Running Green: Making the Switch to Biofuels

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Goal of this Presentation

To give the audience an understanding of

• What biofuels are,
• Where they come from,
• Why they are important
• Consideration in their usage
• Where they can be sourced in Western North Carolina or the surrounding region
Why the interest in biofuels?

• The USA (both President Bush and President Obama) has made energy security a priority
• Europe has made addressing climate change a priority
• Brazil (and other developing nations) see biofuels as an important driver of economic growth and rural development

- Legislation that created the second version of the US Renewable Fuel Standard (aka “RFS2”)

- A biofuels mandate which requires that 36 billion gallons of renewable fuels be used in the United States by 2022.

- Went into effect in mid-2010. Large impact on US Biofuel production.
US Renewable Fuel Standard

U.S. BIOFUELS PLAN

- Biomass-based diesel
- Non-cellulosic advanced
- Cellulosic advanced
- Conventional biofuels

Billions of gallons

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What are biofuels?

Biofuels are liquid fuels derived from biomass, or recently living plant or animal material.

Petroleum-based fuels are derived from plant or animal material that was alive millions of years ago.
Biofuel Types

• Ethanol (dominant biofuel in USA)
  – 13 billion gallons in 2012, 12 billion corn ethanol, 1 billion sugarcane ethanol (mostly from Brazil)

• Biodiesel & Renewable Diesel
  – 1.8 billion gallons in 2013

• Advanced Biofuels (Cellulosic Ethanol, Algal Fuels)
  – 5-6 Plants coming online in 2014/early 2015
Biofuels for Gasoline Engines

FUEL ETHANOL
Rise of corn ethanol in the USA

• Growth in the US ethanol market due to following factors:
  – Need for a replacement for MTBE (oxygenate replacement) to boost octane and improve air emissions
  – Desire from agricultural industry for better corn prices (additional market for corn)
Gasoline Consumption in the USA

The USA consumed approx. 134.5 billion gallons of gasoline last year.

The United States relied on net imports (imports minus exports) for about 40% of the petroleum.

Dependence on Foreign Oil has decreased since its peak in 2005.
US Ethanol Production

The 10% "Blend Wall"

2013
134 billion gallons of Gasoline
13.3 billion gallons of Ethanol

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E85 and Flex Fuel Vehicles

• >16 million E85 capable vehicles on the road in the USA, approx. 3,200 stations
• FFVs typically get about 25-30% fewer miles per gallon when fueled with E85
  – Ethanol's energy content ~34% lower per unit volume than gasoline
• Simple modifications to the vehicles
  – Sensor automatically detects the alcohol/gasoline mix
    • Adjusts fuel injection and spark timing according to the gas/EtOH blend level
  – Material compliant elastomers used

Avg. Price Spread of 4.43%
Where to get fuel ethanol?

- Most gasoline in the United States contains about 10% ethanol
- Only about 3200 stations have E85 pumps, out of a total of about 176,000 stations (1.8%)
- Previously there were E85 stations in Western NC
- Closest E85 Stations to you can be located through the DOE’s Alt Fuels Data Center: [http://www.afdc.energy.gov](http://www.afdc.energy.gov)
Biofuels for Diesel Engines

BIODIESEL
What is Biodiesel?

• Biodiesel: a renewable fuel produced to an ASTM standard (d6751) that can be used as an additive, supplement, or substitute for diesel fuel and heating oil.

• Biodiesel is made from vegetable oil or animal fats. (Biodiesel is not vegetable oil.)

• Biodiesel is recognized as a fuel by the US Dept. of Energy, US Dept. of Transportation, and US Environmental Protection Agency.
US Biodiesel

• Dollar tax credit
  – In both 2011 and 2012 it was retroactively approved at the end of the year. In 2012 it was applied for 2 years.
  – Still no word on a retroactive producers credit for 2014.

Recent News
  – Home heating oil is now approved for RFS

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Applications of Biodiesel

• As a neat fuel (B100).
  – All diesel vehicles can use up to 100% biodiesel without modification, however there are special considerations to be aware of (see next slides)

• As a medium-level blend (B20-B50).
  – Most OEMs moving to officially approve up to 20% blends
  – Practically, all vehicles can use of up to 20% with no difference in performance

• As a low-level blend (1% - 5%). Small amounts of biodiesel can restore lubricity to low-sulfur fuels.
  – Current ASTM definition of diesel fuel (d975) includes up to 5% biodiesel
  – No labeling requirement for up to 5% blends

• Bioheat
  – Biodiesel can be used as supplement for home heating oil
Biodiesel is easy to use
(no modifications required)

- Biodiesel works in nearly any diesel engine from B5-B100
- Up to B20 may use existing fueling infrastructure.
- Biodiesel is widely available
- Biodiesel Handling and Use Guidelines available online
  (Google “NREL Biodiesel Handling & Use”)

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Materials Compatibility

• Biodiesel is a solvent – it may dislodge and “clean” the fuel system.
  – Any dirt or debris on the inside of the fuel tank or in the fuel lines may be dissolved and lead to fuel filter clogging.

• Biodiesel will remove paint, varnish, and will dissolve asphalt with prolonged exposure.
  – Always clean spills, and wipe any fuel off that spills around the vehicle fuel filling port.

• Hoses, seals, & gaskets – All rubber components should be replaced with biodiesel compatible elastomer materials.
  – Not generally an issue for biodiesel blends of B20 and less.
  – For blends from B20 to B100, Viton is the generally recommended elastomer material, though others have also been shown to work
  – Alternating use of biodiesel and diesel fuel can cause leaking gaskets (shrinking and swelling).

• Metals - brass & copper fuel system components may be a concern.
Cold Weather Performance

Biodiesel will begin to freeze ("cloud point" and "pour point") at relatively high temperatures, depending on the feedstock and the blend level.

– In Western NC, B100 from UCO is fine during non-winter months, and blends ≤ B50 may be used during the winter months to avoid problems.

Table 5. Cold Flow Data for Various B100 Fuels\textsuperscript{15}

<table>
<thead>
<tr>
<th>Test Method for B100 Fuel</th>
<th>Cloud Point (ASTM D2500)</th>
<th>Pour Point (ASTM D97)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(°F)</td>
<td>(°C)</td>
</tr>
<tr>
<td>Soy Methyl Ester</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>Canola Methyl Ester</td>
<td>26</td>
<td>-3</td>
</tr>
<tr>
<td>Lard Methyl Ester</td>
<td>56</td>
<td>13</td>
</tr>
<tr>
<td>Edible Tallow Methyl Ester</td>
<td>66</td>
<td>19</td>
</tr>
<tr>
<td>Inedible Tallow Methyl Ester</td>
<td>61</td>
<td>16</td>
</tr>
<tr>
<td>Yellow Grease 1 Methyl Ester</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Yellow Grease 2 Methyl Ester</td>
<td>46</td>
<td>8</td>
</tr>
</tbody>
</table>

Source: NREL Biodiesel Handling & Use Guide, 4\textsuperscript{th} Edition
Biodiesel Shelf Life

Biodiesel is less stable than diesel fuel, and needs to be used more quickly

– Biodiesel should normally be used within 6 months.
  • Never store more than one year, unless specific storage precautions are taken.
– Storage is best in a cool, low moisture vessel, shaded from direct sunlight.
– Keep the storage tank as full as possible.
– Recommended to use biocide and a tank vent desiccant.
Biodiesel has a lower energy content than diesel fuel:

- Soy biodiesel has 12.5% less energy than diesel per pound. However, biodiesel is slightly denser than diesel, so when measured by volume biodiesel contains just 8% less energy.

- Improved combustion due its higher cetane number and superior lubricity of biodiesel make up for loss in energy content.

- Most drivers will not notice any power or mileage loss due to use of biodiesel (even B100), though very minor loss is theoretically possible.

<table>
<thead>
<tr>
<th></th>
<th>Btu/lb</th>
<th>Btu/gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2 Diesel</td>
<td>18,300</td>
<td>129,050</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>16,000</td>
<td>118,170</td>
</tr>
<tr>
<td></td>
<td>(12.5% less)</td>
<td>(8.5% less)</td>
</tr>
</tbody>
</table>
Biodiesel Quality

**ASTM D 6751 Standards**

- Fuel quality is critical for proper functioning
- Standards ensure satisfactory operation in diesel engines

**BQ 9000 Certification**

- Certifies biodiesel producers and marketers
- Provides confidence in biodiesel quality for:
  - Biodiesel Producers
  - Engine and Vehicle Manufacturers
  - Distributors
  - Consumers
Certificate of Analysis

• Provides consumers with the assurance that the fuel they are purchasing meets ASTM standards set for biodiesel.

• Should clearly state each test performed on fuel being sold by producer.

• Failure of any quality control test should prevent the sale of fuel for on-road use.

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Engine Warranties

• Most engine manufacturers have agreed to warranty vehicles for use up to B20.
  – Some (e.g. Daimler-VW) still only officially allow up to B5.

• Magnuson-Moss Warranty Act is a federal law protecting consumers from deceptive warranty practices, however if you are using a biodiesel blend over the allowed amount, and you have a fuel system failure, the dealership may choose not to cover the repair under your warranty, especially if it is difficult to determine the specific reason for the fuel system problem.

• More details on biodiesel and engine warranties can be found on the National Biodiesel Board website.
Upcoming technologies

RENEWABLE DIESEL AND GASOLINE
CELLULOSIC ETHANOL
ALGAE-DERIVED FUELS

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Cellulosic Ethanol

• Ethanol production from cellulosic plant material
  – Enzymatic and thermochemical pathways
• First commercial plant in the USA was Ineos Bio (Vero Beach, FL). Yard Waste. Still in commissioning (over 1 year).
• Poet, Abengoa, and Dupont all in final stages of construction. Planned to come online in the next six months.
• Chemtex had one of the first plants globally to go online, in Crescentino, Italy. Next plant planned for eastern NC.
Cellulosic Feedstocks

- Corn Stover and other Agricultural Residues
- Forestry Residues and Thinnings
- Perennial Grasses (Miscanthus, Switchgrass, Big Blue Stem)
- Other (Arundo Donax, etc...)
Renewable Diesel

- “R-Diesel” became a commercial reality around 2011.
- Main technology providers: UOP, Syntroleum, Neste Oil
- Neste has three plants online outside of the USA: (Two plants in Europe and one in SE Asia)
- Dynamic = Syntroleum + Tyson JV, recently became **REG Geismer** (75 MMGY, Geismar, LA)
- Diamond Green Diesel = JV Between Valero and Darling, UOP technology (142 MMGY, Narco, LA)
  - ~11% of the USA’s used cooking oils and animal fats will be processed at the facility
- In June 2013 the NBB agreed to allow Renewable Diesel producers into its membership
SUSTAINABILITY ISSUES FOR BIOFUELS
Greenhouse Gas Emissions

GHG emissions of biofuels may be listed in absolute terms – “Carbon Intensity” or relative to the fossil fuel they replace (diesel / biodiesel & gasoline / ethanol).
- Units: Absolute – g CO2 eq/megajoule; Relative – XX % of fossil fuel comparator

Different types of biofuels & feedstocks have very different carbon characteristics.

Different regions of the world have different fossil fuels that are being replaced.

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>CO2 (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>92.0</td>
</tr>
<tr>
<td>Diesel</td>
<td>92.5</td>
</tr>
<tr>
<td>Jet Fuel</td>
<td>89.9</td>
</tr>
</tbody>
</table>

*2005 National Fossil Fuel Baselines in USA (NETL, 2009)*

(kg CO2 / MMBtu LHV fuel consumed)
Fossil Fuel Baselines in USA

CO₂ Emissions (kg CO₂/MMBtu LHV fuel consumed)

- Conventional Gasoline
- Conventional Diesel
- Kerosene-Based Jet Fuel

LC Stage #1: Raw Material Acquisition
- Conventional Gasoline: 5.1
- Conventional Diesel: 4.5
- Kerosene-Based Jet Fuel: 4.7

LC Stage #2: Raw Material Transport
- Conventional Gasoline: 1.5
- Conventional Diesel: 1.3
- Kerosene-Based Jet Fuel: 1.4

LC Stage #3: Liquid Fuels Production
- Conventional Gasoline: 9.4
- Conventional Diesel: 9.2
- Kerosene-Based Jet Fuel: 5.8

LC Stage #4: Product Transport and Refueling
- Conventional Gasoline: 0.9
- Conventional Diesel: 0.8
- Kerosene-Based Jet Fuel: 0.9

LC Stage #5: Vehicle / Aircraft Operation
- Conventional Gasoline: 75.0
- Conventional Diesel: 76.6
- Kerosene-Based Jet Fuel: 77.1

Total Well-to-Wheels
- Conventional Gasoline: 92.0
- Conventional Diesel: 92.5
- Kerosene-Based Jet Fuel: 89.9
## Greenhouse Gas Emissions
### CAL-GREET Model

<table>
<thead>
<tr>
<th>Biofuel Pathway</th>
<th>Direct Emissions</th>
<th>Indirect Effects (e.g. iLUC)</th>
<th>Total</th>
<th>Fossil Fuel Baseline</th>
<th>% Emission Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean Biodiesel</td>
<td>21.25</td>
<td>62</td>
<td>83.25</td>
<td>98.03</td>
<td>15%</td>
</tr>
<tr>
<td>UCO Biodiesel</td>
<td>15.84</td>
<td>0</td>
<td>15.84</td>
<td>98.03</td>
<td>84%</td>
</tr>
<tr>
<td>Corn Ethanol</td>
<td>65.66</td>
<td>30</td>
<td>95.66</td>
<td>99.18</td>
<td>3.5%</td>
</tr>
<tr>
<td>Sugarcane Ethanol</td>
<td>27.40</td>
<td>46</td>
<td>73.40</td>
<td>99.18</td>
<td>26%</td>
</tr>
</tbody>
</table>

Based on default values from Cal GREET
Credit: California Air Resources Board
Indirect Land Use Change (iLUC)

- Biofuels have been beneficial to agricultural commodity prices, helping raise prices for both corn and soybeans in the USA.
- Agricultural commodities are fungible – price changes in a commodity affect other types.
- As agricultural prices in one part of the world increase, farmers in other parts of the world are encouraged to clear more land and plant more crops.

This phenomena is known as: “Indirect Land Use Change” or “iLUC”
Crop Expansion & Food vs. Fuel

- Economics dictate that high agricultural prices will cause one of three things to happen: (1) **Expansion**: farmers expand into new lands, (2) **Intensification**: farmers become more efficient, or (3) **Reduced demand**: Higher prices cause demand to decrease.

- Crop expansion (1) is the manifestation of indirect land use change, whereby new lands are cleared in other parts of the world.
  - Because GHG emissions is a global phenomena, land clearing in SE Asia releases carbon that impacts all of mankind

- Reduced demand (3) is one manifestation of food vs. fuel, whereby those in the world who spend the largest percentage of their income on food are forced to reduce consumption due to high agricultural prices.
A FINAL WORD...
...Conservation

It’s important to remember that while sustainable biofuels are a better option than petroleum diesel; the use of less natural resources is ultimately the right answer.

As the population increases, the demand for natural resources will also rise. Conservation and efficiency are a must for our society to continue enjoying the quality of life we have come to know.

Conserve First: The only thing better than using biofuel is not using any fuel at all.