CONTACT: Raj Sekar | Argonne National Laboratory | rsekar@anl.gov

ARES Connection to AMO Mission

Distributed energy systems improve energy efficiency, reduce carbon emissions, optimize fuel flexibility, lower company operating costs, and facilitate market opportunities for U.S. electricity generating capacity, enabling U.S. manufacturers to be cost-competitive and energy-independent.

Opportunity

ARES technology could generate several gigawatts of distributed electricity worldwide.

ARES Goals

- Develop engine/generator systems with high efficiency at high power output, that emit very low exhaust emissions while maintaining excellent durability, at a low installed cost.
- Technical end goals include 50% brake thermal efficiency (BTE) and 0.1 g/bhp-hr NO_x emissions.

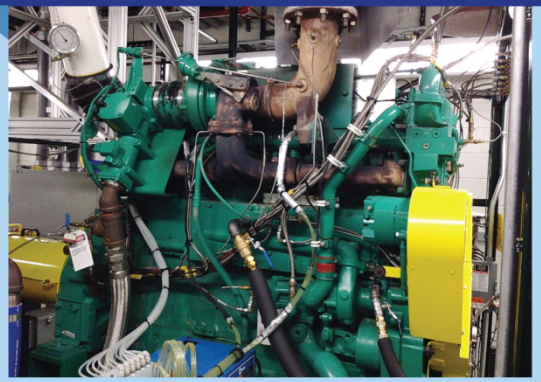
This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office.
Argonne National Laboratory is managed by UChicago Argonne, LLC, for the U.S. Department of Energy.

Advanced Reciprocating Engine Systems (ARES) R&D – Cross-Cutting Technologies Enable Efficient Manufacturing

CONTACT: Raj Sekar | Argonne National Laboratory | rsekar@anl.gov

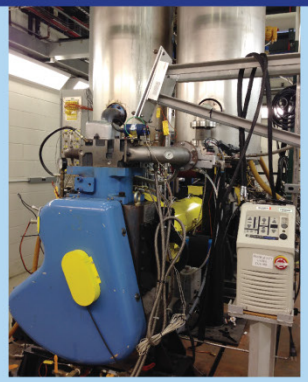
Distributed Energy Research Center (DERC) — a User Facility for Clean Energy Manufacturing

Cummins Six-Cylinder Engine



Capstone Micro-Turbine

ETECH Single-Cylinder Research Engine



Opportunity Fuel System

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office.
Argonne National Laboratory is managed by UChicago Argonne, LLC, for the U.S. Department of Energy.

CONTACT: Raj Sekar | Argonne National Laboratory | rsekar@anl.gov

Argonne's Contribution to ARES

Argonne National Laboratory established the Distributed Energy Research Center (DERC) to improve distributed energy (DE) performance by developing the following technologies:

- **Advanced Laser Ignition System for higher efficiency and lower emissions**
- **NO_x Reduction Using Air Separation Membranes – An EGR Alternative**
- **Fuel Flexibility Research Using the Opportunity Fuel System**
- **Engines in DERC**
  - Cummins QSK19G Six-Cylinder Natural Gas Engine
  - Capstone C65 Micro-Turbine
  - ETECH Single-Cylinder Research Engine

Argonne has also organized and managed four national conferences and five workshops attended by major engine and parts manufacturers and end users.

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office.
Argonne National Laboratory is managed by UChicago Argonne, LLC, for the U.S. Department of Energy.

CONTACT: Raj Sekar | Argonne National Laboratory | rsekar@anl.gov

Higher Efficiency with Lower Emissions Using Advanced Laser Ignition System

Objective:

Develop advanced ignition systems that achieve the efficiency, emissions, and durability goals of the ARES program.

Argonne's Approach:

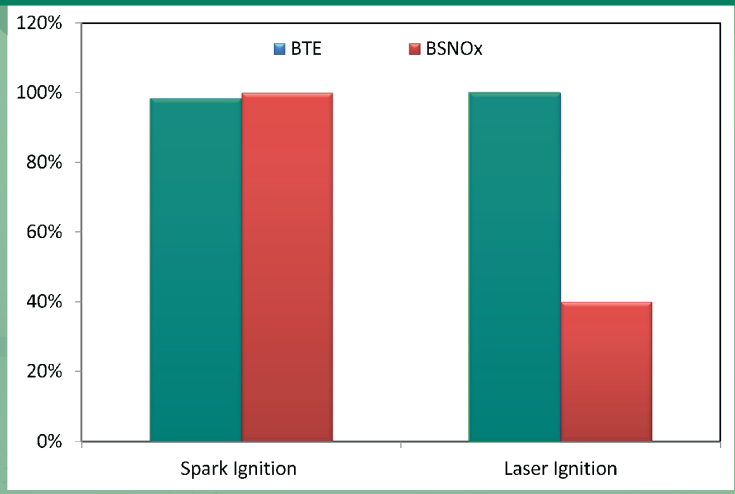
Use free-space transmission of mechanically multiplexed high-power pulsed lasers to produce ignition.

Results & Accomplishments:

Single-cylinder engine test results show 60-70% reduction in NO_x emissions and/or efficiency gains of up to 3% with higher combustion stability compared to spark ignition.

The first demonstration of the Argonne-developed laser ignition system was performed on a Cummins six-cylinder engine.

Cummins Six-Cylinder Engine Results



Advantages:

- Higher efficiencies
- Lower NO_x emissions
- Less heat transfer loss
- Support for lower-quality fuels
- Higher burn rates
- No after-treatment required

Patents:

- "A Method to Distribute High-Energy Laser Pulses to Multiple Channels," U.S. *Patent 7,699,033 B2*
- "Laser Based Ignition System for Natural Gas Reciprocating Engines, Laser Based Ignition System Having Capability to Detect Successful Ignition Event, and Distributor System for use with High-Powered Pulsed Lasers," *U.S. Patent 7114858*

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office.
Argonne National Laboratory is managed by UChicago Argonne, LLC, for the U.S. Department of Energy.

CONTACT: Raj Sekar | Argonne National Laboratory | rsekar@anl.gov

NO_x Reduction Using Air Separation Membranes

Objective:

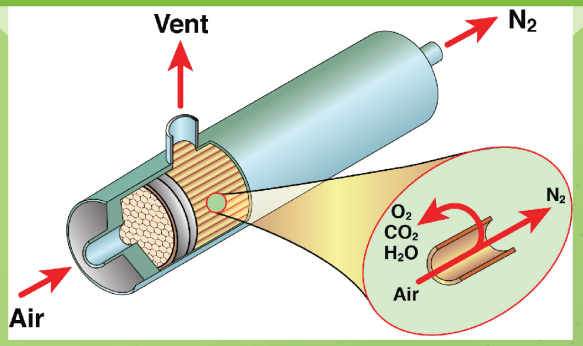
Reduce NO_x emissions from gas-fueled reciprocating engines.

Argonne's Approach:

Air Separation Membranes (ASM) generate nitrogen-enriched air (NEA) and oxygen-enriched air streams by using thousands of thin, hollow fibers coated with a polymeric material.

The fibers selectively permeate O_2 molecules over N_2 molecules. NEA in the intake system reduces NO_x emissions via dilution effect during combustion.

Air Separation Membrane



Results & Accomplishments:

- NO_x reduction (25-50%) consistent across all fuel/air ratios with a small efficiency penalty
- 2% NEA (19% O_2 in air) equivalent to 20% EGR

Advantages:

- Unlike Exhaust Gas Recirculation (EGR), the ASM-generated NEA does not introduce contaminants into the engine and therefore reduces maintenance costs significantly.
- Existing engines can be retrofitted with ASMs.
- No major hardware modification is required.

Patent:

"Nitrogen Enriched Combustion of a Natural Gas Internal Combustion Engine to Reduce NO_x Emissions," *U.S. Patent 7455046*

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office.
Argonne National Laboratory is managed by UChicago Argonne, LLC, for the U.S. Department of Energy.

CONTACT: Raj Sekar | Argonne National Laboratory | rsekar@anl.gov

Fuel Flexibility Using Opportunity Fuel System

Objectives:

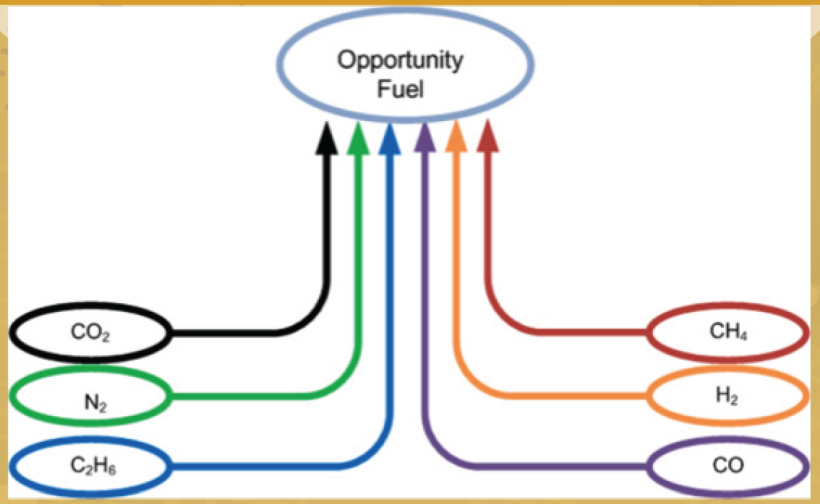
Evaluate untapped/underutilized energy potentials of low-BTU gaseous fuels, and their effects on ARES engines:

- Improve the fuel flexibility
- Investigate the effect of natural gas composition variation

Argonne's Approach:

Create an Opportunity Fuel (Op-Fuel) system that can blend Methane (Natural gas), Ethane, Propane, Hydrogen, Carbon Monoxide, Carbon Dioxide and Nitrogen to simulate low-quality/low-BTU fuels, natural gas blends, and propane as a standalone fuel.

Opportunity Fuel System



Advantages:

Low-BTU-fueled prime movers reduce the need for expensive fuel processing and refinement.

Future Prospects:

The op-fuel system will enable collaboration with industry and academia to develop advanced engine technologies.

This work was funded by the U.S. Department of Energy, Advanced Manufacturing Office.
Argonne National Laboratory is managed by UChicago Argonne, LLC, for the U.S. Department of Energy.