

Perspectives on Biodiesel Use in Off-Road Transportation



GE Transportation

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Engine Engineering



a product of
ecomagination

Topics of discussion

- ❖ **GE**
- ❖ **Market drivers**
- ❖ **Alternative fuel focus**
- ❖ **Biodiesel... a typical engine program**
- ❖ **Close**





. . . a history of innovation

Founded in 1878 as the Edison Electric Co.

127 years of successful operation... only remaining company from original Dow Jones Index in 1896



320,000 employees worldwide

Research centers in Germany, India, China, U.S.



Six business segments



GE Commercial Finance



GE Industrial



GE Consumer Finance



GE Healthcare



GE Infrastructure



NBC Universal



ecomaginationSM



Grow revenues to \$20B by 2010 ... 12% CAGR

Double R&D to \$1.5B

45+ eco-products and counting

Reduce emissions/fuel

Inform public



Sustainable Energy

Developing new ways to power an energy-hungry, eco-conscious world

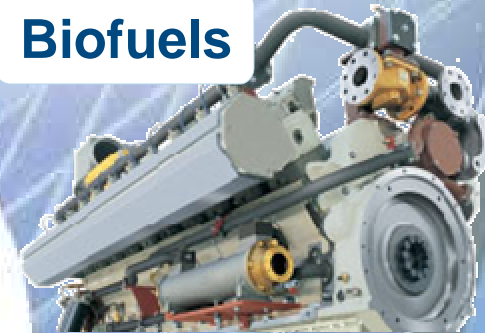
Solar



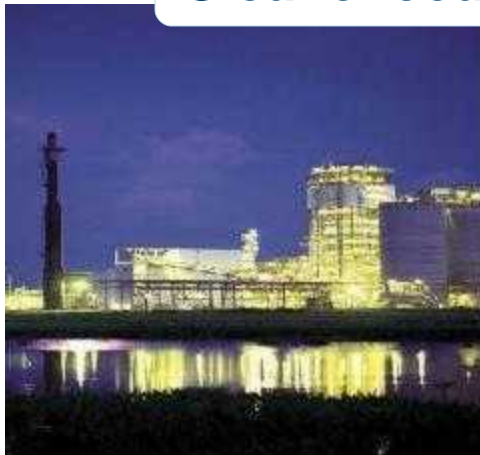
Wind



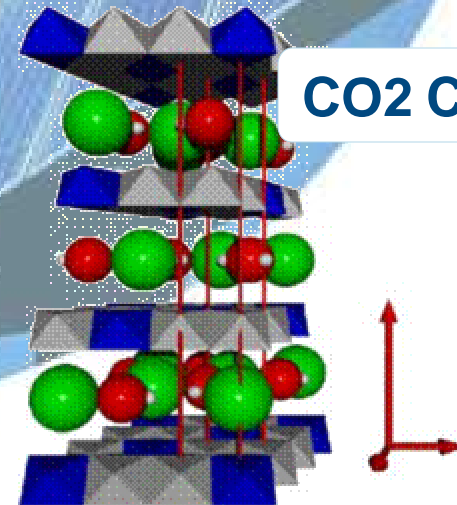
Biofuels



Cleaner coal



CO2 Capture



Green technology in the market

“Evolution Series®” Locomotive



Common Control Architecture



Advanced Cooling System



GEVO 12 Engine

Reduced fuel consumption AND reduced emissions

- 40% lower emissions compared to existing locomotives
- 3% better fuel efficiency - Saves over 9,000 gallons of fuel per locomotive per year*
- 2,200+ Backlog, ~1,500 Shipped in <3yrs on market



*Assumes average of 300,000 gallons of fuel consumption per year



Topics of discussion

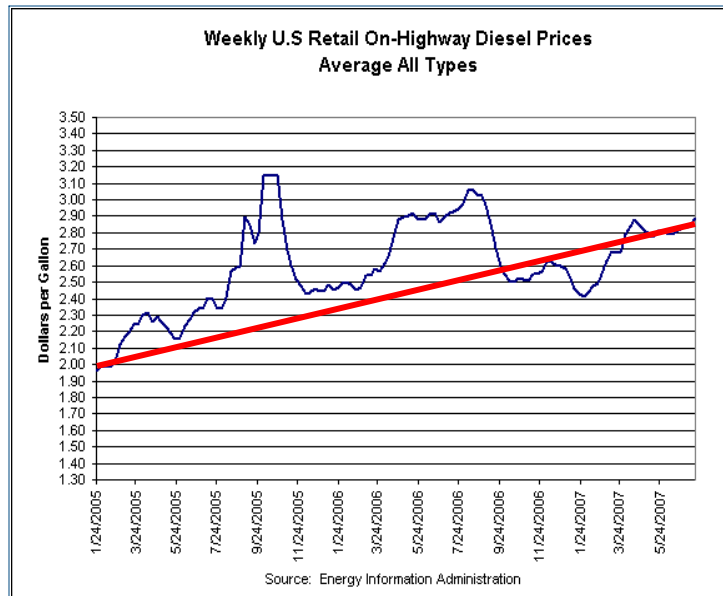
- ❖ GE

- ❖ **Market drivers**



Why the focus on fuel

Cost



Emissions

- Next Tier loco regulation...
- PM & NOx. . .
- Aftertreatment forcing . . . Potential fuel impact
- States & municipalities taking a more active role



Security, sustainability and survival

- Energy/fuel supplies now considered a “National Security” issue
- “Renewable” fuels slow consumption of capacity-limited fossil fuels
- Global warming and greenhouse gases linked



Topics of discussion

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❖ Market drivers

❖ **Alternative fuel focus**



GE Infrastructure – a \$40B engine business

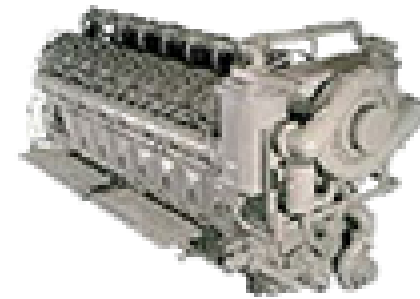
GE Energy

Power Gas Turbines



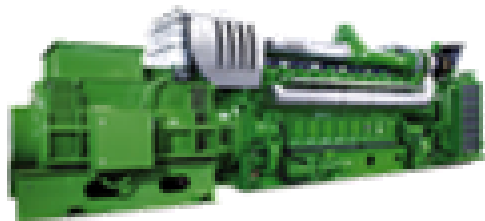
GE Transportation

Diesel Engines – Locomotive, Marine, Power, Mechanical Drive



GE Jenbacher

Gas Engines - Gensets



GE Aviation

Aircraft Gas Turbines
Aeroderivative Engines



Broad GE alternative fuel focus



GE Energy

- Gas turbine – expand fuel variation capability
- Gas turbine rapeseed biodiesel characterization: performance, operability
- Gas engine fuel capability: landfill, blast furnace, ag waste gases...
- IGCC/H₂ gas turbine – coal derived syngas



GE GRC

- Hydrogen fuel: production, storage and utilization
- Fuel conversion.... Coal to liquids - automotive
- CO₂ separation/sequestration
- Fuel blending



GE Aviation

- Flight demo on blended biofuel.
- GE/Snecma ground demo on a 30/70 blend of a biofuel.
- GE developing a bio-JP8 fuel

Alternative “jet fuels” in the near future (2010) are expected to be “drop-in replacement” (will have to meet current specs)



GE Transportation

- Bio-fuel – GEVO engine running raw palm oil
- Loco Bio-diesel – two phase program to determine performance and durability
- Coal-to-liquid fuel performance characterized
- Expanding to dual fuel (liquid/gas) operation



Over \$100MM investment



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- ❖ **Biodiesel**



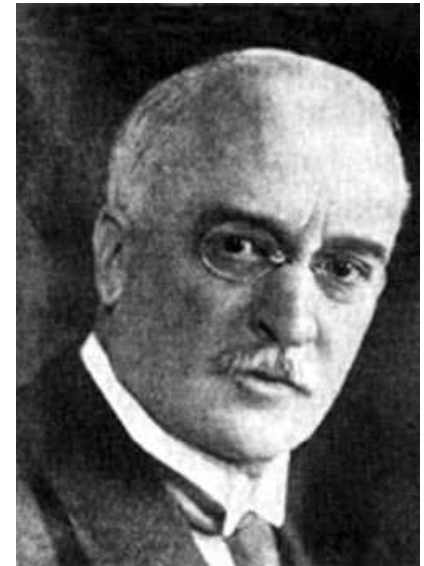
The new(?) science of biofuels and diesel engines

1893: Rudolph Diesel invents the compression ignition engine

1900: Diesel uses peanut oil as a fuel when demonstrating the engine at the Paris World's Fair

1912: In a speech, Diesel says: **“The use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the use of time, as important as petroleum and the coal-tar products of the present time”**

1913: Diesel disappears mysteriously after dining on a steamboat. His body is found floating in the English channel.



Creating/producing alternative fuels . . . only half the challenge



updated: 8/21/2007 4:35:03 PM
[UPDATED] Soybean Processing, Biofuels Plant Opens in Northern Indiana
InsideIndianaBusiness.com Report

The world's largest soybean processing and biofuels plant officially opened this morning in northern Indiana in Claypool. Louis Dreyfus Commodities says when fully operational, the facility will buy about \$450 million in soybeans from Indiana farmers annually and will use about 50 million bushels of soybeans per year. The plant will also employ about 70 workers.

Source: Inside Indiana Business

The plant can produce over 88 million gallons of soybean-based biodiesel annually.

Biodiesel plant opens in Michigan

08/15/07, 03:42pm, EDT



Although Detroit [automakers](#) aren't world-renown for being the greenest car companies on the planet, the state of Michigan is taking major steps to change this perception. Just yesterday, a group of West Bloomfield investors opened a \$20 million NextDiesel plant, which produces biodiesel from animal fats and soybean oil.

Biodiesel plants (large)

Bulk of the funding is going to only half of the issue

- **\$450M** USDA 2003-2006 for biofuels development
- **\$800M** House Farm Bill 2008-2012 Biorefinery Finance Program
- **\$420M** House Farm Bill 2008-2012 Bio Fuels/Chemicals Research Program
- **\$1.4B** House Farm Bill 2008-2012 incentive for biofuels development
- **\$200M** DOE Providing 2008-2012 Funding for Biorefineries
- **\$33.8M** DOE Providing 2008-2012 Funding for bio-refinery enzymes
- Etc . . .



The engine is the 2nd half of the challenge

Developing engines capable of effectively & reliably utilizing these fuels *has been neglected*

Reinforcing the need to focus on both halves of the challenge:

- 2005: Minnesota law imposing 2% biodiesel blend
- Within weeks of introduction, trucking companies experienced problems
- Clogged filters, sluggish performance cold weather shutdowns
- The law was temporarily suspended pending further examination
- Minnesota now pushing to achieve 20% biodiesel blend by 2015



Biodiesel breakdown

Trucking companies report engine problems after switching to blended fuel

By RICK BARRETT
rbarrett@journalsentinel.com

Posted: Jan. 7, 2006

Only days after a Wisconsin trucking firm switched to biodiesel fuel, its trucks started breaking down on the road.

Trucking Headlines

Minnesota boosts biodiesel initiative to 20%

By eTrucker Staff

Minnesota Gov. Tim Pawlenty recently unveiled a schedule for taking the state's biodiesel requirement from B2 to B20 over the next eight years. Designed to boost the level of biodiesel sold in Minnesota from the current 2 percent to 20 percent by 2015, Pawlenty says he would bring this plan to the Legislature during the regular 2008 session.

Biodiesel – engine builder's perspective

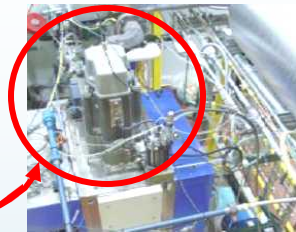
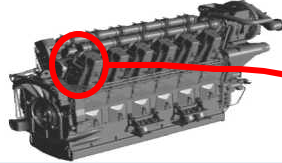
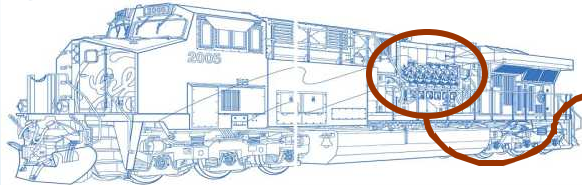
- For a variety of reasons, Biodiesel use will increase in all regions but there is no internationally adopted standard
- Engine Builders and Fuel System Suppliers currently restrict the use of biodiesel during warranty periods
- Biodiesel more likely to stay in the crankcase as fuel dilution - oxidation leads to higher levels of deposits and lead corrosion
- Biodiesel is less stable than #2 diesel – can suffer in cold weather
- Performance additives can potentially offset some of the impact of biodiesel use
- Engine testing is needed to determine safe and appropriate biodiesel use levels



Delivering fuel flexibility

GE fuels development strategy

Single cylinder research engine... *(performance)*



Stationary engine fuels testbed... *(durability)*



Locomotive alternate fuels testing... *(operability)*



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Alternative fuels projects

Locomotive Testing:

- Soy Methyl Ester – SME
- B2, B10, B20 and B100 levels evaluated
- 100+ hrs multi-cylinder engine operation
- Performance
 - Thermal efficiency not measurably different
 - NOx trends ↑ while THC, CO and PM trend ↓ with increasing bio concentration



Where will biodiesel make an impact

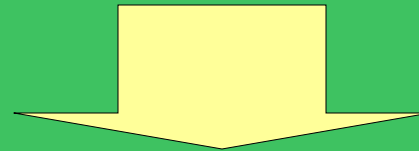
US Diesel fuel consumption....

63B gallons/yr: US total

40B gallons/yr: On-highway

4B gallons/yr: RR's

← *A unique market for biodiesel introduction*



- ❖ Captive service – 6 major RR's
- ❖ Focused fuel depots
- ❖ Strong connection to Ag industry



Loco Biodiesel validation– Phase #1

Performance impact validation

- Quantify impact on HP, fuel efficiency & emissions
- Engines tested on locomotives
 - GEVO (ES44AC / ES44DC)
- Fuels tested
 - Various blends - B20, B10, B5, B2
 - Various base fuels - S5000, S500 & S15
- Data collected
 - Fuel
 - Emissions . . . NOx, PM, HC, CO & CO₂
 - Various cylinder, turbo, exhaust, fuel & oil pressure & temperature
- Test conducted at independent lab . . . Southwest Research Institute

~6 months
and \$0.5MM

Performance, emissions understood



Loco Biodiesel validation - Phase #2

In house validation

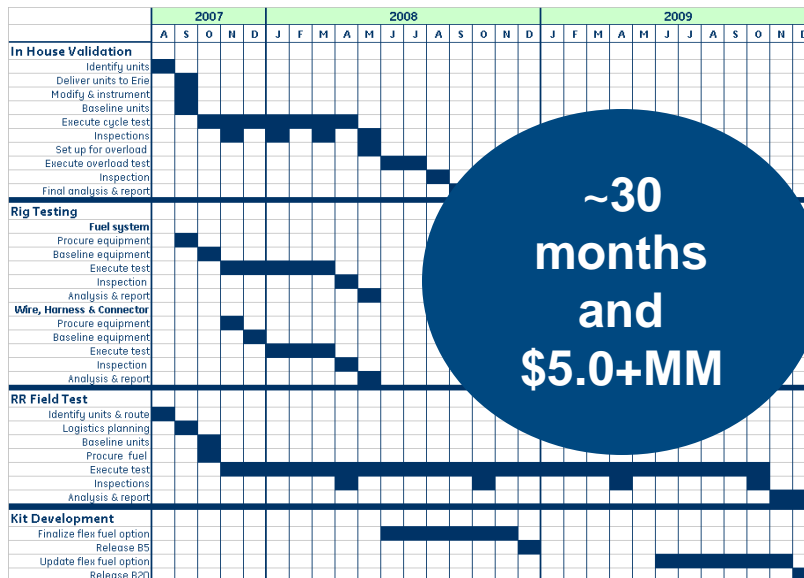
- Operation in controlled lab
- Validating wear, deposits & fouling

Rig testing

- Conducted at fuel system supplier
- Validate wear, cavitation & deposits

Railroad field test

- Burn fuel under actual RR conditions
- Validating deposits, fouling & intangibles



~30 months and \$5.0+MM

Likely developments:

- New oil additive
- Water separator
- Fuel filter
- Fuel temp. control
- Altered timing
- Fuel sensor
- Maintenance practice



Alternative fuels projects

Stationary Testing:

- RBD Palm Oil – Refined Bleached and Deodorized
- 125 hrs multi-cylinder engine perform
- 400+ hrs single cylinder operation
- Performance as Expected
 - Thermal efficiency not measurably different
 - NOx trends h while THC, CO and PM trend i



Final thoughts

- Biodiesel clearly receiving attention for political, environmental and economic reasons..GE wants to lead in markets we play
- Significant investment for biodiesel production, little for utilization
- Railroad industry is a noteworthy proving ground for biodiesel fuel use

The Positives

Captive service - targeted fuel depots
Strong connection with agriculture industry... RR's want to support their customers

The Negatives

One of the most reliability conscious industries around
Slow fleet turnover – the old stuff has to work too

Economic justification a struggle... need more aggressive public/private partnership approaches to deliver with speed



imagination at work