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Heat Recovery: Information for Ultra-Low Temperature Waste Heat

Additional submitted attachment is included below.

Ultra-Low Temperature Heat Recovery Request for Information
19-ERDD-1
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The California Energy Commission seeks information on innovative waste heat recovery technologies to inform future research initiatives aimed at reducing natural gas use and greenhouse gas emissions in the industrial sector. We are interested in answers to the following:

1. What California industries have large volumes of ultra-low (<250º F) or ultra-high temperature (>1,600º F) waste heat?

According to DOE's Western Combined Heat Power (CHP) Technical Assistance Partnership, there is >700 MW of Waste Heat to Power (WHP) technical potential in California. The largest source of technical potential is contained within manufacturing facilities. Currently, Petroleum Refining has the highest volumes of ultra-low temperature waste heat with combined potential >500 MW. Stone/Clay/Glass industries have the second highest volume with >100 MW potential followed by Primary Metals and Oil and Gas Extraction with >10 and >5 MW respectively. California's refineries primarily located in San Francisco Bay, Los Angeles, and the Central Valley area with the cumulative two million barrels of petroleum processing capacity present significant volumes of waste heat and the highest Natural Gas consumption among the major CA industry (>100 TBtu/yr).

This report and our other analysis show ultra-high temperature (>1,600º F) waste heat is not available in California.

2. What research is needed on advanced technologies or materials (including coatings) for recovering waste heat cost effectively in ultra-low heat or ultra-high temperatures?

Current waste heat to power technologies using Carnot cycles are very expensive (>$4,000/kW) and inefficient (<10% electrical efficiency). Advanced materials/cycles capable of upgrading ultra-low temperature (<250º F) to higher value electricity under hundreds of cycles cost effectively are not available. Research investment is required to develop, demonstrate, followed by their deployment in strategic market segments.

CEC has initiated in funding multiple low-level waste heat technologies with >15% electrical efficiency target under **GFO-17-501**. The preliminary results are encouraging, and additional investment opportunities are being identified. Further increase in electrical efficiency (from 15 to >20%) can be achieved by additional investment from CEC. We believe additional research in **Thermochemical technologies** to upgrade ultra-low temperature (<250º F) waste heat at higher (>20%) efficiency is warranted. Thermochemical technologies have a potential to provide higher storage density, lower volume requirements, low heat loss, and low charging temperature, making it ideal for recovering ultra-low temperature (<250º F) and converting to useful work with multiple applications (as described in Answer 6).

The proposed research funding should focus on:

1. Materials development
2. Component technology development
3. Integrated system design development and validation
4. Prototype development: Design for Manufacturing

Selection and optimization of thermochemical materials such as polymers operational under hundreds of cycles are important. The CEC funding should also explore efficient conversion methods of captured waste heat to power and other higher value applications. The reuse of thermochemical materials is a critical need in increasing energy return on investment (EROI) of the recovery technology. As such, robust and low-cost material recovery and reuse methods and technologies should be investigated in tandem.

3. Should research focus primarily on the ultra-low or ultra-high temperature waste heat or, if not, what other temperature ranges?

Research should primarily focus on the ultra-low temperature (<250º F) waste heat – huge opportunity for waste to value in California. Market research by gas industry (GTI, previously GRI) and California utilities show multi-billion-dollar market potential for this ultra-low-level heat.

Significant research is required to recover ultra-low (<250º F) waste heat. There is a greater prevalence of ultra-low waste heat from process steam condensate, boilers, cooling water from air compressors, internal combustion engines, air conditioning, and refrigeration condensers, and drying, baking, and curing ovens across the entire chemicals, refining, food, transportation, equipment and paper sectors in CA. Current limitations include dependence on Carnot cycle, low-efficiency power generation, and large heat exchanger area requirement. New research funding from CEC to explore advanced heat recovery technology of ultra-low temperature waste heat to higher value is critical.

Why not high-temperature waste heat?

-Limited Market w/ Unfavorable Return for CEC Investment:

According to 2015 US DOE Waste Heat Recovery Technology Assessment Report, currently there are plenty of ultra-high temperature (>1,600º F) waste recovery technologies including refractory (ceramic) regenerators, regenerative burners, radiation recuperator, waste heat boilers, and load or charge preheating. These technologies convert ultra-high temperature to either supercritical CO_2 or steam for preheating, processing heating or for mechanical electrical work. Further, significant research has been already conducted with funding from US DOE to maximize power generation, and heat transfer rate per area. But the state-of-the-art technology performances are still very poor.

Additionally, sources of ultra-high temperature waste heat are significantly limited, especially in California. Thus, return for CEC investment is extremely low.

4. What advanced heat recovery technology improvements are needed to increase widespread deployment by industry?

A. Increased efficiency with hundreds of cycles for long-term stable operation
B. Compact footprint (Modular and Scalable)
C. Competitive costs (Capital and Operational & Maintenance)
D. Retrofit capability (Value Added to the Ongoing Operation)

Currently, barriers to ultra-low temperature recovery systems include low-efficiency power generation, few end uses for ultra-low temperature heat, and acidic condensation and corrosion associated with using process exhausts. The advanced heat recovery technology must have higher efficiency, the heat storage materials must be robust (readily withstand chemical and physical stress under hundreds of cycles), the system must be scalable, and the technology must provide flexibility for retrofitting with all industrial operations.

5. What are the cost and technical targets that must to be met to drive customer adoption (such as minimum rate of return or minimum percent heat recovery)?

On the most recent CEC Waste-Heat to Power procurement (GFO-17-501) released in 2017, the target electrical efficiency was >15%. For wider customer adoption of ultra-low temperature waste heat (<250º F), we recommend CEC to consider following targets:

A. Electrical efficiency target must be increased to >20%.
B. Capital cost target should be <$2,000/kW
C. Operating life: >20 years
D. Operating and maintenance cost: <$50/kW per year
E. Footprint target: Modular, Retrofittable

6. What complementary technologies and approaches can be combined to increase the value proposition of waste heat recovery systems?

Typical waste heat streams also contain exhaust gases from industrial processes. They may include harmful emissions such as NOx, SOx, CO, PM, CO_2, and CH_4.

How can we create higher value from these streams?

Higher value could means upgrading ultra-low temperature waste heat to electricity, mechanical work, or chemical process advantages/intensification.

A. Simultaneous GHG reduction through CO_2 capture and NOx/SOx removal
B. Direct use of captured CO_2 within the process for increased process efficiency and EROI
C. Inherent energy storage capability for rapid demand response in case of anticipated and/or unanticipated facility shutdown or blackouts.