8th International Supercritical CO_2 Power Cycles Symposium
San Antonio, TX U.S.A.
February 26 - 29, 2024

Fast Pitch

February 27, 2024

Natural Refrigerant, High Temperature Heat Pump: Decarbonizing Industrial Heat

Lalit Chordia, PhD, Vahid Vahdat, PhD, **Marc Portnoff**

ThарEnergy

150 Gamma Drive
Pittsburgh, PA 15238
www.tharenergy.com

Technological Advantage:

Thar Brand core competencies

Sales, design-build, install and service

- **30+ years commercializing "Green" supercritical fluid technologies**
- **Designer and developer of supercritical fluid processes, systems & major components**
- **Industrial scale 24/7/365 installations, worldwide:**
  - **Food**
  - **Chemicals**
  - **Neutraceutical**
  - **Pharmaceutical**
  - **Electronics industries**
- **Full customer support services**

Thar Energy
Turning concepts into hardware
150 Gamma Drive
Pittsburgh, PA 15238
www.tharenergy.com

COMPACT Heat Exchangers

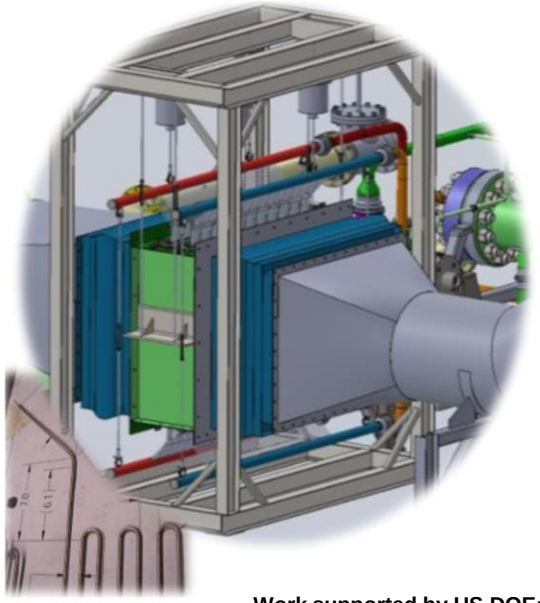
Higher Performance *Smaller Footprint* *Lighter Weight*

Recuperators Primary Heater Gas/Air Coolers Water Coolers

- **Advanced Manufacturing Methods**
- Optimized material use
  - *Aluminum*
  - *Stainless Steels*
  - *Nickel Super Alloys*
- **Modular Design & Factory Fabricated**
- ***Demonstrated at extreme T & P***
- ***Thermal capacity from kWt to MWt***

sCO_2 Primary Heater

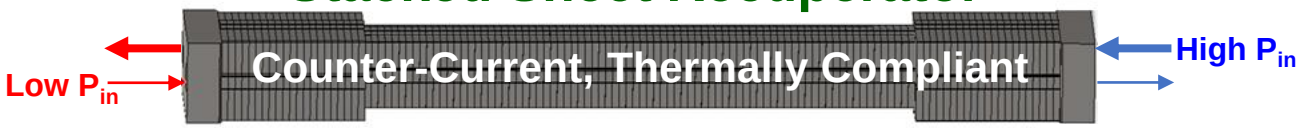
Installed, Commissioned and Operated at SwRI



Work supported by US DOE: DE-EE0005804\

Gas Cooler

Stacked Sheet Recuperator



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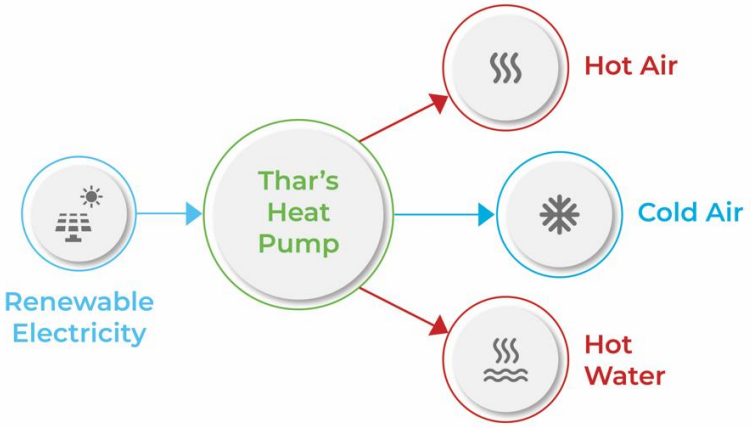
System & Product Development

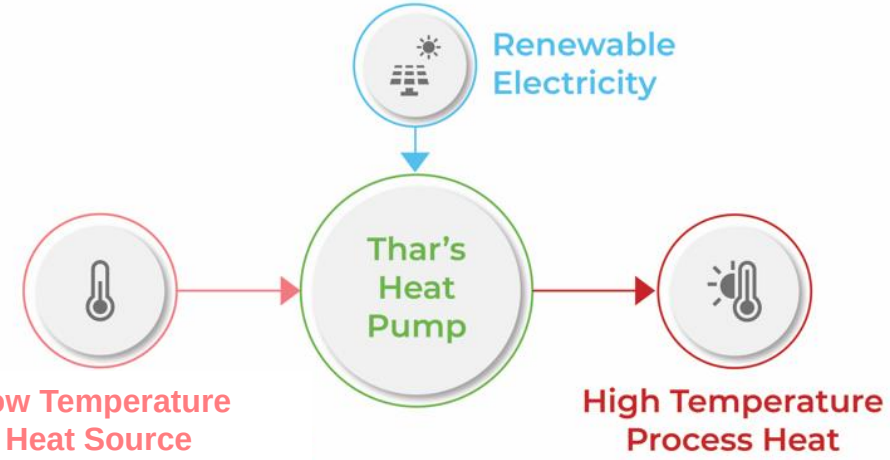
Geothermal Power

Cost Effective - Efficient - Modular

Simultaneous Heating & Cooling



High Temperature Heat Pump



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Market Opportunity: Decarbonize industrial process heating

Renewable Thermal Collaborative, Report in Brief, 02/2021

In the U.S.A., fossil fuel combustion produces heat and steam used for example:

- ***Process heating***
- ***Process reactions***
- ***Process evaporation, concentration, & drying***

Industrial sector currently accounts for ~1/3 of our nation's energy-related CO_2 emissions.

This creates ~52% of the country's industrial direct greenhouse gas emissions.

Deep decarbonization market for industrial heating - expected to top 1 Trillion $US

https://mhi-inc.com/decarbonization-project-costing-analysis-energy-efficiency

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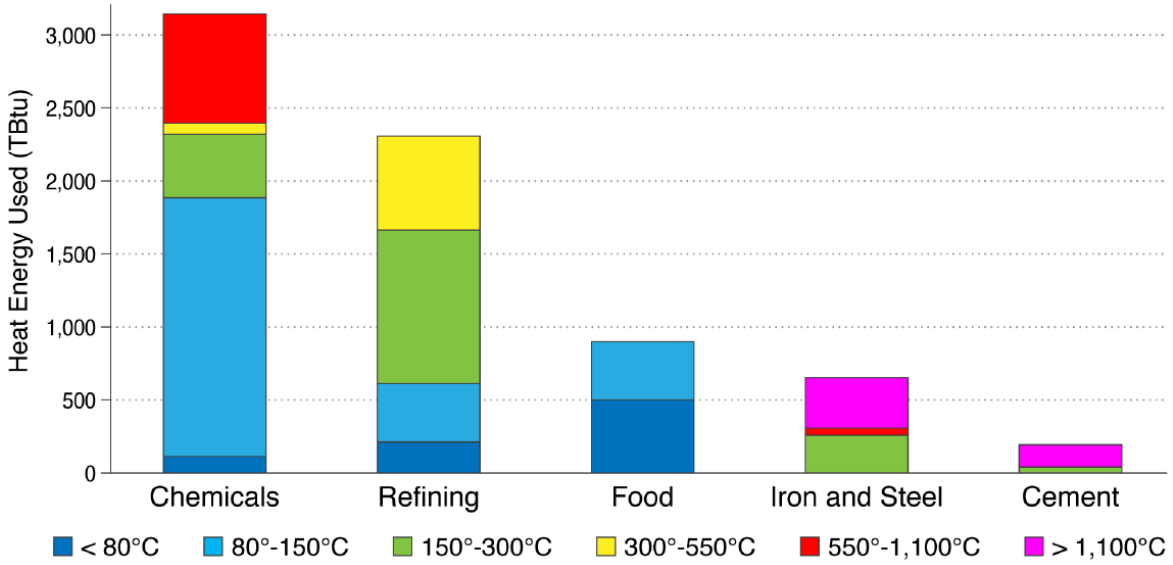
High Temperature Heat Pump

Process heat to the chemical, refining and food industries

Refining

Process temperature - Industry Distribution



Chemicals

Food

130°C accounts for ~42% of industrial thermal emissions
200°C accounts for ~60% of industrial thermal emissions

McMillian 2019
Thermal Process Intensification: Transforming the Way Industry Uses Thermal Process Energy, Advanced Manufacturing Office, May 2022

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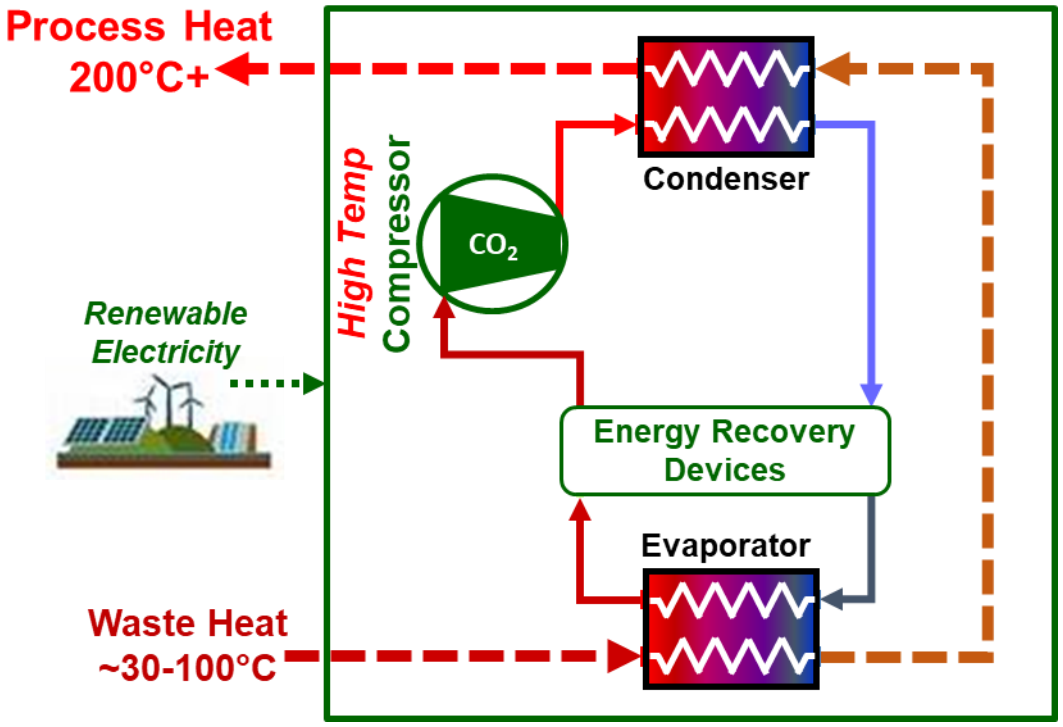
Higher temperatures – Greater market opportunities

Chemical, Refining and Food Industries

Natural Refrigerant, CO_2, High Temperature Heat Pump



Designed to reduce the cost and environmental impact of process heat.

Options:

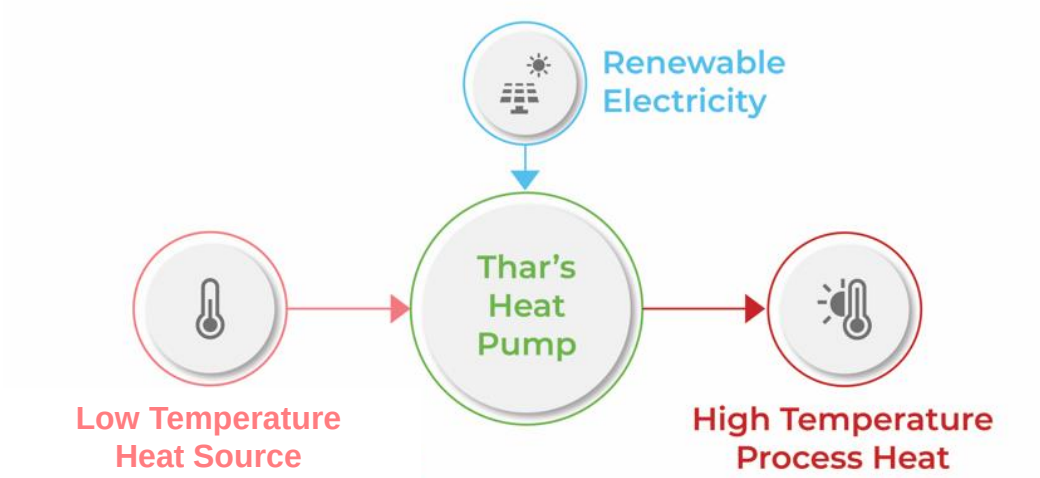
- **Hot Air**
- **Hot Water**
- **Steam**
- **w/wo Chilled Water**

- ***Novel technology development, 200°C+***
- ***Roll out new products with market ready technology, 120°C -160°C***

Thank you for your kind attention!

Questions?

Natural Refrigerant, CO_2, High Temperature Heat Pump



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