Opportunities and Challenges for Biofuels

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May 31, 2013
Growing Biofuel Production

In the US
Ten-fold increase since 1996

Largest producer in the world

Competitive with gasoline

### Corn Ethanol Production (B Gallons)

<table>
<thead>
<tr>
<th>Year</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
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</thead>
<tbody>
<tr>
<td>USA</td>
<td>3.6</td>
<td>5.3</td>
<td>5.8</td>
<td>7.0</td>
<td>9.2</td>
<td>11.1</td>
<td>12.8</td>
<td>15.9</td>
<td>21.3</td>
<td>29.5</td>
<td>34.7</td>
</tr>
<tr>
<td>EU27</td>
<td>n/a</td>
<td>0.2</td>
<td>0.2</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
<td>0.8</td>
<td>1.5</td>
<td>1.6</td>
<td>2.1</td>
<td>2.9</td>
</tr>
<tr>
<td>Brazil</td>
<td>12.5</td>
<td>9.2</td>
<td>10.9</td>
<td>12.8</td>
<td>13.1</td>
<td>13.9</td>
<td>14.7</td>
<td>16.5</td>
<td>21.3</td>
<td>21.6</td>
<td>21.6</td>
</tr>
<tr>
<td>China</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.8</td>
<td>1.3</td>
<td>1.4</td>
<td>1.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>

### Biofuel Production in Major Countries, 1996–2009 (million ton)

- **Ethanol**
  - EU27: n/a (1996), 0.2 (2000), 0.2 (2001), 0.4 (2002), 0.4 (2003), 0.5 (2004), 0.8 (2005), 1.5 (2006), 1.6 (2007), 2.1 (2008), 2.9 (2009)

- **Biodiesel**
  - USA: n/a (1996), n/a (2000), n/a (2001), n/a (2002), n/a (2003), 0.1 (2004), 0.2 (2005), 0.8 (2006), 2.1 (2007), 2.9 (2008), 1.8 (2009)

**Notes:**
- n/a: data not available.
- --: nearly zero.
Costs have declined with experience (Cumulative production)

Processing Costs of Corn Ethanol (1983-2005)

Each doubling of production has lowered processing costs:
13%-25% for corn ethanol
20% for sugarcane ethanol

(Chen and Khanna, 2012)

Van den wall Bake, 2009
Production of co-products corn oil and Distillers Dried Grain Solubles is increasing profitability.
Corn Ethanol: Profitable for blenders and exporters
Biofuel Policies

• Renewable Fuel Standard - volumetric mandate for different types of biofuels
  – Upper limit of 15 B gallons on corn ethanol

• Blender’s tax credit: 51c/gallon reduced to 45c/gallon for ethanol till Dec 2011
  – $1 per gallon for biodiesel

• Import tariff of 54 c per gallon on sugarcane ethanol till Dec 2011
**Energy Independence and Security Act, 2007**

**Renewable Fuel Standard**

- Cellulosic biofuel
- Renewable diesel
- Advanced biofuel
- Corn Ethanol

**Biofuels**

- Fall short of the goal in 2022, but exceed the 36 billion gallon RFS target by 2030

**36 B G**

**Nested Mandate**

- Cellulosic Biofuel
  - Min. 16 B Gallons

**21 billion gallons**

- Advanced Biofuel
  - 5 Billion gal

**15 Billion Gallons**

With Greenhouse Gas Intensity Thresholds

**Potential Ethanol Imports**

(19 B gallons)
Role of Policy Mix

- RFS - created incentives for investment in ethanol; assurance of demand
- Tariff protected domestic corn ethanol from sugarcane ethanol (prior to 2007)
- VEETC - offset costs of blending for blenders and lowered fuel price for consumers
  - Allowed biofuel production beyond the mandate
- VEETC and tariff
  - Exacerbated effect of biofuels on food prices
  - Encouraged greater vehicle miles travelled and reduced the gasoline displacement and greenhouse gas benefits of biofuels
Some Controversies with Biofuels

- Food vs. Fuel: Competition for limited land will result in higher food crop prices

- Carbon debt: Higher food crop prices will lead to conversion of grassland and forests to crop production and release carbon stocks

- Domestic fuel prices for consumers: Higher or lower with biofuels?

- Global rebound effect: Displacement of demand for oil in the US will lower the world price of oil and cause oil consumption to rebound back in the rest of the world
World Bank Chief: Biofuels Boosting Food Prices

April 11, 2008  12:01 AM

Secret report: biofuel caused food crisis
Internal World Bank study delivers blow to plant energy drive

Aditya Chakrabortty
The Guardian, Thursday 3 July 2008 14:35 EDT

Demand for ethanol and biodiesel in the world, World Bank says. Droughts, financial crises and increased demand for food have created "a perfect storm" that has contributed significantly to the rising cost of food, according to a leaked World Bank report obtained by The Guardian.

Biofuels have forced global food prices up by 75% - far more than previously estimated - according to a confidential World Bank report obtained by the Guardian. The damming unpublished assessment is based on the most detailed analysis of the crisis so far, carried out by an internationally-respected economist at global financial body.
Table 2
Projected impact of biofuel growth on prices and production in 2015 (%): Partial equilibrium models.

<table>
<thead>
<tr>
<th></th>
<th>OECD</th>
<th>IFPRI</th>
<th>FAPRI</th>
<th>WEMAC</th>
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</thead>
<tbody>
<tr>
<td><strong>World</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize: World price</td>
<td>14.6</td>
<td>16.1</td>
<td>–</td>
<td>52.6</td>
</tr>
<tr>
<td>Maize: World production</td>
<td>2.9^a</td>
<td>4.7</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Sugar cane: World price (raw)</td>
<td>37.1^b</td>
<td>3.4</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Sugar cane: World production</td>
<td>7.4</td>
<td>1.1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Vegetable oil: World price</td>
<td>15</td>
<td>0.4</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Vegetable oil: World production</td>
<td>2.6</td>
<td>0.1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Maize</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize: US producer price</td>
<td>–</td>
<td>16.1</td>
<td>16.2</td>
<td>49.6</td>
</tr>
<tr>
<td>Maize: US production</td>
<td>–</td>
<td>5.0</td>
<td>5.8</td>
<td>18.9</td>
</tr>
</tbody>
</table>

^a World production of coarse grain, instead of maize, is reported.

^b World price of sugar, instead of sugar cane is reported.

^c Vegetable oil, a composite of oilseed oil (soybean oil, rapeseed oil and sunflower oil) and palm oil, is reported for OECD; the oil item reported for IFPRI includes all oil products (oilseed oil, palm oil, etc.).

Table 3
Projected impact of biofuel growth on prices and production in 2015 (%): General equilibrium models.

<table>
<thead>
<tr>
<th></th>
<th>LEITAP^d</th>
<th>Purdue I^f</th>
<th>Purdue II</th>
<th>FARM II</th>
<th>GF</th>
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</thead>
<tbody>
<tr>
<td>Maize: US price</td>
<td>4.7^a^g</td>
<td>22.7^b</td>
<td>14^b</td>
<td>23</td>
<td>45.2</td>
</tr>
<tr>
<td>Maize: US production</td>
<td>4^a</td>
<td>16.6^b</td>
<td>10.8^b</td>
<td>33</td>
<td>51.3</td>
</tr>
<tr>
<td>Sugar cane: Brazil price</td>
<td>1.5^c^g</td>
<td>18.6</td>
<td>17.5</td>
<td>24</td>
<td>83.7</td>
</tr>
<tr>
<td>Sugar cane: Brazil production</td>
<td>4^c</td>
<td>8.4</td>
<td>8.4</td>
<td>53</td>
<td>147.1</td>
</tr>
<tr>
<td>Oilseeds: EU price</td>
<td>5.5^g</td>
<td>62.5</td>
<td>56.4</td>
<td>–</td>
<td>38.0^d</td>
</tr>
<tr>
<td>Oilseeds: EU production</td>
<td>4</td>
<td>51.9</td>
<td>53.1</td>
<td>–</td>
<td>95.0^d</td>
</tr>
</tbody>
</table>
Food-based biofuels can spur climate change

By Deborah Zabarenko, Environment Correspondent

WASHINGTON (Reuters) - Alternative fuels made from corn, soybeans, sugar cane and palm trees can in some cases increase the amount of climate-warming carbon dioxide that goes into the atmosphere, U.S. researchers reported on Thursday.

These so-called food-based biofuels can actually hurt the environment if they are produced on land that was formerly grassland, rain forest or savanna, the scientists said in the Journal Science.

Industry groups took issue with the findings, calling them simplistic and noting the use of environmentally sound techniques to cultivate biofuels can reduce emissions. At the same time, agriculture groups said

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

Timothy Searchinger¹, Ralph Heimlich², R. A. Houghton³, Fenguia Dong⁴, Amani Elobeid⁴, Jacinto Fabiosa⁴, Simla Tokgoz⁴, Dermot Hayes⁴, Tun-Hsiang Yu²
Indirect Land Use Change Related GHG Intensity Estimates for Biofuels

Khanna and Crago, 2012
Effect of Policies on Fuel Prices

• By reducing demand for oil, likely to reduce the price of oil imports for the US
  – Depends on how OPEC reacts to large scale biofuels

• But implicitly or explicitly penalize gasoline and credit biofuel consumption

• Net impact on consumer price will depend on
  – the responsiveness of world oil price to reduction in demand in the US
  – Stringency of the policy
  – Carbon intensities of various fuels
  – Extent to which the costs of biofuels are passed on to consumers
Study: Low-Carbon Fuel Standards Are Unlikely to Reduce Warming

By KATE GALBRAITH

Green under Low

By STEPHEN P. HOLLAND, JON

A low carbon fuel standard would kill millions of jobs, double gasoline prices and increase GHG emissions

By Administrator

WASHINGTON – This week, the National Low Carbon Fuel Standard (LCFS) Project is holding a series of public briefings to release findings from two reports which they claim will provide evidence that LCFS programs can be successfully implemented across the US. Several previously released studies have shown that LCFS programs will have devastating impacts on fuel prices and greenhouse gas emissions.

More Voices Emerge in Support of California’s Low Carbon Fuel Standard

In the past few weeks, California’s California Low Carbon Fuel Standard (LCFS) received a heavy dose of positive news: strong support from major companies to develop cleaner transportation fuel options and solid evidence to prove the standard is working.

On April 2, major business interests and non-profit organizations across the state filed four separate briefs supporting the LCFS in the state Appeals Court in Fresno. The briefs state: "The LCFS is the only way to meet the state's ambitious climate objectives, reduce air pollution and provide environmental and economic benefits to California and the nation. The LCFS is specifically designed to reduce greenhouse gas emissions and mitigate the impacts of climate change without raising fuel prices to unreasonable levels."

'Positive steps':

"It is positive to see the significant support for the LCFS from major companies and organizations," said Crystal Mack, Sacramento office manager of the Environmental Defense Fund. "It proves that the LCFS can help us meet our ambitious climate goals while also creating economic opportunities.

"As the state moves towards the LCFS, it is important that we continue to have strong support from businesses and organizations of all sizes. It is encouraging to see the continued support for the LCFS, and we look forward to working with all stakeholders to ensure the LCFS is successful."
Challenges for Biofuels

- Demand side constraints: Blend Wall with consumption limited to E10
- Supply side: Limits to the use of corn for biofuels; currently using 40% of corn produced
- Technology for cellulosic biofuels not yet commercially viable
**Waiver of the Cellulosic Biofuel Mandate: Create Uncertainties in the Biofuel Industry**

<table>
<thead>
<tr>
<th>EPA Proposed U.S. Biofuels Mandates for 2013</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Cellulosic biofuel</td>
</tr>
<tr>
<td>Biomass-based diesel</td>
</tr>
<tr>
<td>Advanced biofuels</td>
</tr>
<tr>
<td>Total biofuels</td>
</tr>
<tr>
<td>Implied corn starch ethanol</td>
</tr>
</tbody>
</table>

The only categories where the proposed mandates deviate from the EISA mandates are (1) a much lower cellulosic biofuel mandate than called for in the 2007 legislation and (2) a substantially higher biomass-based diesel mandate than the minimum required by the EISA. Thus, biodiesel is projected to offset a substantial part of the shortfall from the low cellulosic biofuel production.
Second Generation Biofuels

Wide range of feedstocks: crop/forest residues, energy crops, woody biomass

Potentially:
Crop and forest residues require no diversion of land from other uses

High yields of energy crops per unit land, even on marginal land; rainfed and low chemical input requirements

Small carbon footprint; high soil carbon sequestration with energy crops; residues can be carbon neutral if collected in sustainable amounts

Environmental benefits for soil and water quality with energy crops
Choices for Second Generation Biofuel Feedstocks

Figure 1: Biofuel Yields with Alternative Feedstocks (ethanol equivalent gallons/acre)
Miscanthus
Delivered Corn Stover Yield

Delivered Wheat Straw Yield

Delivered Switchgrass Yield

Delivered Miscanthus Yield

2-4 tons per ha

1-3 tons per ha

8-22 tons per ha

15-35 tons per ha
Spatial Distribution of Least Cost Biofuel Feedstocks on Marginal Land

Feedstock

- 0
- Corn Stover
- Miscanthus
- Switchgrass
- Energy Cane
Agricultural Land in the US in 2007 (M Hectares)

11 M ha @15 metric tons of biomass/ha and 300 liters of biofuel per ton = 13 B gallons
Greenhouse Gas Intensity

Average Carbon Intensity of Alternative Fuels

$g \text{ CO}_2/\text{MJ}$

- Emissions Including Direct Land Use Change
- EPA's ILUC Related CI

Huang et al., 2011
High Costs of Cellulosic Biofuels (cents/MJ)

Production unlikely to occur in the absence of policy support
Low Carbon Fuel Policies

– Allow the blend of low carbon fuels to be determined based on carbon intensity and cost-effectiveness
  • Not just least cost in each category

– Create incentives for continuous efforts at lowering GHG intensity of fuels even after they meet the thresholds set under the RFS

– Accelerate cost reducing technological innovation in advanced biofuel due to learning by doing

– Incentivize a broader range of low carbon fuel alternatives

– But may not achieve the energy security benefits of the RFS
Carbon Tax

– Would achieve emissions reduction primarily by reducing fuel use and vehicle miles travelled

– Would have to be very high
  • to stimulate advanced biofuels
  • to achieve large reductions in fossil fuel use

– But would raise tax revenue which could be used to reduce other distortionary taxes

– Provides certainty/limit on carbon price
Performance of the RFS (2007-2035)

RFS can reduce US GHG emissions by 4%
While allowing aggregate miles consumed to increase by 1%

But 61% of 537 B gallons of biofuels would be from corn

Increases corn price in 2030 by 38%
Reduces fuel price: 6-10%
Large economic benefits for the US

Similar reduction of 4% in GHG emissions could be achieved by

- LCFS with target for 8% reduction in GHG intensity by 2015-2030 and 337 B gallons of biofuels
- Carbon tax of $50 per ton of CO2 (2015-2032) with 113 B gallons of biofuels
Mix of Biofuels Under Alternative Policies that Achieve the Same GHG Reduction as the RFS (2007-2035)

**RFS Targets**
- Corn Ethanol: 61%
- Cellulosic Ethanol (Crop Residues): 17%
- Cellulosic Ethanol (Energy Crops): 12%
- Sugarcane Ethanol: 7%
- Biodiesel: 3%

**LCFS with 8% Reduction Target for GHG Intensity**
- Corn Ethanol: 16%
- Cellulosic Ethanol (Energy Crops): 71%
- Cellulosic Ethanol (Crop Residues): 4%
- Sugarcane Ethanol: 6%
- Biomass Diesel: 2%
- Biodiesel: 1%

**Carbon Tax**
- Corn Ethanol: 79%
- Biodiesel: 2%
- Sugarcane Ethanol: 19%

$50 per ton of CO2 Carbon Tax
Key Policy Questions

• What is the mix of policy needed to achieve multiple objectives for the energy sector?
  energy security, GHG reduction and domestic economic benefits

• What are the trade-offs we are willing to make to promote a transition to renewable energy?

• How can we avoid the unintended consequences of policies offsetting the intended benefits?
In Summary

Media is an important means to communicate information about science to people

Good science journalism

- Must be critical, based on knowledge and understanding of issues
- Ability to put things in perspective; not simply act as a “translator”
- Make well-informed judgments on how to present both sides of the issue - Not necessarily as two equal camps for the sake of balance
- Re-visit and re-assess information provided as new science emerges

Provide the public with a realistic impression of

- What is well established and what are hot topics
- Uncertainties and controversies
- Methods and social context for the science

Stefan Rahmstorf, “Is Journalism Failing on Climate?” Environmental Research Letters, 2012
Useful Websites

http://www.agmrc.org/
http://www.farmdocdaily.illinois.edu/
http://www.eia.gov/biofuels/issuestrends/
http://www.theicct.org/

Data sources
http://www.nass.usda.gov/Quick_Stats/
http://www.eia.gov/

Biomass Profitability Calculator
http://miscanthus.ebi.berkeley.edu/Biofuel/

My publications and contact: khanna1@illinois.edu
http://ace.illinois.edu/directory/madhu-khanna
http://scholar.google.com/citations?user=LPH4gbUAAAAJ&hl=en