Principles of Sustainability

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Materials online at: http://rael.berkeley.edu

Joint Forum on Bioenergy Sustainability and Lifecycle Analysis
Sacramento Convention Center, May 28, 2008
Sustainable Fuel LCA Research Team

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<th>UC Berkeley:</th>
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<td>Naïm Dargouth (food/fuels, Africa)</td>
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<td>Kevin Fingerman (water)</td>
<td>Purdue University</td>
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<td>Andy Jones (LCFS)</td>
<td>USP (Brazil)</td>
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<td>Derek Lemoine (PHEVs)</td>
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<td>Michael O’Hare (LCFS)</td>
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<td>Richard Plevin (LCFS)</td>
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<td>Deepak Rajgopal (multipurpose crops, India)</td>
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<td>Sabrina Spatari (methods)</td>
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Margaret Torn (biogeochemistry)  

Alex Farrell

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High & low carbon pathways

Theoretical carbon emissions profiles published in IPCC 3rd Assessment Report

>900 ppm Trajectory
Energy by 2050:
- Coal over 2x, no Carbon Capture & Storage (CCS), some coal to liquids.
- Oil up 50%
- Gas over 2x
- Biofuels make up 10% of vehicle fuel mix.
- Electricity 1/3 of final energy.
- Modest increase in nuclear.
- Renewables provide 1/3 of electricity generation.
- Vehicle efficiency up 50%.

<550 ppm Trajectory
Energy by 2050:
- Coal up 50%, but half of power stations use CCS.
- Oil down 10-15%.
- Gas nearly 2-3x (note: adds volatility)
- Green Hydrogen in use
- Strong shift to electricity as final energy (~50% final energy).
- Large increase in nuclear.
- Renewables provide half of electricity generation.
- Vehicle efficiency up 100%
- Sustainable biomass practices

WRE1000 - we start planning now
WRE 550 - we start acting now
WRE 450 - we started to act in 2000, or ...

2002 IEA reported fossil emissions plus correction for unsustainable biomass & deforestation.
Energy Usage & ‘Content’ Labels

Next? Sustainability Labeling - requires definitions and transparent accounting ...

And is not just about efficiency per use, but also total use
Sustainability issues (direct/indirect):

• **Ecological:**
  • Energy security/greenhouse gas impacts
  • Land erosion
  • Pesticide and fertilizer run-off / eutrophication toxics
  • Biodiversity/invasive species
  • Water sustainability (total demand; irrigation; pollution)
  • Soil conservation

• **Socio-economic:**
  • Food security and economics
  • Displacement of indigenous people from land
  • Environmental justice
  • Labor law violations, particularly in other countries
Total Fossil Fuel Resources Are Vast:

‘Peak dirty energy’ is very far off, even if there is ‘peak (conventional) oil’

We must create our way to a clean future, not just hope prices get us there ...
New Fuel Pathways: Tar Sands Example

One million barrels per day of production ... almost a decade ahead of schedule

$40 US in energy costs/barrel for production

$CH_4 \rightarrow H_2S$ separation, then $H_2$ & elemental sulfur separation

(photograph: Kammen July 2006 survey)
We are running out of atmosphere *much* faster than fossil fuels...


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A $500 million biofuel development grant from BP
DM Kammen, primary author & Executive Committee
An Alternative Fuel is Not Necessarily a Low-Carbon Fuel, but it can be
(California Executive Order S-7-01)

Assessment ... without INDIRECT LAND USE CHANGE
Ethanol Can Contribute to Energy and Environmental Goals

Alexander E. Farrell, Richard J. Plevin, Brian T. Turner, Andrew D. Jones, Michael O’Hare, Daniel M. Kammen

Open access, online, biofuel calculator tools: http://rael.berkeley.edu/ebamm

EBAMM

The ERG Biofuel Analysis Meta-Model (EBAMM) was developed by students and faculty of the Energy and Resources Group and Richard & Rhoda Goldman School of Public Policy at UC Berkeley to review the current state of biofuel energy analyses. The paper was published in Science on January 27, 2006 and is available here. Use the links below to download the paper, the spreadsheet model, and the supplemental materials.

- Download the paper (175 KB)
- Download the model (895 KB)
  Contains energy and greenhouse gas (GHG) analyses of all papers reviewed, plus summary sheets facilitating comparison between studies. Requires Microsoft Excel or work-alike.
- Download the Supplemental Online Materials (951 KB)
  Contains detailed model descriptions and a summary of errors and omissions found in the studies reviewed. Requires PDF file viewer.
- Download a zipped archive (1.1 MB)
  Contains both the model and the supplemental materials.

Not so fast ...

Additional environmental metrics are now being developed for biofuels, and a few have been applied to ethanol production, but several key issues remain unquantified, such as soil erosion and the conversion of forest to agriculture (18, 20).
Land use, GHG emissions, and ‘carbon debt’

What we found without Land Use Change

Net energy and net GHG estimates for 6 studies of corn ethanol, as well as 3 cases. Gasoline is shown for reference. The cellulosic case is switchgrass grown on prime crop land. Adapted from - Farrell et al, 2006
Considering land use change (LUC)

What may actually be the case

Net energy and net GHG estimates for 6 studies of corn ethanol, as well as 3 cases. Gasoline is shown for reference. The cellulosic case is switchgrass grown on prime crop land. Adapted from - Farrell et al, 2006 and Searchinger et al, 2008.
Biofuel Optimistic Scenarios

Status quo
- CRP Land (30 MM)
- U.S. Cropland (400 MM)
- 36 gal Geq/ton, current mpg, no ag. integration, 5 tons/acre*yr
- 1,030

Advanced processing
- Vehicle efficiency 2.5X↑
- 91 gal Geq/ton
- 410

Biomass yield 2.5X↑
- 65

Agricultural integration
- I. Soy → switchgrass or large biomass soy
- II. Corn stover (72%)
- III. Other

Early-cut switchgrass produces more feed protein/acre than soy; similar benefits from “large biomass soy”
Feasibility of stover utilization enhanced by rotation
Winter cover crops, other residues, increased productivity of food crops, increased production on under-utilized land…

Vehicle Types
- Light Duty
- Heavy Duty

U.S. mobility demand, the largest per capita in the world, could be met from land now used for agriculture while maintaining food production (L. Lynd)
Feedstocks that use degraded land or no land require advanced technologies

- Waste stream biofuels
- No-ag land biofuels
- Degraded land ‘restoration food and fuels’
U.S. soy exports go down and world soy prices rise

Price Adjustment

Soy farmers everywhere use more inputs to increase yields

Intensification

U.S. corn farmer switches from corn/soy to corn/corn

New Demand

Substitution

World consumption of soybean decreases

Extensification

Additional land in Brazil (for instance) is put into soy production

Indirect Process Emissions

Indirect Land Cover Change Emissions

Process Emissions

Additional land in Brazil (for instance) is put into soy production
Temporal Profile of Emissions
(Jones, Plevin, Torn, O’Hare & Kammen, in preparation)

Suggests many lines of policy analysis:
- Fuel certification (land use genealogy)
- Market payments to offset carbon debt
- Zero-tolerance (for arable-land based fuels)
Sustainability Metrics: Water for Bio-Ag

FEEDSTOCK
Agricultural Biomass Production

OUTFLOWS/IMPACTS
- Climate Forcing
- Water quantity & quality
- Ecosystem Services
- Social & Economic

Sustainability Metrics:
Gallons water per gallons fuel
Gallons water per acre, or per kg biomass

Source: Kevin Fingerman & Margaret Torn
Water Use Initial Results. Water consumed in ethanol production from feedstocks grown in California (ET = evapotranspiration)

- Water intensity of California ethanol = 900 -1500 gal H₂O/ gal EtOH
- More than 95% of water consumed in agricultural phase (but industrial phase is important for pollution and plant siting)
- Water Intensity depends on crop type and climate (effect ET and yield)

- Water intensity of fuel depends on ET/ha and yield/ha. Some water-efficient are very low yield and vice-versa.
- Cellulosic, high-yield feedstock requires only 60% as much water as does corn grain per gallon ethanol.

**Methods:** Modeled crop evapotranspiration (ET) and geographic heterogeneity in ET & yield. Assumed literature values for industrial process water consumption. Water consumption = ET + industrial losses.
Water Use Initial Results, continued.

- Water intensity of fuel depends on ET/hectare and yield/hectare.
- Some feedstocks are water-efficient but low yield.
- Cellulosic (high yield) feedstock requires half as much water as does corn grain ethanol per J.

Plug-in Hybrids: Can they move rapidly to scale?
PHEV Deployment Scenarios (Lemoine, Kammen, Farrell, *ERL, 2008*)

- **(a) Optimal Charging**
- **(b) Evening Charging**
- **(c) Twice Per Day Charging**
- **(d) Twice per day PHEV SUV charging**
Renewable Energy Use With Real-Time Electricity Pricing and Plug-in Hybrid Electric Vehicles

- customers use less fossil power when paying real-time prices
- PHEVs use "surplus" renewable power

statewide electricity use in current system

- solar power production
- wind power production

hour of day (June 24-25, 2003)
Generation/Transmission/Storage Platform
(CA region analysis - Matthias Fripp, Dan Kammen & C3 team)

<table>
<thead>
<tr>
<th>carbon cost ($/ton CO₂)</th>
<th>$0</th>
<th>$100</th>
<th>$200</th>
</tr>
</thead>
<tbody>
<tr>
<td>new transmission capacity (MW)</td>
<td>1,110</td>
<td>2,641</td>
<td>6,890</td>
</tr>
<tr>
<td>emission reductions vs. 1990</td>
<td>20%</td>
<td>51%</td>
<td>66%</td>
</tr>
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</table>
From a Low Carbon Fuel Standard to a Sustainable Fuel Standard

Note: values without indirect land use
Renewable Energy Portfolio Standards (RPS)

29 states + Washington, DC, and counting

- **PA:** 18% by 2020
- **NJ:** 22.5% by 2021
- **CT:** 10% by 2010
- **MA:** 4% by 2009 + 1% annual increase
- **WI:** requirement varies by utility; 10% by 2015 goal
- **IA:** 105 MW
- **MN:** 10% by 2015 goal + Xcel mandate of 1,125 MW wind by 2010
- **TX:** 5,880 MW by 2015
- ***NM:** 10% by 2011
- **AZ:** 15% by 2025
- **CA:** 20% by 2010
- **NV:** 20% by 2015
- **ME:** 30% by 2000; 10% by 2017 goal - new RE
- **MA:** 4% by 2009 + 1% annual increase
- **RI:** 15% by 2020
- **CT:** 10% by 2010
- **NY:** 24% by 2013
- **NJ:** 22.5% by 2021
- **PA:** 18% by 2020
- ***MD:** 7.5% by 2019
- ***DE:** 10% by 2019
- **DC:** 11% by 2022

* Increased credit for solar or other customer-sited renewables
  - **PA:** 8% Tier I (renewables)

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Global CO$_2$ Abatement Opportunities

- ~27 Gton CO$_2$e below 40 EUR/ton
- ~7 Gton of negative and zero cost opportunities
- Fragmentation of opportunities

Vattenfall, 2007
Online GHG calculator: http://www.coolcalifornia.org

Team: McGrath, Jones, Torn, Horvath, Matthews (CMU), Kammen

Source: Berkeley LEAPS Model: http://bie.berkeley.edu
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<thead>
<tr>
<th></th>
<th>Cigarettes 1968</th>
<th>Cars 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed cost</strong></td>
<td>Low</td>
<td>Low (easy credit)</td>
</tr>
<tr>
<td><strong>Benefit from first use</strong></td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td><strong>Marginal spot price of single use</strong></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Pervasive (vending machines!)</td>
<td>Pervasive (streets)</td>
</tr>
<tr>
<td><strong>Complements</strong></td>
<td>Cheap (ashtrays)</td>
<td>Cheap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--Insurance (pay later)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--Gas (credit card)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--Parking (free to cheap)</td>
</tr>
<tr>
<td><strong>Social status</strong></td>
<td>High (especially for youth)</td>
<td>High (especially for youth)</td>
</tr>
<tr>
<td><strong>Advertising</strong></td>
<td>Pervasive, glamorous, sexy</td>
<td>Pervasive, glamorous, sexy</td>
</tr>
<tr>
<td><strong>TV and movies</strong></td>
<td>Pervasive, admirable</td>
<td>Pervasive, admirable</td>
</tr>
<tr>
<td><strong>Alternatives to use</strong></td>
<td>Miserable withdrawal</td>
<td>Transit: slow, distant, expensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bicycle: scary, weather</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Feet: slow, boring, weather</td>
</tr>
<tr>
<td><strong>Costs</strong></td>
<td>Later, shifted to others</td>
<td>Later, shifted to others, remote</td>
</tr>
<tr>
<td><strong>Pervasiveness</strong></td>
<td>Enormous industry, tax dependency</td>
<td>Enormous industries, tax dependency</td>
</tr>
<tr>
<td><strong>Social Support for Nonusers</strong></td>
<td>None to scarce</td>
<td>None to scarce</td>
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O’Hare (2008)
Extra
Study reviews:

- 13 studies of job creation
- 3 - 5 times more jobs per dollar invested in the renewables sector than in fossil fuels
Calif.: AB 32 Emissions Reductions

Required % Change from 1990 levels

- CEC Data
- Business as Usual
- AB 32 Scenario

[Graph showing emissions reductions from 1990 to 2020, with labels for CEC Data, Business as Usual, and AB 32 Scenario.]
Pro-poor strategies: Use of degraded lands

- Degraded soils can be suitable for biofuel feedstocks.
- The poor have access to degraded lands.
- Synergies between increased increase in soil C and food crop yields
- Case study: sweet sorghum

Can Biofuels Displace Petroleum in Africa
(N. Dargouth and Kammen, in prep.)

- Using only post-harvest crop losses as inputs (up to 50 percent of yields), can biofuels can play a (positive) role?

- Implications for poverty alleviation, job creation, urban health, and foreign currency savings

- Metrics for ecological and cultural sustainability must be part of the planning and project decision/support process