The Potential for Alternative, Sustainable Energy

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Presentation Outline

• **Energy Usage/Demand**
  – United States Energy Use by Sector and Type
  – Global Energy Use

• **Future Projections of Energy Usage**
  – Global Demand
  – US Resources Available

• **Alternative Energy**
  – Sustainable Energy Pathways (without the hype)
  – Can US Meet Future Sustainable Energy Goals?
Estimated U.S. Energy Use in 2008: ~99.2 Quads

Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527
Figure 1.5 Energy Consumption and Expenditures Indicators

Energy Consumption, 1949-2007

Energy Expenditures, 1970-2005

Energy Consumption per Real Dollar\(^a\) of Gross Domestic Product, 1949-2007

Energy Consumption per Person, 1949-2007

Energy Expenditures per Person, 1970-2005

Energy Expenditures as Share of Gross Domestic Product, 1970-2005

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\(^1\) See “Nominal Dollars” in Glossary

\(^a\) In chained (2000) dollars, calculated by using gross domestic product implicit price deflators. See Appendix D1.

Source: Table 1.5.
U.S. Energy Consumption History and Outlook, 1949 - 2030

Includes petroleum-derived fuels and non-petroleum-derived fuels, such as ethanol and biodiesel.

Source:
US is world’s biggest oil consumer

Top World Oil Consumers, 2006

Million barrels per day

0 5 10 15 20 25

US

China

Japan

Russia, Germany, India

Canada, Brazil, South Korea, Saudi Arabia, Mexico, France, UK, Italy, Iran

US/Canada per capita oil consumption
> 22 barrels/year
Approximately 17 gallons/week (Tank full of fuel/week)

Source: BP statistical review of world energy, June 2007, p. 12
Middle East dominates world oil reserves

- Proved oil reserves by region, end-2006

Source: BP statistical review of world energy, June 2007
Salton Sea
Approximately 58 Billion Barrels of Oil
Approximately 2 Years Global Usage
Approximately Equivalent to US Oil Reserves
Global Carbon Footprint

- **World**: 8.00E+09 Population, 6.00E+09 Total Carbon Emissions
- **USA**: 7.00E+09 Population, 5.00E+09 Total Carbon Emissions
- **OECD**: 3.00E+09 Population, 2.00E+09 Total Carbon Emissions
- **Asia**: 0.00E+00 Population, 1.00E+09 Total Carbon Emissions

Legend:
- Population
- Total Carbon Emissions
World’s Perception of USA

- World Per Capita Carbon Emissions: 1
- USA Per Capita Carbon Emissions: 6
- OECD Per Capita Carbon Emissions: 4
- Asia Per Capita Carbon Emissions: 2

Per Capita Carbon Emissions
Watch out for China and India!

Vehicle fleet trends, 1980-2030: US, Japan, Germany, China, India

- Population growth combined with exponential motorization in China and India will dramatically increase vehicle fleet.

Sources:
United Nations, 2007, ESA, Population Division
International Monetary Fund, 2005, *World economic outlook*
Dargay et al. (2007)
150 more vehicles for every 550 Chinese

- Chinese motorization skyrockets from 1980-2030, while US motorization changes little.

**China**
- 553 to 3.7 Persons per vehicle

**United States**
- 1.4 to 1.1 Persons per vehicle

1980

2030
Sustainable Resources

Source: Lee Lynd, Dartmouth College

- Biomass: 47%
- Hydroelectric: 45%
- Nuclear: 8%
- Natural Gas: 23%
- Petroleum: 40%
- Coal: 23%
- Renewable: 6%
- Wind: 2%
- Solar: <1%
- Geothermal: 5%

Note: Total U.S. Energy Supply is 100.278 Qfut; Energy Information Administration, August 2005.
U.S. Biomass Resource Potentials

Over 1 billion tons/year of lignocellulosic biomass (trees, grasses, etc.) could be available in the U.S.

- Potential to displace 50-70% of our gasoline
  - Future – protein extraction from grasses to provide animal feed as well as energy

Corn (currently the largest volume grain and source of EtOH in U.S.)

- Potential to displace 10-20% of our gasoline

Soybeans, fats & greases (largest sources of biodiesel)

- Potential to displace 5-10% of our diesel

**Short-term:** improve cost and efficiency of corn ethanol & biodiesel
**Mid to Long-term:** focus on lignocellulose (trees, grasses, & residues)
Required Growth of Cellulosic Ethanol to Supply 30% of U.S. Gasoline Demand by 2030
Leading Biofuel Technology Options

**Near Term**

- **Ethanol** – as a blending agent from either grain or cellulosic material from Ag and/or Forestry industry
- **Biodiesel** – Transesterified vegetable oils blended with diesel
- **Green Diesel/Gasoline** – fats, waste oils, or virgin oils blended with crude oil as a feedstock for making low-sulfur diesel/gasoline in petroleum refinery
- **Pyrolysis Liquids** – as alternative feedstock to petroleum refinery or gasification facility, also a future source of aromatics and/or phenols
- **Synthesis Gas** – for conversion to Fischer Tropsch liquids, MeOH/DME, or mixed alcohols

**Long Term**

- **Algae** – as alternative source of triglycerides for biodiesel or green diesel
- **Alkanes** – from hydrogenation of carbohydrates, lignin, or triglycerides
Comparison of Microalgae with Other Biofuel Feedstocks

<table>
<thead>
<tr>
<th>Plant source</th>
<th>Seed oil content (% oil by wt in biomass)</th>
<th>Oil yield (L oil/ha year)</th>
<th>Land use (m² year/kg biodiesel)</th>
<th>Biodiesel productivity (kg biodiesel/ha year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn/Maize (Zea mays L.)</td>
<td>44</td>
<td>172</td>
<td>66</td>
<td>152</td>
</tr>
<tr>
<td>Hemp (Cannabis sativa L.)</td>
<td>33</td>
<td>363</td>
<td>31</td>
<td>321</td>
</tr>
<tr>
<td>Soybean (Glycine max L.)</td>
<td>18</td>
<td>636</td>
<td>18</td>
<td>562</td>
</tr>
<tr>
<td>Jatropha (Jatropha curcas L.)</td>
<td>28</td>
<td>741</td>
<td>15</td>
<td>656</td>
</tr>
<tr>
<td>Camelina (Camelina sativa L.)</td>
<td>42</td>
<td>915</td>
<td>12</td>
<td>809</td>
</tr>
<tr>
<td>Canola/Rapeseed (Brassica napus L.)</td>
<td>41</td>
<td>974</td>
<td>12</td>
<td>862</td>
</tr>
<tr>
<td>Sunflower (Helianthus annuus L.)</td>
<td>40</td>
<td>1070</td>
<td>11</td>
<td>946</td>
</tr>
<tr>
<td>Castor (Ricinus communis)</td>
<td>48</td>
<td>1307</td>
<td>9</td>
<td>1156</td>
</tr>
<tr>
<td>Palm oil (Elaeis guineensis)</td>
<td>36</td>
<td>5366</td>
<td>2</td>
<td>4747</td>
</tr>
<tr>
<td>Microalgae (low oil content)</td>
<td>30</td>
<td>58,700</td>
<td>0.2</td>
<td>51,927</td>
</tr>
<tr>
<td>Microalgae (medium oil content)</td>
<td>50</td>
<td>97,800</td>
<td>0.1</td>
<td>86,515</td>
</tr>
<tr>
<td>Microalgae (high oil content)</td>
<td>70</td>
<td>136,900</td>
<td>0.1</td>
<td>121,104</td>
</tr>
</tbody>
</table>
UCR Initiatives in Biofuels

• Develop Technical Foundation to Accelerate Emergence of Large Scale Biological Processing of Cellulosic Biomass to Commodity Products and Fuels (Wyman and Mascoma)
• Develop Thermal Chemical Conversion of Biomass, Problematic Solid Wastes and Coal into Diesel and Jet Fuel (Norbeck, Chan and Viresco)
• Commercial Facilities within 5 years
Technology features for Thermal Conversion

Simplified process flow diagram

Recycle excess H₂

H₂
Carbon
H₂O

CH₄, H₂O, etc

H₂, CO
H₂/CO = 2.1

Clean Synthetic Diesel Fuel
CE-CERT Process for Producing F-T fuel

Commercial Diesel

F-T product Organic Portion
Solar Thermal Energy

• Current world production: ~0.1 Quads/year
• Technical potential: ~1575 Quads/year
• Cost 0.21-0.79 KwH

1,000 Megawatts

History

Projects

Solar Thermal

Solar Photovoltaic


2007 Dollars per Watt

Solar Photovoltaic
Solar Thermal

Wind Energy

- Current world production: \(~0.12\) Quads/year
- Technical potential: \(~640\) Quads/year
- Cost \(0.4 - 0.11\) per KwH
EU - USA wind energy (2007)

- EU: 56,535 MW
- USA: 16,596 MW
Federal lands, lower 48 States, with wind energy resource potential of 4, 5 or 6; located within 20 miles of a 115-230 kV transmission line; and weighted by land use class

Lands with high potential for wind energy are defined as areas:
- with wind energy potential of 4, 5, or 6; and
- within 20 miles of a 115-230 kV transmission line

The acreage for these areas are then weighted using the weights in Table 1. The sum of weighted acres is the estimate of lands with high potential for wind energy.

- % that high potential Federal lands are of total U.S. high potential lands: 25%
- % of total Federal lands that have high potential for wind energy: 18%
- % of U.S. electric energy generated by wind power: 0.1%

Area within Federal lands with a wind energy resource potential of 4, 5 or 6 & located within 20 miles of a 115-230 kV transmission line
Area not on Federal lands with a wind energy resource potential of 4, 5 or 6 & located within 20 miles of a 115-230 kV transmission line
Lands under Federal management
Electric generating plants (67) using wind power

As of the end of 1998, there were no wind powered electric generating plants located on Federal lands.

Rating Scale
6 - outstanding potential for wind energy generation
5 - excellent potential for wind energy generation
4 - good potential for wind energy generation

Source of wind energy resource potential measures:
Source of wind powered generation and wind powered electric power plant locations:
EIA
EPA Egrid database (1998)
Geothermal Energy Locations
Federal lands, lower 48 States, with geothermal resource potential of 60 or greater

- Area within Federal lands with a geothermal resource potential of 60 or greater
- Area not on Federal lands with a geothermal resource potential of 60 or greater
- Lands under Federal management
- Electric generating plants (42 using geothermal energy)
- Plants (1,944) using geothermal energy located on Federal lands

Ratings are heat flow in units of milliwatts per square meter squared. Areas with ratings of 60 or higher have high potential for energy generation using geothermal resources.

Source of geothermal resource potential measures:
- Geothermal Lab, Department of Geological Sciences, Southern Methodist University
- Source of geothermal inputs and geothermal plant locations:
  - EIA
Sustainable Electricity Cost Trends

Need: <$0.10/kWh

Levelized cents/kWh in constant $2000

Wind

Photovoltaics

Geothermal

Solar thermal

Biomass

Source: National Renewable Energy Laborato
Global Coal Reserves

Promise of Sustainable Energy

• Total global primary energy use in 2001: ~500 Quads
• Total world sustainable energy production: ~60 Quads/year
• Total technical potential of sustainable energy: >1800 Quads/year
• Issues are cost and availability of technology
• Sustainable Energy has been given the term alternative energy
Present Administration’s Short Term Sustainable Energy Timetable

“Double Alternative Energy in Three Years”

President-elect Obama, January 9, 2009

• Current Use: 7 Quads of 101 Quads
• Estimated cost > $13 Billion/year (approximately = Auto Bailout)
• Only Feasible Pathway for Transportation is Biofuels
• Corn Ethanol and Biodiesel is being implemented now but not cost effective
• Cellulosic Ethanol and Synthetic Fuels are at close to Commercial Scale
• Wind and Solar are also being implemented but cost is issue
Conclusions

• Energy will continue to be global concern for years to come.
• Cost for energy will most certainly increase in future
  – Expect $200/barrel in future years
• US cannot solve climate change problem alone
• US energy technologies can be a new industry and a major economic opportunity
• China and India will utilize fossil fuels in the future so need to explore carbon capture processes
Conclusions

- More research needs to be done to understand different processes advantages and efficiencies (eliminate snake oil)
- Federal Government needs to provide stimulus for high risk sustainable fuel systems
- Sustainable energy supplies may be within reach by next decade and US energy independence is possible
- Synthetic Gasoline, Ethanol, and Clean Synthetic Diesel Fuel good bets for fuels for the future
- **Changes in Lifestyle are An Absolute Necessity**