# Fuel-Flexible Combustion System for Refinery and Chemical Plant Process Heaters

## Displacing Natural Gas Consumption and Lowering Emissions

By enabling process heaters to utilize opportunity gaseous fuels with a fuel-flexible combustion system, this technology lowers carbon and nitrogen oxide ($NO_x$) emissions and reduces energy costs for industry.

## Introduction

The refining and chemical sectors account for more than 40% of total industrial natural gas use. Prior to the completion of this project, an enabling technology did not exist that would allow these energy-intensive industries to take full advantage of opportunity fuels and thereby reduce their natural gas consumption.

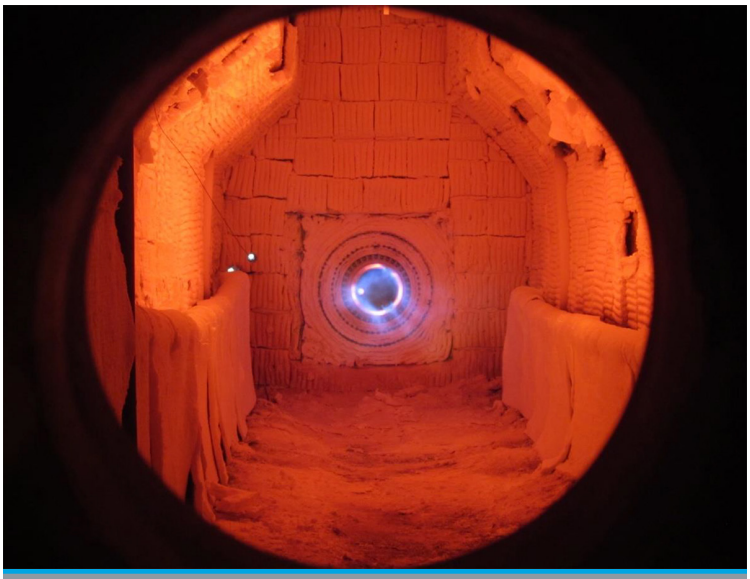
Opportunity gas fuels include biogas from animal and agricultural wastes, wastewater plants, and landfills, as well as syngas from the gasification of biomass, municipal solid wastes, construction wastes, and refinery residuals. The primary challenge to using gaseous opportunity fuels is that their composition and combustion performance differ from those of conventional fuels such as natural gas and refinery fuel gas. An effective fuel-flexible combustion system must accept fuels that range widely in quality and change in composition over time.

To enable the combustion of opportunity fuels, this project modified an existing commercial burner design. The project applied computational fluid dynamics (CFD) analysis to optimize the prototype system's aerodynamic, combustion, heat transfer, and emissions performance. To complete the development process, the project conducted full-scale testing of the prototype system and then demonstrated the technology at an industrial facility.

## Benefits for Our Industry and Our Nation

The development of an opportunity gas combustion system for process heaters will produce environmental, energy, and economic benefits:

- Reduce carbon emissions: the project's burner can enable utilization of renewable bio-fuels.
- Reduce energy costs: use of opportunity fuels can mitigate the impact of natural gas price increases.



Fuel compositions representative of the entire range of opportunity and conventional fuels were successfully fired in two burner configurations. *Photo credit Zeeco USA, LLC.*

- Lower $NO_x$ emissions: the project's burner produces ultra-low emissions levels with conventional fuels; many of the biogases yield even lower $NO_x$ levels.
- Enhanced plant safety: rapid fuel quality swings can be accommodated without loss of flame stability.

## Applications in Our Nation's Industry

This research specifically targets the refining and chemical sectors due to their scale, energy intensity, and capability to integrate the technology. These sectors already use a range of gaseous fuels, have expertise in process engineering, handle feedstocks and feedstock conversions, and process and distribute fuels.

The project's findings are also applicable to process heaters in other industries and toward the use of opportunity fuels in industrial boilers.

## Project Description

The goal of this research effort was to develop and demonstrate a combustion system capable of automatic, safe, reliable, efficient, and low-emission operation across a broad range of fuel compositions, including syngas, biogas, natural gas, and refinery fuel gas.

## Barriers

- Establishing accurate scenarios for future opportunity fuel availability in order to evaluate burner performance against realistic fuel characteristics
- Achieving the lowest possible emissions of criteria pollutants while maintaining stable and reliable operation
- Developing a fuel-flexible burner that accepts fuels that range widely in quality and change in composition over time, often rapidly

## Pathways

The project was structured in three phases of research and development.

- Phase one identified the most likely scenario for widespread deployment of opportunity fuels in refinery and chemical plants and then developed the preliminary product design using engineering studies and detailed simulations.
- During phase two, full-scale tests verified the performance of the prototype system using a range of opportunity fuels.
- In phase three, a field demonstration test established the technology's performance in a commercial process heater.

## Milestones

- Development of the prime concept design
- Optimization of the design through chemical kinetics and CFD analyses
- Fabrication and testing of a single full-scale prototype
- Validation of the refined, commercial prototype through a multi-burner commercial field demonstration
- Demonstration to the industry that the technology is practical, cost-effective, and meets performance goals

## Commercialization

Several industrial partners participated in the project and are contributing to the successful commercialization of the innovative combustion system technology.

ENVIRON International, an environmental and energy consulting firm, was the prime contractor.

etaPartners LLC managed the technology development activities and conducted the modeling analyses.

Zeeco USA, LLC, a leading manufacturer of combustion systems for use in refinery and chemical plant process equipment, contributed to the conceptual designs, led test activities, and is now prepared to manufacture and market the technology.

Shell Global Solutions (US), Inc. provided practical end user input and insight into which feedstocks and processing technologies are most likely to have a near-term impact in providing opportunity fuels. Shell also hosted a full-scale field demonstration of the technology in one of their facilities.

## Accomplishments

- Fuel compositions representative of the entire range of opportunity and conventional fuels were successfully fired in two burner configurations.
- $NO_x$ emissions at the design firing rate were at levels that are comparable to current, state-of-the-art, ultra-low-emission burners.
- The fuel-flexible burners were able to operate at efficient excess air levels with low carbon monoxide (CO) emissions. From a combustion perspective, this combination maximizes thermal efficiency.

## Project Partners

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Project final report available at
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