DOCKETED	
Docket Number:	23-ERDD-01
Project Title:	Electric Program Investment Charge (EPIC)
TN #:	254488
Document Title:	Climate Action California Comments - Low GWP Heat Pump Draft Solicitation
Description:	N/A
Filer:	System
Organization:	Climate Action California
Submitter Role:	Public
Submission Date:	2/15/2024 2:27:49 PM
Docketed Date:	2/15/2024

Comment Received From: Climate Action California
Submitted On: 2/15/2024
Docket Number: 23-ERDD-01

Low GWP Heat Pump Draft Solicitation -- Comment by CAC

Please see file.

Additional submitted attachment is included below.

February 15, 2024

Karen Perrin
California Energy Commission

Re: Comments in response to Docket no. 23-ERDD-01 Draft solicitation:

Developing Next Generation, All Electric Heat Pumps Using Low Global Warming Potential Refrigerant

Proposed Electric Program Investment Charge Solicitation

Ms. Perrin:

Climate Action California and 350 Humboldt appreciate the opportunity to provide responses to the following questions:[1]

1. **What type of considerations should the Energy Commission (CEC) consider in order to encourage participation and achieve project success, and why? Please provide relevant comments regarding other considerations not explicitly listed above.**

   Response: We believe that "success" of California's project is two-pronged. On one hand, widespread adoption and installation of heat pump technology is a clear goal. On the other, considering society's urgent need to reduce greenhouse gas emissions, project success will require widespread adoption of electric heat pump technology that does not exacerbate global warming. This means technology using refrigerants with ultra-low global warming potential (<10 GWP).

   In general we believe the solicitation of proposals should focus on propane in order to draw submissions by the most advanced heat pump developers.[2] Proposed solutions

[1] Climate Action California, P.O. Box 20001, Oakland, California 94620, is a 501c(4) social welfare organization. The Climate Action California Foundation is a 501c(3) public charity. See https://www.climateactioncalorg. 350 Humboldt is a climate advocacy group in Humboldt County that collaborates with CAC and a coalition of climate advocacy groups throughout California.
[2] We are not discounting CO2 or ammonia, but propane seems best suited to the proposed solicitation.

based on HFOs will only delay the roll-out of ultra-low GWP heat pump technology for the future.

In Europe and Asia heat pump systems using natural refrigerants, primarily propane (GWP >1)[3] are highly developed and well accepted. California's goal, and indeed the nation's, should be to get European companies and their American affiliates interested in the proposed solicitation and committed to entering the US market with US-based manufacturing.[4] Your project will do so if it requires technology using natural refrigerants. American companies like Emerson will undoubtedly also respond to the challenge. In this way the CEC's project will have an outsize effect on the US heat pump market across the nation, spurring significant avoided refrigerant emissions.

Following an IEC ruling in 2022, heat pumps may use 988 grams of propane (up from 340 grams). However, a recent German research break-through may offer many new propane heat pump applications, possibly including central heating. In 2023 the Fraunhofer Institute announced:[5]

> "The project goal was to develop a nearly market-ready heat pump module which uses the climate-friendly refrigerant propane, does not exceed the 150g limit for indoor use and yet still provides sufficient heat for single-family homes," explained Dr Lena Schnabel, head of the heating and cooling department at Fraunhofer ISE. "We have now achieved this goal in cooperation with our industry partners and have given them the tools to develop a market-ready heat pump."

It seems critical that these breakthroughs be developed further and made available in the U.S., with California taking the lead. Getting a response from this group would be ideal.

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[3] The Intergovernmental Panel on Climate Change (IPCC) released its *Climate Change 2021 – The Physical Science Basis* report on Monday (August 9), which includes official global warming potential (GWP) figures for hydrocarbons for the first time. The report states that popular natural refrigerant propane (R290) has a 20-year GWP of 0.072 and a 100-year GWP of 0.02. Butane (R600) has a GWP20 of 0.022 and a GWP100 of 0.006. These figures are much lower than traditionally assumed. https://hydrocarbons21.com/ipcc-includes-gwps-for-hydrocarbons-in-new-report/

[4] "The North American market has often lagged behind the rest of the world in modernizing standards and codes. Hundreds of millions of household fridges using hydrocarbons proliferated around the world for decades with nearly zero market uptake in the U.S. and Canada due to more restrictive standards that allowed only a tiny amount of 57 grams of hydrocarbon refrigerant to be used. When the U.S. and Canadian safety standard (UL/CSA 60335-2-24) was updated in 2018 to harmonize with international standards allowing up to 150 grams, it allowed North America to begin a transition to hydrocarbons in new household fridges to be complete by 2023." (https://us.eia.org/blog/20200325-room-for-improvement/) Around 400 models of air-to-water heat pumps are already included in the German BAFA subsidy list, showcasing the wide availability of heat pumps with natural refrigerants as well as the market reaction of heat pump manufacturers (the number of R290 heat pumps was around 175 models in April 2023, and grew by 228% over the next six months). (https://www.bafa.de/SharedDocs/Downloads/DE/Energie/beg_waermepumpen_pruef_effizienznachweis.pdf?__blob=publicationFile&v=8) R290 heat pumps also have the highest energy efficiency which is another important factor in reducing the overall climate and environmental impact of the products. For the air-to-water heat pumps in the BAFA list, the R290 models are about 7% more efficient (ETAS 55) than the F-gas models.

[5] https://www.coolingpost.com/world-news/engineers-develop-optimised-propane-heat-pump/

2. **Are the GWP limits of 150 reasonable for the current state of the art systems? If not, why and what should the limit be? Do the three Project Groups in Section IV of this document address the primary objectives of expanding and improving heat pump technology? If not, why? Are there alternative pathways or priorities that should be considered?**

   Response: The goal of 150 GWP is more than 150 times too high! Natural refrigerants are available with a GWP of less than 1. We are rightfully alarmed about a GWP of 25 for methane. Why would we want to encourage development of products with six times that amount of warming?

   - From a research point of view, a very broad range of high level academic and technical institute researchers in Europe have already made it clear in a white paper that the future of heat pumps is propane:[6] "Any development of new products should clearly focus on natural refrigerants." The white paper makes these key points:
     - Efficiency: Propane is a highly efficient refrigerant, and this has been proven amply in practice.
     - Safety: "[P]ropane and other hydrocarbons are highly flammable, and of course, this needs to be considered carefully when designing systems. The use of natural gas (e.g., LNG as fuel in cars), which is common and accepted almost all over the world, involves similar risks. Hydrocarbons used in heat pumps, however, are contained in hermetic systems. International safety standards are already in place and are constantly being improved." Propane has been used safely in heat pumps for decades, particularly air-to-water heat pumps installed outdoors, which are the most used type of heat pumps. Even for in-house installation, propane heat pumps are possible and available with adequate safety measures (e.g., ventilation tubes) to comply with safety standards.[7]
     - Availability: "A recent survey has shown that several hundred designs of hydrocarbon heat pumps from about 48 different manufacturers are commercially available in Europe. All the basic research and development work to optimize the design of heat exchangers as well as compressors using low-GWP refrigerant has been done in the past 15 years. Air-to-water heat pumps are already well established in the market. Other product groups will follow this transition and the dynamics of its demonstrated path."[8]
     - Future: "The change to propane for indoor heat pumps is still challenging and will probably require more than three years, due to complex safety regulations and building requirements. Therefore, we argue for the early announcement of clear

[6] https://www.energy.kth.se/polopoly_fs/1.1241311.1679563728!/PositionPaper_ReviewFGas.pdf
[7] Examples that it's technologically possible: https://hautec.eu/sole-wasser-waermepumpe-r290/ (brine) and https://hautec.eu/wasser-wasser-waermepumpe (water)
[8] Around 400 models of air-to-water heat pumps are already included in the German BAFA subsidy list, showcasing the wide availability of heat pumps with natural refrigerants as well as the market reaction of heat pump manufacturers (the number of R290 heat pumps was around 175 models in April 2023, and grew by 228% over the next six months). (https://www.bafa.de/SharedDocs/Downloads/DE/Energie/beg_waermepumpen_pruef_effizienznachweis.pdf?__blob=publicationFile&v=8) R290 heat pumps also have the highest energy efficiency which is another important factor in reducing the overall climate and environmental impact of the products. For the air-to-water heat pumps in the BAFA list, the R290 models are about 7% more efficient (ETAS 55) than the F-gas models.

and ambitious fade-out dates of synthetic refrigerants, taking different development time spans for different product classes (indoor/ outdoor/ monobloc/ split/ multi-split/VRF) and application areas (residential/commercial/industrial) into account. Any development of new products should clearly focus on natural refrigerants."

The available propane heat pumps are primarily hydronic systems with the heat pump located outside. There is still need for development of propane heat pumps that are air-to-air, as most commonly used in California, which can be located inside the building. Currently, the latter is not possible commercially due to lags in adopting IEC 60335-2-40 (2022). But the CEC would do a service by including these alternative pathways.

Aside from the very important issue of GWP, it is critical to recognize that the GWP standard in this docket allows HFOs to be used. These substances are PFAS. PFAS are currently being regulated by the U.S. EPA, California, and other states, and are likely to be banned here as they are proposed to be in Europe.[9]

Here are the problems with HFOs that the CEC and California should strive to avoid:

- The manufacture of HFOs uses as a feedstock carbon tetrachloride, which is a prime source of tropospheric ozone depletion and has a GWP of 1,730. This use is projected to increase rapidly with the manufacture of HFO-1234yf, a widely used automotive refrigerant. This use and production is not controlled by the Montreal Protocol and could lead to more ozone depletion if some fraction of feedstock production continues to be emitted.
- All or most of fugitive HFOs are converted to trifluoroacetic acid (TFA). TFA is mobile, persistent, and cumulative in the environment for hundreds or thousands of years.
- TFA has been found in indoor dust and in beer, tea, and other herbal infusions as well as drinking water; for example, it is found in 80% of groundwater wells in Denmark. In one study it was found in 97% of human blood samples and in another study in 70% of human urine samples. It is ubiquitous in aquatic environments.
- In one hand, TFA has been found unlikely to cause human health or safety problems with concentrations that are likely to be found up to the year 2100. On the other hand, Germany has determined it is a threat to liver function in mammals and has established safety standards for drinking water.TFA has been

[9] The U.S. EPA does not consider trifluoroacetic acid (TFA), a breakdown product of HFO-1234yf and HFC-134a, *or* HFO-1234yf to be in the PFAS category. The U.S. EPA view is in direct contradiction to the European Chemical Agency (European Chemical Agency. PROPOSAL FOR A RESTRICTION SUBSTANCE NAME(S): Per- and polyfluoroalkyl substances (PFAS). 2023. PrePrint (https://cdn.ca.emap.com/wp-content/uploads/sites/11/2023/02/rest_pfas_axv_report_en.pdf) and the Organization for Economic Co-operation and Development, an organization that includes 38 countries. See OECD (2021), Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance, OECD Series on Risk Management, No. 61, OECD, Publishing, Paris. (https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/terminology-per-and-polyfluoroalkyl-substances.pdf) Regardless of what the U.S. EPA may eventually decide, states can adopt their own definitions. California is among 27 states pursuing litigation against chemical companies for PFAS contamination of water (https://www.saferstates.com/toxic-chemicals/pfas/). TFA yields for HFOs differ greatly, with most producing small amounts, but HFO-1234yf yields 100%. (https://www.fluorocarbons.org/news/eeap-2022-tfa-yields-from-hfcs-and-hfos/) Thanks to Richie Kaur of NRDC and Christina Starr of the Environmental Investigation Agency for these references.

inadequately studied in aquatic organisms. Numerous scientists have called for the additional study of chronic low dose exposure in humans.

- TFA has been increasing exponentially and, unlike HFCs, concentrates regionally so is a greater hazard to low-income populations near transportation centers.
- TFA is difficult to remediate. Ironically, TFA is a byproduct of some attempts to remove other PFAS from the environment.

In sum, TFA from F-gas refrigerants constitutes a risk of potentially irreversible harm in the future. The precautionary principle would suggest avoiding all PFAS refrigerants.

This means California must avoid adoption of a third generation of environmentally destructive refrigerants (following the CFC and HCFC refrigerants that destroy tropospheric ozone and the HFC refrigerants that are hundreds to thousands of times more warming than CO2). Because the adoption of heat pumps is projected to be 50% complete by 2032, it is imperative that ultra-low refrigerants be used in them rather than HFC and HFO refrigerants. We should go to the correct solution, natural refrigerants (carbon dioxide, propane, and ammonia) immediately, and not to the less attractive intermediate solution of HFOs or HFO blends, which will prolong the conversion process and create unnecessary health and global warming dangers.

3. **What are the near-term and medium-term technical targets (e.g., costs, efficiency, ramp rate, emissions levels) to advance low GWP heat pump technologies to a higher Technology Readiness Level?**
    a. **What should be the starting and target Technology Readiness Level for these groups?**

Response: There are a variety of technical targets applicable to propane heat pumps.

- As noted above, a German group at Fraunhofer research institute has developed highly efficient heat pumps that can heat a house with less than 150 grams of propane. There is additional research needed along these lines in order to have centralized indoor heat pumps.
- A U.S. firm making propane heat pumps, Treau, specifically made the request (of CARB in a public comment) that CARB focus development on propane:

  "We are a seed-stage hardware startup in San Francisco, California that is building AC/heat pump units that are easier to install and more pleasant to use. Our technology allows us to make a 9K BTU heat pump that uses 350 grams of R-290 in a safe manner by containing the refrigerant to a hermetically sealed outdoor unit. Regulation that pushes the industry towards the safe and timely uptake of units using very-low-GWP natural refrigerants would help us introduce climate-friendly heat pumps into more homes, particularly in the United States."[10]

  The same comment applies to the developments proposed in this docket: restricting proposals to propane would help US companies like Treau.

[10] https://www.energizeinnovation.fund/projects/treau-low-gwp-high-efficiency-heat-pump-and-air-conditioner Treau already is partially funded by the CEC.

- A German consortium of universities has recently been funded to understand the behavior of the typical oil-refrigerant mixtures in the compressor of a heat pump, something that is not currently fully understood thermodynamically but which affects heating or cooling performance.[11]
- In general the technical readiness level (TRL) for the proposal should reflect the status of European and Asian propane heat pump technology. It is unproductive to set a TRL that is far lower than already exists.
- The CEC could make the transition to natural refrigerants more rapid by convening a conference of refrigerant researchers to generate priorities for on-going natural refrigerant research that CEC might fund.

4. **Are the proposed levels of project funding for each group appropriate to achieve the desired outcomes? If not, why?**

   No response.

5. **What would be the typical range of costs (e.g., capital costs) for the anticipated projects, and could projects leverage CEC funding to encourage private investments?**

   No response

6. **A minimum 20% match would likely be required with the funding levels listed above, and this requirement would be waived for projects sited in and benefitting Disadvantaged Communities (DACs) and Low-Income Communities (LICs). Is this sufficient to encourage DAC and LIC projects? If not, how could this be improved?**

   No response

7. **Should Group 1 in Section IV also include small commercial? If so, why?**

   Response: It is hard to believe that the 120 volt specification would be necessary or advantageous for commercial uses, even small ones.

8. **Should Group 3 in Section IV narrow its focus? e.g., to only residential or only commercial. If so, which one and why?**

   Response: No. The broader focus is appropriate.

9. **Is four years a feasible project timeline? Are there potential barriers or challenges in implementing the proposed projects in that timeframe?**

   Response: The timeline is feasible. The main barriers are regulatory. Within four years we hope those barriers will be eliminated.

[11] https://www.coolingpost.com/world-news/e4m-funding-for-heat-pump-efficiency-research/

10. **Which end-use sectors, facilities, or communities are expected to be most positively impacted by these types of projects?**

    Response: If you choose to limit to GWP of 10 or less and focus on natural refrigerants, especially propane, the effects will be positive across the board.

11. **How could this solicitation encourage projects to more fully center equity and community engagement?**

    Response: Propane is more efficient and much cheaper because is not under commercial monopoly. Both characteristics will lead to greater equity. Freedom from PFAS and F-gases, when explained, will increase community engagement and health.

Thank you for the opportunity to comment on this proposed solicitation. If you or colleagues would like to discuss any of these comments, we will be happy to meet and include experts familiar with the state of heat pump technology in other parts of the world.

Sincerely,

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