Supercritical Carbon Dioxide (sCO2)

Request for Information (RFI)

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Outline

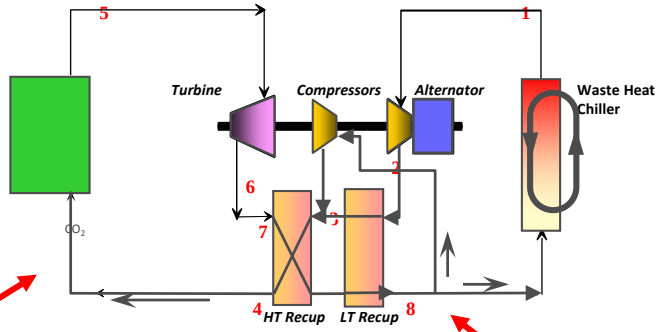
- History
- The interface of the sCO2 Tech Team
- Technology development by Program
- Overview of the RFI process
- Why NE (sCO2 Tech Team) released an RFI
- An overview of the questions focused on R&D and Market analysis
- Who was the RFI audience and why
- What were the results
- Overall Path Forward

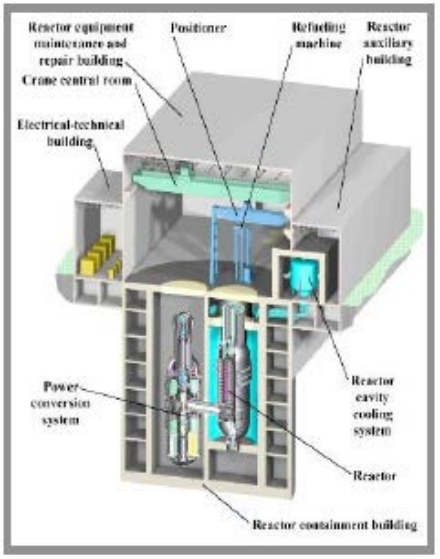
sCO_2 Cycle Applicable to Most Thermal Sources

Solar

Shipboard Propulsion

Supercritical CO_2 Brayton Cycle





Nuclear
(Gas, Sodium, Water)

Fossil

History - sCO_2 Development

- NE has pursued research on sCO2 (Brayton Cycle) for over a decade
- In 2009 NE presented the economic impacts of sCO2 to DOE Offices
- Offices of Fossil Energy (FE) and Energy Efficiency and Renewable Energy (EE) developed program specific R&D activities
- sCO2 Power Cycles Technology Road Mapping Workshop (Feb 2013)
  - Presented current research and development efforts
  - Highlighted the need for a collaborative path forward
- FY14 sCO2 Technology (Tech) Team was formed in a multi-office partnership; FE, EE & NE
  - All Offices, stakeholder and industry agreed that a commercial scale demonstration was needed to confirm benefits of sCO2 technology

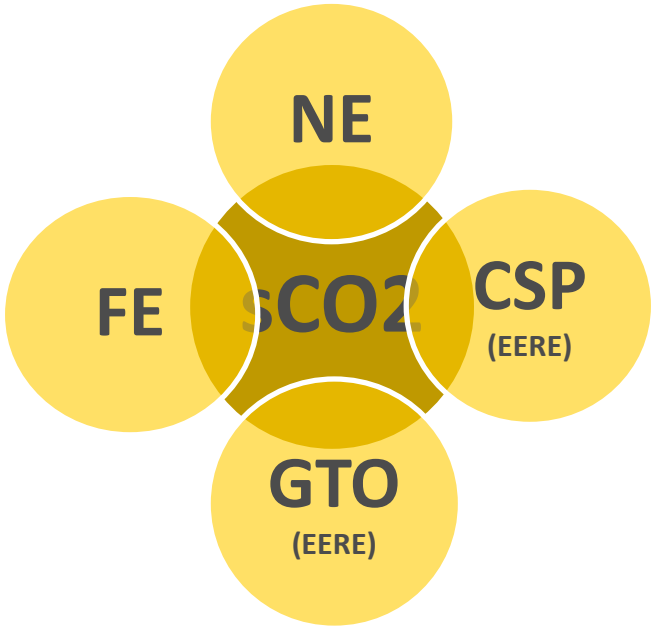
Technology (Tech) Team

The purpose of the Supercritical Carbon Dioxide (sCO_2) Technology Team is to work with industry to develop, and facilitate commercialization of sCO2 technologies

- Collaboration and Technical Integration between Program Offices:
  - FE, NE, EERE, ARPA-E

Potential benefits:

- Represents a potential multi-billion dollar market with significant potential energy savings
- Accelerate future commercialization
- Reduce capital costs, energy costs, water consumption, and greenhouse gas emissions
- Maturing this promising technology is consistent with DOE strategic goals and supports the administrations "all of the above" energy strategy and Climate Action Plan



Overview of the Request for Information (RFI)

- June '14, DOE-NE issued a Request for Information (RFI) to seek information, comments, feedback, and recommendations for the continued development of the sCO2 Brayton Cycle Energy Conversion R&D program
- The RFI is to obtain an understanding of the key R&D needs and the current state of the sCO2 market
- RFI Questions focus:
  - Technology issues
  - R&D capabilities and Priorities
  - Parameters
  - Codes (Modeling)
  - Commercialization Market & Timeframe

RFI Respondents

- 17 Respondents
  - 4 National Labs
  - 3 Research Institutions
  - 5 Vendors
  - 1 EPC
  - 1 Utility
  - 3 Other

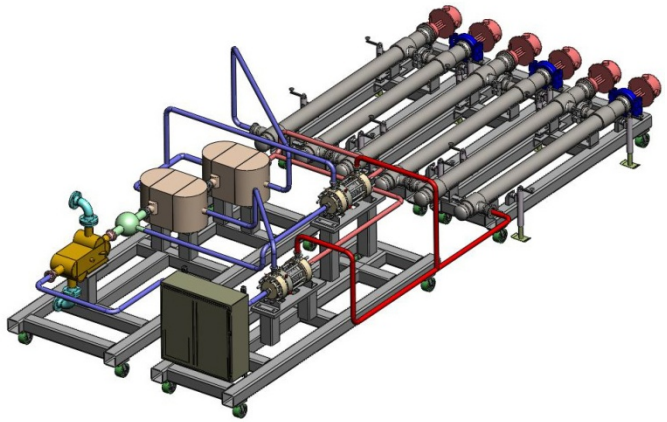
Complete RFI Respondents List

- 3SL, Inc., Huntsville, AL
- Aerojet Rocketdyne, Canoga Park, CA
- Areva, Charlotte, NC
- Argonne National Laboratory, Argonne, IL
- CFD Research Corporation, Huntsville, AL
- Dresser-Rand, Wellsville, NY
- Echogen, Akron, OH
- Electric Power Research Institute, Palo Alto, CA
- ESI North America, Farmington Hills, MI
- GE Global Research, Niskayuna, NY
- National Renewable Energy Laboratory, Golden, CO
- NET Power and 8 Rivers Capital, Durham, NC
- Oak Ridge National Laboratory, Oak Ridge, TN
- Sandia National Laboratory, Albuquerque, NM
- Southwest Research Institute, San Antonio, TX
- Southern Company Services, Inc., Birmingham, AL
- University of Wisconsin-Madison, Madison, WI

sCO2 Brayton Cycle energy conversion R&D needs

Questions

- Technical issues, challenges, and gaps
- R&D activities, capabilities and/or infrastructure
- Priority and timeframe needed
- Optimum parameters (e.g., temperature, pressure ranges and size/output)
- Models and simulation methods and codes
- Additional commercial constraints or risks
- Other supercritical fluids to support Brayton Cycles



sCO_2 Technology Issues

Most common responses:

- Compact Heat Ex.
- Turbomachinery
- System Design & Optimization
- Material Development
- Manufacturing
- Systems Operation & Control
- Scaling to commercial sizes

Other responses:

- Valves
- Material Interactions
- Integrated Safety Analyses
- Particulate & Contaminant Control
- Maintenance & Reliability
- Temperature Effects
- Procedures

sCO_2 Parameters (T, P & Size)

- Answers were dependant on application
- Most respondents outlined a phased approach to higher temperatures
- Many listed multiple systems
- Responses were consistent with our expectations

Most common responses:

- 5-10 Mwe
  - 350-550C
  - 200-300 Bar

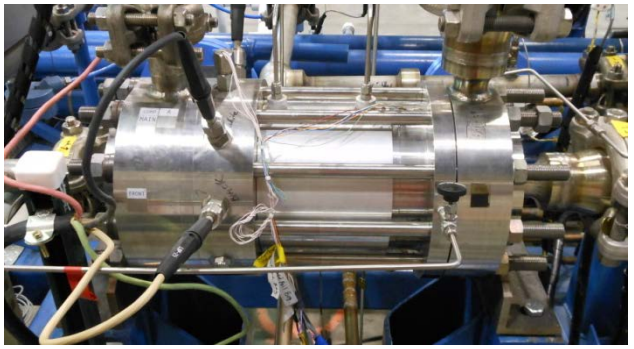
Other Responses:

- 30-100MWe
  - 600 C/200 Bar
- 100-200 Mwe
  - 700 C/200Bar

sCO2 Brayton Cycle energy conversion market needs

Questions

- Current and future market
- Industry's want, or need
- Commercialization success
- Role of entities
- Information sharing
- Other relevant information



Factors for Commercialization & Market

- Key success factors for commercialization
  - Government role
  - Sustain funding
  - Clearly identified goals
  - Engagement by industry at the beginning of planning
- Markets have been identified for various applications

Most common responses:

- Waste Heat Recovery is a near-term application (2-7 years)
- Concentrated Solar Power is a mid-term application (7-10 years)

Other responses:

- Longer-term applications (10-16 years)
  - Fossil higher temperature applications
  - Renewables are dependant of DOD applications
  - Nuclear need well established processes

Overall Path Forward

- Continue outreach with industry and other stakeholders
- Summarize RFI results and release to the public
- Finalize Options Analysis/Study
- Continue compiling current program related activities and infrastructure
- Continue to develop market research

Backup

Technology Development

- Utilized industry partnerships and visited vendors to provide input, assisted in defining R&D and in organizing workshops
- Utilized experienced national laboratory employees to help inform and mature the path forward
- Gathered, solicited and shared information on past, present and future program plans and activities
- Held regular Tech Team meetings to review program development and define strategies for path forward
    - Identified problems, technical challenges, concerns and potential solutions