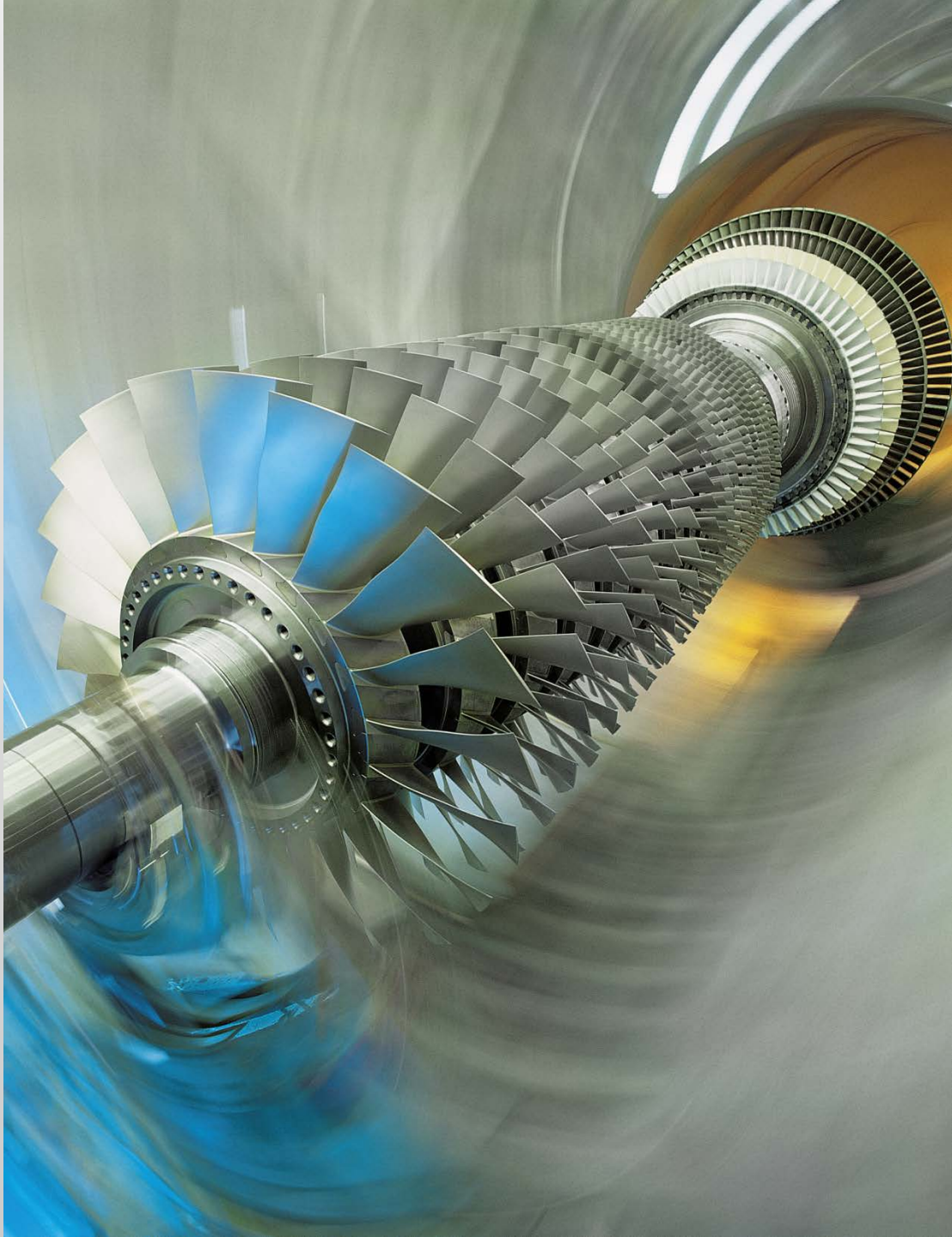
Summary of U.S Department of Energy Supercritical CO_2 Projects



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U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

DOE SCO2 Project Summaries Outline / Objective

- **Provide a brief listing of current projects supported / funded by the DOE.**

- **Include projects by:**
  - FE
  - ARPA – E
  - EERE
  - NE
  - International

FE Projects

SCO2 Project Summaries
FE

- **Title:** *Advanced Turbomachinery Components for Supercritical CO2 Power Cycles*
- **Objective:** Develop and bring about the maturity of innovative turbomachinery components for indirectly and directly heated supercritical CO_2 power generation cycles. The project would enable indirectly heated cycle efficiencies and directly heated plant efficiencies (with carbon capture and sequestration) greater than 52 percent.
- **Schedule: 10/1/2014-3/31/2016**
- **Performer PI: Aerojet Rocketdyne**
- **Other Performers/Partners: EPRI, Duke Energy, Alstom, ORNL**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Development of Low-Leakage Shaft End Seals for Utility-Scale SCO2 Turbomachinery*
- **Objective:** Develop expander shaft end seals for utility-scale supercritical CO_2 power cycles, achieving a total leakage of less than 0.2 percent of the expander mass flow.
- **Schedule: 10/1/2014-3/31/2016**
- **Performer PI: General Electric**
- **Other Performers/Partners: Southwest Research Institute**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *High Inlet Temperature Combustor for Direct Fired Supercritical Oxy-Combustion*
- **Objective:** Develop a high inlet temperature oxy-combustor suitable for integration into a direct-fired supercritical oxy-combustion power plant for fossil energy applications.
- **Schedule: 10/1/2014-3/31/2016**
- **Performer PI: Southwest Research Institute**
- **Other Performers/Partners: Thar Energy LLC, Knolls Atomic Power Lab**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Coal Syngas Combustor Development for High-Pressure, Oxy-Fuel SCO2 Cycle*
- **Objective:** Develop a coal syngas-fueled combustor for use with high-pressure, high-temperature, oxy-fuel, supercritical CO_2 (SCO_2) power cycles, with particular focus given to the conditions required by the Allam Cycle.
- **Schedule: 10/1/2014-3/31/2016**
- **Performer PI: 8 Rivers Capital**
- **Other Performers/Partners: Toshiba Corporation**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *High Temperature Heat Exchange Design and Fabrication for Systems with Large Pressure Differentials*
- **Objective:** Design a compact heat exchanger for operation at high temperature, up to 700° C, and high pressure differentials, approximately 2,500 psi between streams, intended for use in high efficiency, electrical generation systems, such as super critical CO2 power cycles.
- **Schedule: 10/1/2014-8/31/2015**
- **Performer PI: Dr. Lalit Chordia - Thar Energy, LLC**
- **Other Performers: SwRI**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Low-Cost Recuperative Heat Exchanger for Supercritical Carbon Dioxide ($ScCO_2$) Power Systems*
- **Objective:** Design and build a 500 kilowatt (kW) thermal compact mini-channel recuperative heat exchanger and test it in a supercritical carbon dioxide power system to show that the heat exchanger will meet the performance and economic targets for the application of interest**.**
- **Schedule: 10/1/2014-4/30/2016**
- **Performer PI: Altex Technologies Corporation**
- **Other Performers: Babcock & Wilcox Power Generation Group, Inc.; Echogen Power Systems, LLC; Dresser-Rand**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *High Volume Manufacturing Process Development for Low Cost High Performance Heat Exchangers for SCO2 Applications*
- **Objective:** Develop manufacturing processes for low-cost, high-performance heat exchangers appropriate for high-temperature, high-pressure applications that utilize the heat transfer surface morphology of screen mesh.
- **Schedule: 10/1/2014-12/31/2015**
- **Performer PI: Brayton Energy LLC**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Design, Fabrication and Characterization of Microchannel Heat Exchangers for Fossil Fired Supercritical CO2 Cycles*
- **Objective:** Develop reliable, versatile, effective, low-pressure-drop designs for high-temperature, high-pressure heat exchangers (HTPHXs) for fossil-fired supercritical plants by using microchannel architectures.
- **Schedule: 10/1/2014-9/30/2016**
- **Performer PI: Oregon State University**
- **Other Performers: Carnegie Mellon University**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Development of Thin Film Primary Surface Heat Exchanger for Advanced Power Cycles*
- **Objective:** Design and analysis effort to significantly increase the temperature rating of a primary surface heat exchanger that is used for recuperation in existing gas turbines.
- **Schedule: 10/1/2014-8/31/2015**
- **Performer PI: Southwest Research Institute**
- **Other Performers: Solar Turbines Incorporated**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Advanced Oxy-Combustion Technology Development and Scale Up for New and Existing Coal-Fired Power Plants*
- **Objective:** Evaluate a novel process for pressurized oxy-combustion in a fluidized bed reactor to enable economical capture of CO_2 gas. System adaptable to SCO2 power cycle.
- **Schedule:**
- **Performer PI: Aerojet Rocketdyne**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Design And Testing Of CO_2 Compression Using Super Sonic Shock Wave Technology*
- **Objective:** Integrated development of high-efficiency, low-cost CO_2 compression using supersonic shock wave technology to significantly reduce capital and operating costs associated with carbon capture and storage.
- **Schedule:**
- **Performer PI: Ramgen**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Novel Concepts for the Compression of Large Volumes of Carbon Dioxide*
- **Objective:** Advance CO_2 compression and pumping technology to increase composite energy efficiency of a compression system to 85 percent.
- **Schedule:**
- **Performer PI: SwRI**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Novel Supercritical Carbon Dioxide Power Cycle Utilizing Pressurized Oxy-Combustion in Conjunction with Cryogenic Compression*
- **Objective:** The applicant aims to investigate a novel supercritical CO2 power cycle utilizing pressurized oxy-combustion in conjunction with cryogenic compression.
  Schedule:
- **Performer PI: SwRI**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Thermo physical Properties of Carbon Dioxide and CO_2-Rich Mixtures*
- **Objective:** Address the critical need to experimentally obtain accurate thermodynamic and physical property data for CO_2 and CO2/H2O mixtures under specific conditions relevant to advanced power systems to provide a standard, validated, high accuracy set of properties for incorporation into existing public databases.
- **Schedule:**
- **Performer PI: Allan Harvey - NIST**
- **Sponsoring Organization: NETL**

SCO2 Project Summaries
FE

- **Title:** *Supercritical CO2 Turbo machinery (SCOT) Technology Development for Power Plant Applications*
- **Objective:** This study focuses on the application of the SCO2 Brayton cycle to advanced coal power plants, using a zero emission oxycombustion coal power plant with a pressurized fluidized bed combustor (PFBC) and a SCO2 Brayton cycle as the reference case.
- **Schedule:**
- **Performer PI: LTI, Aerojet Rocketdyne**
- **Sponsoring Organization: NETL**

ARPA-E Project

SCO2 Project Summaries
ARPA-E

- **Title:** Rocket Engine-Derived High Efficiency Turbomachinery for Electric Power Generation
- **Objective:** study to define a revolutionary power generation technology, based on the development of regeneratively cooled super critical CO2 turbine (Regen-SCOT) technology.
- **Schedule:**
- **Performer PI: Aerojet Rocketdyne**
- **Sponsoring Organization: DOE ARPA-E Office**

EERE Projects

SCO2 Project Summaries
EERE

- **Title: Supercritical Carbon Dioxide Turbo-Expander and Heat Exchangers**
- **Objective:** Develop a megawatt-scale s-CO2 hot-gas turbo-expander optimized for the highly transient solar power plant profile and optimize novel printed circuit heat exchangers for s-CO2 applications to drastically reduce their manufacturing costs.
- **Schedule: 2012-2015**
- **Project PI: Dr. Klaus Brun – SwRI**
- **Additional Performers: GE, Thar Energy, Bechtel Marine**
- **Sponsoring Organization: EERE**

SCO2 Project Summaries
EERE

- **Title: High-Efficiency Receivers for Supercritical Carbon Dioxide Cycles**
- **Objective:** Develop and demonstrate a low-cost, high-efficiency solar receiver that is compatible with s-CO2 cycles and modern thermal storage subsystems. The goal is to use the solar receiver in utility-scale and distributed electrical power generation.
- **Schedule: 2012-2015**
- **Project PI: Shaun Sullivan - Brayton Energy**
- **Sponsoring Organization: EERE**

SCO2 Project Summaries
EERE

- **Title: High-Flux Microchannel Solar Receiver**
- **Objective:** The objective is to design a supercritical carbon dioxide (s-CO_2) microchannel receiver that operates at a fluid exit temperature of 650ºC and is capable of absorbing an average flux of 100 W/cm^2 with a receiver efficiency of 90% or greater.
- **Schedule: 2012-2014**
- **Project Performer: Dr. Kevin Drost - Oregon State**
- **Additional Performers: PNNL, Diver Solar, LLC**
- **Sponsoring Organization: EERE**

SCO2 Project Summaries
EERE

- **Title: Direct Supercritical Carbon Dioxide Receiver Development**
- **Objective:** Analyze three direct receiver configurations and select a single concept for detailed prototype design and construction for on-sun testing. The criteria for success will be a receiver that can achieve 90% thermal efficiency and produce s-CO2 above 650°C.
- **Schedule: 2012-2015**
- **Project PI: Mike Wagner - NREL**
- **Sponsoring Organization: EERE**

SCO2 Project Summaries
EERE

- **Title:** Degradation Mechanisms and Development of Protective Coatings for TES and HTF Containment Materials
- **Objective:** Produce material systems and conditions (i.e., coatings and surface modification techniques) that result in a corrosion or degradation rate of less than 30 micrometers per year.
- **Schedule: 2012-2015**
- **Project Performer: Dr. Judith Gomez - NREL**
- **Sponsoring Organization: EERE**

SCO2 Project Summaries
EERE

- **Title: Physics-Based Reliability Models for Supercritical-CO2 Turbomachinery Components**
- **Objective:** Develop multi-physics models for performance prediction of these components during a typical sCO2 cycle mission in order to generate a loading history that serves as an input to the physics-based lifing model.
- **Project PI: GE**
- **Sponsoring Organization: EERE**

NE Projects

SCO2 Project Summaries
NE

- **Title:** Advanced Energy Conversion
- **Objective:** Actively developing advanced power generation cycles for advanced reactors, small modular reactors, space reactors, concentrated solar power, gas turbines, and fossil energy, currently focused on the Supercritical Carbon Dioxide (sCO2) Closed Brayton Cycle.
- **Sponsoring Organization: Sandia National Laboratories**

SCO2 Project Summaries
Research at Sandia National Labs

- Corrosion and Erosion Behavior in Supercritical CO2 Power Cycles
- Testing Platform and Commercialization Plan for Heat Exchanging Systems for S-CO2 Power Cycles
- Materials Corrosion Concerns for Supercritical CO2 Heat Exchangers
- Scaling Considerations for SCO2 cycle Heat Exchangers
- Dry-cooled SCO2 Power for Advanced Nuclear Reactors
- Steady State SCO2 Recompression Closed Brayton Cycle Operating Point Comparison With Predictions

Global SCO2 Activity

Additional details on the following projects can be obtained through ASME proceedings for 2013 and 2014, and the 2011 SCO2 Power Cycles Symposium

Global SCO2 Activity
Korea

- **Areas of Activity:**
  - SCO2 Brayton Cycles for SFR
  - SCO2 Brayton Cycles coupled with Small Water Cooled Reactors
  - Centrifugal Compressors with SCO2 as the working fluid
  - Hybrid SCO2 Brayton and CO2 Rankine Cycle Fuel Cell
  - SCO2 Experimental Loops

Global SCO2 Activity
China

- **Areas of Activity**
  - SCO2 Centrifugal Compressor flow characteristics
  - SCO2 Power Conversion Technology
  - SCO2 Part-Flow Cycle combined with Organic Rankine Cycle

SCO2 Project Summaries
Czech Republic

- **Areas of Activity**
  - SCO2 Regeneration Bypass Cycle
  - SCO2 Cycle Thermodynamic Analysis and Comparison
  - Supercritical Fluid Conversion Cycles for Nuclear Plants

Global SCO2 Activity
Spain

- **Areas of Activity**
  - SCO2 High Temperature Fuel Cell Hybrid Systems
  - SCO2 Compressor Design
  - Pressurized Wind Tunnel for CO2 Turbomachinery Development
  - Turbulence and Flow Distortion Effects on the Performance of SCO2 Conical Diffusers

Global SCO2 Activity
Other

- **Netherlands**
  - CFD Analysis of Radial Compressors using SCO2
- **India**
  - Elevation of Heat Rejection Temperature in Transcritical Condensing Cycles using CO_2 and Propane Mixtures
- **Norway**
  - Optimization of Power Cycle and Heat Recovery Heat Exchanger Parameters
- **Australia**
  - SCO2 Close Brayton Cycle Power Loop in a Geothermal Power Plant
- **Italy**
  - Dynamic Model of Solar SCO2 Brayton Cycle Power Plants
- **Switzerland**
  - Thermoelectric Energy Storage using Transcritical CO2 Cycle
- **France**
  - Gas Cycle Testing with SFR Prototype
- **Canada**
  - Comparison of Simple and Recompression SCO2 Cycles