical power from the grid. This proposed technology advancement can provide significant thrust to industrial electrification and decarbonization in California through large reductions in industrial energy consumption and CO_2 emissions as compared to fossil-fuel fired equipment primarily used in industrial facilities today. It will eliminate onsite GHG emissions in industrial facilities and provide a pathway towards the EPIC5 strategic goal of 100% Net-Zero Carbon Emissions using renewable electricity. It will also help to mitigate the significant first cost barrier observed with industrial electric manufacturing equipment. Finally, it will provide a mechanism to implement load flexibility at scale in industrial processes.

4. In accordance with Senate Bill 96[i], 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? Where possible, please provide specific cost and performance targets that need to be met for increased industry and consumer acceptance. For scientific analysis and tools, provide more information on what data and information gaps the proposed concept would help fill, and which specific parties or end users would benefit from the results, and for what purpose(s)?

California's industrial sector consumes 1,457 trillion Btu of energy annually, which is 1/5th of the state's total energy consumption. Natural gas is the primary fuel used in industrial process heating. Over 85% of natural gas use goes towards generating direct process heating or used in boilers to generate steam or hot water for industrial processes and results in significant carbon emissions. Electrification of California's industrial sector lags behind residential, commercial and transportation sectors due to the cost of production downtime, the highly detailed and specific industrial process requirements and associated equipment, and the very high temperature needed for process heating.

Prior research conducted by EPRI has shown that currently available industrial heat pump technology is largely in the lower temperature range between 160-250˚F. It has also been noted by EPRI and the broader industry research that current industrial heat pumps have high upfront costs ($1000-$1500/kW). The production of very high temperature process heat or steam using electricity thus remains a challenge due to limited availability of efficient and simultaneously cost-effective products. A third challenge seen with current industrial heat pumps is that

there is not currently a product offering that includes energy storage capabilities, unlike residential or commercial heat pump products.

EPRI's proposed concept advances the innovations in the design and integration of low-cost, electricity-drive heat pumps for high-temperature applications and incorporates strategies to provide heat independent of availability and cost of using electrical power from the grid for some duration of time. From the point of view of industrial customers, there are several industrial applications that can take advantage of this flexibility to reap cost benefits in energy bills while from a utility point of view, a large increase in energy demand can be offset due to industrial electrification.

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]

In the past CEC has funded two notable research projects on industrial heat pumps, namely to EPRI and Skyven Technologies. The EPRI project was an innovative concept tailored to develop a heat pump that captures waste heat and converts it to low pressure steam @250˚F, while the CEC grant to Skyven technologies was tailored at field demonstration of an existing industrial heat pump product offering. Additional funding from CEC on industrial heat pumps will take these, and the broader industry R&D to the next level – i.e., introduction of low cost, very high temperature heat pumps. At scale, such technologies will allow new industrial sub-sector markets to electrify process heat (e.g. primary metals), as well as increase the applicability of industrial heat pumps for the sub-sectors where they are more relevant today (food, paper and chemical industries) by widening the temperature range. Some of the new areas of application that the higher heat sink temperatures will make available are evaporation (food manufacturing), drying processes within the paper industry, and chemical distillation. Adoption of very high temperature, steam generating heat pumps can help CA move towards industrial electrification very quickly and provide industrial heating electrification potential upwards of 1,000 MW.

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

The proposed quantitative outcomes to evaluate this concept are summarized in Table 1 below.

Table 1: Quantitative Metrics to Evaluate Research Concept

Objective/Goal	**Metric**	**Proposed Minimum Outcome**	**Stretch Target**
Payback period, cost-effectiveness	Years	*≤ 5 years*	≤ 2 years
Efficiency @highest supply temperature	COP	*45% of Carnot COP*	55% of Carnot COP
Lifetime	Years	*≥ 12 years*	*15-20 years*
Reduce direct GHG emissions (refrigerants)	GWP	*< 10*	*< 3*
Energy Density of Thermal Storage	kWh/ cu. ft.	*>15*	

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.

1. CA State Profile and Energy Estimates: https://www.eia.gov/state/?sid=CA#tabs-2.
2. CEC GFO 19-301, Attachment 13 - References for Calculating Energy End-Use and GHG Emissions. Archived CEC solicitation.
3. Opportunities for Demonstrating Industrial Heat Pumps in the United States: Prototype Examples in the Food and Beverage Sectors, Technical Update, EPRI (2024).
4. Zuberi, J., Ali H., and William M. "Electrification of US manufacturing with industrial heat pumps.", LBNL 200-1478 (2022).
5. Prior CEC funded research performed by EPRI: Development of an Advanced High-Temperature Heat Pump for the Efficient Recovery of Low-Grade Industrial Waste Heat: Innovative Technology for Industrial Decarbonization, EPRI (2024).
6. Other Prior CEC funded research on Industrial Heat Pump: Item_14c_EPC-22-012_Skyven_Technologies_Inc._ada .
7. Lee, C., Baroi, D. and Karasawa, A. "Industrial Heat Pump Market Study." (2023). Final Report ET23SWE0036 Prepared by AESC and ASK Energy for Cal NEXT.

8. Stringent emission regulation in South Coast Air Quality Management District Court upholds a landmark clean-heat rule in Southern… | Canary Media.
9. Industrial Electrification Is Likely To Lead To A Major Increase In Energy Demand: https://www.aceee.org/sites/default/files/pdfs/enabling_industrial_demand_flexibility_-_aligning_industrial_consumer_and_grid_benefits.pdf.

8. The EPIC 5 Investment Plan must support at least one of five Strategic Goals:[vii]
    a. Transportation Electrification
    b. Distributed Energy Resource Integration
    c. Building Decarbonization
    d. Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas
    e. Climate Adaptation

    Please describe in as much detail as possible how your proposed concept would support these goals.

The proposed concept herein has close relevance to goal (d) of the EPIC 5 Investment Plan: “Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas”, the main objective of which is to seek cost-effective opportunities for investment in hard-to-decarbonize energy-consuming sectors through Electrification. This proposed concept clearly fulfills these objectives because it seeks innovation in industrial heat pump technology whose heating energy consumption and associated emissions will be significantly lower than current industrial boilers, while at the same time having a low first cost premium. While the concept is pertinent to the whole state, it is the most relevant to the South Coast Air Quality Management District, where landmark measures exist to sharply reduce emissions from boilers and process heaters. Additionally, the concept aims to provide better industrial load flexibility by using built-in thermal energy storage. Such a heat pump will be able to uninterruptedly serve the industrial process heating loads during power curtailment or outage events and thus support goal (e), which seeks to identify opportunities for improving grid resiliency.

About EPIC

The CEC is one of four EPIC administrators, funding research, development, and demonstrations of clean energy technologies and approaches that will benefit electricity ratepayers of California's three largest investor-owned electric utilities.

EPIC is funded by California utility customers under the auspices of the California Public Utilities Commission.

To learn more about EPIC, visit: https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program

EPIC 5 documents and event notices will be posted to: https://www.energy.ca.gov/proceeding/electric-program-investment-charge-2026-2030-investment-plan-epic-5

Subscribe to the EPIC mailing list to stay informed about future opportunities to inform the development of EPIC 5: https://public.govdelivery.com/accounts/CNRA/signup/31897

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i See section (a) (1) of Public Resources Code 25711.5 at: https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PRC&sectionNum=25711.5.

ii EPIC innovations should improve the safety of operation of California's electric system in the face of climate change, wildfire, and emerging challenges.

iii EPIC innovations should increase the reliability of California's electric system while continuing to decarbonize California's electric power supply.

iv EPIC innovations should fund electric sector technologies and approaches that lower California electric rates and ratepayer costs and help enable the equitable adoption of clean energy technologies.

v EPIC innovations should continue to reduce greenhouse house gas emissions, criteria pollutant emissions, and the overall environmental impacts of California's electric system, including land and water use.

vi EPIC innovations should increasingly support, benefit, and engage disadvantaged vulnerable California communities (DVC). (D.20-08-046, Ordering Paragraph 1.) DVCs consist of communities in the 25 percent highest scoring census tracts according to the most recent version of the California Communities Environmental Health Screening Tool (CalEnviroScreen), as well as all California tribal lands, census tracts with median household incomes less than 60 percent of state median income, and census tracts that score in the highest 5 percent of Pollution Burden within CalEnviroScreen, but do not receive an overall CalEnviroScreen score due to unreliable public health and socioeconomic data.

vii In 2024 the CPUC adopted five Strategic Goals to guide development of the EPIC 5 Investment Plan. A description of the goals can be seen in Appendix A of CPUC Decision 24-03-007 available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M527/K228/527228647.PDF