Alternate Energy Research and Technology Challenges in the New Millennium

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Washington, DC 20375
**Alternate Energy Research and Technology Challenges in the New Millennium**

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- **c. This Page:** unclassified

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Global Issues

- Energy
- Water
- Environment
When asked shortly after WWII:

“Prof Einstein, what do you see as the greatest threat to mankind?”

His prompt reply:

“Exponential growth.”
Future of Energy After Oil
The Problem
The ENERGY REVOLUTION (The Terawatt Challenge)

Sources of Energy Supply - Worldwide

2002

13 Terawatts

Source: International Energy Agency
Setting the Stage: A Global Overview

• Consider in 1900 less than 1 million barrels of oil per day vs. today at 85 million barrels per day

• “Optimistic case for output of 100 million barrels per day could outstrip supply before 2020”
  C. de Margerie, TOTAL

• “By 2010 nearly 40% of the world’s daily oil output will have to come from the fields that have not been tapped or even discovered.”
  J. Mulva, ConocoPhillips

• “By 2015 we need to find, develop and produce new oil that is equal to 8 out of 10 bbl being produced today.” President Exxon Mobil 2003
Crude Oil Production in the Lower 48

- Discovery
- Production
- Consumption

M. King Hubbert, 1956
Deffeyes, Hubbert’s Peak, 2001
World Proven Oil Reserves

Proven Oil Reserves (2000)

Saudi Arabia 25%

USA 3%

Mexico 3%

China 3%

Libya 2%

Nigeria 2%

Qatar 1%

Venezuela 8%

Iran 9%

Kuwait 9%

Russia 5%

UAE 10%

Iraq 11%

Other 9%
Depletion of Oil Reserves

World oil reserves accumulated since 1930 are now being depleted. Industrial growth in Asia will accelerate the depletion.

The Coming Oil Crisis, Colin J. Campbell
Alternatives (Renewables and nonrenewables)

- **Conservation / Efficiency** -- not enough

  **Renewables**
  - Biomass -- large land mass, cost?, aviation?
  - Hydrogen -- cost? safety? Beyond horizon for large scale use
  - Wind -- commercial, not enough
  - Nuclear Fusion -- technology challenges, cost? Beyond horizon
  - Solar terrestrial -- commercial, large land mass, cost?
  - Geothermal -- not enough
  - Wave -- not enough, coastal issues
  - Ocean thermal -- confined to tropical / equatorial regions, cost?
  - Hydroelectric -- not enough
  - Synthetic fuel -- technology challenges

  **Non Renewables**
  - Clean Coal / CTL -- sequestration?, cost?
  - Nuclear Fission -- radioactive waste?, cost??
  - Natural Gas -- resource and usage limits
  - Oil shale -- Technology? Environment? Cost?
  - High energy density fuel -- research challenges
  - Methane Hydrates -- clean and in abundance

  • Potential candidates for Navy / DOD
Biomass: A Potential Renewable Energy Source
• The oldest known energy source since the discovery of fire

• World’s 4th largest energy source (47 quads/year; 13.6x10^{15} watt hr; 47x10^{15} BTU)

• Domestic Biomass Source for Energy
  • Agricultural Waste
  • Forestry Waste
  • Municipal Solid and Industrial Waste
  • Energy Crops (Grown for Fuel)

• Goals for Energy Contribution from Biomass by 2020 (NREL/DOE)
  • 10% Transportation Fuels
  • 5% Electric Power Production
  • 18% Chemicals and Materials

Robert Armstrong, NDU Report
Range in Biofuel Production

<table>
<thead>
<tr>
<th>Feed Stock</th>
<th>~ Gal Oil / Acre / Yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>350</td>
</tr>
<tr>
<td>Soybeans</td>
<td>48</td>
</tr>
<tr>
<td>Safflower</td>
<td>83</td>
</tr>
<tr>
<td>Sunflower</td>
<td>102</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>127</td>
</tr>
<tr>
<td>Oil Palm</td>
<td>635 (2 crops)</td>
</tr>
<tr>
<td>Sugar Cane</td>
<td>662 (2 crops)</td>
</tr>
<tr>
<td>Cassava</td>
<td>410</td>
</tr>
<tr>
<td>Sweet Sorghum</td>
<td>374</td>
</tr>
<tr>
<td>Algae*</td>
<td>1000-5000**</td>
</tr>
<tr>
<td>Camelina*</td>
<td>75-100</td>
</tr>
<tr>
<td>Cyanobacteria*</td>
<td>700?</td>
</tr>
<tr>
<td>Jatropha*</td>
<td>125</td>
</tr>
<tr>
<td>Switchgrass*</td>
<td>Low?</td>
</tr>
</tbody>
</table>

A comprehensive study is needed to evaluate investment, production, cost and future implications

*Non food crops
** requires massive CO₂ injection for higher gallon number
Alternate renewable fuels
From biomass
(diesels & alcohols)

### Feedstocks
- **Algae**
- **Vegetable Oils**
- **Animal Fat** (Conoco Philips and Tyson Foods) (Neste Oil)
- **Multiple Biomass** (Municipal Waste)
- **Corn / Sugar Cane**

### Processes
- **Esterification** (methanol, Strong Base)
  \[ \text{CH}_3\text{OH} + \text{NaOH} \]
- **Hydro-treating** (Hydrogen)
- **Biomass to Liquid** (BTL Gasification) (formation of syngas)
- **Hydrolysis/ Fermentation**

### Products
- **Biodiesel**
  Fatty Acid Methyl Ester (FAME)
- **Green diesel**
- **Fischer-Tropsch (FT)** diesel
- **Ethanol/C2+ Alcohols**

### Problems
- **Stability** (microbial, emulsions, solvation)
- **Stability** (Meet Navy Specifications??)
- **Navy Specification Testing**
- **Navy Specifications** (Flashpoint, Energy Density)
Demonstration of Biofouling in a Diesel Fuel/Water Mixture
Biodiesel provides carbon source for microbial growth resulting in sulfide production and corrosion.

<table>
<thead>
<tr>
<th>Biodiesel</th>
<th>Persian Gulf SW</th>
<th>Carbon Steel Coupon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sterilized Persian Gulf Seawater + Biodiesel</td>
<td>Natural Persian Gulf Seawater + Biodiesel</td>
<td>Natural Persian Gulf Seawater</td>
</tr>
</tbody>
</table>
Hydrocarbon Yields from Corn / Sugar cane
Gasoline Gallon Equivalent

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>BTUs/gal</th>
<th>Gal. Equivalent</th>
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</thead>
<tbody>
<tr>
<td>Gasoline, regular unleaded</td>
<td>114,100</td>
<td>1.00</td>
</tr>
<tr>
<td>Diesel (typical)</td>
<td>129,800</td>
<td>0.88</td>
</tr>
<tr>
<td>Methanol</td>
<td>56,800</td>
<td>2.01</td>
</tr>
<tr>
<td>Ethanol</td>
<td>76,100</td>
<td>1.50</td>
</tr>
</tbody>
</table>

• Low energy density
• Low flash point
• Hygroscopic
• Energy Input exceeds output
• Unsuitable for naval use
Switchgrass to Ethanol

• A perennial grass native to the Great Plains
• Grows in marginal land
• Needs seeding once / decade
• Cultivation requires fertilizers (~ 100 lbs N / acre) and irrigation
• Low yield in marginal land
• Needs higher cost enzymes for bioreactors, cost / gal about that for corn