## San Diego State University Research Foundation

**Title:** Energy Innovations Small Grant Program Natural Gas Research Solicitation 09-01G
**Amount:** $284,463.00
**Term:** 12 Months
**Contact:** Patrick McCarthy
**Committee Meeting:** 8/4/2010

### Recommendation

Staff respectfully recommends approving the four highest ranking research grant applications from the Energy Innovations Small Grant natural gas solicitation 09-01G in the amount of $379,463. Staff recommends placing this item on the discussion agenda of the Energy Commission Business Meeting.

### Issue

The Energy Innovations Small Grant (EISG) Program is a component of the Public Interest Energy Research (PIER) Program that is managed by the California Energy Commission (Commission). The purpose of the PIER Program is to provide benefit to California electric and gas ratepayers by funding energy research, development and demonstration (RD&D) projects that are not adequately provided for by competitive and regulated energy markets.

The Commission recognizes the need for a program to support the early development of promising new energy technology concepts, a niche not covered by PIER general solicitations that focus primarily on development of established concepts. The Commission established the EISG program to meet this need. The EISG program provides up to $95,000 for hardware projects and $50,000 for modeling projects to small businesses, non-profits, individuals and academic institutions to conduct research that establishes the feasibility of new, innovative energy concepts. Research projects must target one of the PIER R&D areas, address a California energy problem and provide a potential benefit to California electric and natural gas ratepayers.

### Background

The Energy Commission has conducted the EISG program since its initiation in 1998 by issuing multiple competitive solicitations a year for new and innovative concepts that, if proven feasible, are expected to open new paths to public interest energy research and development and subsequent public benefit. Three annual surveys of completed projects show that 50 percent of the completed projects attract follow-on RD&D funding from a wide variety of sources, thus enabling the innovative development to continue beyond EISG grant funding. The gross follow-on funding is some ten times the total Energy Commission grant funding to all completed EISG projects since the beginning of the program. Approximately 85 percent of the follow-on development work is located in California.

### Proposed Work

The Energy Innovations Small Grant Program solicitation 09-01G yielded the following response:

- 9 grant applications were received for consideration

- 4 passed initial screening and advanced to technical review
- 4 exceeded the minimum required score in technical review and advance to the PTRB
- 3 proposals were recommended for funding by the PTRB valued at $284,463.

The four proposals that are being recommended for funding are as follows:

Project Title: Residential Gas-Fired Heat Pump Water Heater
Principle Investigator: Michael Garrabrant, Stone Mountain Technologies Inc. Unicoi, TN
Rank: 1
Amount: $94,463
Project Summary:

The goal of this project is to determine the feasibility of a gas-fired residential heat pump water heater that utilizes a miniature absorption system. The expected primary efficiency of the finished product is considerably greater than conventional gas storage or electric heat pump water heaters resulting in significant reductions in greenhouse gas emissions from domestic hot water use. This technology potentially is positioned to gain significant market penetration because of its efficiency, conventional installation, standard footprint, and reasonable economic payback.

Project Title: Advanced Control Techniques and Sensors for Gas Engines with NSCR
Principle Investigator: Daniel B. Olsen, Colorado State University, Fort Collins
Rank: 2
Amount: $95,000
Project Summary:

The goal of this project is to determine the feasibility of using a control system in conjunction with an electronically programmable carburetor, nitrogen oxide (NOx) sensors and Non Selective Catalytic Reduction (NSCR) catalyst systems on industrial natural gas engines. By precisely controlling the Air/Fuel (AF) ratio, this project expects to reduce NOx and carbon monoxide emissions and reduce the operating cost of these engines by eliminating some of the maintenance and calibration requirements; current AF ratio control systems often drift lean or rich, resulting in excessive emissions.

Project Title: Advanced Low Temperature Natural Gas Combustion using Turbulent Jet Ignition
Principle Investigator: Dr. William Attard, MAHLE Powertrain LLC, Novi, MI
Rank: 3
Amount: $95,000
Project Summary:

The goal of this project is to apply modern hardware and control measures to the relatively unexplored technology of turbulent jet ignition, and develop the system as a direct replacement of the spark plug in a vehicle based natural gas engine. This project has the potential to achieve diesel like thermal

efficiency while reducing emissions by up to 80 percent and maintaining a production cost similar to standard spark ignition gasoline engines.

## PROJECT SUMMARY

**Residential Gas-Fired Heat Pump Water Heater**
**Michael Garrabrant, Principal Investigator**

Feasibility and testing of a gas-fired residential heat pump water heater with a primary fuel efficiency ***2.4 times higher than conventional gas storage water heaters, and 2.1 times higher than electric heat pump water heaters*** is proposed. The heat pump system extracts low grade heat from the ambient air and produces high grade heat suitable for heating water in a storage tank for domestic uses at a projected Energy Factor (EF) of 1.5.

The proposed project is an initial step towards the development of an appliance that features conventional installation practices, standard footprint, and reasonable economic payback. These characteristics position the technology to gain significant market penetration, resulting in a large reduction in green house gas emissions from domestic hot water use.

Proof of feasibility is the first step of a larger project to develop a gas-fired heat pump residential water heater with an approximate 3 kW (10,000 Btu/hr) heating capacity, combined with a conventional residential water storage tank (60 – 80 gallons) to provide a first hour rating of at least 50, with an installed cost less than $1,800. The heat pump system efficiency is expected to be approximately 160%, resulting in an EF of 1.5 taking into account stand-by losses. The heat pump module will be mounted directly on top of the storage tank, with a capacity and storage volume that align with electric heat pump models currently under development by the industry. The heat pump module will utilize a simple $NH_3$-$H_2O$ cycle and high efficiency heat and mass exchangers to keep the footprint small and the refrigerant charge very low.

Project tasks include thermodynamic cycle optimization, heat and mass exchanger design and prototype fabrication, breadboard performance testing and a budgetary manufacturing cost estimate. In order to minimize system complexity and manufacturing cost, and maximize reliability and efficiency, a simple single-effect ammonia-water cycle with high internal recovery rates will be utilized. At the end of the proposed project, the technology will be ready for development activities towards a packaged prototype.

## B. Project Summary

**Title: "Advanced Control Techniques and Sensors for Gas Engines with NSCR"**

**Principal Investigator: Dr. Daniel B. Olsen**

Stationary reciprocating internal combustion engines provide power generation and horsepower for compression and pumping in a variety of applications. Trends in emissions regulations continue to reduce emissions limits, requiring development of new technologies for emission reduction. Emissions compliance of stationary engines can be successful with the application of a Non Selective Catalytic Reduction (NSCR) catalyst system. To accomplish this, the air-fuel ratio must be precisely controlled within a narrow range. The ability of AF ratio control systems to maintain the engine air-fuel ratio in the required narrow operating range long term under field conditions has not been established. Current research shows that AF ratio control systems in field applications often drift lean or rich, resulting in excessive emissions of NOx or CO, respectively. Drift in lambda sensor calibration appears to be one of the main problems with these systems.

The project goal is to determine the feasibility of using a minimization algorithm with a NOx sensor to control NSCR catalyst systems. This approach will improve the control of NSCR systems for industrial natural gas engines. The project goal will be accomplished by (a) a unique implementation of NOx sensors to control NSCR systems and (b) the development of an innovative control algorithm. The proposed control system relies on minimization of a NOx sensor electrical signal, and is not dependent on sensor calibration. There are no NSCR control systems that operate in the manner described, based on our literature search. To our knowledge this will be the first implementation of NSCR control by minimizing a NOx sensor signal. This approach has the potential to vastly improve NSCR control, and have a major impact on the market.

Cost share is an important aspect of this project. Cost share from industry validates the relevance of the work. The Pipeline Research Council International (PRCI) is providing $50,000 cash cost share and Continental Controls Corporation is providing in-kind cost share valued at $18,000.

Addressing emissions from industrial natural gas engines in the manner proposed will benefit California customers by improving air quality and reducing the cost of engine operation. We estimate $20 million per year savings in operating costs if the technology is widely implemented. Continental Controls Corporation is participating in this project. They are a California manufacturer of AF ratio controls equipment for NSCR catalysts. Continental Controls is likely to take the technology to market if the feasibility study is successful. This will create new jobs and revenue for California. The new technology would be sold to operators of industrial natural gas engines, which includes electric utilities, water districts, manufacturing plants with distributed energy generation and natural gas pipelines.

# 1 PROJECT SUMMARY

***Advanced Low Temperature Natural Gas Combustion Using Turbulent Jet Ignition***

Principal Investigator: Dr. William Attard

This proposal has been prepared by MAHLE Powertrain and Michigan State University in response to the California Energy Commission's grant solicitation, "Energy Innovations Small Grant Program for Natural Gas" (Solicitation 09-01G). The project is expected to be completed over a 10 month period, involving hardware commissioning together with experimental testing and data analysis.

Turbulent Jet Ignition combustion is a relatively old concept, first conceived in the 1950's. For this research, an advanced Turbulent Jet Ignition combustion system has been designed and developed for an otherwise standard spark ignition engine found in on-road vehicles. The current design simply replaces the spark plug in a modern pent roof, four valve spark ignition engine. Turbulent jet ignition enables very fast burn rates due to the ignition system producing multiple, distributed ignition sites, which consume the main charge rapidly and with minimal combustion variability. The fast burn rates allow for increased levels of dilution (lean burn/EGR) when compared to conventional spark ignition combustion, with dilution levels being comparable to other low temperature combustion technologies (homogeneous charge compression ignition - HCCI) without the complex control drawbacks.

The technical approach taken in this proposal is to apply modern day hardware and control systems to a state-of-the-art design to overcome previous drawbacks of the complex and relatively unexplored combustion system. To date, no research has been completed with the proposed jet ignition combustion system in a modern engine design or with natural gas fueling. It is anticipated that the research will extend the knowledge base of this relatively unknown form of combustion, providing a pathway forward for assessing Turbulent Jet Ignition technology in current day and potentially future vehicles. This type of research is needed as California's increasingly stringent greenhouse gas emission standards require the development of new more fuel efficient combustion technologies. Turbulent Jet Ignition with natural gas is potentially one way forward, offering diesel like efficiency, low engine out emissions and simple emission clean up strategies which result in both improved fuel consumption and emissions.

The quantitative and measurable goals to be achieved in this proposal when compared to baseline spark ignition combustion are to demonstrate near diesel like thermal efficiency (~45%), display up to a 20% improvement in fuel economy and illustrate that engine out NOx emissions can be reduced by up to 80%.

Besides MAHLE Powertrain (Teir 1 supplier) and Michigan State University, additional support for the program will be provided by a CARB-EPA recognized natural gas outfitter (Natural Drive), who will supply components and review progress reports. The project budget to carry out the outlined scope of work and assumptions identified herein is $199,483 USD, of which we are requesting that the California Energy Commission cost share 48% of total project costs. Hence, the total requested PIER funding is:

**$ 95,000 USD**