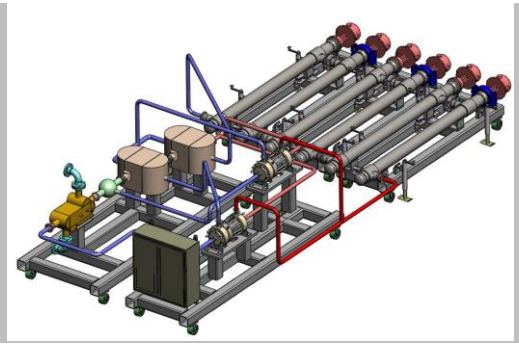
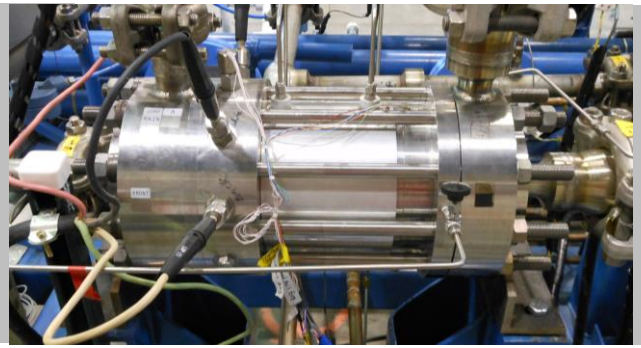
Exceptional service in the national interest

Sandia National Laboratories





Closed Brayton Cycle Research Progress and Plans at Sandia National Labs

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Nuclear Energy Systems Laboratory/Brayton Lab (ne.sandia.gov/nesl)

U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Overview

Sandia National Laboratories

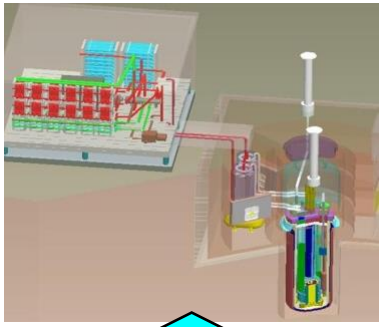
- Why am I here
- Description of facilities and services at the Sandia Nuclear Energy Systems Laboratory (NESL) / Brayton Lab.
- Long term DOE-NE vision
- DOE cross-cut initiative
- How Huntsville fits in – “the perfect storm”

Why Am I Here?

- In 2012, Sandian Yasmin Dennig and Qualis' Roger Herdy recognized a synergistic opportunity.
  - Huntsville is unique in it's approach to energy production progress.
  - Sandia is the world leader in R&D of a revolutionary new power generation technology.
- Sandia needs a community to place and operate the first demonstration plant.
- Huntsville will be on the cutting edge of this technology.
- We need to get to know each other.

Advanced Energy Conversion

Sandia National Laboratories



Nuclear

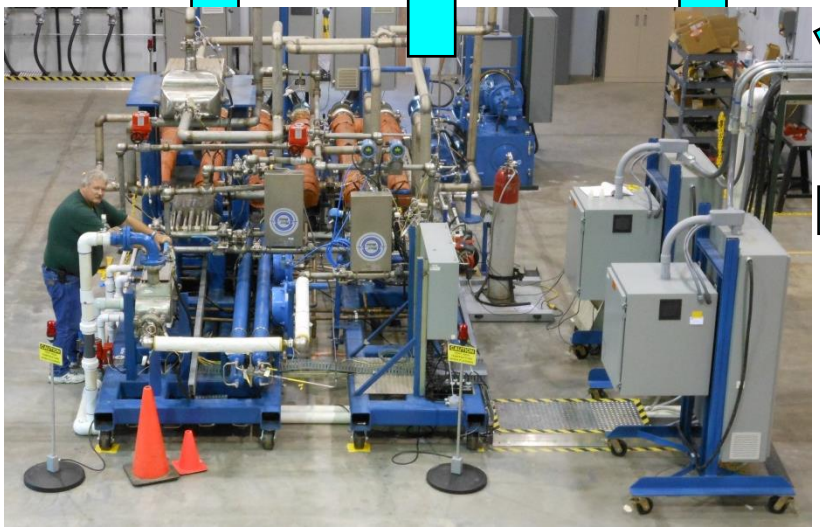
- **Using Supercritical Fluids**
- **Higher Conversion Efficiency**
- **1/10 of the Cost**
- **1/100 of the Plant Volume**

Fossil

Concentrated Solar

Geothermal

Turbomachinery



Industrial Heat

The DOE-NE RCBC Test Assembly at Sandia NESL / Brayton Lab

Sandia National Laboratories

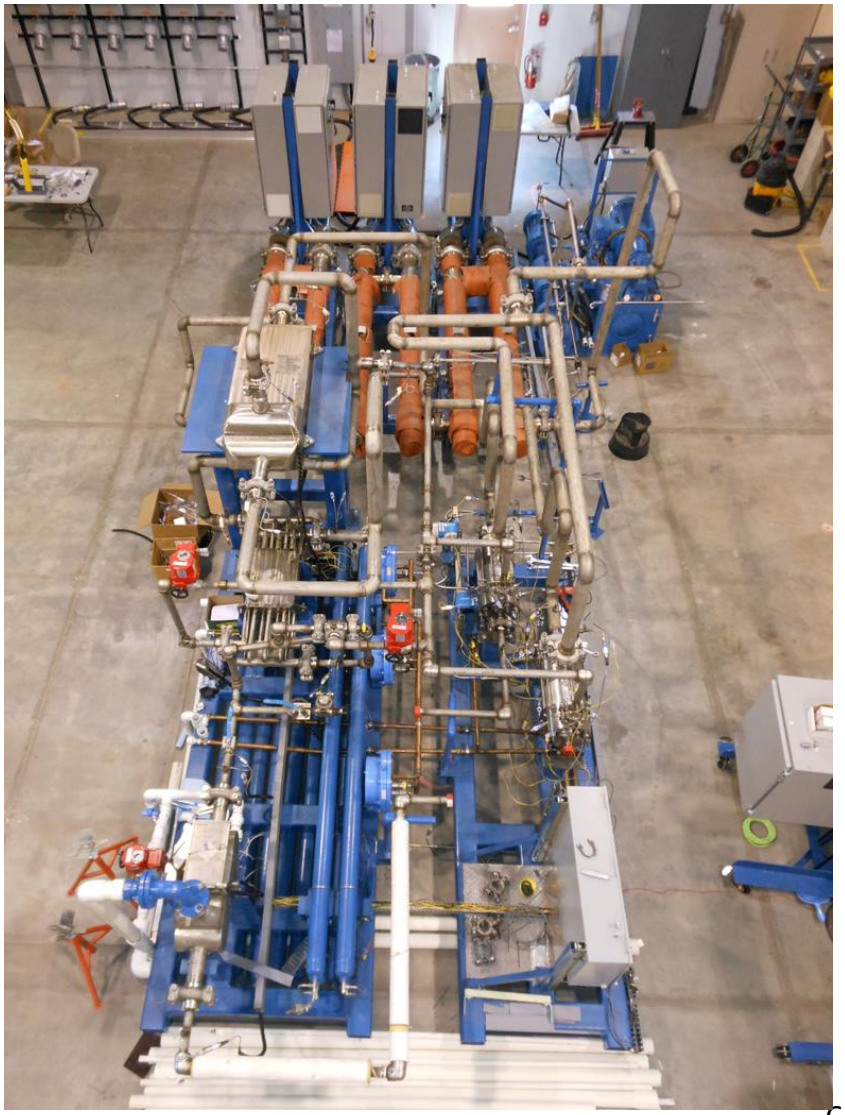
- Primary focus for the Sandia Brayton program is developing and commercializing an RCBC for a sodium fast reactor operating at 550°C by 2020
- This path will not be direct because of DOE-NE budget limitations.
- Therefore, get creative in how we get there
  - Work related projects that advance the technology.
  - Advocate for collaborative efforts within government and industry
- NESL / Brayton Lab is Sandia's approach to get there

- NESL / Brayton Lab offers
  - Contracts development (CRADA, WFO)
  - Project development and test definition support
  - Test architecture design and development
  - Purchasing and subcontracting
  - Test execution support with experienced engineers and technologists
  - Data acquisition, analysis, and delivery

The DOE-NE RCBC Test Assembly at Sandia NESL / Brayton Lab

Sandia National Laboratories

- 2 Turbo-Alternator-Compressors (TACs) rated for operation at 75,000 rpm and 125 kWe net power generation
- 6 shell-in-tube heaters rated at 130 kW each (780 kW total)
- 2 Printed Circuit Heat Exchanger (PCHE) rated at nominally 2.3 MW and 1.7 MW duty.
- Gas cooler PCHE rated at 0.6 MW duty.
- All components have flanges, making the testing architecture highly versatile
- 0.75 MWe load bank
- Well-developed controller interface and data acquisition system (5 Hz).
- 13.8 MPa, 538°C, 5.7 kg/s

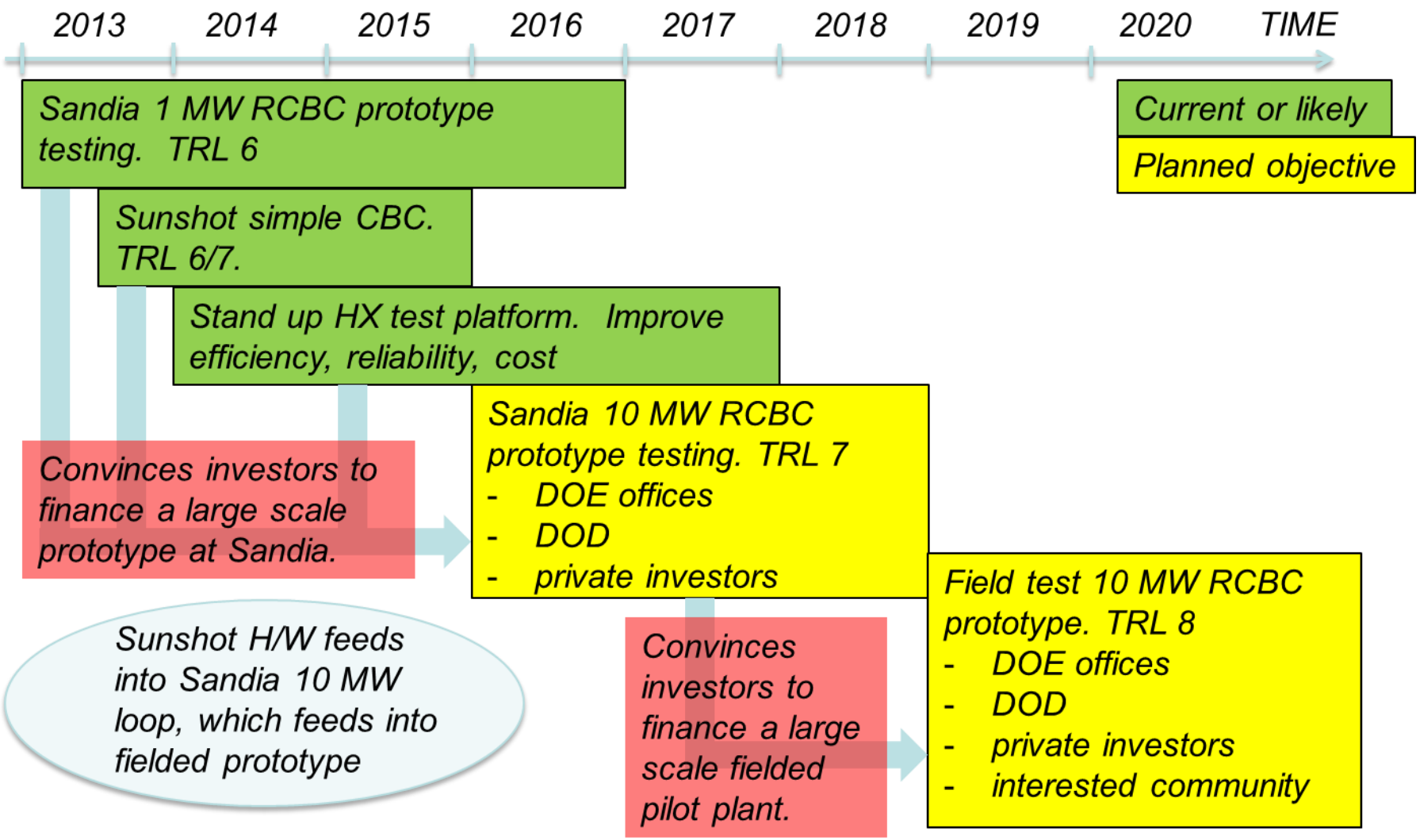


DOE-NE 2020 10 MWe RCBC Vision

Sandia National Laboratories

- Develop and commercialize an RCBC by 2020
- Address all perceived risks and concerns of investors.
- Promote and operate intermediate projects that lead to the 2020 vision.
- Design and test a nominal 10-15 MWe RCBC that industry agrees scales to 300 MWe. Advance TRL to 7
- Take TA to the field to implement a Pilot Facility and advance to a turn-key operation (TRL 8)
  - Convert a current steam facility or newly dedicated heat source
  - Mostly utility operation
  - Technology Transfer

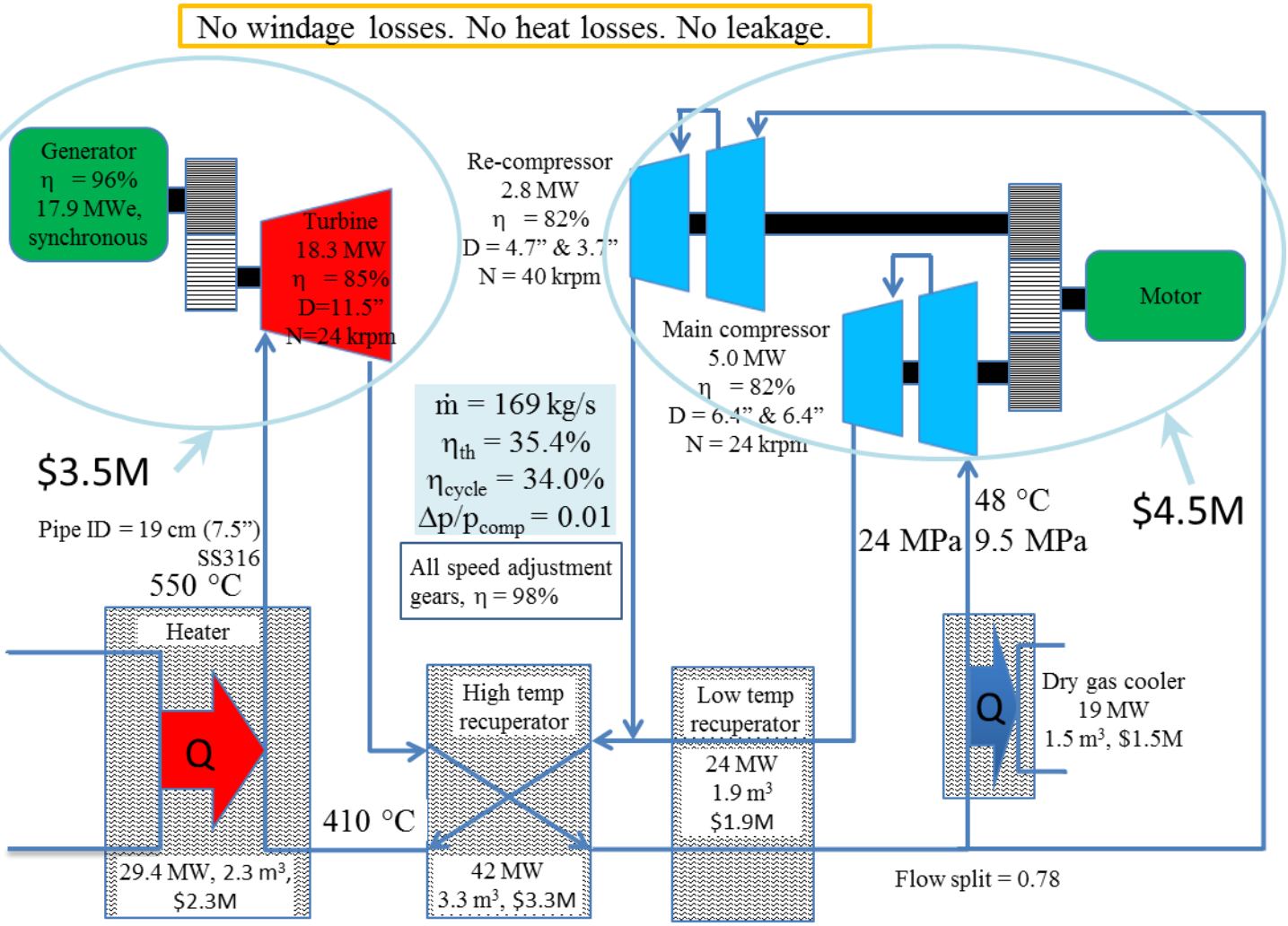
RCBC Development Plan



2020 10 MWe RCBC for Nuclear Reactor

Sandia National Laboratories

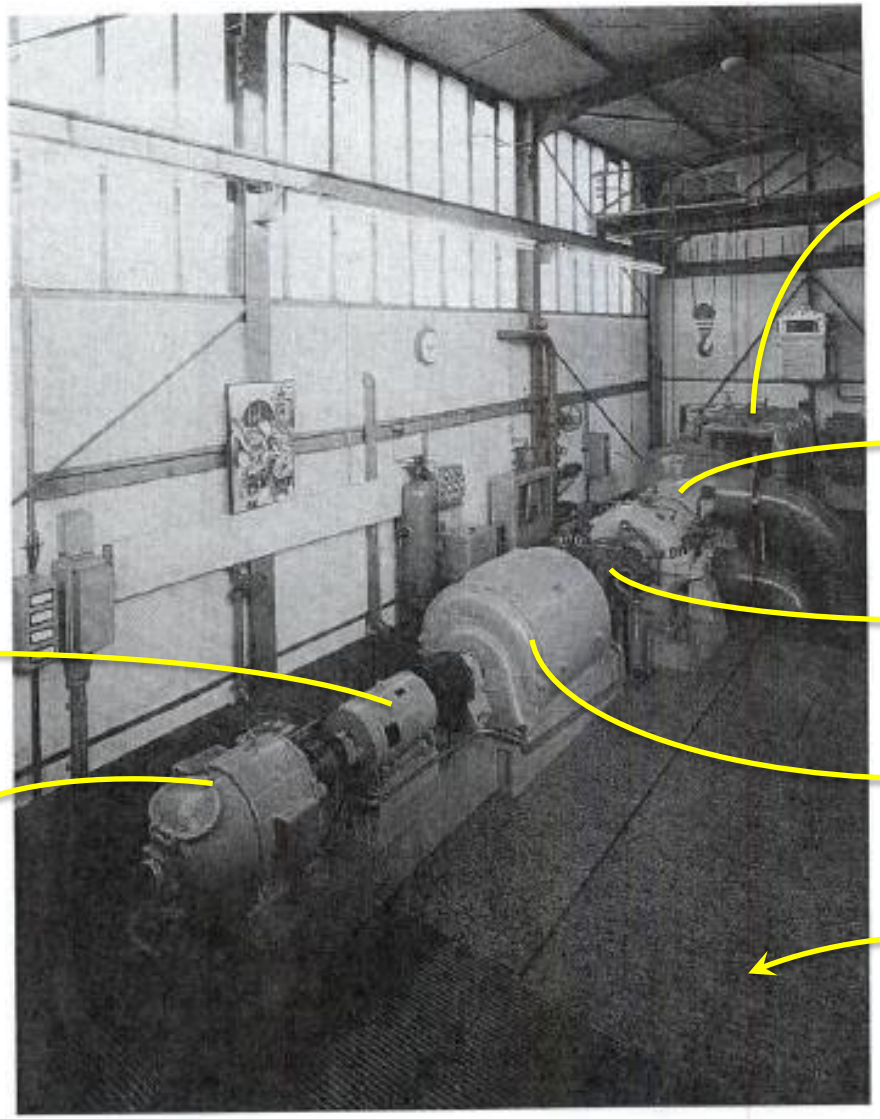
Best current estimate of a 10 MWe Net SCO2 RCBC configuration and cost for the DOE-NE sodium fast reactor operating with dry cooling at 550°C.



Ravensburg Plant – Turbo Set

Sandia National Laboratories

Total mechanical losses = 260 kW, giving a mechanical efficiency of 89.9%



Pre cooler

Turbomachinery
$\eta_{turb,ad}$ = 88%
$\eta_{comp,ad}$ = 78%

Planetary gear

Exciter

Generator
η = 96.5%

Starting motor

Intercooler and recuperator below this level

DOE Offices Cross-cut Initiative

Sandia National Laboratories

Note that the excerpts from the SCO2 Power Cycle Initiative Proposal are in DRAFT form and pre-decisional

- "As a strategic cross-cutting overtarget request, the Solar Energy Technologies Office,… Office of Nuclear Energy (NE), Office of Fossil Energy (FE), and ARPA-E, … are proposing a $110M collaborative initiative starting in FY2015 to develop the [closed Brayton cycle using SCO2] for diverse applications of relevance to the Department of Energy (DOE)."
- "… the SCO2 cycle is of great interest to several power generation industries and has strong potential for revolutionizing the future of power generation"
- This initiative is unprecedented!

X-cut Applications of Interest

Sandia National Laboratories

Note that the excerpts from the SCO2 Power Cycle Initiative Proposal are in DRAFT form and pre-decisional

Application	Organization	Motivation	Size [MWe]	Temperature [C]	Pressure [MPa]
Nuclear	DOE-NE	Efficiency, Size, Water Reduction	10 – 300	350 – 700	20 – 35
Fossil Fuel (Indirect heating)	DOE-FE, DOE-NETL	Efficiency, Water Reduction	300 – 600	550 – 900	15 – 35
Fossil Fuel (Direct heating)	DOE-FE, DOE-NETL	Efficiency, Water Reduction, Facilitates CO2 Capture	300 – 600	1100 – 1500	35
Concentrating Solar Power	DOE-EE, DOE-NREL	Efficiency, Size, Water Reduction	10 – 100	500 – 1000	35
Shipboard Propulsion	DOE-NNSA	Efficiency, Size	10 – 100	500 – 1000	35
Shipboard House Power	ONR	Efficiency, Size	< 1 – 10	230 – 650	15 – 35
Waste Heat Recovery	DOE-EERE, ONR	Efficiency, Size, Simple Cycles	1 – 10	< 230 – 650	15 – 35
Geothermal	DOE-EERE	Efficiency	1 – 50	100 – 300	15

X-cut Proposed Activities

Sandia National Laboratories

Note that the excerpts from the SCO2 Power Cycle Initiative Proposal are in DRAFT form and pre-decisional

Category	Baseline Funding	Partial Funding	Full Funding
Overtarget Funds	$0	$70M	$110M
Cycle Size	< 10 MWe	10 MWe	50 MWe
Facility Type	Test loop	Test loop	Pilot demonstration
Cycle Type	Simple	RCBC	RCBC
Cycle Efficiency	35%-40%	≥50%	≥50%
TRL	6 (beta prototype)	7 (integrated prototype)	8 (pre-commercial)
Turbomachinery[1]	Prototype	Directly scalable	Potentially full scale
Components[2]	Prototype	Commercial	Commercial
Application-specific HX	No	No	Yes
Materials Characterization	Limited	Qualified for 700C/35 MPa	Qualified for 700C/35 MPa
Control Strategies	Partially validated	Fully validated	Fully validated
Grid-tied?	No	No	Yes
Commercial Risk	High	Medium	Low
Cross-office Collaboration	Informal	Joint FOA	Joint FOA

Summary

- The Sandia NESL / Brayton Lab has been established to achieve the DOE-NE objective of a 10 MWe RCBC for a sodium fast reactor by 2020.
  - Work related projects that advance the technology.
  - Advocate for collaborative efforts within government, industry, and communities.
- The Sandia NESL / Brayton Lab is well positioned to advance the TRL of the various CBC components and procedures.
- MUST REDUCE RISK FOR INDUSTRY INVESTORS.
- This technology is no longer a science project. The science is known. It is an R&D effort.
- The timing to bring a demonstration plant to Huntsville is perfect. The perfect storm.
- If you have an interest in bringing this technology to Huntsville, tell the DOE, DoD, and other D.C. contacts.
- Sandia will continue to engage Qualis, Energy Huntsville, Redstone Arsenal, MSFC, and the community of Huntsville to further this opportunity.