Supercritical Transformational Electrical Production (STEP) R&D: sCO2 Advanced Energy Conversion

Program Overview

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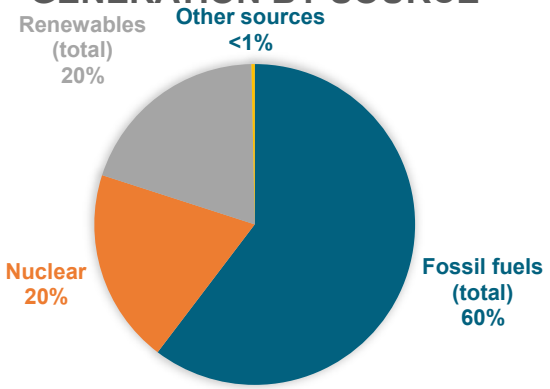
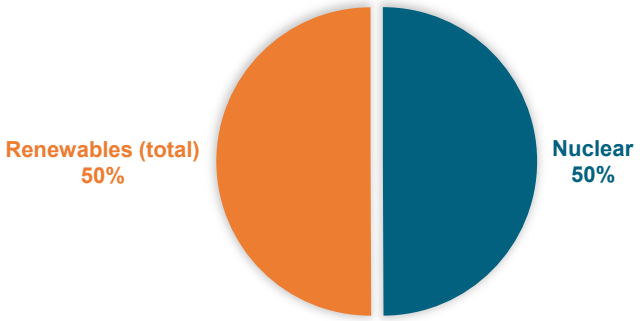
Nuclear generation today

2020 U.S. UTILITY-SCALE ELECTRICITY GENERATION BY SOURCE



2020 U.S. UTILITY-SCALE NON-EMITTING ELECTRICITY GENERATION BY SOURCE



2020	Billion kWh
Nuclear	790
Renewables (total)	792

Data from EIA – U.S. Electricity generation by energy source

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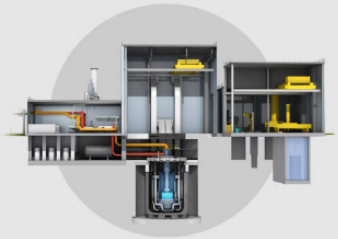
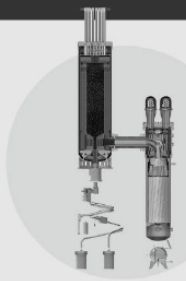
Innovation in Nuclear
Advanced Reactor Demonstration Program (ARDP)

DEMONSTRATION

GOAL: *Test, license and build operational reactors within 5 - 7 years.*



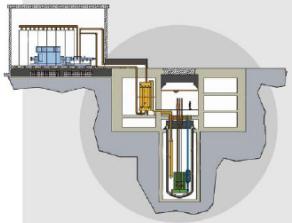
Natrium Reactor
Sodium-cooled fast reactor + molten salt energy storage system
TERRAPOWER



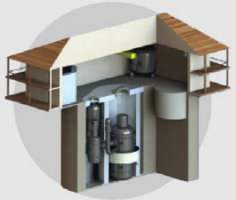
Xe-100
High-temperature gas reactor
X-ENERGY

CONCEPT DEVELOPMENT

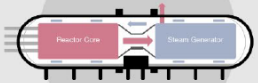
GOAL: *Solidify concept to mature technology for potential demonstration by mid-2030s.*



Advanced Sodium-Cooled Reactor Facility
ADVANCED REACTOR CONCEPTS



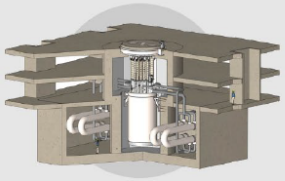
Fast Modular Reactor
GENERAL ATOMICS



Horizontal Compact High-Temperature Gas Reactor
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

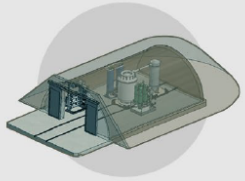
RISK REDUCTION

GOAL: *Solve technical, operational and regulatory challenges to support demonstration within 10 - 14 years.*



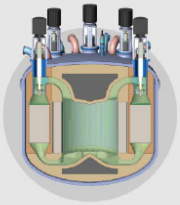
KP-FHR
Fluoride salt-cooled high-temperature reactor
KAIROS POWER

eVinci
Heat pipe-cooled microreactor
WESTINGHOUSE NUCLEAR



BWXT Advanced Nuclear Reactor (BANR)
High-temperature gas-cooled microreactor
BWX TECHNOLOGIES

SMR-160
Advanced light-water small modular reactor
HOLTEC INTERNATIONAL



Molten Chloride Fast Reactor
SOUTHERN COMPANY

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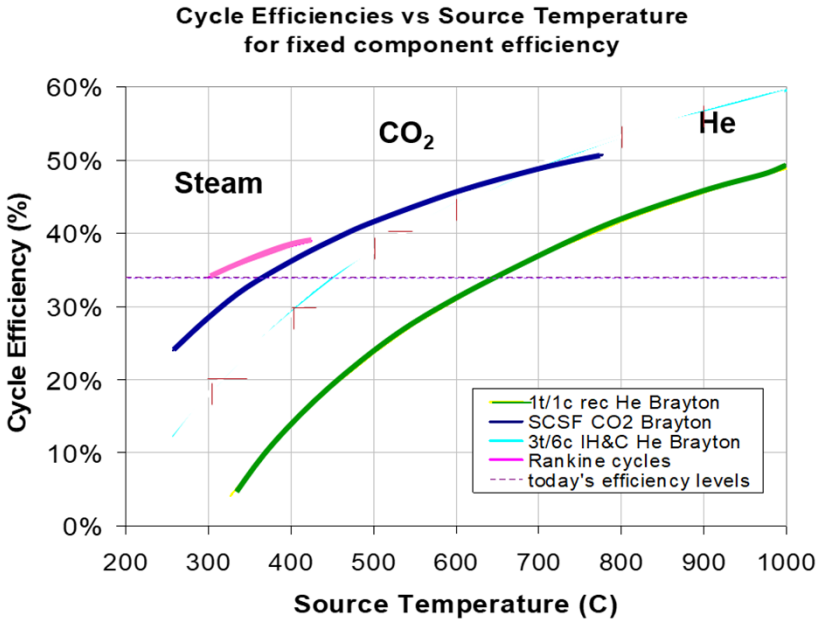
History of NE support

- **ARC-20 awards**
  - General Atomics
  - ARC LLC.
- **NEUPs**
  - UW
- **SBIRS**
  - Advanced supercritical CO2 bearings
  - Advanced supercritical CO2 seals
  - Advanced supercritical CO2 heat exchangers

Advanced Energy Conversion and the sCO2 Brayton Cycle

Benefits of s-CO2 energy conversion technology over competing cycles:

- Smaller size relative to steam system (reduced capital cost)
- Increased efficiency (resulting in increased electricity production for same thermal input)
- Environmental improvement from greenhouse gas reduction
- Vastly reduces water consumption
- Dry cooling/suitable for arid environments



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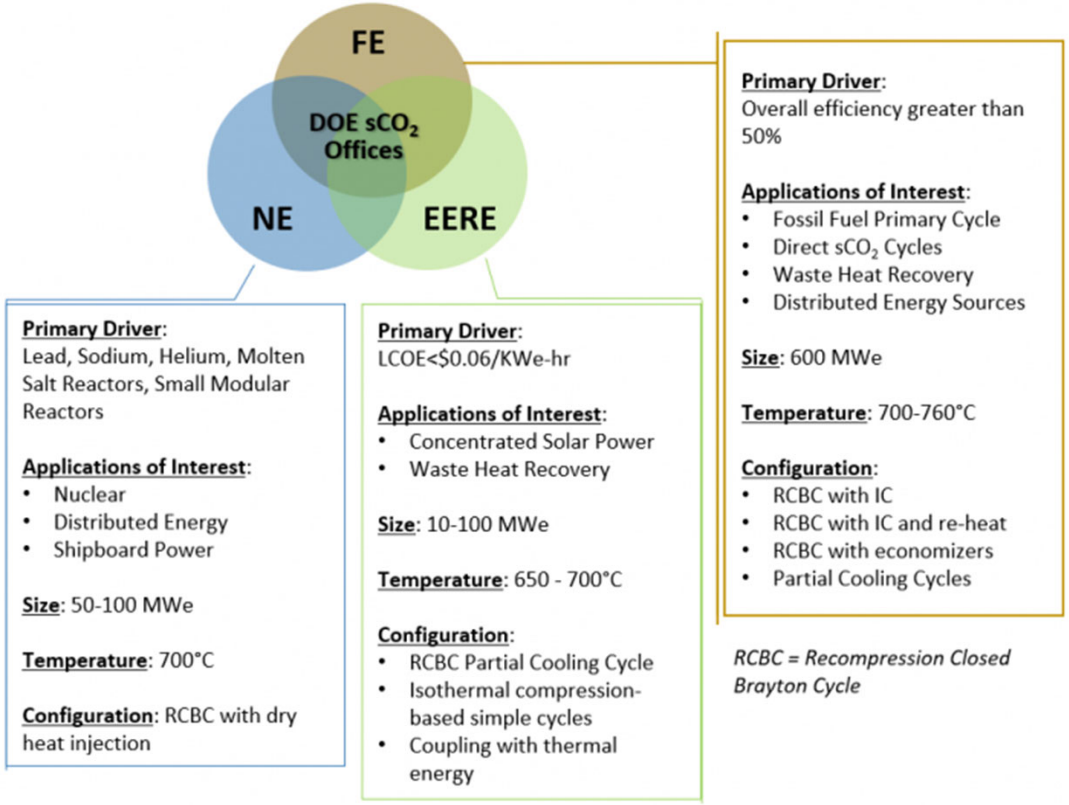
DOE STEP Collaboration Offices and Targets



- The first likely commercial application of sCO2 Brayton cycles will not be nuclear.
- Supporting the development of other applications through collaboration with partners is critical to expedite technology development
- Commercial viability requires a demonstration of performance, operability, reliability, and cost

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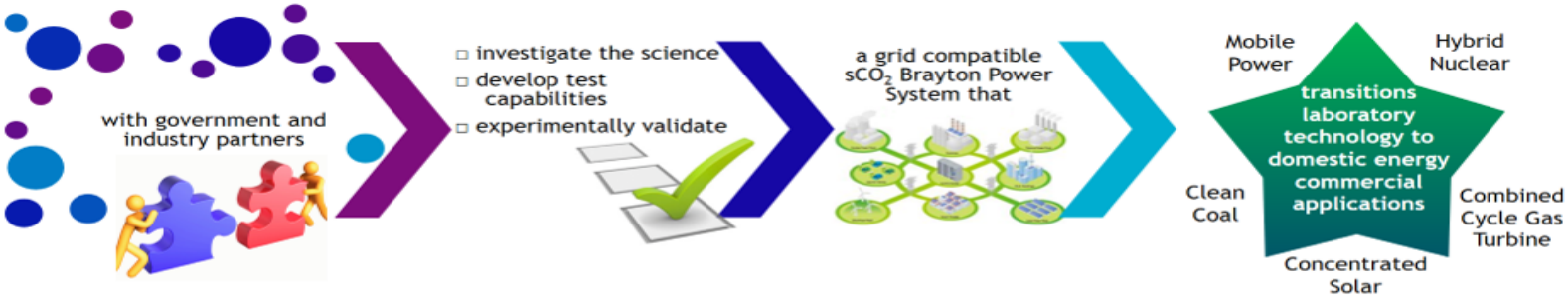
STEP R&D Mission

- Sandia National Laboratories, in collaboration with government and industry partners, shall investigate the science, develop the test capabilities, and experimentally validate a grid compatible sCO2 Brayton Power System that transitions laboratory technologies to domestic energy commercial applications.



1. To support coordination and collaboration across labs and with industry
2. To lead R&D that ensures systematic identification and retirement of risks to ensure component readiness
3. To lead R&D that is inclusive of elements that increase the reliability and resiliency of electric power systems
4. To establish the foundations for successful commercialization of the technology

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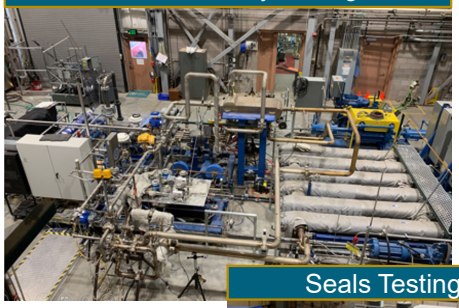
STEP R&D Capabilities

Turbomachinery Development Platform	A reconfigurable testing rig featuring 780 kW of heating power, 560 kW of heat rejection capacity, recuperators, and extensive state of the art data acquisition (DAQ) and controls. The system is rated for 538 °C (1000 °F) and 13.8 MPa (2000 psi) operation
Seals Test Rig	The seals test rig has the capability to test seals ranging from 1” to 8” in diameter at 700 °C (1292 °F) and 27.6 MPa (4000 psi)
Bearings Test Rig	The bearings test rig has the capability to test up to 121°C (250 °F) and 11 MPa (1600 psi) to test a variety of bearing types
High Pressure Fatigue / Hydrostatic Test Platform	75 ksi hydrostatic and fatigue test facility to measure the mechanical performance of compact heat exchangers and other equipment
sCO_2 Visualization Loop	Optical test platform to measure flow and density distributions of sCO_2, including Particle Image Velocimetry (PIV)

Turbomachinery Testing



Seals Testing

Bearings Testing

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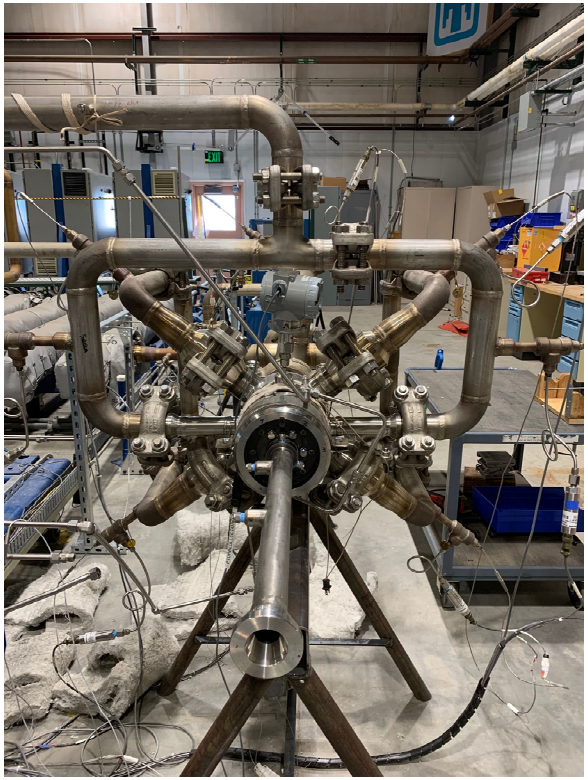
sCO2 Brayton Cycle Development (1-10 Mwe)



- Testing of turbocompressor for 1MWe system:
- Over 450 operating hours achieved
- Demonstration of off-design performance
- Bearing issues currently being resolved

- New motor controllers to reject power on the grid using 250 kWe turbine alternator compressors
- “off the shelf” component

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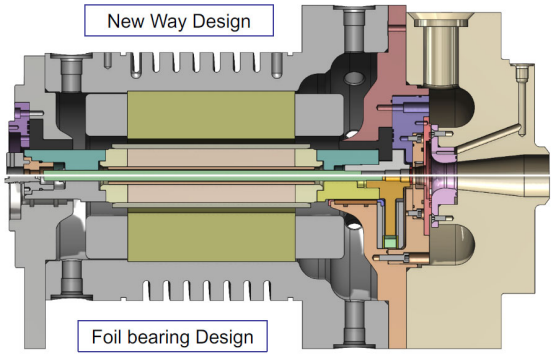
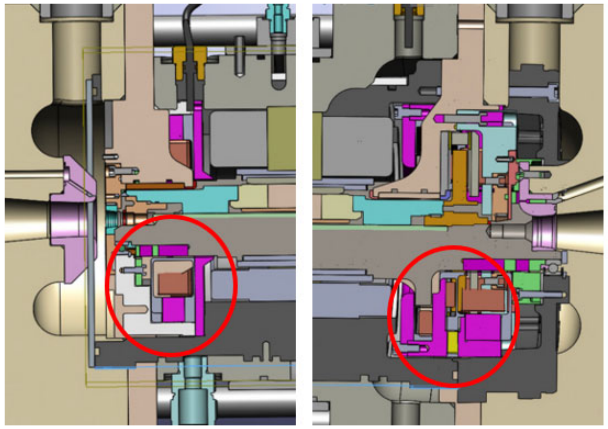
sCO2 Brayton Cycle Development (>10 Mwe)

Supercritical CO2 seals test rig
4,000 psi @700C 40,000 rpm
- Shaft size of 10MWe system

Bearing development
- Being tested at kW scale
- Could scale in the future



Re-design of TAC's to use porous media bearings



Re-design of TAC's to use magnetic bearings

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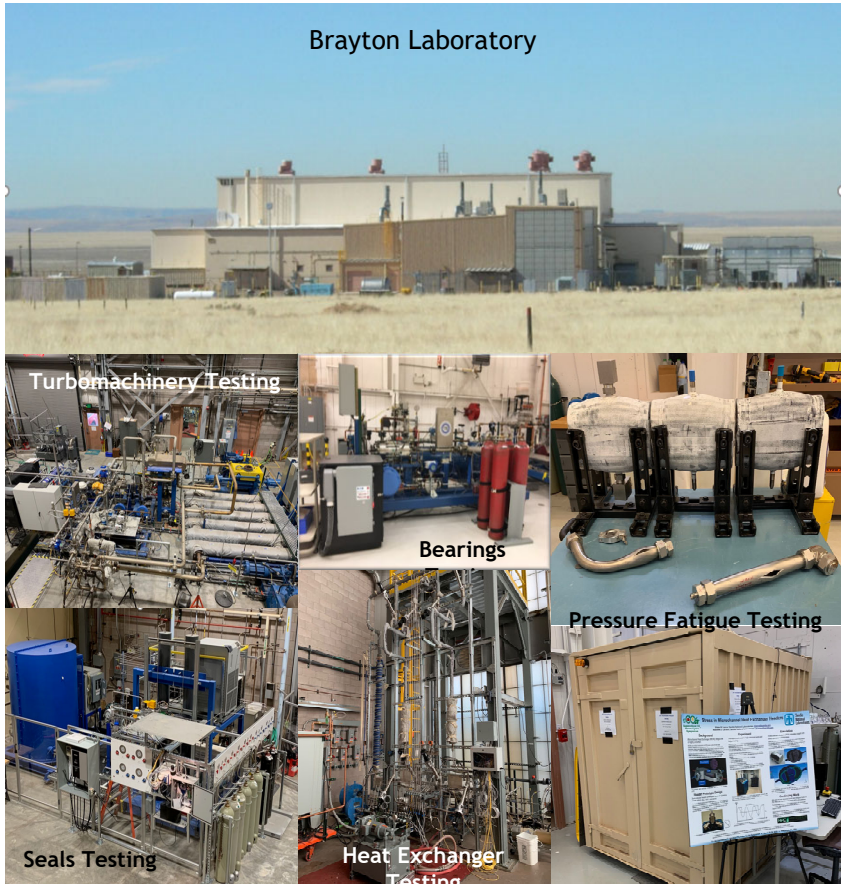
Key Accomplishments in Testing and Commercialization

- **Testing of Turbomachinery, Bearings, Seals, Heat Exchangers, and Pressure Fatigue**



Turbocompressor Development:

- Demonstration of blowdown start method: 15 starts performed
- Rotor thrust balance achieved: thrust balance was achieved through valve control strategies
- Limits of SNL loop achieved: Maximum of 1000F @ 2000 psi achieved
- 67.5 hours achieved on unit, 51 hours at limits of loop

Bearings Test Rig:

- Bearings test capability in sCO2 of 40,000 rpm, 1250 psi, and 250°F
- Pressure transducers, RTDs, and thermocouples measure bearing conditions inside motor casing
- Integrated CO2 inventory for flows up to (process conditions)

PEREGRINE TURBINE TECHNOLOGIES

- SNL purchased the first of a kind sCO2 turbo-compressor from PTT in 2017
  - Motorless – only known turbo-compressor to be started with a "blowdown method"
- SNL turbomachinery development platform was reconfigured to test turbo-compressor
  - 1 MW electric heating
  - ~500 kW water cooling
  - Data Acquisition and Control System
- 465 hours of operation over >70 tests.

FLOWSERVE

SNL and Flowserve CRADA to validate high temperature Dry Gas Liftoff seals.

Capabilities:

- Rated Pressure: 4595 psi
- Rated Temp.: 1292°F
- Max. Speed: 40,000 rpm

VPE

CRADA with Vacuum Process resulted in:

- Manufacturing of PCHE now in U.S., believe resulted in international PCHE vendor price drop
- Versatile SNL test platform design validated for evaluating HX performance characteristics
- Advanced U.S. manufactured compact heat exchanger design & manufacturing
- Positioned to advance industry development of critical sCO2 Brayton power cycle components

Capabilities:

- Performance test pressure drop, efficiency, failure modes
- Accommodates 1 in3 to 2 ft3 HXs
- 5-120 gpm flow range
- 100 kWth heating/cooling
- Pressure Fatigue testing (atm. - 27,000 psi)

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Questions

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