Food and Sustainable Biofuels: Thinking Clearly about the Issues
(If we only had a brain: resolving the apparent food vs. fuel conflict by using our heads)

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(Renewable) Energy is Critical for Human Well Being

1. Rate of energy use (rate of doing work) strongly affects (determines?) national wealth and opportunities for human development

2. All rich societies use a lot of energy (~33% oil)

3. “Energy efficiency” is essential but insufficient in itself

4. Fossil energy use makes us rich today—what energy sources will make our children rich?  
   Answer: fossil energy cannot, it will be gone in the next few decades....

5. How will the billions of poor people in the world ever access enough fossil energy to develop their potential?  
   Answer: they cannot, it will be gone in the next few decades...

6. We must have renewable energy— lots of it—in the next few decades

7. Of all forms of energy, liquid fuels are the most valuable and most problematic in terms of supply, price and price volatility

8. Peak oil has already arrived- 2005 by my rear view mirror

9. Only large scale, low cost, low carbon energy sources can reduce GHGs, provide energy security and long term wealth

10. Biofuels (liquid fuels from plant material) are not optional—we must have them—but they must also become much more sustainable
Power Consumption and GDP (World Regions)

The regression line is derived with the constraint that 0 kilowatts per person = $0 GDP per capita.

GDP = 5,121*PC
R² = 0.926

Information on which countries are included in the classifications is available at: http://data.worldbank.org/about/country-and-lending-groups


Per Capita Primary Power Consumption (kilowatt per person)

GDP per Capita, PPP (current international $ per person)
Energy Consumption & Human Well Being are Linked: How Much Energy is “Enough”?

Energy Efficiency is Essential but Insufficient


\[ HDI = 0.217 \times \log(\text{PC}) + 0.637 \]

\[ R^2 = 0.818 \]
Some Basic Energy Facts:

**Why Liquid Fuels are So Important**

- **Services** we need from energy (current primary sources of these services: fossil and renewable)
  - **Heat** (natural gas, coal—solar, wind, geothermal, biomass)
  - **Light/electricity** (coal, natural gas, hydro/nuclear—solar, wind, geothermal, biomass)
  - **Mobility** (liquid fuels from oil—96%, some ethanol & biodiesel, & CNG)—most commerce

- **All energy services** (all BTU, ergs, GJ) are not created equal—we value mobility (=oil) above all other energy carriers
- **Electricity/batteries** can never provide more than about half of mobility needs—and they cannot support commerce at all
- **Commerce** moves by trucks, ocean shipping, rail & jet aircraft
- **Economic chaos** results when liquid fuel demand exceeds supply
- **Liquid fuels**: not “energy” is the key economic security issue—and right now liquid fuels means refined oil products
- **The only potentially sustainable, very large scale source of renewable liquid fuels** is sustainable plant matter—or “biofuels”
Love that Volt!
“The power of population is so superior to the power of the earth to produce subsistence for man, that premature death must in some shape or other visit the human race…”

Thomas Robert Malthus
1766 - 1834
Biofuels: A crime against humanity?

“[I]t's a crime against humanity to convert agricultural productive soil into soil... which will be burned into biofuel.”

– Jean Ziegler, UN Special Rapporteur, 2007
Comparative Value of U.S. Energy Sources over Time

Prices are adjusted to 2005 US$ using the GDP price deflator. All values are for domestic production. Coal is the free-on-board price and includes all types of coal. Natural gas is the wellhead price. Crude oil is the first purchase price average for the entire country. Prices were reported as $/short ton for coal, $/thousand cubic feet for natural gas, and $/barrel for crude oil. The conversions used for each were: coal (19.858 million BTU per short ton), natural gas (1.025 million BTU per thousand cubic feet), and crude oil (5.800 million BTU per barrel). All values and conversion factors are from the U.S. Energy Information Administration.

http://www.eia.gov/kids/energy.cfm?page=about_energy_conversion_calculator - basics
Worldwide Crude Oil Production – Subdivided into World Regions and Top 10 Producers in 2010

Figure 1 – Annual Oil Production in Texas (in Thousands of Barrels)

Adapted from: Railroad Commission of Texas$^{13}$
Alaska Crude Oil Production
(thousand barrels per day)

Data from US Energy Information Administration
Crude Oil Prices from 1861 to 2010


Do we want this fuel future?
Grasses: Sustainable Sources of Protein & Calories for Animal Feed-- & Biofuel Feedstock

Winter rye cover crop
May 5, 2005  Holt, MI
Declining Oil (Energy) Use & Declining Income?

• US oil consumption peaked in 2007 at 20.7 million barrels/day
• Oil consumption was ~18.9 million barrels/day in 2011 – down 8.7%
• Since 2007 median US household annual income has declined 8.2% (from $55,000 to $50,500)

• Are people using less oil because they are poorer, or are they poorer because of the wealth = energy use relationship?
Steak

Cow/Calf Operator: Florida

Feedlot: Amarillo, TX

Truck: 72 miles

Truck: 1,432 miles

Meat Packer
Friona, TX

Distributor
Los Angeles, CA

Grocery Store
Los Angeles, CA

Truck: 1,046 miles

Truck: 50 miles

informa economics
an AGRA informa company
Does the Oil Price Drive the Price of all Other Commodities?


Prices were reported as 2005 US$/bbl for crude oil (spot price average of West Texas Intermediate, Brent, and Dubai), 2005 US$/mt for urea (E. Europe, bulk) and steel rebar, and 2005 US$ (2005 = 100) for food and metals & minerals.
If we only had a brain: resolving the apparent food vs. fuel conflict by using our heads
Agriculture and Biofuels: 
we are not asking the right questions

• We are asking: Can we impose a very large new demand for biofuels on the existing agricultural system without creating problems?
• We should be asking: Can we redesign US agriculture to produce biofuels, food/feed & environmental services?
• Would you enter the Indy 500 race driving a golf cart?
• Would you use a toothbrush to sweep the floor?
• Agriculture has changed before; it can change again
• Examine actual land uses: most land is used for animal feed
• One solution: coproduce animal feeds with biofuels
• Another solution: make much better use of pasture land
Nutritional Requirements: **Livestock vs. Human**

**Nutritional Requirement of All U.S. Livestock in Terms of the Nutritional Requirement of the Entire U.S. Population**

<table>
<thead>
<tr>
<th></th>
<th>Protein (Tg/yr)</th>
<th>Calories (trillion kcal/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Cattle</td>
<td>5.1</td>
<td>190</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>25.8</td>
<td>558</td>
</tr>
<tr>
<td>Pigs</td>
<td>7.7</td>
<td>153</td>
</tr>
<tr>
<td>Laying Chickens</td>
<td>2.7</td>
<td>50</td>
</tr>
<tr>
<td>Poultry</td>
<td>11.2</td>
<td>178</td>
</tr>
</tbody>
</table>

**U.S. livestock consumes 11.4 X and 4.8 X the amount of protein and calories that would fulfill the nutritional requirements of the U.S. population.**

All data from 2010/2011. Livestock population data from USDA-NASS, human nutrition from USDA/USDHHS, U.S. population data from U.S. Census Bureau and animal nutrition from Dale et al., “Protein feeds coproduction in biomass conversion to fuels and chemicals.”
**Biorefinery**

- **3 ML Fermenter Train**
- **2 M kg (2000 tons)**

**Daily Feed**
- **160 L Rumen**

**Physical/Thermochemical**
- Enzymes Break Down Fiber
- Microbes Convert Fiber

**Pretreatment**
- Microbes Ferment Sugars

**Process**
- **CH₄ & CO₂**

**Products**
- **Fuel Molecules**
- **CO₂**

**Energy**
- **Waste Gases**

**Bovine**
- **14 kg**
Biofuel Production Flowchart: Sugar Platform

Cellulose Process

- Corn Process
- Sugar Cane Process

Corn Process

- Corn Kernels
- Cellulose
- Pretreatment
- Cellulose Conversion (Cook or Enzymatic Hydrolysis)
- Starch Conversion
- Sugar Cane
- Sugar
- Fermentation
- Distillation
- Drying
- Biofuels

Sugar Cane Process

- Corn Stover
- Grasses
- MSW
- Forest Residues
- Ag Residues
- Wood Chips

MY LAB WORKS HERE - AFEX PROCESS

Co-Product Recovery
Animal Feed Chemicals
AFEX™ Biomass Pretreatment

- Applicable to variety of ag residues
- Dry-in, dry-out, no waste process
- AFEX pellets 9-fold denser than biomass
- Stable, storable, readily transportable

Reaction → Expansion → Densification → Ammonia Recovery

Raw Biomass  →  Treated Biomass  →  AFEX Pellets
AFEX™ Pellets: A Versatile Biomass Commodity

- Biorefinery sugar feedstock
- Releases 75+% of sugars for fuels and chemicals
- Ruminant animal feed for beef and dairy cattle
- Potential to displace corn grain

www.glbrc.org
Depot Considerations

- Availability of 50 – 200 tons per day of agricultural residue biomass
- Cluster of 7 to 10 depots could serve cattle feed and biorefinery demand
- Depot envisioned to be associated with existing infrastructure
- Capital investment estimated at $10 MM to $15 MM per depot
- Foster economic, ecological and social sustainability
ALL BIOMASS IS LOCAL

System Boundary

Inputs
- Fertilizers
- Fuel
- Agrochemicals

Local power grid
- Electricity
- Steam

Energy Inputs
- Electricity
- Steam

Biorefinery

Pre-Processing
- Sugars
- Lipids
- Lignin
- Ash
- Protein

Final Processing
- Ethanol
- Biodiesel
- Biopolymers
- Chemicals
- Ash

Cogeneration
- Nutrient

Animal operation

Animal waste treatment
- Food
- Other products

Cropping systems
Double Cropping

• Grow crops (grasses) over winter & spring on corn or soy land while still growing corn/soy
  – Does NOT require new land
  – Increases sustainable corn stover harvest rate
  – Biomass can be used for biofuels, animal feed, etc
  – Reframes the “food vs. fuel” debate
More options for end use

Current Land Use:
- Corn
- Soybean
- Alfalfa
- Grass Hay
- Pasture

Future Land Use:
- Corn Stover
- Double Crop
- Soybean
- Canola
- Alfalfa
- Energy Crop

End uses:
- Energy Feed
- Ethanol
- Protein Feed
- Vegetable Oil
- Fiber Feed
Current vs Possible Land Use

- Total biomass production increases by 2.5 fold on same land area
  - Displaces 50% of US gasoline & 5% of US electricity
  - Reduces US GHGs by over 10% & nitrate losses by 75%
  - Food & feed production remain the same - no iLUC
Cover Crops Reduce Nitrogen Losses Tenfold*

Inorganic nitrogen losses (kg N/ha)

Cropping system

CPSN (grain)  CC (grain)  CC (56%)  CwCo (70%)  CwSCo (70%)  CS (54%)

*40 year time scale, Washington County, Illinois
High Double Cropping gives Most Liquid Fuel & Most GHG Reductions

![Graph showing EtOH Production (GL/yr) and GHG Reduction (Tg CO2 eq/yr) for different scenarios.]

- **Base Case (Max EtOH)**
- **No Row Crop Constraint**
- **56.8 GL Max Corn EtOH**
- **100% Double Crop**
- **No AFEX/High Fiber**
- **Partial SOC**
- **Current Tillage**

**EtOH Production (GL/yr)**

**GHG Reduction (Tg CO2 eq/yr)**

Legend:
- **EtOH Production**
- **CO2 Reduction**
Some Thoughts on the Sustainability Transition

- We are in a time of profound transition in how the world will be fueled & fed– we cannot continue much longer on our current pathways, we must change & the sooner the better
- The changes required will be far reaching, profound, revolutionary, upsetting, painful, exciting…pick your adjective
- *Liquid fuels from plant matter (biofuels) are an essential part of the sustainability transition—this will cause a huge impact on the economic, physical & social “landscapes”*
- We should be seeking large, complementary, beneficial changes: *we need food (feed) and fuel and sustainability and rural economic development and better social outcomes*
- This will not happen by accident—we must envision (use our heads), and design (do the research) and then implement sustainable biofuel systems to achieve multiple objectives
Design Criteria for Sustainable Biofuel Systems??

**Biofuel systems will:**

1. increase the fertility of the lands on which they are based
2. produce large amounts of excess energy for the rest of society
3. maintain or increase nutritional services currently provided by the lands on which they are based
4. significantly reduce life cycle greenhouse gases versus petroleum or other fossil based liquid fuels
5. benefit both socially and economically the local communities where biomass raw materials are grown
6. be economically profitable without subsidies
7. improve water quality in the areas where raw materials are grown and around processing plants
8. enhance plant and animal biodiversity

**Biofuel systems will not:**

1. impact the quantity of local water supplies without local consent
2. rely on key inputs which themselves are not sustainably produced
Questions ??
“Absolutely!”
Maximum Ethanol Production Tracks with Maximum CO2 Reduction

- Very little difference in performance over a range of assumptions
Influence of Personal Preferences on Allocation of Impacts

LIFECYCLE GREENHOUSE GAS EMISSIONS

Difference in GHG Emissions due to Personal Preferences

Low Fuel Efficiency  High Fuel Efficiency
Influence of Personal Preferences on Allocation of Impacts

**Land Use Change**

**Land Needed to Grow Animal Feed**

Difference in Land Use Change due to Personal Preferences

**Land Needed to Grow Vegetable Protein**

**Protein from Animal Sources**

**Protein from Plant Sources**