

# Supercritical Transformational Electric Power (STEP) Demo



8<sup>th</sup> International Supercritical  
CO<sub>2</sub> Power Cycles Symposium  
San Antonio, TX, USA



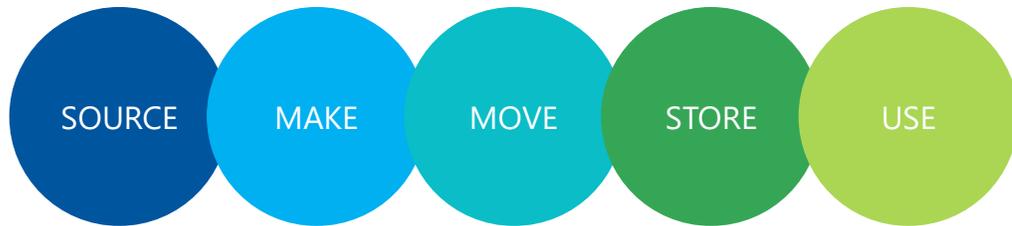
Don Stevenson, VP – Carbon Management & Conversion

GTI Energy

February 28, 2024

# GTI Energy at a Glance

GTI Energy is a leading energy research and training organization



**500+**  
Enterprise Employees



**Valued Partners**

**175+**

80+ years of experience and leadership in energy production, storage, delivery and use

**Research & Development**

**\$1B+**

In the past decade

Leading and convening collaborative R&D

**Innovation & Commercialization**

**1,300+** Patents

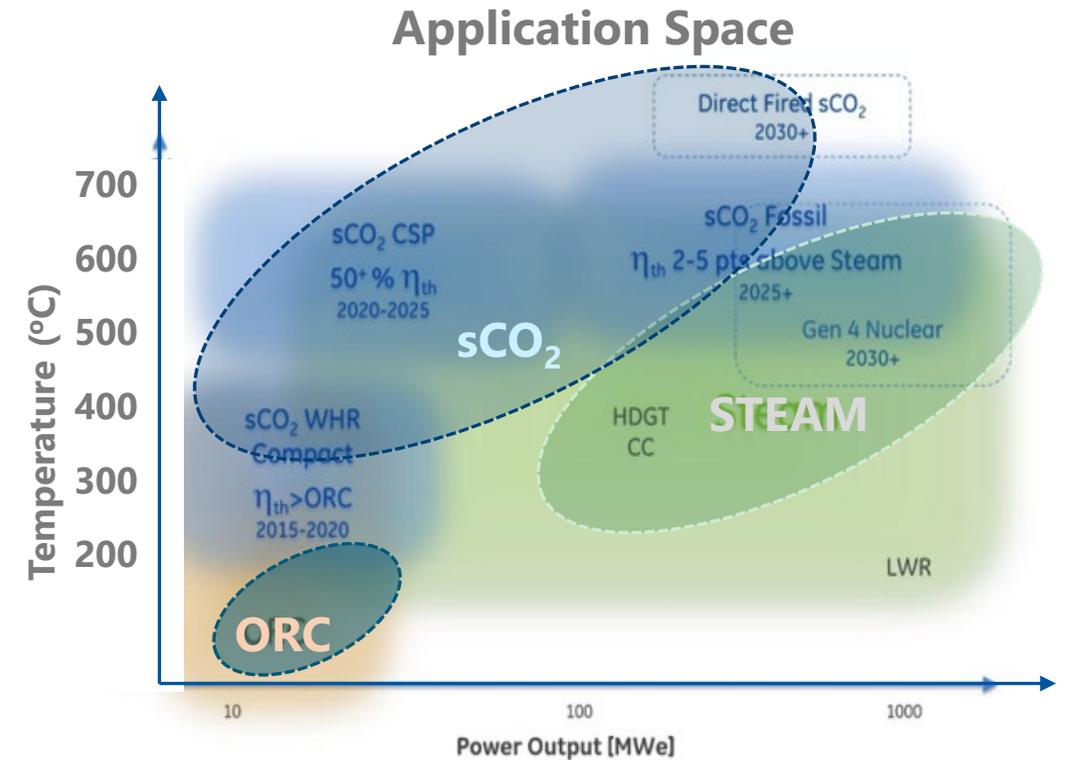
**500** Products    **750+** Licensing Agreements

**10+** Industry Collaboratives



# sCO<sub>2</sub> Power Cycles

- **Advantages of sCO<sub>2</sub> power cycles**
  - Heat source flexibility
  - Higher efficiencies
  - Compact turbo-machinery
  - Economic scalability
  - Lower emissions & water consumption
  - Facilitates and economizes low-carbon power production



Concentrated Solar



Fossil Fuel/Biomass



Geothermal



Nuclear



Energy Storage



Waste Heat Recovery

# Supercritical Transformational Electric Power (STEP) Demo Project



- \$165.6M project to design, construct, commission, and operate a 10 MWe sCO<sub>2</sub> demonstration power plant
- **Objectives:**
  - Advance sCO<sub>2</sub> power cycle technology from TRL3 to TRL7
  - Demonstrate pathway to net plant efficiency > 50%
  - Demonstrate operability at 500°C and  $\geq 700^\circ\text{C}$  turbine inlet temperature with 10 MWe power generation



## • Project Partners:

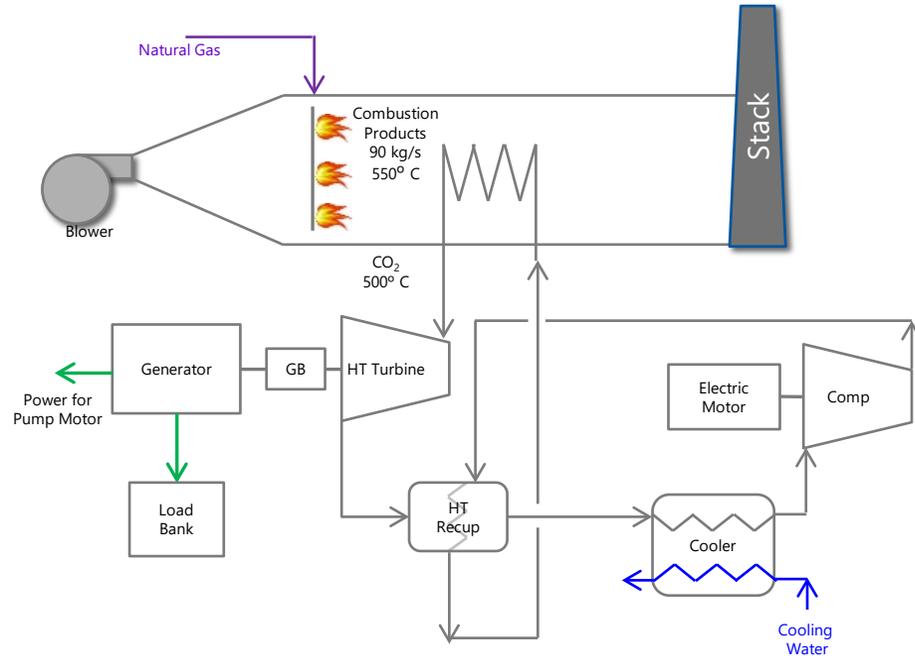


[www.STEPdemo.us](http://www.STEPdemo.us)

## • Industry Co-Funders:



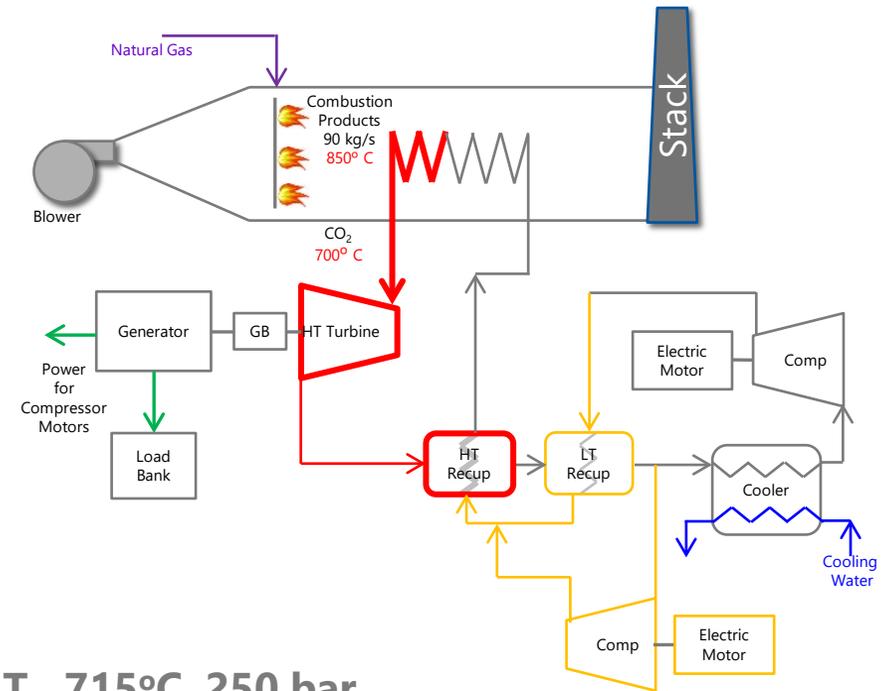
# 2-Phase Development of STEP



$T_{iT}$  500°C, 250 bar

## Simple Cycle

- Shortest time to initial data
- Controls & safety
- Component performance
- Steady & transient cycle data



$T_{iT}$  715°C, 250 bar

## Recompression Cycle

- Inventory management
- Starting transients
- Parallel compressor control
- SOA component efficiencies
- Cycle efficiency > 50%

# STEP Test Facility 2024

sCO<sub>2</sub> Inventory Storage

Test Facility

sCO<sub>2</sub> Heater

Cooling Water Towers

Electrical Load Banks

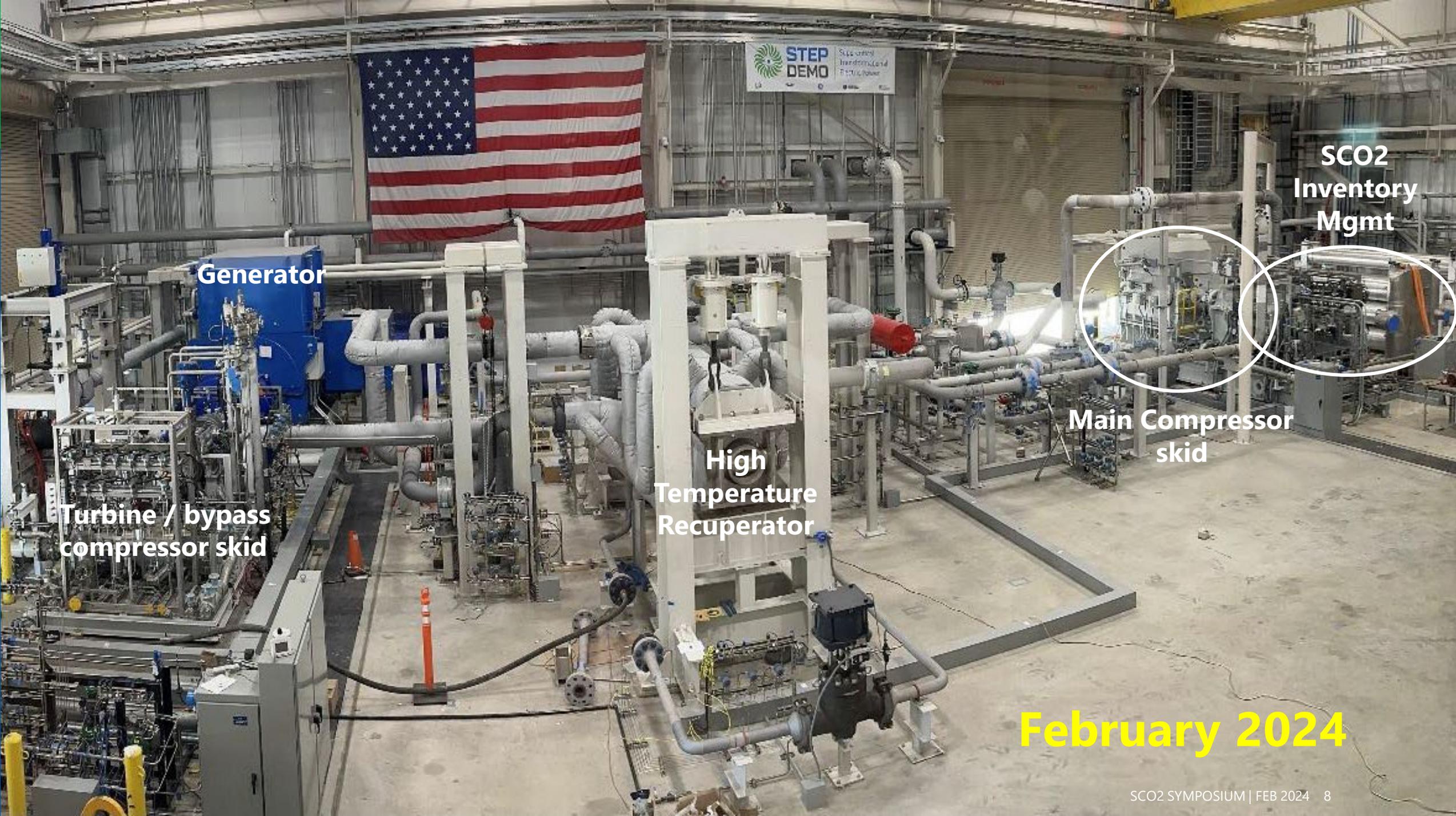
Electrical Power & Back Up Generators





**STEP DEMO**  
Supercritical Transnational Electric Power

**February 2022**



**STEP DEMO**  
Six units, 100 MW, 100% power



**Generator**

**Turbine / bypass compressor skid**

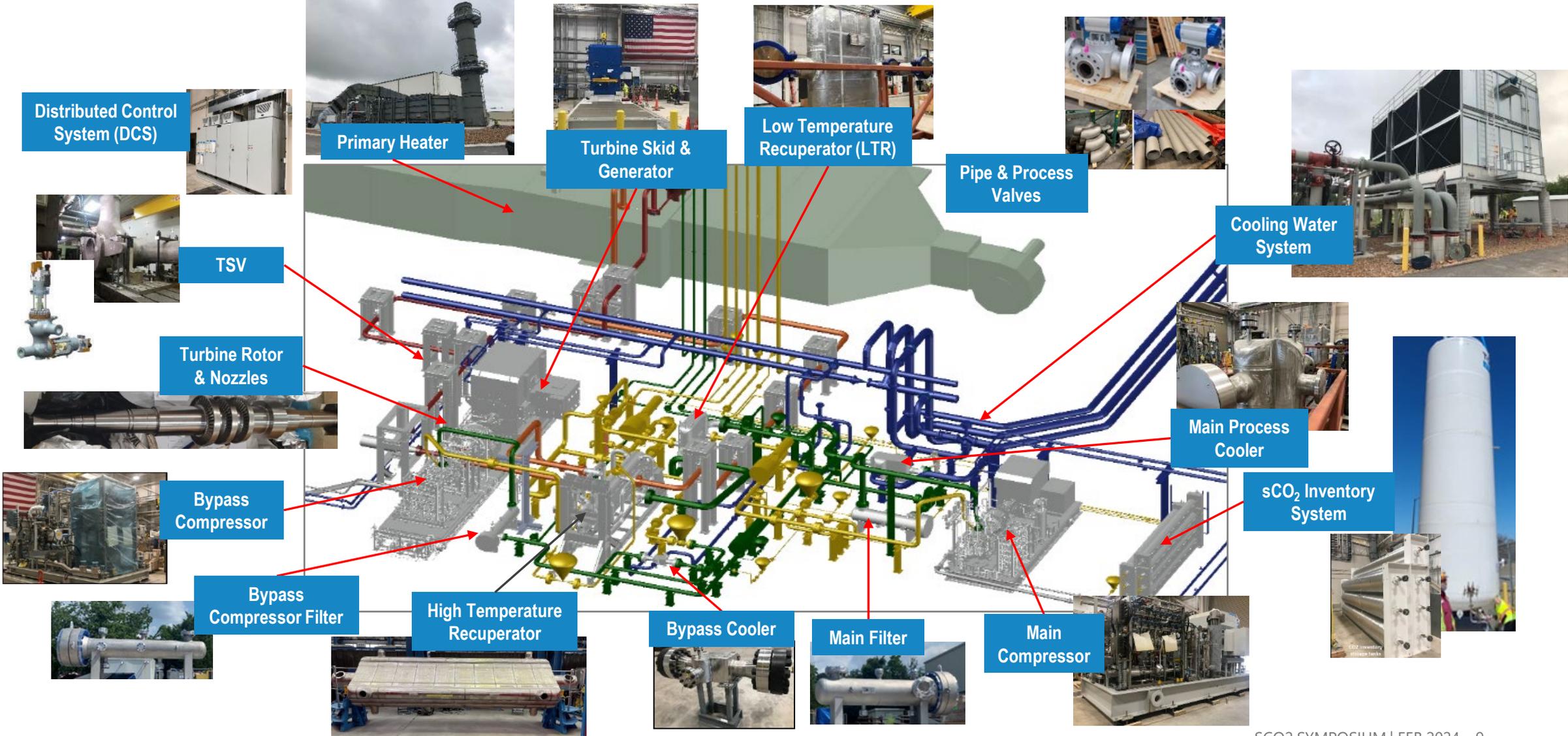
**High Temperature Recuperator**

**Main Compressor skid**

**SCO2 Inventory Mgmt**

**February 2024**

# STEP Process Equipment Layout



# STEP Project Milestones



Compressor Commissioning Turbine Test



# Component Development Achievements

## sCO<sub>2</sub> turbine

- At ~1/10 the size of an equivalent steam turbine, has the world's highest power density for a terrestrial turbine
- 21,500 horsepower produced by 180 lb rotor (120 HP/lb, or 200 kW/kg)



## High temperature recuperator (HTR)

- World's largest high temperature printed circuit heat exchanger (PCHE)
- 22.5 MWth and ~50 tons (~45,300 kg)



## Heater

- World's largest high temperature Inconel heater tube bundle
- 22.54 MWth tube bundle heat duty

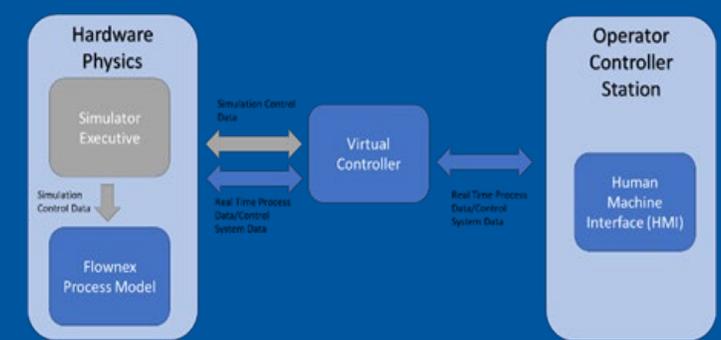
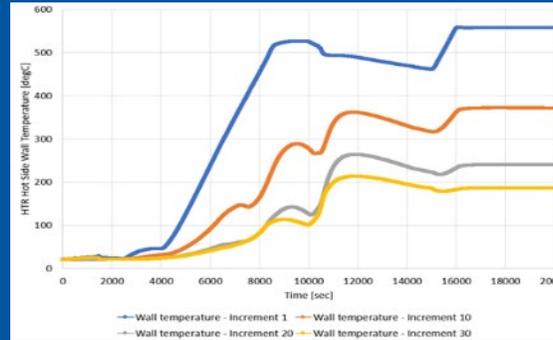
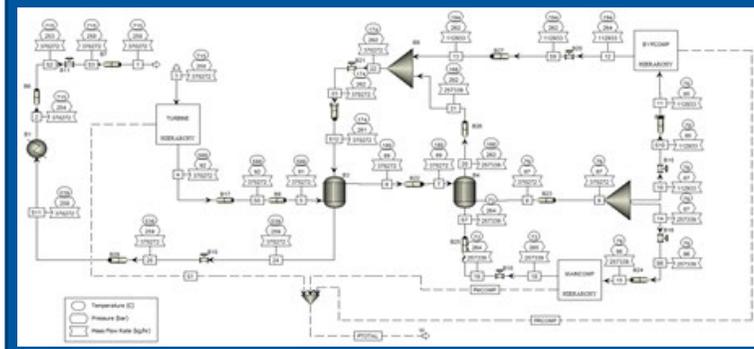


## Turbine stop valve

- World's largest high temperature Haynes 282 casting
- 9,250 lbs (4196 kg)



# System Modeling – Critical Tools



## Steady state modeling

- Started **Aspen Plus** modeling ~10 years ago for system studies
- Continuous improvement with realistic pressure loss & equipment performance
- Cross verification w/other models
- Use for Cycle performance, pipe sizing, equipment specification
- Evaluate other sCO<sub>2</sub> cycles & applications

## Dynamic modeling

- Created FLOWNEX model to support STEP
- Calibrated against steady state model
- Provide feedback on system & equipment designs
- Test controls narrative & methodology
- Operations planning (startup, normal shutdown, and trips/shutdown)

## Facility simulator

- Human machine interface mimics facility controls (GE Mark VI DCS)
- Ties into a virtual controller accesses real time data
- Flownex model used for hardware physics
- Operator training – runs at real time
- Operation planning

# Key STEP Learnings to Date

- **Programmatic (large, DOE-sponsored pilot projects)**

- Securing/maintaining Congressional support critical
- DOE grant-style contracting (as normally structured) not conducive to projects with substantial construction/procurement risk
  - e.g. contingency not allowed but should be required (beginning to be recognized)
- Partnering is necessary – but establish partner alignment and incentives early
  - Must be clearly contracted, to include consideration of unexpected developments
- Commercial equipment procurement terms don't serve you well in development setting
  - e.g. "fixed price" contracting provides inadequate risk mitigation
- Component tech development risk underestimated

- **Technical**

- Fabrication experience with high temperature materials advanced
  - PCHE (HTR), Haynes 282 castings (TSV) and Inconel 740H applications (heater, turbine casing, piping)
- Thermal management key to turbine dry gas seal life, even during pressurized holds
- Turbine designed to be scalable to 100+ MW
- Identified gaps in knowledge and performance for commercial sCO<sub>2</sub> compressors
- Liquid operation an important compressor requirement for cold start-ups
- Commissioning the heater with air instead of CO<sub>2</sub> accelerates schedule and simplifies commissioning processes and safety precautions

# Interest from Around the World



**AURA**

Énergie

## Une turbine à CO2 de la taille d'une table peut alimenter 10 000 foyers

**Rinnovabili.it**  
IL QUOTIDIANO SULLA SOSTENIBILITÀ AMBIENTALE  
DIRETTORE MAURO SPAGNOLO

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Home > Energia > Efficienza Energetica > Turbina a CO2 supercritica, inaugurato il maxi impianto pilota

### Turbina a CO2 supercritica, inaugurato il maxi impianto pilota

Taglio del nastro in Texas per l'impianto dimostrativo Supercritical Transformational Electric Power da 10 MW. Hamilton (SwRI): "Cambierà il modo in cui pensiamo alla produzione di energia"

2 Novembre 2023

**CleanTechnica**

A high tech supercritical carbon dioxide power plant is taking shape behind the walls of a building in Texas, with the potential to lower the cost of concentrating solar power system

## A Tiny Supercritical Carbon Dioxide Turbine Can Power 10,000 Homes

**Report**  
SAN ANTONIO BUSINESS JOURNAL

### \$155M demonstration plant at Southwest Research aims to revolutionize energy industry

By Tracy Hall-Quinn  
October 23, 2023

19 USA focus: H<sub>2</sub> hubs, gas with CCS, wildfire mitigation  
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32 European offshore wind: immediate action needed  
38 Fusion power: optimizing generates to reduce emissions

**MPS**  
modern power systems  
Volume 43 | Number 9 | November/December 2023  
www.modernpower.com

## Supercritical CO<sub>2</sub>

STEP Demo project achieves mechanical completion

**EnergyPortaleu**

NEWS | MARKETS | SOLAR | WIND

### The Future of Power Generation: Supercritical Carbon Dioxide

By Daniel Hall  
OCT 27, 2023

**ENERGY DAILY**  
the power of earth and beyond

CARBON WORLD

## STEP Demo Plant Ushers in Next Era of Power Generation With sCO<sub>2</sub> Technology

Zelosos por Buenas  
Renovables  
Energía sostenible ahora

SIN CATEGORÍA | ESG | XTR | SRS | XT | XTR

### La revolución de la tecnología de dióxido de carbono supercrítico (sCO<sub>2</sub>)

Por Enrique Cánem Corvera  
OCT 27, 2023

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## STEP forward for Brayton high efficiency demo

7 November 2023

Print | Email

GTI Energy and its partners, Southwest Research Institute (SwRI) and GE Vernova, have marked what they believe is a significant leap forward in energy technology advancement with the opening of their Supercritical Transformational Electric Power (STEP) Demo test facility in San Antonio, Texas. Funded by the US Department of Energy and industry partners, the STEP Demo facility is said to be a first-of-a-kind

**SAN ANTONIO BUSINESS JOURNAL**

REAL ESTATE  
Crane Watch >

### \$155M facility could change power landscape

Email | Share | Tweet | Print | Order Reprints

**POWER Engineering**

Emissions

### GTI, KEPCO collaborating on supercritical CO<sub>2</sub> power cycle research

GTI and KEPCO will explore opportunities for joint research and development on sCO<sub>2</sub> technologies over the next five years.

Clarion Energy Content Directors

(Editor's Note: This story originally published on May 2).  
The non-profit research organization Gas Technology Institute and a unit of Korea Electric Power Co. (KEPCO) have signed an agreement to jointly research and develop supercritical carbon dioxide (sCO<sub>2</sub>) power cycle technologies that could impact power generation efforts.  
The memorandum of understanding between GTI and Korea Electric Power Research Institute (KEPRI) focuses on sCO<sub>2</sub> work which can lead to the potential for higher power conversion efficiencies and more compact turbomachinery. Such achievements could help lower capital costs and reduce plant footprints for power generators.  
GTI and KEPRI will explore opportunities for joint research and development on sCO<sub>2</sub> technologies over the next five years. The partners will cooperate, share technical information, and potentially exchange research staff for sCO<sub>2</sub> technology development and commercialization.



# STEP Team @ the sCO2 Symposium

Tuesday

- Michael McDowell (GTI): Evaluation of the rapidity of sCO2 cycle power up and down events using the STEP dynamic simulation model
- Darryl Hino (GTI): Simple Cycle Test Validation of the STEP Dynamic Simulation Model

Thursday

- Jeff Moore (SwRI): STEP 10 MWe sCO2 Turbine Design, Assembly and Commissioning
- Bill Follett (GTI): The STEP 10 MWe sCO2 Pilot Installation and Commissioning Status Update
- Mike Kutin (GTI) and Josh (SwRI): Commissioning and Simple Cycle Testing of the STEP Main Compressor
- Craig Nolen (SwRI): Controls and Data Acquisition Systems Architecture for the DOE STEP 10 MWe Pilot Scale sCO2 Power Plant
- **STEP Facility Tour at SwRI (1:30 – 4:30pm)**

# Gratefully Acknowledge the Support from U.S. DOE-NETL and Project Partners



GE VERNOVA



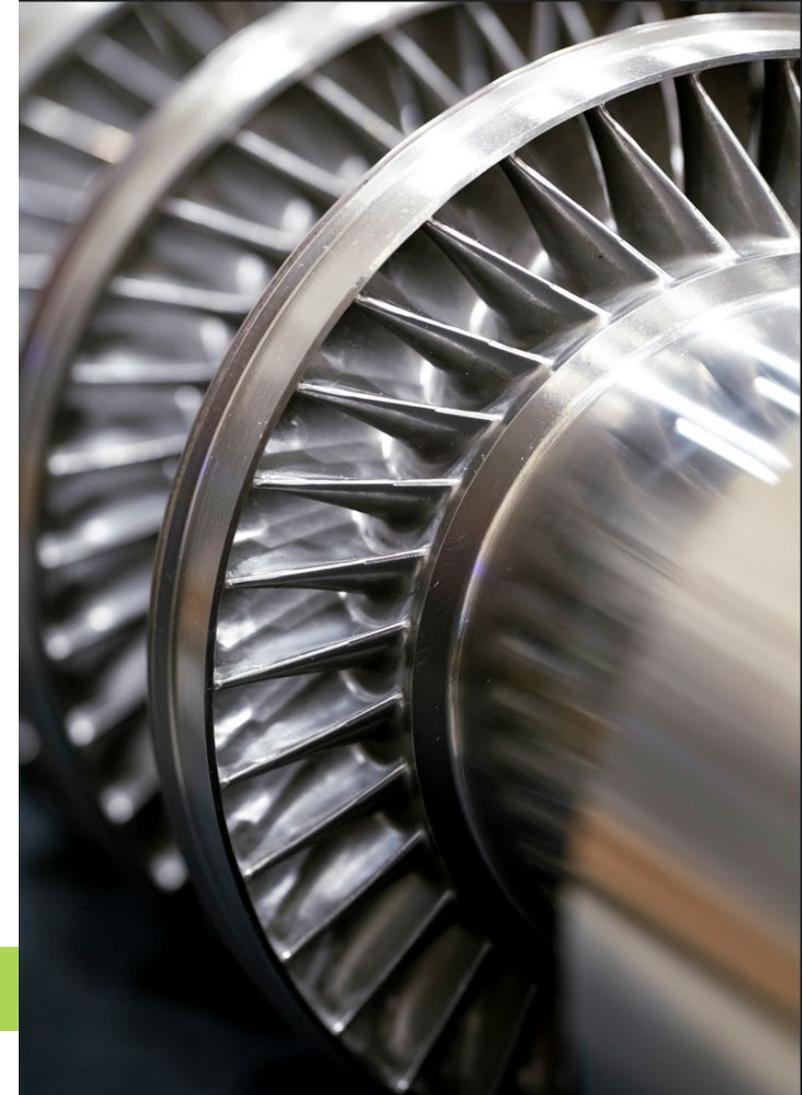
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# Summary

- sCO<sub>2</sub> power cycles are versatile to heat source and application
- Potential for performance AND cost benefits over steam cycles
- Technology maturation by the STEP project will provide path to future commercial systems with higher efficiency and lower emissions
- STEP test operations are planned for early 2024 (Simple) and early 2025 (RCBC)
- Valuable programmatic learnings as well as technical learnings on design and fabrication with advanced alloys
- Opportunity for deep technology and operations insights available through Joint Industry Partnership

Keep up to date on STEP Project progress at [www.STEPdemo.us](http://www.STEPdemo.us)



# Thank You!

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