Alternatives to Petroleum Based Fuel for Marine Vessels

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RESEARCH QUESTIONS:
Comparing petro-diesel and biodiesel . . .

What kind of performance do you get when you use biodiesel and blends?	Pope
What are the operational issues associated with using biodiesel and blends?	Pope
What biodiesel production process improvements are needed?	Hasan
What are current and projected supply and demand for biodiesel production?	Skurla
What will be the economic impact of using more biodiesel fuel in maritime commerce?	Skurla

Why use biodiesel?

- Renewable energy
  - Energy Balance Ratio of at least 2.5:1
- Can be used in current diesel engines
- Similar energy content to diesel
  - Little impact on performance
- Better lubricity than diesel
  - Compensate for Ultra Low Sulfur Diesel (ULSD)

Why use biodiesel?

- Reduced emissions
  - EPA National Clean Diesel Campaign
    - EPA Clean Ports USA Program
- Can use current distribution infrastructure
  - Some modifications for cold weather
- Biodegrades faster than diesel
- Legal mandates and incentives
- Price stability

FINDINGS:
Engine test data

For operational issues associated with using biodiesel and blends . . .

- Power and torque comparable, better emissions
- Cold weather recommendations:
  - Same as #2 diesel (heated fuel lines, blended with petro, additives)
- Engine conversion issues:
  - Synthetic hoses and seals

Maritime Usage:

- Main propulsion on some vessels
  - EMD engines
- Electrical power
  - Diesel generator sets
  - Emergency generator

Maritime Usage

- Auxiliaries
  - e.g. Crane

- General observations
  - Systems vary from ship to ship
  - Some systems exposed to external environment (deck crane)
  - Fuel turnover is rapid during shipping season
  - Two-month winter lay-up period:
    long-term fuel storage concern

Long-Term Storage of Fuel

Stability

- Refers to thermal stability (current tests)
  - "Long" time at elevated temperature → fuel degrades

- Winter → biodiesel blend at low temperatures
  - Does blend separate → gelling of biodiesel

Microbial Growth

- More rapid at elevated temperatures
  - ***May*** not be a concern during winter lay up

- Can clog fuel filters

FINDINGS:
Process enhancement

Studied catalysts for the production process

- Found a better one: lipase - biocatalyst
  - Allows better conversion, more quickly
  - But expensive, must be recycled
  - Recycling process is under investigation

Lipase

- Biocatalyst
  - Replaces base catalyst in current operation
- Producible in large quantities by microorganisms
- Highly selective in reaction setting
  - Minimal side reactions
- But expensive
  - Must be reusable

Immobilization Required

- Lipase immobilization
  - Carrier particles/fabrics
  - Allows for easy separation after reaction
  - Lipase shaken in solution with carrier particle to immobilize

Drawbacks

- Methanol hinders lipase activity
  - Typically after 3-5 batches considerable losses in conversion are noticed
- Expensive catalysts

Process Improvements

- Stepwise addition of methanol
  - Greatly decreases the enzyme hindering by the alcohol (enzyme stays active longer)

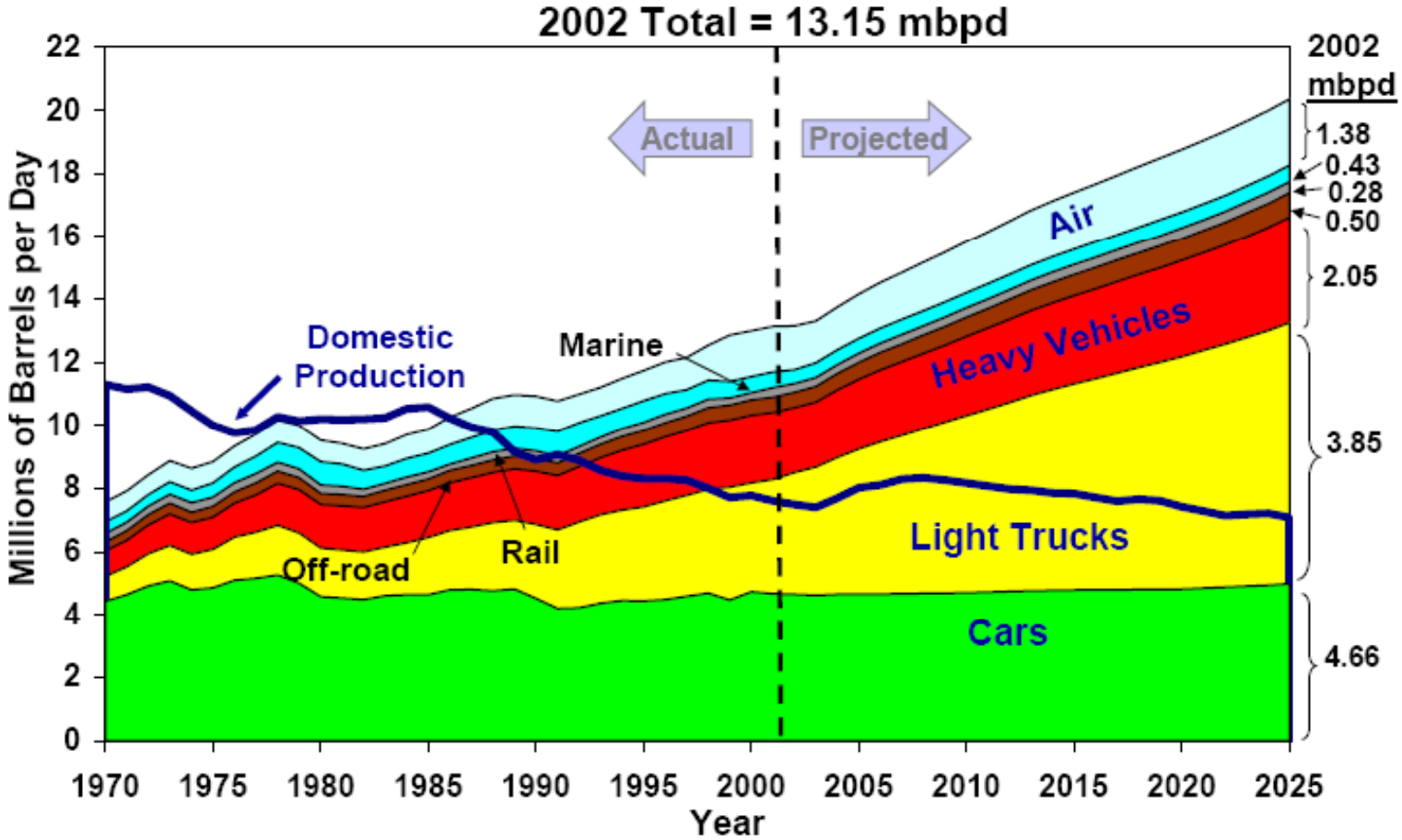
- Alternate alcohols considered
  - Instead of methanol, alternative primary alcohols may have less hindering of enzyme and higher conversion

- Glycerol adsorption
  - Higher % conversion

FINDINGS:

U.S. marine petroleum demand:

[approx. .43 mbpd; or 157 mb per year in 2002]



Source: Transportation Energy Data Book: Edition 23, DOE/ORNL-6970, October 2003, and EIA Annual Energy Outlook 2003, January 2004

FINDINGS: Great Lakes marine biodiesel demand and supply:

Table 3.7: Great Lakes States Soybean Production and Price Trends for Maritime Use 2005

Year	GL State	Production *(thousands of bushels)*	Gallons possible from 2005 GL soybean production (thousands of gallons)*	**Gallons forecast to satisfy 2005 Great Lakes maritime demand**
2005	Illinois	439,425	615,195	**54,058**
2005	Indiana	263,620	369,068	**32,430**
2005	Michigan	76,615	107,261	**9,425**
2005	Minnesota	306,000	428,400	**37,644**
2005	New York	7,896	11,054	**971**
2005	Ohio	201,600	282,240	**24,801**
2005	Pennsylvania	17,220	24,108	**2,118**
2005	Wisconsin	69,520	97,328	**8,552**
				170,000
2005	Totals	1,381,896	1,934,654	

According to the US Department of Agriculture's (USDA) Farm Service Agency, one bushel of soybeans yields approximately 1.4 gallons of biodiesel.
Source: USDA - National Agricultural Statistics Service; NASS - Data and Statistics - Quick Stats.
See: www.nass.usda.gov/Data_and_Statistics/Quick_Stats/; UMD BBER

FINDINGS:
Economic impact

Data show that there was domestic demand for 2.1 billion gallons of distillate fuel oil for vessel bunkering in 2004.

How quickly vessels will convert to biodiesel is unknowable, but some of this demand could be supplied by increased biodiesel production.

To meet this increased demand a new Great Lakes Biodiesel Plant, of typical production capacity of 30 million gallons per year, should be feasible.

FINDINGS:
Economic impact

Table 4.9: Great Lakes Biodiesel Plant Construction Totals Impact Comparisons, U.S., Great Lakes Region (2005 dollars); Year 1, Year 2

Source: IMPLAN

	Year	*1*	*2*	*Total*
United States	*Value Added Totals*	$33,169,760	$16,809,880	$49,979,640
	Employment Totals	529	265	NA
	Output Totals	$65,410,434	$32,705,217	$98,115,651
Great Lakes	*Value Added Totals*	$22,606,772	$11,303,386	$33,910,158
	Employment Totals	365	182	NA
	Output Totals	$43,003,008	$21,501,504	$64,504,513

Table 4.10: Great Lakes Biodiesel Plant Operation Totals Impact Comparisons, U.S., Great Lakes Region (2005 dollars); Typical Year

Source: IMPLAN	*Value Added*	*Employment*	*Output*
United States	$61,545,932	845	$181,918,066
Great Lakes	$20,187,559	231	$79,035,226

Further economic research: Risks and incentives

- Risks include market for by-product glycerin
- Incentives will be studied in cost benefit analysis:
  - Government incentives, federal and state
  - Tradable Discharge Permits
    - Total emission target
    - Distribution of permit/credits (historical, auction, etc.)
    - Trading mechanisms
    - Examples of "Cap-And-Trade" Programs (CAP)
      - SO_2 emissions (1990 Clean Air Act Amendments)
      - NO_x emissions (Ozone Transport Committee)
      - VOM (Volatile Organic Material) emissions (Chicago)

CONCLUSIONS

- Biodiesel production
  - Process improvement, lipase catalyst

Hasan

- Engine performance
  - Operational issues

Pope

- Economics
  - Future market growth
  - More production facilities required
  - Facilities will have large economic impact

Skurla

RECOMMENDATIONS:
Future Research

- Fuel storage during winter lay up
  - Cold storage stability test

- Focused cost benefit analysis of maritime commerce incentives
  - Carbon credit trading market modeling
  - Feasibility, business plan for biodiesel plant for maritime commerce supply