

## Low-NO<sub>x</sub> Gas Turbine Injectors Utilizing Hydrogen-Rich Opportunity Fuels

### Increasing the Fuel Flexibility of Industrial Gas Turbine Combustion Systems

This project will modify a gas turbine combustion system to operate on hydrogen-rich opportunity fuels. Increasing the usability of opportunity fuels will avoid greenhouse gas emissions from the combustion of natural gas and increase the diversity of fuel sources for U.S. industry.

#### Introduction

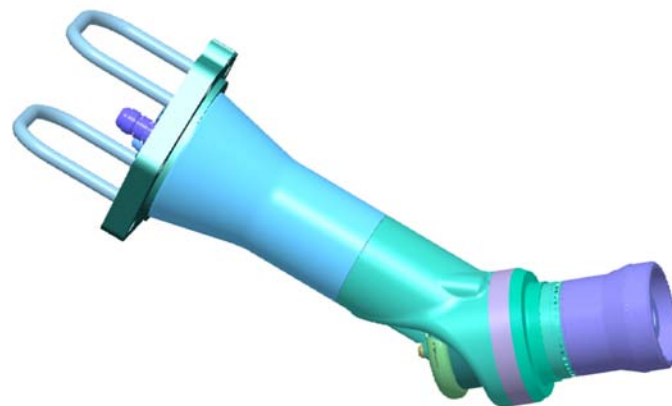
Gas turbines are commonly used in industry for onsite power and heating needs because of their high efficiency and clean environmental performance. Natural gas is the fuel most frequently used to power gas turbines because of its availability, historically low cost, and consistent composition.

However, a combination of recent factors, including unstable natural gas prices, actions toward carbon emissions regulation, and excess risk from reliance on a single fuel source, have made natural gas substitutes attractive from both environmental and economic standpoints.

These alternative fuels, commonly referred to as opportunity fuels, are unconventional fuels that have the potential to become economically viable sources for power generation. They are often derived from agricultural, industrial, and municipal waste streams or from byproducts of industrial processes. Common examples include synthesis gas derived from coal or biomass, anaerobic digester gas, and refinery gas from petroleum refineries.

Despite the prospects for increased opportunity fuel utilization, the inability of typical industrial gas turbines to operate effectively when powered by these fuels remains a challenge. Opportunity fuels are often rich in hydrogen, which combusts differently than methane, the primary component of natural gas.

This project aims to address this barrier by developing and testing new fuel-flexible gas turbine injector concepts targeted at hydrogen-rich fuel applications. The project will develop a detailed understanding of the kinetic mechanisms, combustion dynamics, and flame structure of opportunity fuel combustion.



A fuel injector for the Solar Titan gas turbine

*Illustration courtesy of Solar Turbines Incorporated.*

#### Benefits for Our Industry and Our Nation

Implementing fuel-flexible gas turbines, which provide a high-efficiency, low-emissions source of electricity and process heat, will have major energy, economic, and environmental benefits, including the following:

- Utilization of an untapped energy source of significant potential
- Increased diversity of eligible fuel sources for gas turbines used in U.S. industry, including many fuels that cost less than natural gas
- A decrease in greenhouse gas emissions from the combustion of natural gas by substituting renewable fuel sources or combining gasification with carbon capture and sequestration
- A reduction of solid hazardous waste through the use of gasifier technology
- Reduction or avoidance of waste disposal fees

#### Applications in Our Nation's Industry

This advanced combustion technology will particularly benefit industries that currently generate waste or byproducts consumable as opportunity fuels, including the chemical, petrochemical, refinery, food processing, pulp and paper, steel and metals, cement, and glass industries.

#### Project Description

The objective of this program is to redesign a gas turbine combustion system to operate on hydrogen-rich opportunity fuels. This technology should maximize efficiency and maintain satisfactory emissions performance while delivering reliability and durability to the customer.

## Barriers

- Applying dry-low nitrogen oxide (NO<sub>x</sub>) emissions technology to hydrogen-rich fuels
- Overcoming the detrimental effect of the fuel composition variability of gasified waste streams to turbine performance and durability

## Pathways

The University of Southern California (USC) will test the selected fuels and obtain fundamental combustion characteristics of these fuels.

The Pennsylvania State University (PSU) will measure flame response and combustor pressure oscillations to characterize the effect of fuel composition.

Solar Turbines Incorporated will redesign and test modified fuel injectors in their ambient and high-pressure test facilities based upon results from PSU and USC testing. Full-scale testing and field testing at a customer site will follow.

Concurrently, Solar will perform a market study of gas turbines operating on renewable and opportunity fuels, leading to a full commercialization plan to address market introduction of the technology.

## Milestones

- Fuel characterization
- Flame structure and combustion pressure oscillation characterization
- Definition of the concept based on fuel characterization, flame structure, injector performance testing results, and other relevant factors
- Development of the concept, including design, analysis, fabrication, and rig testing
- Single injector rig testing
- Development and testing of the technology in a full-scale system in the field

## Commercialization

In commercializing the project technology, Solar Turbines will ensure maximum durability, conversion efficiency, and thermal output with the lowest possible emissions.

Solar Turbines will lead a commercial demonstration project to verify preliminary results in the field. The company will also partner with another firm to develop an appropriate gas cleanup system and will verify the technology as part of the field evaluation program.

## Project Partners

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