Supercritical CO_2 Power Cycles Symposium
San Antonio, TX, USA

Enabling a Low Carbon Future with sCO_2 Power Cycles

22 February 2022

Don Stevenson
Vice President & Managing Director
Energy Supply & Conversion
Gas Technology Institute

GTI: Over 80-year history of turning raw technology into practical energy solutions

Delivering Technology Solutions Across Entire Value Chain

SUPPLY ▶ CONVERSION ▶ DELIVERY ▶ UTILIZATION

RESEARCH & DEVELOPMENT

PROGRAM MANAGEMENT

TECHNICAL/ ANALYTICAL

CONSULTING

TRAINING

COMMERCIALIZATION

400+ EMPLOYEES

501(c)(3) not-for-profit corporation

World-class piloting facilities headquartered in Chicago area

Gas Technology Institute

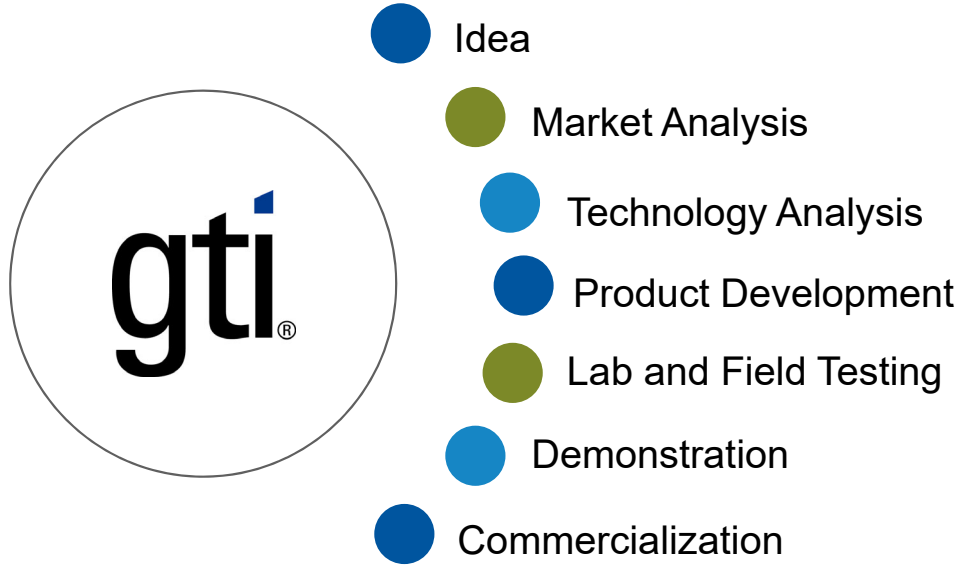
Mission

GTI ***solves important energy challenges*** worldwide, turning technology and insights into solutions that ***create exceptional value*** for our customers in natural gas and broader ***clean energy systems***.

Objectives

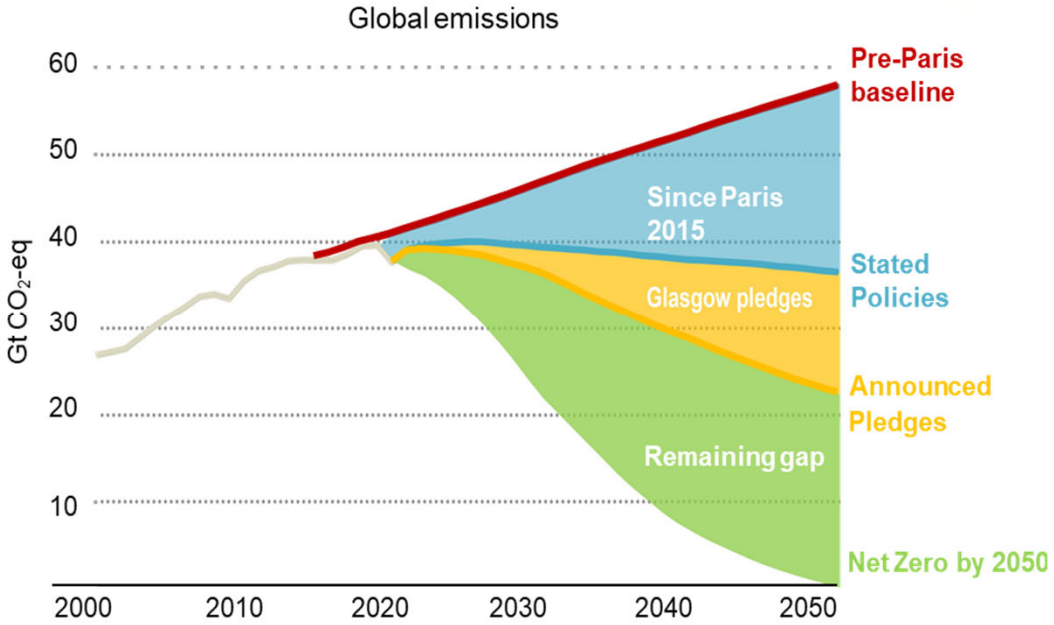
- *Expanding supplies of affordable and clean energy*
- *Ensuring safe, efficient, resilient and reliable energy infrastructure*
- *Delivering solutions for efficient and environmentally responsible use of energy*
- *Reducing and managing carbon emissions*
- *Advancing innovations that protect air, land, water and communities while enhancing economic growth*

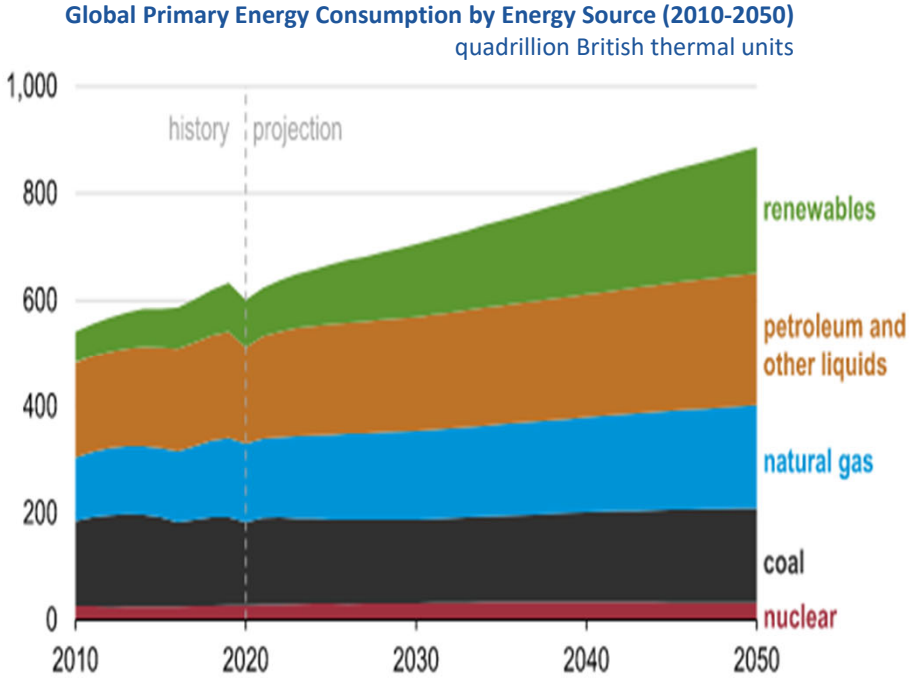
From Concept to Commercialization



Dual Imperatives

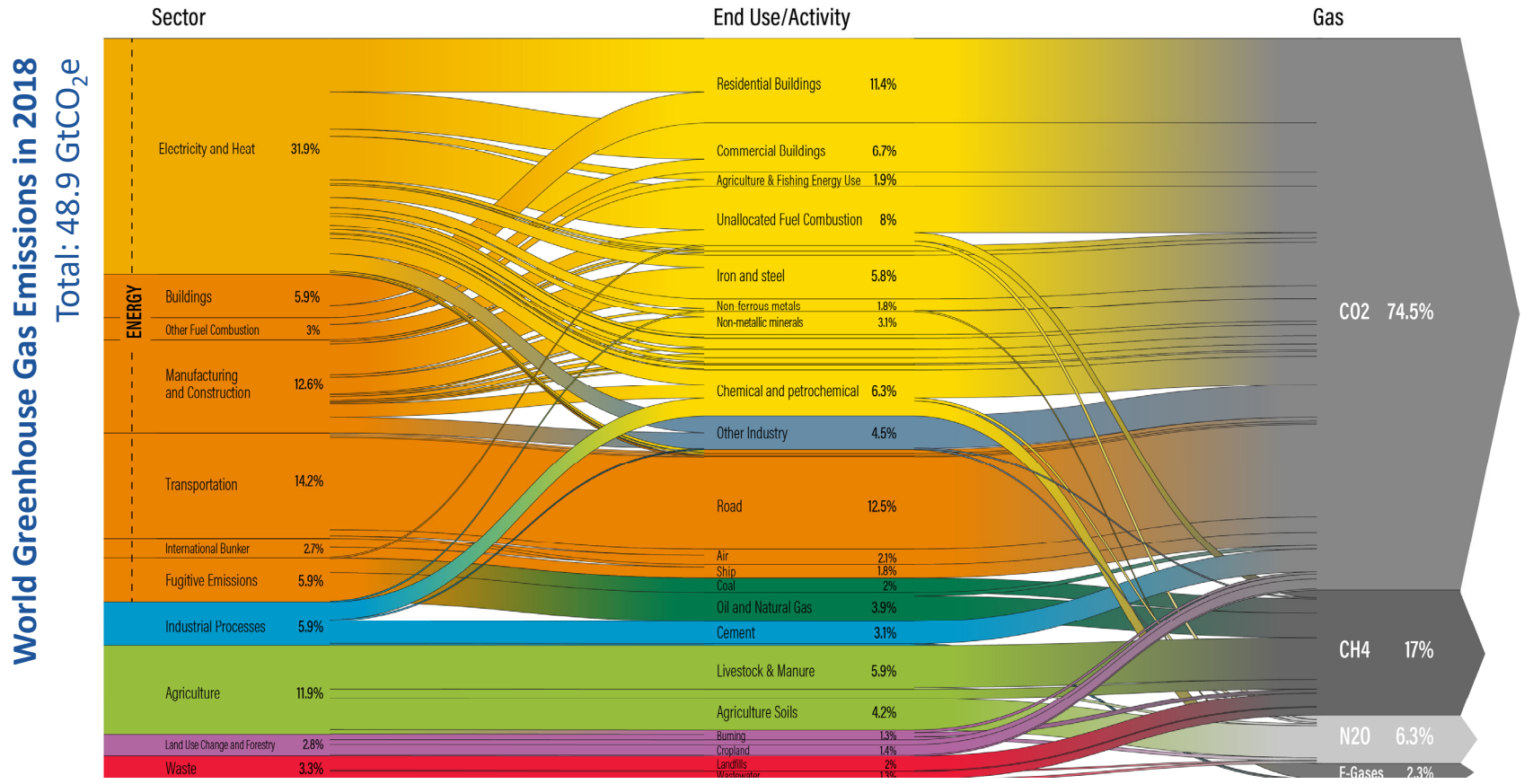
*We must both **decarbonize energy systems** and **supply the energy needed to support economic growth around the world***





Source: International Energy Agency

Electricity and heat sector is largest single source of worldwide CO_2 emissions

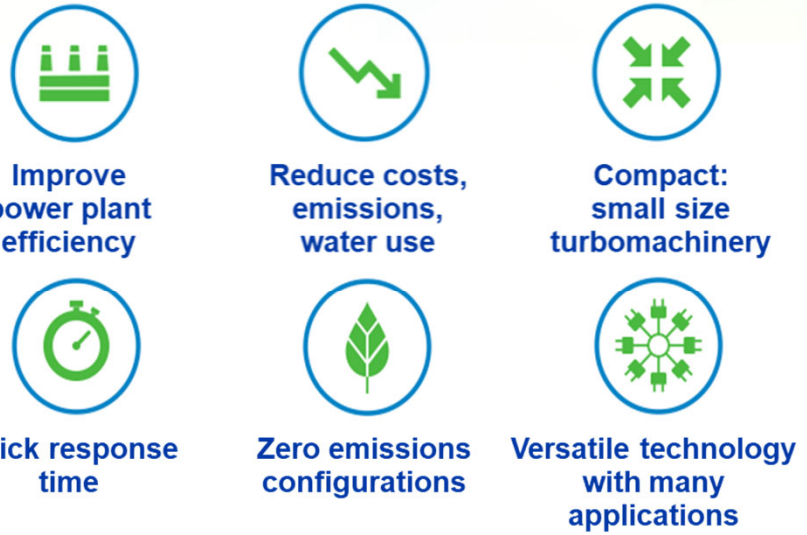


Source: Greenhouse gas emissions on Climate Watch. Available at https://www.climatewatchdata.org

Why are sCO_2 Power Cycles Important?

sCO_2 offers efficient, compact, scalable, low-water, low-carbon power generation

- Smaller “footprint” and lower construction costs
- 2-5% point net plant efficiency improvement
- 3-4% reduction in LCOE (Levelized Cost of Electricity $/kWhr)
- Reduced fuel and water usage
- Quick response time for load-following
- Reduced emissions



Versatile Technology – Broad Applicability


Concentrated Solar


Waste Heat Recovery


Nuclear


Fossil Fuel


Geothermal


Ship-board Propulsion

Supercritical Transformational Electric Power (STEP) Project

Scope: Design, construct, commission, and operate a **10 MWe sCO_2 Pilot Plant Test Facility**

Team: Gas Technology Institute (**GTI**)
Southwest Research Institute (**SwRI**)
GE Research (**GE**)
U.S. Department of Energy (**DOE NETL**)

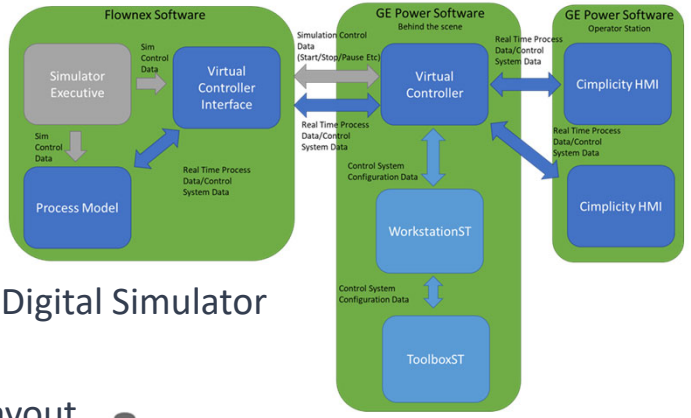
Joint Industrial Partners:

Schedule: Three budget phases over seven years (2016–2023)

Cost: $156MM total / $115MM federal funding

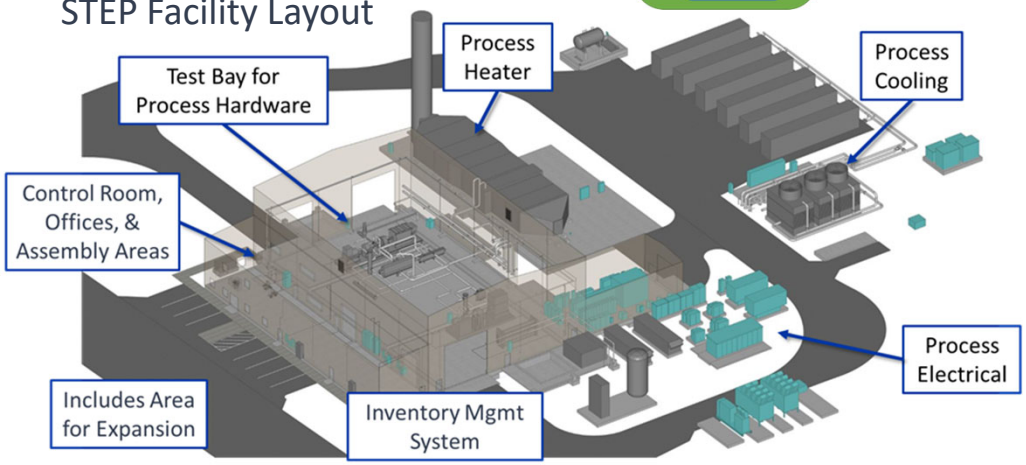
STEP System Objectives

- Advance state of the art for high temperature sCO_2 power cycle performance from TRL 3 to TRL 7
- Demonstrate pathway to efficiency > 50%
- Demonstrate operability at 500°C turbine inlet temperature
- Demonstrate operability >700°C turbine inlet temperature at 10 MWe net power
- Verify system performance and operability
- Facility to be re-configurable to enable new components or technologies



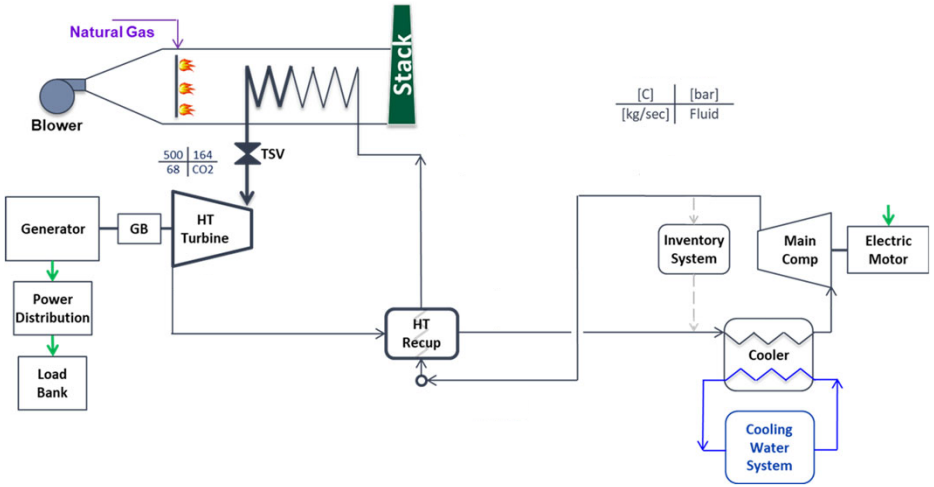
STEP Digital Simulator

STEP Facility Layout



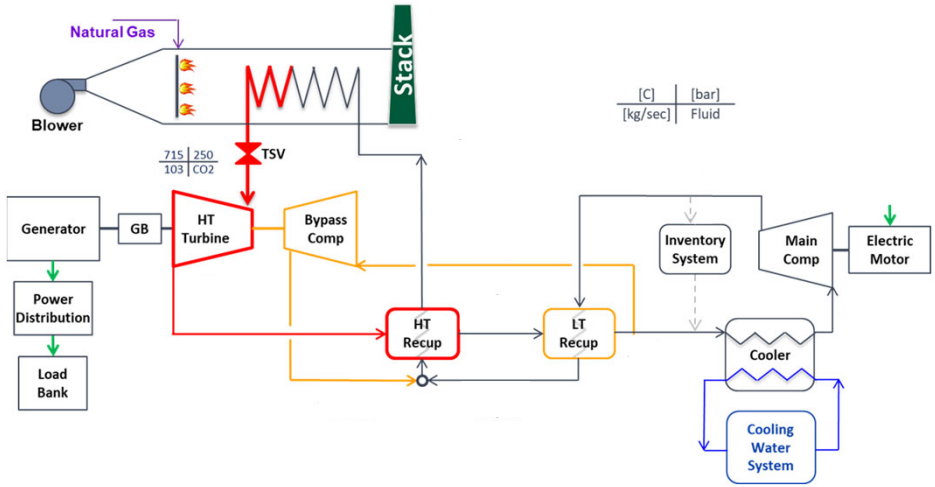
Simple and Recompression Brayton Cycle Testing Planned to Achieve Project Objectives

Simple Recuperated Brayton Cycle



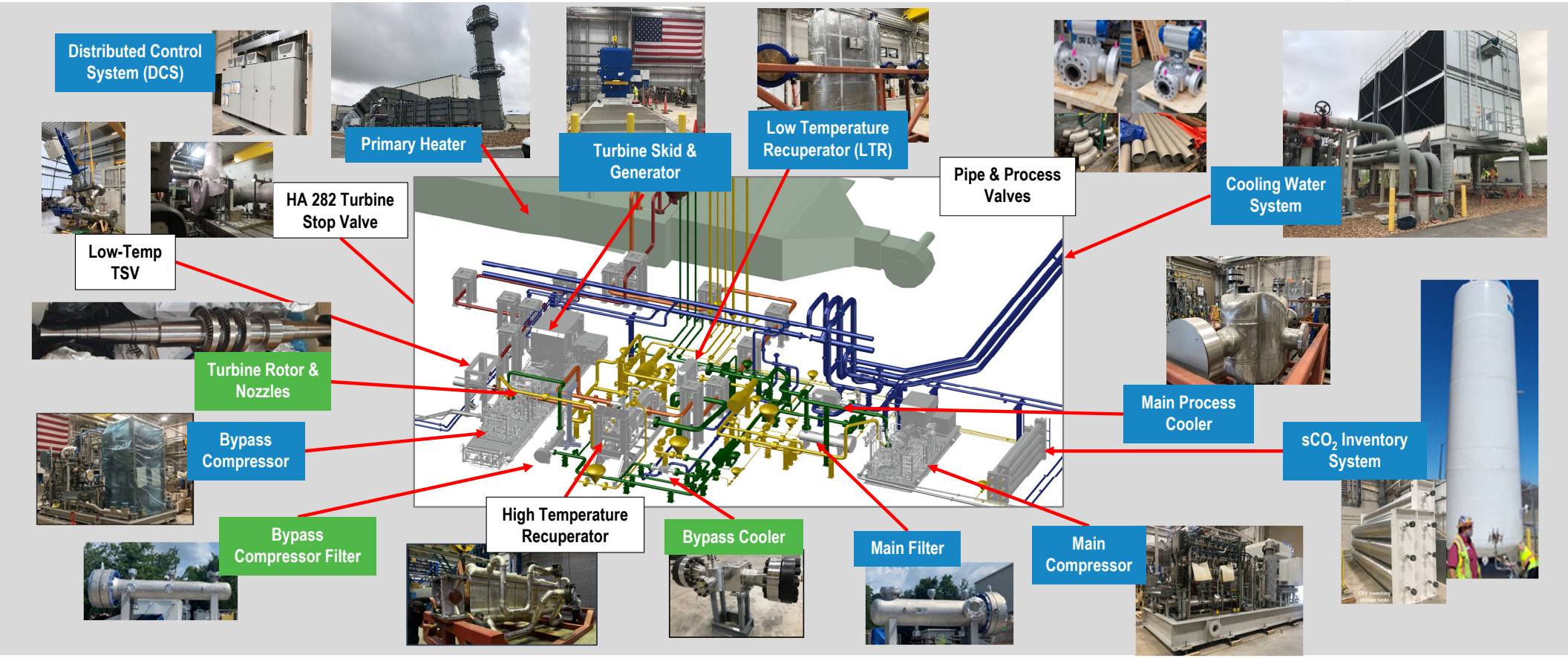
- Demonstrate cycle performance with reduced risk
- Turbine inlet at 500°C (applicable to WHR application)
- Single compressor
- Provides steady & transient cycle data

Recompression Brayton Cycle (RCBC)



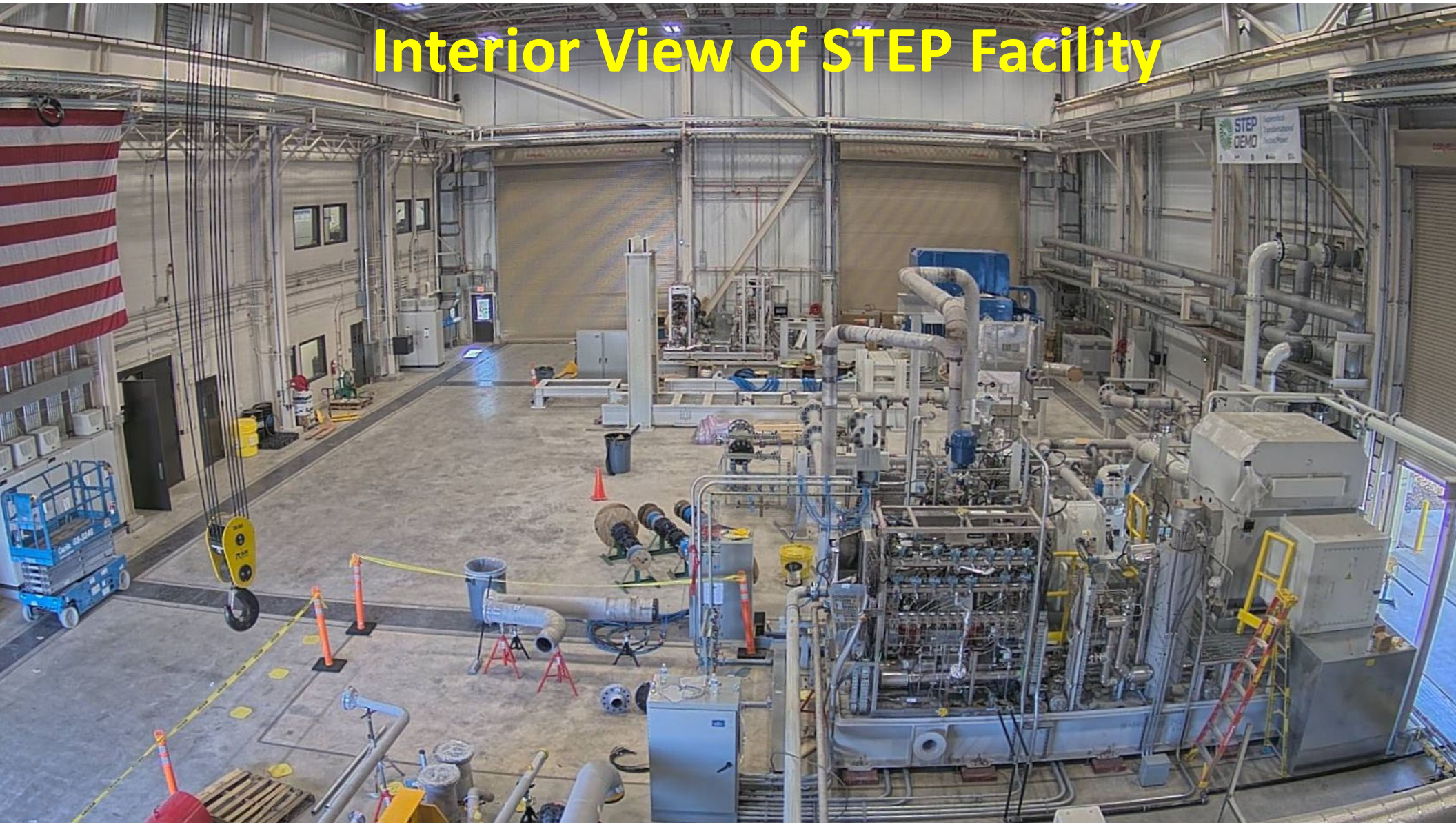
- Demonstrate high performance cycle with parallel compressors and multiple recuperators
- Turbine inlet at 715°C
- Demonstrate pathway to 50% thermal efficiency

Progress Toward Mechanical Completion



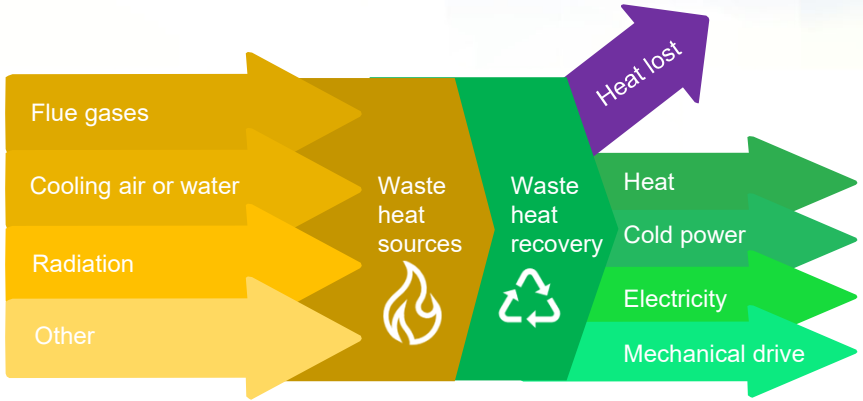
Blue – Received and Set, Green – Received, White – To be delivered

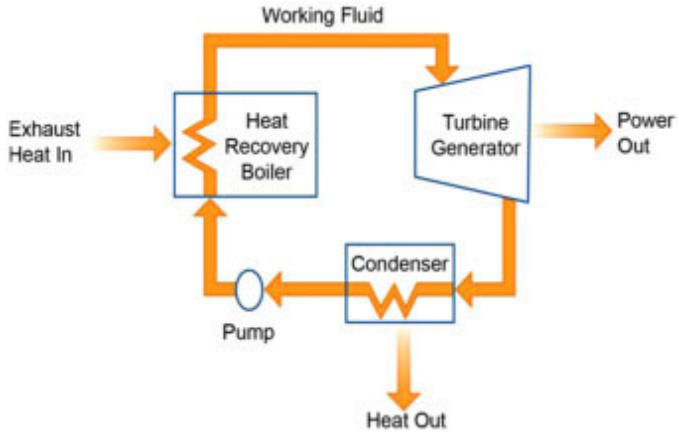
Interior View of STEP Facility



Benefits of sCO_2 to Waste Heat Recovery

- ~4,000 TWh of heat are wasted annually worldwide
  - corresponds to CO_2 emissions of 2.8 billion metric tonnes of CO_2*
- sCO_2 power cycles well suited to WHR applications due to small footprint and high conversion efficiency
- Power produced is **zero emission** (no net new emissions when added to existing industrial or power plant source)

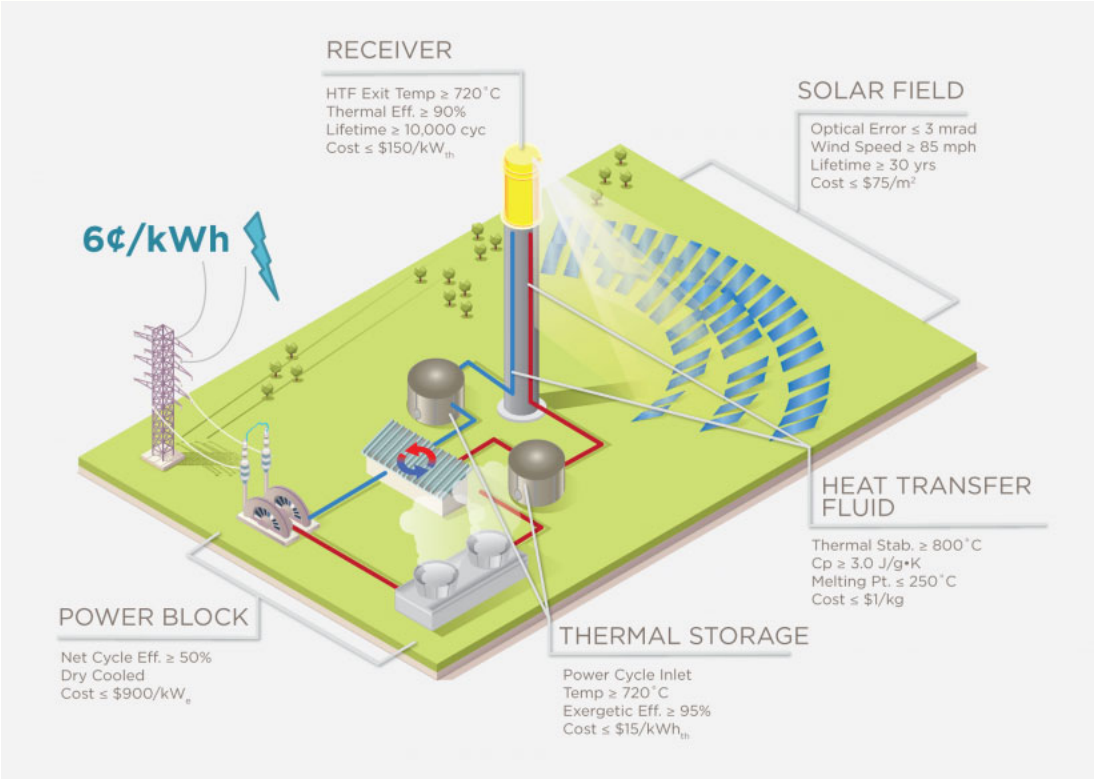




*source: US Department of Energy and ADEME

Benefits of sCO_2 for Concentrating Solar Power

- Increases net plant efficiency from 41% to over 50% vs steam-based, molten-salt tower CSP plants
- Smaller size of sCO_2 turbomachinery allows for rapid startup and shutdown
- Reduced component capital costs due smaller footprint
- Increasing heat transport temp from 550°C to 700°C with sCO_2 reduces LCOE by 41%
- Reducing power block cost is a critical element to achieving 6¢/kWhr DOE goal



Summary

- Stated national emissions policies leave a large gap relative to achieving net zero emission goals
- Deployment of new technologies is critical to close this gap
- The cross-cutting nature of sCO_2 power cycles provides maximum benefit to the entire power generation sector
- sCO_2 power cycles can significantly reduce emissions through greater efficiency, improved economics, utilization of waste heat and enabling of renewables
- The 10MWe STEP project provides the necessary demonstration at scale to help realize the commercialization of sCO_2 power cycles

STEP Team @ the sCO2 Symposium

Tuesday

- John Marion (GTI): Panel Session I – Status of Technology Maturation
- Douglas Heim (GTI): Dynamic Modeling for the 10 MWe sCO_2 Test Facility Program (Track 1 Modeling & Control)
- January Smith (SwRI): Supercritical CO_2 Controls Strategies for a Fixed-Speed Recompression Closed Brayton Cycle (Track 1 Modeling & Control)
- Ganesan Subbaraman (GTI): Panel Session II – Steps to Commercialization
- Jason Mortzheim (GE): Panel Session II – Steps to Commercialization

Wednesday

- John Shingledecker (EPRI): Investigation of Weldment Cracking During Fabrication of a 700°C Fired sCO_2 Heater (Track 1 – Materials)
- Stefan Cich (SWRI): Aeromechanical Design of a 10 MWe sCO_2 Turbine (Track 1 – Turbomachinery)
- Mark Winquist (GTI): Combustor for Direct-Fired Supercritical CO_2 cycle (Track 3 – Oxy combustion)
- Craig Nolan (SwRI): Building a 10 MWe sCO_2 Power Plant: Design Considerations for the DOE STEP Pilot Plant Test Facility (Track 1 – Testing)
- Jonathan Wade (SwRI): Prediction Methods of Settle Out Conditions and Design in sCO2 Power Cycles (Track 1 – Testing)
- January Smith (SwRI): Inventory Management Operational Strategies for a 10 MW sCO_2 Power Block (Track 2 – Modeling and Control)

Th

- **STEP Facility Tour at SwRI (1:30 – 4:30pm)**

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Thank you!

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