forward on sCO$_2$ Power
Supercritical Transformational Electric Power project

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Working With Industry and Governments to Increase Access to Abundant, Affordable, and Acceptable Energy

FOR A BETTER ENVIRONMENT AND A BETTER ECONOMY

SUPPLY ➤ CONVERSION ➤ DELIVERY ➤ UTILIZATION

World-class piloting facilities headquartered in Chicago area
GTI Completed sCO$_2$ Projects

1. Applicability and system performance/benefit studies for large-scale nuclear (LMR), solar (CSP) and fossil applications


3. Costs and technology roadmap for recuperators

4. Advanced turbomachinery for indirect (T<760C) and direct (T>760C) sCO$_2$ power cycles

5. Oxy-fired pressurized fluidized bed combustor reference plant study of performance and LCOE (indirect-fired, un-cooled turbine)
Versatile Technology - Broad Applicability

- Concentrating Solar
- Fossil Fuel
- Geothermal
- Nuclear
- Ship-board Propulsion
- Waste Heat Recovery
Promise of sCO₂ Power Cycles

- Heat-to-power conversion cycles with supercritical CO₂ working fluid promise several advantages
  - Heat source flexibility
  - Higher efficiencies
  - Compact turbo-machinery
  - Economic scalability
  - Lower emissions & water consumption
  - Facilitates and economizes low-carbon power production
Challenges of Advanced sCO₂ Power Cycles

- Technology and process development to confirm advantages
  - Materials: corrosion, creep, fatigue
  - Turbomachinery: life, aero performance, seals
  - Recuperators: design, size, fabrication, durability
  - Cycle operability: startup, transients, load following
Supercritical Transformational Electric Power (STEP) Program

**Scope:** Design, construct, commission, and operate a 10 MWe sCO₂ Pilot Plant Test Facility

**Goal:** Advance state of the art for high temperature sCO₂ power cycle performance from Proof of Concept (TRL3) to System Prototype validated in an operational system (TRL7)

**Team:** Gas Technology Institute (GTI)
Southwest Research Institute® (SwRI®)
General Electric Global Research (GE-GR)

**Schedule:** Three budget phases over six years (2016-2022)

**Cost:** $113MM Total / $80MM Federal Funding

Building a flexible platform for long-term use to validate component performance, quantify cycle efficiency, and study plant operability in an integrated, grid-connected system.
STEP Program Objectives

Demonstrate pathway to RCBC cycle efficiency > 50%

Demonstrate cycle operability up to 700°C turbine inlet temperature and 10 MWe net power generation

Quantify performance benefits:
- 2-5% point net plant efficiency improvement
- 3-4% reduction in LCOE
- Reduced emissions, fuel, and water usage

Reconfigurable facility to accommodate future testing

Pilot Site: SwRI in San Antonio, TX
STEP Project Plan

Budget Period 1
ends Oct 2018
Detailed Facility and Equipment Design
25 months
• System analysis, P&IDs, Component Specs
• Design major equipment
• Procure heat source, cooling tower & long-lead items
• Materials & seal tests
• Start site construction

Budget Period 2
ends January 2021
Fabrication and Construction
27 months
• Complete site construction and civil works
• Fabrication & installation of major equipment
• Commissioning and simple-cycle test

Budget Period 3
ends September 2022
Facility Operation and Testing
20 months
• Facility reconfiguration
• Test recompression cycle
Transitioning from Component and Cycle Design to Integrated System Demonstration
Flexible Test Facility Designed with Alternate Indirect Cycle Configurations

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

**Recompression Cycle**
- Inventory management
- Starting transients
- Parallel compressor control
- SOA component efficiencies
- Cycle efficiency > 50%
STEP Current Status: Turbine

> Turbine improvements over SunShot
  - Increased casing and rotor life, 100,000 hrs vs 20,000 hrs
  - Increase bolt retightening schedule to 30,000 hr vs 1,000 hrs
  - Design for couplings on both shaft ends
  - Improved aero performance with increased volute flow area

> Current design activities
  - Torsional train dynamics
  - Rotor flowpath preliminary design
  - Flowpath mechanical and aeromechanical integrity
STEP Current Status: Recuperators

- Evaluating replies to RFQ from several suppliers
- Alternate compact technologies
  - heat transfer surface vs. volume
- STEP is a significant scale-up
- Evaluating performance vs. cost and plant integration
STEP Current Status: Other Major Components

> Finalizing selections

Compressor  Cooling Tower  Process Heater
STEP Current Status:
Facility and Site

- General arrangement defined
- EA ready for public review
- Building design being finalized
- Major BOP hardware specifications in progress
- Ground breaking in 2018
Summary

- sCO$_2$ power cycles promise substantial cost and emissions benefits
- Applicable to coal, natural gas, solar, geothermal, nuclear, waste heat
- STEP 10MW$_e$ program well underway – groundbreaking at SwRI site this year
- Strong team in place and executing smoothly
- Additional partners welcome
sCO₂ Step-by-Step Commercialization

**Phase I** 2015 - 2016

- System Definition and Materials Compatibility (TRL 2-3)
  - Perform trades
  - Define reference system
  - Select/validate materials suitable for use in sCO₂

**Phase II** 2016 – 2022

- Component Tests and Small Pilot Plant (TRL 7)
  - Demonstrates:
    - Compressor performance
    - Seal operation
    - Component Life
    - System Operation and Control

**Phase III** 2022 – 2027

- Large Pilot / Demo Plant (TRL 7-8)
  - Demonstrates:
    - Operation at scale
    - Component life
    - Operating parameters
    - Maintenance approaches

**Phase IV** 2025 – 2030

- Commercial Demonstration 5+ years (TRL 9)
  - Validates:
    - Heat source integration
    - System efficiency
    - Capital costs
    - O&M costs

10 - 20MWe

50-100MWe

275+ MWe

**Early product off-ramp for 10-20 MWe distributed power generation systems**
Turning Raw Technology into Practical Solutions

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