BIOETHANOL

How sustainable?
How convenient?

Guido Ghisolfi
Vice President Corporate Operations & Research
A lot has been said about bioethanol production cost, price and environmental sustainability.

The interests involved are so large that it would be at least ingenuous to think that all statements on feasibility are moved by scientifical rather than political convictions.

I would like to present a strategical assessment to explain why ethanol can be considered in the portfolio of large chemical companies.
<table>
<thead>
<tr>
<th>Country</th>
<th>Bioethanol Supply / Demand</th>
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<tbody>
<tr>
<td><strong>USA</strong></td>
<td>Mandatory: 7.5 billion gallons = 22 million tons protected by 54 ¢/gallon import duty on Brazilian ethanol. Mandate has been increased in the last Energy Bill to 35 billion gallons by 2022. Capacity installed and under construction: 12 billion gallons.</td>
</tr>
<tr>
<td><strong>EU</strong></td>
<td>Mandatory: 5.5% by 2010 equivalent to 11 million tons. New target set on January 24 by the European Commission to 10% by 2020. Current installed capacity: 3 million tons.</td>
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<tr>
<td><strong>Brazil</strong></td>
<td>Production: 17 million tons from sugar cane. Brazil has 5 million hectares at sugar cane and can double its plantations in the near future.</td>
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</table>
European Sustainability

The targets of 20 million tons of biofuel for 2010 and 40 million tons for 2020 are not going to be achieved without import. In fact:


<table>
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<tr>
<th>Ha</th>
<th>Year</th>
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<tbody>
<tr>
<td>12,000,000</td>
<td>2010</td>
</tr>
<tr>
<td>16,000,000</td>
<td>2020</td>
</tr>
<tr>
<td>19,000,000</td>
<td>2030</td>
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</table>

- With a yield of biofuel of 2 t/ha in 2010 and 3 t/ha in 2020, the land might be there.

- Logistics and agricultural economics will prevent though the use of part of this land demanding the import of at least 30% of the necessary biofuel.
Bioethanol: A Global Strategic Assessment

**Prof. Ricardo Hausmann**, Director of Harvard University’s Center for International Development, writes that *(Financial Times, November 7, 2007)*:

1) In some 95 countries there are more than 700 million hectares of good quality land which is not cultivated;

2) Depending on the assumption about productivity per hectare, today’s production of 85 million b/d of oil can be completely satisfied by the biofuels produced on such land;
3) Even if partially used, this large potential biofuel supply will cap the price of oil because its supply is much more elastic than the supply of oil.

This will cause the price of oil to be set at marginal cost of bio-energy.

If OPEC tries to raise prices above the price of biofuel, profitability will only crowd in more biofuels.
4) The countries which have the largest endowment of under-utilized lands are in the developing countries, especially Latin America and Africa. Bioenergy will make the needed infrastructure investments socially profitable creating a possible stepping stone into other industries.
Is bioethanol worth the effort?

- A recent study published by Argonne National Laboratory of the University of Chicago and endorsed by the US Department of Energy, updates the Well-to-Wheels Study of Life Cycle Analysis for Fuel Ethanol.

- The LCA takes into consideration both the in- and output energy balance in the production of fuel ethanol and the impact on GHG for the various feedstocks and compares it with all fossil fuels including the possible extraction from oil sands.
Updated Well-to-Wheels Results of Fuel Ethanol with the GREET Model

Michael Wang

Center for Transportation Research – Argonne National Laboratory

Presentation to the Biomass R&D Technical Advisory Committee
Detroit, MI, Sept. 11, 2007

Available at www.transportation.anl.gov/software/GREET/index.html
The GREET Model

**Greenhouse gases, Regulated Emissions, and Energy use in Transportation**

- Developed at Argonne since 1994;
- More than 100 fuel production pathways from various feedstocks;
- 75 vehicle/fuel systems.
Energy and Emission Outputs with GREET

- **Emissions of greenhouse gases (GHG)**
  - CO₂, CH₄ and N₂O (and other optional GHGs)

- **Emissions of six criteria pollutants**
  - VOC, CO, NOₓ, SOₓ, PM₁₀ and PM₂.₅;
  - Total and urban separately.

- **Energy use by type**
  - All energy sources (fossil and non-fossil);
  - Fossil fuels (petroleum, natural gas and coal combined);
  - Petroleum;
  - Coal;
  - Natural gas.
Fuel Production Pathways from various Energy Feedstocks (Well-to-Pump) in GREET

**Petroleum:** Conventional Oil Sands
- Gasoline
- Diesel
- LPG
- Naphtha
- Residual Oil

**Natural gas:**
- NA
- Non-NA
- Coke Oven Gas
- LNG
- LPG
- Methanol
- Dimethyl Ether
- FT Diesel & Naphtha
- Hydrogen

**Nuclear**
- Hydrogen

**Coal**
- Hydrogen
- FT Diesel
- Methanol
- Dimethyl Ether

**Sugar cane**
- Butanol
- Ethanol

**Soybeans**
- Biodiesel

**Cellulosic Biomass:**
- Switchgrass
- Fast growing trees
- Crop residues
- Forest residues
- Ethanol
- Hydrogen
- Methanol
- Dimethyl Ether
- FT Diesel

**Residual Oil Coal Natural Gas Nuclear Biomass Other renewables**
- Electricity
Feedstocks for biofuel production are diversified and vary across regions.

- **Sugar Crops**
  - Sugar cane
  - Sugar beet

- **Oil Seed Crops**
  - Soybean
  - Rapeseed
  - Palm

- **Others**
  - Waste cooking oil
  - Animal fat

- **Grain Starch**
  - Corn
  - Wheat
  - Barley
  - Sorghum

- **Cellulosic Biomass**
  - Corn stover, rice straw, wheat straw
  - Forest wood residue
  - Municipal solid waste
  - Energy crops
  - Black liquor
  - Fast growing trees

*The feedstocks that are underlined are already included in the GREET model.*
GREET Ethanol Life-Cycle Analysis includes activities from fertilizer to ethanol at refueling stations.

- Agricultural chemical production
- Agricultural chemical transportation
  - Corn farming
  - Crop residue collection
  - Switchgrass farming
  - Fast growing tree farming
  - Forest residue collection
  - Sugar cane farming
- Corn ethanol production
- Cellulosic ethanol production
- Sugar cane ethanol production
- Ethanol transportation
- Ethanol blending at bulk terminal
- Ethanol blends at refueling station
- Co-produced electricity
- Animal feed

These pathways are already included in the GREET model.
Key Issues for Bioethanol Life-Cycle Analysis

- Nitrogen fertilizer production:
  - Nitrogen fertilizer is produced primarily from natural gas. About 40% of total US ammonia demand is met by imports (2005).

- Use of fertilizer and chemicals in farms:
  - \( \text{N}_2\text{O} \) emissions from N-fertilizer application;
  - Lime application: \( \text{CO}_2 \) emissions

- Farming is a key activity for cellulosic biofuel life cycle.

- Open field burning in sugar cane plantations causes significant emissions (80% of can is harvested by burning in Brazil).
Key Issues for Bioethanol Life-Cycle Analysis

- Energy use in corn ethanol plants:
  - The amount of process fuels for steam production;
  - The type of process fuels.
- Co-products:
  - Animal feeds for corn ethanol;
  - Electricity for cellulosic and sugar can ethanol.
- Potential land use change and resulted CO₂ emission.
Improved technology and plant design has reduced energy use and operating costs in corn ethanol plants.

Data for new ethanol plants is from Mueller and Cuttica (2006).
Life-Cycle Fossil Energy Use: Corn Grain Ethanol

- 57.2% EtOH Production
- 17.1% Farming
- 18.3% Fertilizers / Chemicals
- 1.5% Farming machinery
- 2.3% EtOH Transport
- 3.6% Feed transport
- 0.0% Vehicle use

Corn
Most recent studies show positive net energy balance for corn ethanol
Use of renewable process fuels improves net energy balance significantly for corn ethanol

1 million Btu fuel produced – Btu fossil energy input

Current Future Current Future NG NG & Wet NG & CHP New EtOH with gasification of biomass
Large Avoidance of GHG Emissions by Corn Ethanol with Use of Renewable Process Fuels

Relative to gasoline in 2010

- Current Average: -19%
- Future Average: -21%
- NG: -28%
- NG & Chp: -32%
- NG & Syrup: -36%
- NG & Wet DGS: -39%
- Gasification of Biomass: -52%
From corn to sugar cane to cellulosic biomass, GHG emissions avoidance are increased.

<table>
<thead>
<tr>
<th>Source</th>
<th>GHG Emission Reductions by Ethanol Relative to Gasoline (per Energy Unit Basis)</th>
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</thead>
<tbody>
<tr>
<td>Sugar Cane</td>
<td>-19%</td>
</tr>
<tr>
<td>Cellulosic ethanol (hydrolysis of biomass)</td>
<td>-28%</td>
</tr>
<tr>
<td>Corn ethanol</td>
<td>-39%</td>
</tr>
<tr>
<td>Switchgrass EtOH</td>
<td>-52%</td>
</tr>
<tr>
<td>Forest Residues EtOH</td>
<td>-76%</td>
</tr>
<tr>
<td>DGS</td>
<td>-80%</td>
</tr>
<tr>
<td>Biomass</td>
<td>-85%</td>
</tr>
<tr>
<td>Current</td>
<td>-90%</td>
</tr>
</tbody>
</table>
WTP GHG results show that oil sands operations are carbon-intensive
It is clear that the target is:

- A cellulosic ethanol competitive with fossil fuels...
- ...produced by a relatively cheap biomass...
- ...which can be intensively grown...
- ...on less available land...
- ...using less water and less fertilizers!
Ligno-Cellulosic Ethanol – EU and Italian Overview

Agricultural Waste Potential - EU

Ligno-Cellulosic Ethanol – EU and Italian Overview

Agricultural Waste Potential - EU

**Corn Stover**
- **Italy**: 27%
- **France**: 41%
- **Spain**: 10%
- **Germany**: 14%
- **Others**: 8%

**Wheat Straw**
- **France**: 38%
- **UK**: 16%
- **Italy**: 13%
- **Spain**: 5%
- **Others**: 20%

**Barley Straw**
- **France**: 19%
- **Spain**: 15%
- **UK**: 13%
- **Denmark**: 7%
- **Others**: 27%

- **Germany**: 27%

Gruppo Il Sole 24 ore
La cultura dei fatti.
Ligno-Cellulosic Ethanol – EU and Italian Overview

Agricultural Waste Potential - Italy

Source: FAO (1999)
M&G believes that the objective is at reach.

A biomass that yields 60 dry tons/ha vs. 12 for corn with only 50 unitN$_2$/ha vs. 170 for corn and no irrigation requirement vs. 3500 m$^3$/ha of corn

M&G has launched the PRO.E.SA. project to achieve this goal within 2012.
Bioethanol: Conclusions

- M&G has the only corn based 200 kt ethanol plant under construction in Italy with start-up expected for Q3 2009.
- M&G has started a € 120 million R&D program to identify the optimal biomass and the most competitive hydrolysis process for second generation EtOH.
- M&G expects to have a proven 20,000 t/y semi-industrial plant by 2011

and

- Convert the corn ethanol to cellulosic by 2012 reducing the necessary hectares to supply the plant from 65,000 to <10,000.
Thank you!