7th International
Supercritical CO_2 Power Cycles Symposium
San Antonio, TX U.S.A.
February 21-24, 2022

Panel Session I:

Industry Panel – Status of Technology Maturation

2/22/22

sCO_2 Brayton Power Block Components & Cycle Development

Turning concepts into hardware

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

TharEnergy

Pittsburgh, PA 15238 USA

Thar Energy

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150 Gamma Drive
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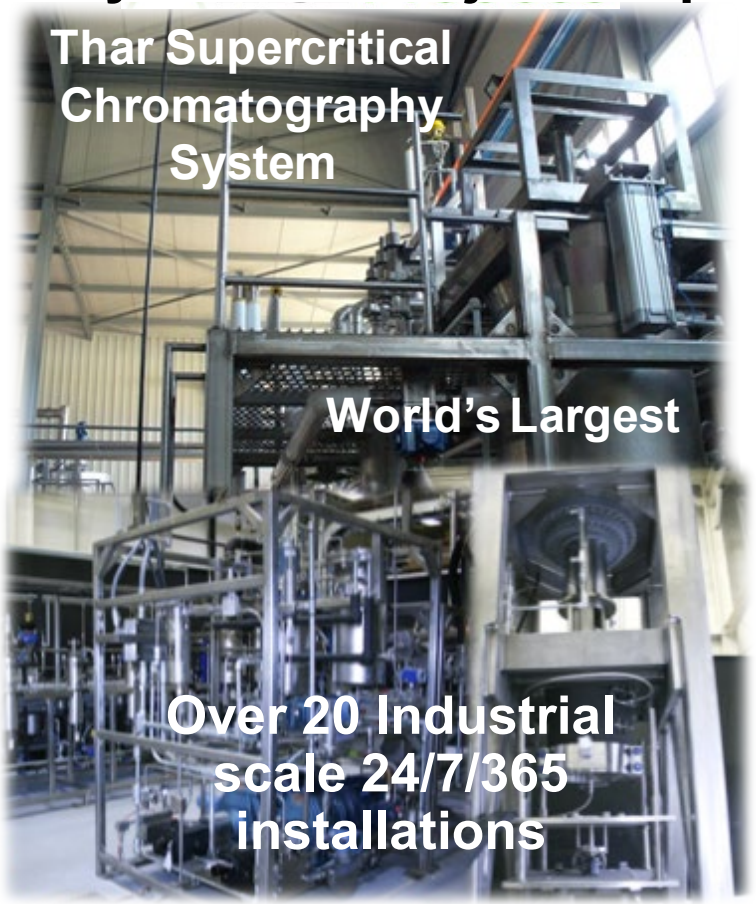
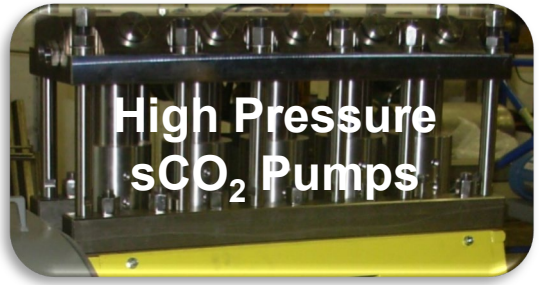
The Thar Brand - Over 30 years of Innovation with "Green" Supercritical Fluid Technologies

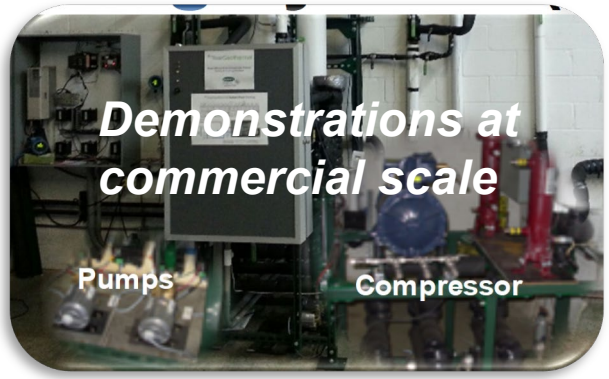
Design and commercialization of supercritical systems & major components





Over 5,000 scientific instruments installed

Direct Exchange, R744 (CO_2) Geothermal Heating & Cooling



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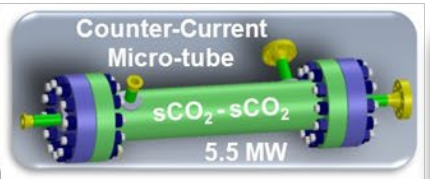
Timeline (recent past)

2014

sCO_2 Brayton Power Cycle Development

COMPACT **Heat Exchangers for sCO_2 Power Cycles**



3D Printed, Inconel 718, sCO_2-sCO_2 Recuperator

2015

Design – Construct – Install
Primary Heater for Sunshot
One MWe sCO_2 Test Loop

2016

Design – Construct – Operate
sCO_2 Heat Exchanger Test Loop
Superior Thermal Performance Confirmed

Gas Cooler Air-sCO_2

2017

TharProcess

Design – Construct – Operate Largest GMP sCO_2 Extraction System in USA

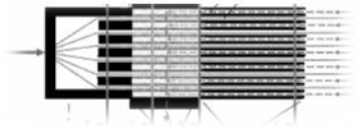
Oxy Combustion Test Facility
Design – Construct – Operate
Demonstrate auto-combustion

Expands into Liquid Chromatography

Thar Pharmaceuticals sold to GRUNENTHAL

United States Patent and Trademark Office

Patent - Notice of Allowance
Counter Current Heat Exchanger/Reactor



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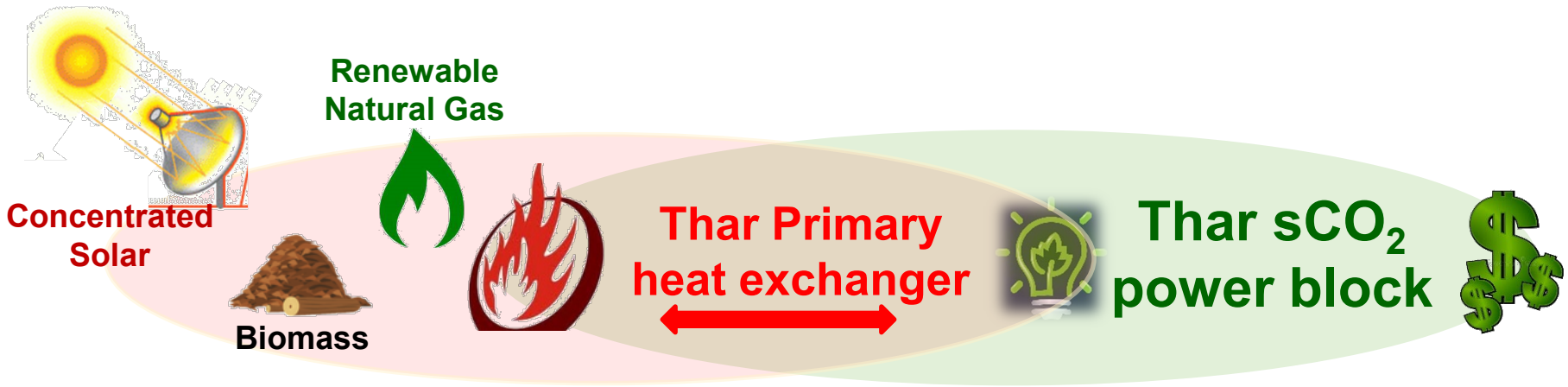
Thar is interested in commercializing <1 MWe, recuperator sCO_2 power systems, that efficiently converts heat to electricity and hot water/steam

ARPAe HITEMMP Project



You bring the heat! **We provide the power!**

Work supported by US DOE ARPA-E HITEMMP DE-AR0001129

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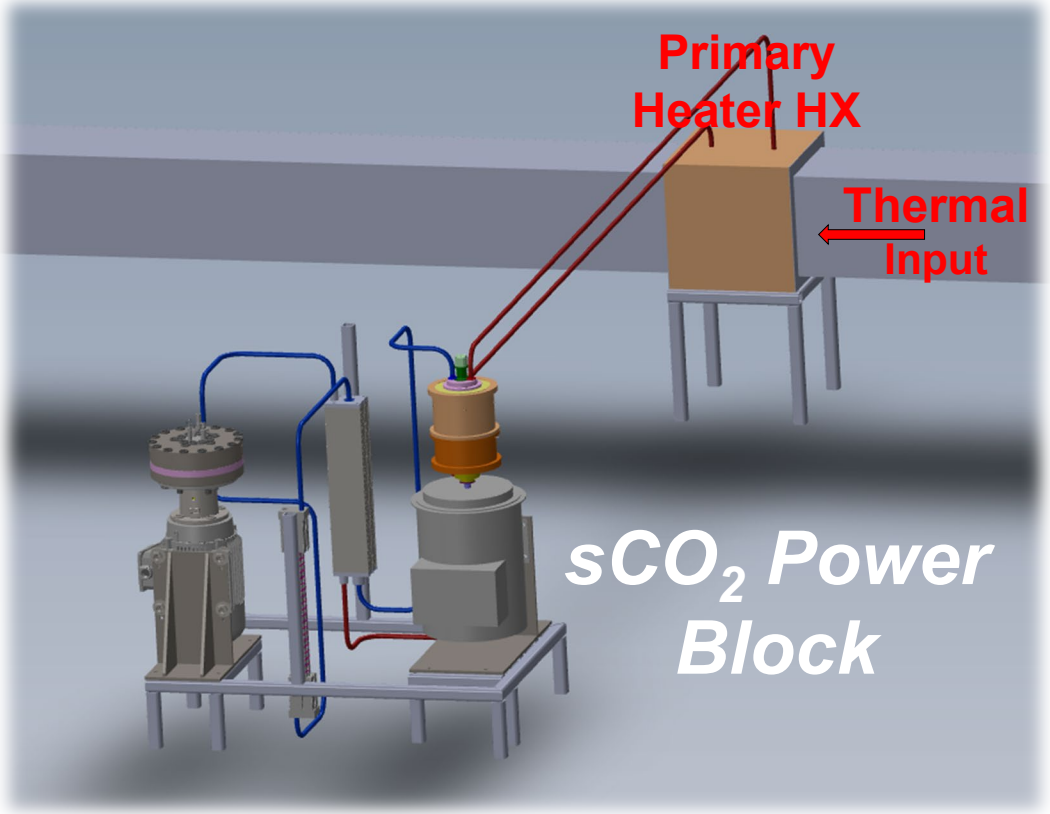
sCO_2 Recuperated Power Block

- **Thar Energy's CHP sCO_2 Power Block is designed to be efficient, modular, compact and competitively priced**
  - **Electrical cycle efficiency: > 45%**
  - **CHP Efficiency: > 70%**
  - **Low cost of ownership**
  - **Reduced environmental impact**
- **Systems sized from 25 kW to < 1 MW electric capacity**
- **Fuel source agnostic**
- **Load following**
- **Able to integrate with existing burner systems**



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Heat Exchangers are key to making sustainable electricity

Efficient & Economical

Thar Energy provides a range of compact heat exchangers

- ***Recuperators***
- ***Primary Heater***
- ***Gas Coolers***
- ***Water Coolers***

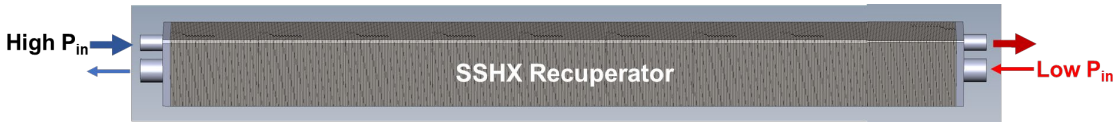
Optimized material use

- ***Aluminum***
- ***Stainless Steels***
- ***Nickel Super Alloys***

Proven design flexibility to optimize performance/cost metrics

SSHX Recuperator meets/exceeds STEP criteria | ***APPA-E project goals***

Criteria	S.T.E.P. State of Art Target	Thar SSHX Recuperator	ARPA-E Category A Target	Thar Project Goals
Thermal Effectiveness	97%	✓	≥ 80%	> 95%
Temperature Limit	577°C	✓	≥ 800°C	> 800°C
Low Pressure	85 bar	✓	≥ 80 bar	≥ 80 bar
High Pressure	255 bar	✓	≥ 250 bar	≥ 300 bar
Pressure Loss	ΔP_h < 1.5%	✓	ΔP_h < 2%	ΔP_h < 2%
	ΔP_c < 0.6%	✓	ΔP_c < 2%	ΔP_c < 2%
Cost	< $100 / kWt	✓	$2000/UA	< $1000/UA
	347H Stainless Inconel 625		***γ' strengthened Nickel Super-alloys***	



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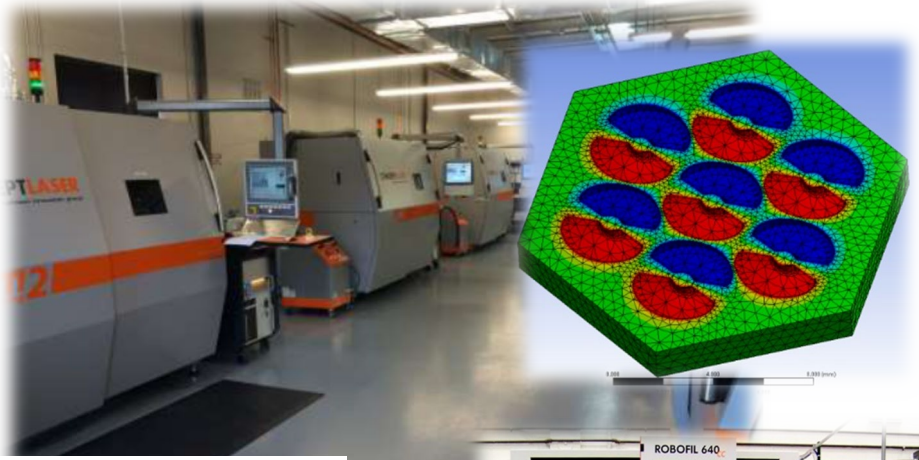
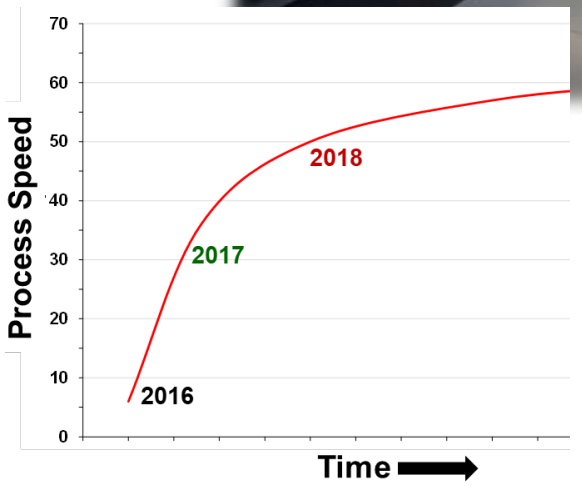
Manufacturing technologies are advancing as a rapid pace

Subtractive Manufacturing
Additive Manufacturing
QA/QC Methods

- Laser cutting
- Laser welding
- Water jet cutting
- 3D metals printing
- Electrochemical etching
- Electrochemical machining (ECM)
- Electro discharge machining (EDM)
- EDM wire cutting
- Sheet bending/forming
- Metal plating
- Stamping
- Brazing
- Welding
- Diffusion bonding





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Summary

The future is hopeful!

Thank you for your kind attention!

Questions?

Thar Energy's new Pittsburgh location
200 RIDC Park West Drive, Building 2, Pittsburgh, PA

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