Renewable Energy II: Biofuels, Ethanol, Methanol, and Algae

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Class Web Site: http://www.atmos.umd.edu/~rjs/class/spr2015

Topic for today:
  • A discussion of the pros and cons of various aspects of meeting the energy needs of society by means of combustion of biomass, biofuels, and biowaste

Lecture 20
28 April 2015
Concentrated Solar Power (CSP)

• Parabolic mirrors heat fluid that drives Stirling engine
  – Fluid is permanently contained within the engine's hardware
  – Converts heat to energy
  – Theoretical efficiencies often challenging to achieve
    

• Highest electrical efficiencies for solar → lowest costs!

  [http://www.powerfromthesun.net/Book](http://www.powerfromthesun.net/Book)

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Kramer Junction, Calif

Fully operational in 1991: 350 MW capacity
Low output in 1992 due to Pinatubo aerosol!
Present operating cost: ~11 ¢ / kWh

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Nevada Solar One

Output: 64 MW capacity / 134,000 MW-hr / year
Could supply all US electricity needs if built over a ~ 130 mile × 130 mile area
Construction cost: ~$2 / kW-hr for one yr’s prod
### Hydro

#### Annual Production of Electricity, Three Gorges Dam

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of installed units</th>
<th>TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>6</td>
<td>8.607</td>
</tr>
<tr>
<td>2004</td>
<td>11</td>
<td>39.155</td>
</tr>
<tr>
<td>2005</td>
<td>14</td>
<td>49.090</td>
</tr>
<tr>
<td>2006</td>
<td>14</td>
<td>49.250</td>
</tr>
<tr>
<td>2007</td>
<td>21</td>
<td>61.600</td>
</tr>
<tr>
<td>2008</td>
<td>26</td>
<td>80.812</td>
</tr>
<tr>
<td>2009</td>
<td>26</td>
<td>79.470</td>
</tr>
<tr>
<td>2010</td>
<td>26</td>
<td>84.370</td>
</tr>
<tr>
<td>2011</td>
<td>29</td>
<td>78.290</td>
</tr>
<tr>
<td>2012</td>
<td>32</td>
<td>98.100</td>
</tr>
<tr>
<td>2013</td>
<td>32</td>
<td>83.270</td>
</tr>
<tr>
<td>2014</td>
<td>32</td>
<td>98.800</td>
</tr>
</tbody>
</table>

If Three Gorges had run 24/7/52:

\[
\text{22,500 MW} \times 8760 \text{ hr} = 1.97 \times 10^8 \text{ MWh} \\
= 1.97 \times 10^8 \text{ MWh} \times 10^6 \text{ W/MW} = 1.97 \times 10^{14} \text{ Wh} \\
= 1.97 \times 10^{14} \text{ Wh} \times \text{TW} / 10^{12} \text{ W} = 197 \text{ TWh}
\]

- **Three Gorges Dam, Yangtze River, China:** 22,500 MW
  - Fully operational in 2012
  - Cost: $22.5 billion or 1 million $ / MW
  - Largest construction project in China since Great Wall
  - 1 million people displaced
  - Provides 3.0% of China’s electricity needs

Nevada Solar One

Project capacity: **64 MW** (power = energy / time)

Project output over 2012: **129,000 MW-hr** (energy, or power × time)

Number of hours in year = 365x24 = 8760

Capacity Factor = 129,000 MW-hr / (64 MW × 8760 hr) = **0.23**

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http://en.wikipedia.org/wiki/Nevada_Solar_One#Production

**Nevada Solar One**

Output: 64 MW capacity

Could supply all US electricity needs

if built over a ~ 130 mile × 130 mile area

Construction cost: ~$2 / kW-hr for one yr’s prod
Capacity Factor, Various Energy Sources

http://www.nrel.gov/analysis/tech_cap_factor.html
Largest energy source that does not involve combustion of fossil fuels is **Biomass and Waste**
An analysis of the climate response of soot emissions from fossil fuel and biofuel combustion has suggested that control of soot, in addition to greenhouse gases, is an important measure to slow global warming, especially on short time scales (6, 7). Our results suggest that biofuel combustion could significantly affect atmospheric BC concentrations in the south Asian region. The climate effects of biofuel combustion aerosols have been combined with the effects of open biomass burning in the scientific consensus reports of the Intergovernmental Panel on Climate Change (29). We suggest that biofuel combustion needs to be addressed as a distinct source, and that cleaner cooking technologies not only could yield significant local health and air quality benefits but also could have an important role in climate change mitigation in the south Asian region.
### Black Carbon & Climate

**Global climate forcing of black carbon and co-emitted species in the industrial era (1750 - 2005)**

<table>
<thead>
<tr>
<th>Climate forcing terms</th>
<th>Estimate (Uncertainty range)</th>
<th>LOSU</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BC direct effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atmosphere absorption &amp; scattering</td>
<td>0.71 (0.08, 1.27)</td>
<td>Med</td>
</tr>
<tr>
<td><strong>BC cloud indirect effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined liquid cloud (semi-direct, albedo, and lifetime)</td>
<td>-0.2 (-0.61, 0.1)</td>
<td>Low</td>
</tr>
<tr>
<td>BC in cloud droplets</td>
<td>0.2 (0.1, 0.9)</td>
<td>Very low</td>
</tr>
<tr>
<td>Mixed-phase cloud</td>
<td>0.18 (0, 0.36)</td>
<td>Very low</td>
</tr>
<tr>
<td>Ice cloud</td>
<td>0.0 (0.4, 0.4)</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>BC snow and sea ice effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC snowpack effective forcing</td>
<td>0.10 (0.014, 0.30)</td>
<td>Med</td>
</tr>
<tr>
<td>BC sea ice effective forcing</td>
<td>0.030 (0.012, 0.06)</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Total climate forcing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC only</td>
<td>1.1 (0.17, 2.1)</td>
<td></td>
</tr>
<tr>
<td>BC + co-emitted species (BC-rich sources only)</td>
<td>-0.06 (-1.45, 1.29)</td>
<td></td>
</tr>
</tbody>
</table>

**New Estimate:**
- BC causes 0.7 W m$^{-2}$ RF Direct, warming
- 1.1 W m$^{-2}$ RF Total, also warming

Bond *et al.*, JGR, 2013
Black Carbon & Climate

The impact of BC on snow and ice causes additional warming in the Arctic region and contributes to snow/ice melting. **VERY LIKELY BUT MAGNITUDE UNCERTAIN**

BC in northern hemisphere mid-latitude snow leads to earlier springtime melt and reduces snow cover in some regions. **LIKELY BUT MAGNITUDE UNCERTAIN**

The warming caused by BC is concentrated in the northern hemisphere. **VERY LIKELY**

Absorbing aerosols may have caused changes in precipitation patterns with largest effects likely to be in South Asia.

The hemispheric nature of the BC forcing causes a northward shift in the ITCZ. **LIKELY.**

Absorbing aerosols may cause circulation changes over the Tibetan Plateau and darkening of the snow. The importance of this for glacier melting is unknown.

Bond *et al.*, JGR, 2013
**Aerosol Direct RF of Climate, IPCC**

**Figure 7.18** | Annual mean top of the atmosphere radiative forcing due to aerosol–radiation interactions (RFari, in $W \cdot m^{-2}$) due to different anthropogenic aerosol types, for the 1750–2010 period. Hatched whisker boxes show median (line), 5th to 95th percentile ranges (box) and min/max values (whiskers) from AeroCom II models (Myhre et al., 2013) corrected for the 1750–2010 period. Solid coloured boxes show the AR5 best estimates and 90% uncertainty ranges. BC FF is for black carbon from fossil fuel and biofuel, POA FF is for primary organic aerosol from fossil fuel and biofuel, BB is for biomass burning aerosols and SOA is for secondary organic aerosols.
Surya – Sanskrit for Sun

- 65 villages (6500 homes) covering 1500 km², where most residents use wood for cooking, will be provided with either solar and/or biogas burners.
- Air quality, soot, and particulates will be monitored for 6 months prior to installation of alternate cookers and for at least 1 year subsequent.
- Indoor air quality will be measured in selected homes.
- Outdoor air quality will also be monitored using NASA satellite instruments.
- PI: V. Ramanathan, Scripps.

http://www.projectsurya.org
Surya – Pilot Phase Findings

- Pilot village included 485 households
- Cooking drives local outdoor black carbon concentrations
- New stove technologies could reduce emissions of PM$_{2.5}$ and CO by factors of 4 to 5
- Demonstrated an ultra low power wireless cell phone approach for measuring black carbon

http://www.projectsurya.org/storage/prospectusinsert.pdf
BACKGROUND
Global warming of more than 2°C is considered to be the threshold for dangerous anthropogenic interference (DAI).

Black carbon (BC) & non-\(CO_2\) gases such as methane, ozone, halocarbons account for half of global warming and can be removed from the air 10x-100x faster than \(CO_2\).

Biomass cooking (using dung, firewood, crop residues) is a major source of BC & ozone and leads to \(CO_2\) emission by deforestation; it leads to severe air pollution which is the root cause of millions of cardiovascular & respiratory related deaths.

Surya will introduce cleaner cooking methods.

PILOT PHASE
2009 - 2010
$0.8 Million
2,500 People
COMPLETED

EXPECTED OUTCOME
REGIONAL
Increase food and water supply; decrease mountain-glacier melt; decrease deforestation and aid in poverty alleviation.

GLOBAL
Contribute to the delay of the DAI threshold by up to few decades and saving 2 million lives yearly.

GLOBAL POLICY
2020 - 2025
$20 Billion
Target: 3 Billion people worldwide
Funded and sustained by carbon credits, micro-financing, Global Environment Facility funds and foundations.

REPLICATION
2014 - 2020
$200 Million
Target: 10-20 Million people in Africa, Asia and Latin America.

DEMONSTRATION
2011 - 2013
$13.7 Million
Target: 50,000 people in North India
IMPLEMENTATION
Replace stoves in 10,000 homes with aid of multi-national team of scientists, engineers, health professionals and village leaders.

VALIDATION
Use data collected from cell phones, satellites and other cutting-edge technologies to quantify impacts on climates and health. Develop metrics for carbon credits.

http://www.projectsurya.org/storage/ProjectSuryaWEB-Feb23.pdf
Project Surya is:

- exploring how to include Short Lived Climate Pollutants including BC and O₃ producing gases (CO & VOCs) into carbon credit calculations, which will lead to more revenue for climate credits.

- distribute the funds from carbon credits directly to the participant women instead of the stove distributors or manufacturers

Electricity from Biomass

Table 8.1 Production of electricity from biomass and waste in 2006.

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (TWh)</th>
<th>Percentage of world electricity production from biomass</th>
<th>Percentage of the country's total electricity production</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>58.7</td>
<td>29.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Germany</td>
<td>19.7</td>
<td>9.9</td>
<td>3.4</td>
</tr>
<tr>
<td>Brazil</td>
<td>14.6</td>
<td>7.3</td>
<td>3.9</td>
</tr>
<tr>
<td>Finland</td>
<td>11.8</td>
<td>5.9</td>
<td>14.0</td>
</tr>
<tr>
<td>Japan</td>
<td>11.6</td>
<td>5.8</td>
<td>1.1</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>9.3</td>
<td>4.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Canada</td>
<td>9</td>
<td>4.5</td>
<td>1.6</td>
</tr>
<tr>
<td>Spain</td>
<td>8.2</td>
<td>4.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Rest of the world</td>
<td>57.2</td>
<td>28.6</td>
<td>0.6</td>
</tr>
<tr>
<td>World</td>
<td>200.1</td>
<td>100</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Data source: EDF and IEA key statistics.

Olah et al., Beyond Oil and Gas: The Methanol Economy, 2009.
Electricity from Biomass: Overview

- Plant size average 20 MW
- Efficiencies range from 15 to 30% (electricity only) to 60% (electricity + heat)
  - co-firing uses biomass to supplement fossil fuel
- Use wood, agricultural residues, and municipal waste
- 85 plants in U.S generate some type of energy from waste
- Addresses energy need and growing “mountain of waste”:
  - waste converted to CO$_2$ and water; unburned residue about 10% of initial volume
  - iron-containing metals often recovered and recycled
Electricity from Waste

• Opened in 1984
• Site of old pyrolysis plant
• Burns 2,250 tons of trash per day
• Metals recovered; volume of trash reduced by factor of 10
• Can generate 60,000 kW of electricity ⇒ 60 MW (2700 × size of UP solar array but only 6% typical nuclear plant)
• Heat used for direct steam heating / cooling downtown Baltimore
• One of 16 such plants in the U.S.  
  [Link to EIA webpage for RESCOE Plant]

Baltimore RESCO (Refuse Energy Systems Company) Plant
Russell Street & U.S Interstate 95 (shadow of Ravens Stadium)
Energy from Waste

http://www.seas.columbia.edu/earth/recycle/
Ethanol

- Ethanol: \( \text{C}_2\text{H}_5\text{OH} \)
- Alcohol

- \( \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2 \text{C}_2\text{H}_5\text{OH} + 2 \text{CO}_2 \) \( (\Delta H_f = 228 \text{ kJ/mol} \text{ or } 5 \text{ kJ/g}) \)
- Reaction catalyzed by enzymes; theoretically, can be close to carbon neutral

- Ethanol combustion:

  \[
  \text{C}_2\text{H}_5\text{OH} + 3 \text{O}_2 \rightarrow 2 \text{CO}_2 + 2 \text{H}_2\text{O} + 29.7 \text{ kJ/g}
  \]

  Heat release less than combustion of \( \text{C}_8\text{H}_{18} \) (47.8 kJ/g) because \( \text{C}_2\text{H}_5\text{OH} \) is already partially oxidized

- However ... ethanol has a higher octane than gasoline
Ethanol Production

- U.S.: Ethanol produced from corn
- Brazil: Ethanol produced from sugar cane, which thrives in tropical climate

*Olah et al., Beyond Oil and Gas: The Methanol Economy, 2009.*
Ethanol Production: Good News

- Brazil: Ethanol produced from sugar cane, which thrives in tropical climate
  - energy to convert sugar to ethanol supplied by burning bagasse (sugar cane husk)
- About half cars in Brazil are “flex fuel vehicles (FFV)”
  - can run on 100 percent ethanol or any ethanol-gasoline mixture.
- Ethanol accounts for ~40% of non-diesel fuel use in Brazil
- 2010: Brazil produces 26% of world ethanol (US produces most)

Ethanol Production: Bad News

- Annual Brazil ethanol production < 1 day world petroleum consumption
- Brazil consumes nearly all the ethanol it produces due to high domestic demand

Ethanol Production

- McElroy article suggests considering refinement cost, transportation cost, and energy content of ethanol, "the energy captured in the ethanol exceeds the fossil energy consumed in its production by no more than ~25 %"
- McElroy did not consider ______________
Ethanol Production

- Raging debate over “green” aspects of both sugar and corn based biofuels:
  Excellent point/counterpoint: [http://cen.acs.org/articles/85/i51/Costs-Biofuels.html](http://cen.acs.org/articles/85/i51/Costs-Biofuels.html)

Land Clearing and the Biofuel Carbon Debt

Joseph Fargione,¹ Jason Hill,²,³ David Tilman,²* Stephen Polasky,²,³ Peter Hawthorne²

Increasing energy use, climate change, and carbon dioxide (CO₂) emissions from fossil fuels make switching to low-carbon fuels a high priority. Biofuels are a potential low-carbon energy source, but whether biofuels offer carbon savings depends on how they are produced. Converting rainforests, peatlands, savannas, or grasslands to produce food crop–based biofuels in Brazil, Southeast Asia, and the United States creates a “biofuel carbon debt” by releasing 17 to 420 times more CO₂ than the annual greenhouse gas (GHG) reductions that these biofuels would provide by displacing fossil fuels. In contrast, biofuels made from waste biomass or from biomass grown on degraded and abandoned agricultural lands planted with perennials incur little or no carbon debt and can offer immediate and sustained GHG advantages.

¹The Nature Conservancy, 1101 West River Parkway, Suite 200, Minneapolis, MN 55415, USA. ²Department of Ecology, Evolution, and Behavior, University of Minnesota, St. Paul, MN 55108, USA. ³Department of Applied Economics, University of Minnesota, St. Paul, MN 55108, USA.
Ethanol Production

- Raging debate over “green” aspects of both sugar and corn based biofuels:
  Excellent point/counterpoint: http://cen.acs.org/articles/85/i51/Costs-Biofuels.html

Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change

Timothy Searchinger, Ralph Heimlich, R. A. Houghton, Fengxia Dong, Amani Elobeid, Jacinto Fabiosa, Simla Tokgoz, Dermot Hayes, Tun-Hsiang Yu

Most prior studies have found that substituting biofuels for gasoline will reduce greenhouse gases because biofuels sequester carbon through the growth of the feedstock. These analyses have failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest and grassland to new cropland to replace the grain (or cropland) diverted to biofuels. By using a worldwide agricultural model to estimate emissions from land-use change, we found that corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years.

1Woodrow Wilson School, Princeton University, Princeton, NJ, USA. German Marshall Fund of the U.S., Georgetown Environmental Law and Policy Institute. 2Agricultural Conservation Economics, Laurel, MD, USA. 3Woods Hole Research Center, Falmouth, MA, USA. 4Center for Agricultural and Rural Development, Iowa State University, Ames, IA, USA.
The squeeze on the supply of fertilizer has been building for roughly five years. Rising demand for food and biofuels prompted farmers everywhere to plant more crops. As demand grew, the fertilizer mines and factories of the world proved unable to keep up.

Some dealers in the Midwest ran out of fertilizer last fall, and they continue to restrict sales this spring because of a limited supply.

“If you want 10,000 tons, they’ll sell you 5,000 today, maybe 3,000,” said W. Scott Tinsman Jr., a fertilizer dealer in Davenport, Iowa. “The rubber band is stretched really far.”

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Ethanol Production

- Raging debate over “green” aspects of both sugar and corn based biofuels:
  Excellent point/counterpoint: [http://cen.acs.org/articles/85/i51/Costs-Biofuels.html](http://cen.acs.org/articles/85/i51/Costs-Biofuels.html)
Ethanol Production: US

- Despite these debates the “show goes on”
  - US produced $14 \times 10^9$ gallons of ethanol in 2014
  - 83 million acres (20% of cultivated land area) harvested for corn
  - ~40% of US corn produced goes to ethanol production
  - US govt subsidy of ethanol, $0.45/gallon, expired Jan 2012 leading to rise in fuel prices:
    - [http://green.autoblog.com/2012/01/18/u-s-ethanol-subsidy-expiration-may-be-driving-up-gas-prices](http://green.autoblog.com/2012/01/18/u-s-ethanol-subsidy-expiration-may-be-driving-up-gas-prices)
  - Present debate focused on Renewable Fuel Standard:


[http://www.eia.gov/todayinenergy/images/2014.03.07/main.png](http://www.eia.gov/todayinenergy/images/2014.03.07/main.png)
One Last Comparison:

In prior lectures, we have looked at market forces such as:

- Cost of Fossil Fuel $\uparrow$
- Cost of Electricity from Renewables $\downarrow$

as well as complete life cycle effects of various options:

- Carbon release (early) and methane release (late) from areas flooded for hydro
- $N_2O$ associated with fertilizer production for biofuels

There is one more comparison that could be vital for society to consider, for large-scale transition to energy production from some means other than combustion of fossil fuel
Biofuels and Diesel

• Fuels made from recycled restaurant waste have a CH ratio conducive for use in **diesel** engines and not **gasoline** engines

• Gasoline engine: spark plug ignites fuel/air mixture (Otto cycle)
• Diesel engine: compression ignites fuel in combustion chamber (Diesel cycle)

• Gasoline: C\textsubscript{8}H\textsubscript{18}
• Diesel fuel: C\textsubscript{10}H\textsubscript{20} to C\textsubscript{15}H\textsubscript{28} (average C\textsubscript{12}H\textsubscript{23})

• Main advantage of diesel: better fuel economy due to higher engine efficiency
• Disadvantages:
  − past fuel has contained high amounts of sulfur
  − past engines have released large amounts of NO\textsubscript{x}
  − fuel gels in cold weather!

• Diesel cars much more common in Europe than the U.S. but: diesel cars making a comeback in the U.S.


Sources:
  Smart Power by William H. Kemp, Hushion House Publishing
Biofuels and Diesel

• Fuels made from recycled restaurant waste have a CH ratio conducive for use in *diesel* engines and not *gasoline* engines

Advantages of biodiesel:
• Low sulfur
• Biodegradable
• Climate friendly (C that is combusted recently pulled from atmosphere!)
• Can be “brewed” at home

Disadvantage of biodiesel:
• Weak solvent that could soften rubber hoses, seals, and gaskets over time
• Supposedly, B20 blends (20% biodiesel) combined with modern use of synthetic materials minimize risk … nonetheless, **vehicle warranty could be compromised by use of biofuels**

For more info see:
- [http://www.makebiodiesel.com](http://www.makebiodiesel.com)
- [http://www.biodiesel.org](http://www.biodiesel.org)
- [http://www.biodiesel-canada.org](http://www.biodiesel-canada.org)

FuelMeister II™
*Personal Biodiesel Processor!*
Azure Biodiesel Company
Sully, Iowa 50251

[http://www.azurebiodiesel.com/contact.shtml](http://www.azurebiodiesel.com/contact.shtml)
• Methanol: CH₃OH
• Alcohol
• Methanol combustion:

  \[ 2 \text{CH}_3\text{OH} + 3 \text{O}_2 \rightarrow 2 \text{CO}_2 + 4 \text{H}_2\text{O} + 41.4 \text{ kJ/g} \]

  Heat release considerably more than ethanol (29.7 kJ/g) and close to that of C₈H₁₈ (47.8 kJ/g)
• Octane of 107
• Very clean burning: little or no CO, NOₓ, or particulates
• Can be used in “clean diesels”
• Presently used in Indy 500 race cars!
The Methanol Economy ®

• Methanol production from atmospheric CO₂:
  – \( \text{CO}_2 + 3 \text{H}_2 \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O} \)
  – Exothermic by 49.3 kJ/mol; nonetheless, need a catalyst
  – Need to capture CO₂ out of atmosphere (tall order!)
  – Need supply of H₂ that is “carbon neutral” (i.e., not from CH₄ !)

• Methanol production from atmospheric CO$_2$:
  - CO$_2$ + 3 H$_2$ → CH$_3$OH + H$_2$O
  - Exothermic by 49.3 kJ/mol; nonetheless, need a catalyst
  - Need to capture CO$_2$ out of atmosphere (tall order!)
  - Need supply of H$_2$ that is “carbon neutral” (i.e., not from CH$_4$ !)
  - If electrolysis of seawater to yield H$_2$ could be powered by solar energy, 
    and an energy efficient way to capture and concentrate atmospheric CO$_2$ could 
    be devised (i.e., using KOH or MEA-monoethanolamine (CH$_2$CH$_2$OH)NH$_2$), 
    then CO$_2$+3 H$_2$ → CH$_3$OH+H$_2$O would simulate photosynthesis and could 
    provide a fuel that could be used in cars without major changes to present 
    infrastructure

NOTE: methanol is corrosive to aluminum, zinc, and magnesium, and 
reactive with some plastics and rubber, so some systems specific 
to methanol would be needed
Algae as a Biofuel

Pros:
- High oil content
- Absorbs atmospheric CO₂
- Can use waste as fertilizer
- Not a food staple

Cons:
- Need sunny, warm conditions; certain areas preferred
- Growth limited by “self shading” effect; challenge to exploit entire volume of pond
- Water intensive (rules out many warm, sunny environs for large scale production)
- Efficient processing method still being researched
- Fertilizer intensive
- Water intensive

The promise of algae as an economically viable clean source of fuel is leading many groups to research the large scale viability of this potential resource.

http://cosmiclog.msnbc.msn.com/_news/2011/04/14/6471719-is-algae-biofuel-too-thirsty
http://stateimpact.npr.org/texas/2012/12/17/the-downside-of-using-algae-as-a-biofuel
Algae as a Biofuel

Wigmosta et al., Water Resources Res, 13 April 2011 conclude:

Using current technology, 48% of petroleum needed for US transportation can be produced using:

- 5.5% of U.S. land area (lower 48)
- 3 times the total amount of water used for irrigation

Optimal placement of algae production facility in the humid Gulf Coast, southeastern seaboard, and Great Lakes regions would considerably reduce the water needed.

High yield: 8000 L/ha/year:

U.S. uses 5.2×10^{11} L/year

Hence, need 6.5 ×10^{7} ha
or 2.5 ×10^{5} mi^{2}

500 x 500 miles
(7% land area, lower 48)

Figure 3. Mean annual biofuel production (L ha^{-1} yr^{-1}) under current technology plotted at the centroid of each pond facility.

http://www.eia.gov/tools/faqs/faq.cfm?id=23&t=1