

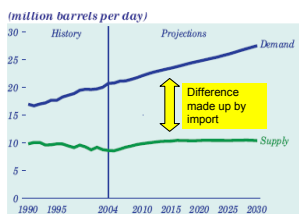
# Clean and Efficient Fuel-Flexible Combustion of Alternative Diesel Fuels Via Closed-Loop Control

Gayatri Adi, Michael Bunce, Armando Indrajana, Chris Satkoski, David Snyder, Prof. Gregory M Shaver

Herrick Laboratories, Energy Center at Discovery Park  
School of Mechanical Engineering, Purdue University

## 1. Background Information

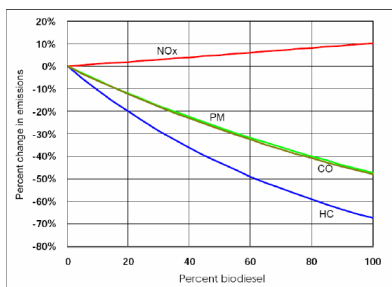
- Rising global demand for petroleum-based fuels is resulting in increases in CO<sub>2</sub> production, a leading contributor to global warming, as well as other harmful emissions
- The rising U.S. demand for fuel translates to higher costs and an increasing reliance on foreign sources of oil
- Biofuels offer a cleaner, sustainable, domestic alternative



Projected demand and supply of petroleum in USA  
Source : 2006 DOE Annual Energy Outlook

## 2. Basics of Biodiesel

- Biodiesel is produced from vegetable oils or animal fats that are reacted with an alcohol (typically methanol)
- The use of biodiesel can reduce CO<sub>2</sub> emissions by more than 50% because it can be produced from plants which absorb CO<sub>2</sub>
- Emissions of PM, CO, and HC are dramatically reduced
- Challenges:
  - Biodiesel has a lower energy density (~10%) than diesel resulting in lower power/torque for the same amount of fuel
  - Increased NO<sub>x</sub> emissions



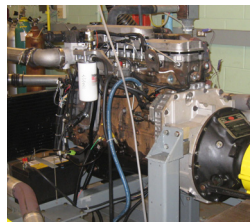
Average Emission Impacts of Biodiesel for Heavy-Duty Highway Engines  
Source: EPA

## 3. Goals

- Understand the combustion characteristics of biodiesel in mixtures of varying concentration with conventional diesel as well as biodiesel from different feedstocks
  - Cetane number (a measure of ignition delay)
  - Energy density
  - Oxygen content
- An understanding of these characteristics may allow their real-time sensing/estimation via:
  - Production-viable in-cylinder pressure transducers
  - O<sub>2</sub> exhaust sensor
- Utilize this data in a closed-loop control of engine actuators to optimize the combustion process
  - Aid engine efficiency
  - Reduce NO<sub>x</sub> emissions without sacrificing PM, CO, and HC reductions

## 4. Experimental Approach

- A 2007 Cummins B-Series 6.7 liter inline-six cylinder diesel engine is being used for experimental work



2007 ISB 6.7L Cummins Engine

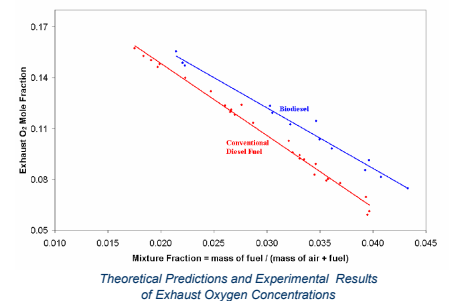
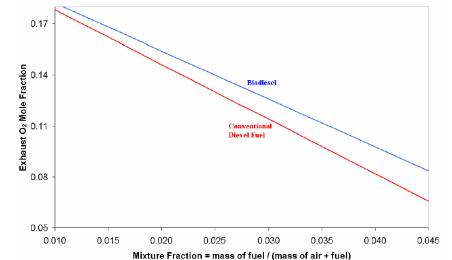
- The engine is run with conventional diesel and biodiesel blends up to B100 (100% biodiesel, 0% conventional)
- Numerous combustion characteristics recorded and controlled using D-space and Calterm software
- HC, CO, CO<sub>2</sub>, NO<sub>x</sub>, and PM emissions are sampled in the exhaust and measured using exhaust gas analyzers
- O<sub>2</sub> in exhaust is measured using commercial-grade O<sub>2</sub> sensor



Combustion Emissions Analyzers

## 5. O<sub>2</sub> Sensor Blend Estimation Technique

- Biodiesel used in this experiment is taken from soybean oil
- Biodiesel is an oxygenated fuel; conventional diesel is not
- The hypothesis is that the specific blend of biodiesel being used in the engine can be accurately estimates by measuring the amount of O<sub>2</sub> in the exhaust



Theoretical Predictions and Experimental Results of Exhaust Oxygen Concentrations

## 6. Modeling Approach

- Diesel and Biodiesel models constructed using GT-Power engine modeling software
- GT-Power allows for wide-ranging customization of chemical and physical properties of fuels (density, viscosity, chemical kinetic properties, etc.)

## 7. Future Work

- Custom cylinder head is being installed with pressure transducers in each of the cylinders
  - A variety of pressure transducers will be used in the head (lab-grade as well as production-intent)
  - These transducers will measure real-time pressure in each cylinder
- The GT-Suite model will be validated with experimental results from the engine
- Various blends of biodiesel will be tested in the engine
- Once the combustion characteristics are modeled for various blends of biodiesel, this data can be incorporated into a closed-loop controller with the goal of optimizing the combustion process to aid efficiency and reduce emissions
- Knowledge gained from work with biodiesel can be leveraged to work with other fuels such as Fischer-Tropsch fuels

## 9. Affiliated Sponsors

