Equity and efficiency trade-off in biodiesel supply chain

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OUTLINE

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- BIODIESEL SUPPLY CHAIN
- SUSTAINABILITY ASSESSMENT
- EQUITY AND EFFICIENCY TRADE-OFF
- CONCLUSIONS
BIODIESEL

• It is an undisputed fact that transport is almost totally dependent on fossil particularly petroleum based fuels such as gasoline, diesel fuel, liquefied petroleum gas, and compressed natural gas. As the amount of available petroleum decreases, the need for alternative technologies to produce liquid fuels increases. The benefits of biofuels over traditional fuels include greater energy security, reduced environmental impact, foreign exchange savings, and socioeconomic issues related to the rural sector. For these reasons, the share of biofuels in the automotive fuel market is expected to grow rapidly over the next decade.

• Biofuel is a renewable energy source produced from natural (biobased) materials, which can be used as a substitute for petroleum fuels. One of the most common biofuels is biodiesel, which can be obtained from oil seeds.

• Biodiesel is a renewable and clean burning combustible fuel for diesel engines. It is nontoxic, biodegradable, and virtually free from aromatics and sulfur contents. This is because its primary components are domestic renewable resources such as vegetable oil and animal fats consisting of long-chain alkyl (methyl, ethyl, or propyl) esters.
BIODIESEL ADVANTAGES

• Renewable and energy efficient.
• Usable in most diesel engines with no or only minor modifications.
• Nontoxic, biodegradable and suitable for sensitive environments.
• A fuel with high flash point, positive energy balance and reduced emissions of carbon monoxide (CO), total hydrocarbon (THC) and particulate matter (PM).
• Biodiesel fuel can also be used in existing oil heating systems and diesel engines without making any alterations.
FEEDSTOCKS

• The choice of feedstock for today’s commercial biodiesel plants depends largely on geography, with rapeseed oil dominating the EU production, soybean oil dominating the US and Latin American production, and palm oil mainly being used in Asia. The composition of the feedstocks varies substantially, depending on source and refining. Typical compositions of oils and fats that can be used for production of biodiesel are presented in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Rapeseed</th>
<th>Soybean</th>
<th>Soybean Palm</th>
<th>Tallow</th>
<th>Palm fatty acid distillate</th>
<th>Used cooking oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triglycerides</td>
<td>96.0</td>
<td>98.6</td>
<td>87.0</td>
<td>74.0</td>
<td>8.0</td>
<td>62.0</td>
</tr>
<tr>
<td>Diglycerides</td>
<td>2.0</td>
<td>0.8</td>
<td>6.0</td>
<td>12.0</td>
<td>5.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Monoglycerides</td>
<td>0.5</td>
<td>0.1</td>
<td>2.0</td>
<td>4.0</td>
<td>2.0</td>
<td>7.0</td>
</tr>
<tr>
<td>FFA</td>
<td>1.5</td>
<td>0.5</td>
<td>5.0</td>
<td>10.0</td>
<td>85.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

• Microalgae: A promising feedstock for biodiesel

• Rapeseed oil is the predominant feedstock in European Union and soybean oil is the main contributor in the USA. However, these food-based raw materials have resulted in the debate “food vs. fuels”. Since biodiesel production grew rapidly in the world, there was a dramatic increase in food prices for vegetable oils.

• Microalgae are a large and diverse group of photosynthetic eukaryotes with a simple cellular structure, ranging from unicellular to multicellular forms; they can be found anywhere water and sunlight co-occur, including soils, ice, lakes, rivers, hot springs, ocean and they have the ability to capture carbon dioxide and convert energy of sunlight to chemical energy. Algal oils, which can be used to product biodiesel, are usually accumulated as membrane components, storage products, metabolites and sources of energy under some special conditions.
FEEDSTOCKS

• Microalgae yield more oils per hectare than some traditional biodiesel feedstocks.

• Microalgae containing 30% oil by weight of dry biomass could yield almost 58700 liters per hectare, far in excess of what can be generated from rapeseed or soybean grow in the same area. Furthermore, the 30% Oil level is quite common in microalgae and the total oil content can be up to 70% in some microalgae species such as Botryococcus braunii and Schizochytrium spp. Biodiesel productivity could reach 121104 Kg/ha per year using 70% oil content algae as feedstock. Thus it was feasible to use algae oil production to completely replace fossil diesel.
CHEMICAL COMPOSITION OF BIODIESEL
TRANSESTERIFICATION REACTION

VEGETABLE OILS
ANIMAL FAT
WASTE

BIODIESEL
BIODIESEL PRODUCTION

- Soap production
- Conversion into ethanol through fermentation
- Formate production
BIODIESEL AS DIESEL ENGINE FUEL

BIODIESEL → 39-41 MJ/kg
PETRO-DIESEL → 43 MJ/kg
GASOLINE → 46 MJ/kg
PETROLEUM → 42 MJ/kg
COAL → 32-37 MJ/kg
PROPERTIES OF BIODIESEL

• Physicochemical properties

**Viscosity:** decreased during transesterification

**Cetane Number:** measurement of the combustion quality (40 - 55)

• Biodegradability of biodiesel

Biodiesel is non-toxic and degrades about four times faster than petro-diesel.

• Higher lubricity

Fatty acid alkyl esters (biodiesel) have improved lubrication characteristics.

• Stability of biodiesel

The oxidation and polymerization of biodiesel fuel during combustion and storage is major concern in terms of the quality of biodiesel.

• Lower emissions of biodiesel

Biodiesel fuel has significantly reduced exhaust emissions 75–83% compared to petro-diesel based fuels.
a) biodiesel from vegetable oil and animal fat. b) fossil diesel.

The different stages of the biodiesel supply chain are: A – feedstock cultivation; B – transportation; C – oil extraction; D – transportation; E – biodiesel production; F – biodiesel distribution; G – Biodiesel final use.

source: Mata, Teresa M., et al. (2011)
SUSTAINABILITY ASSESSMENT

“development or resources that meets the need of the present generation without compromising the ability of future generation to meet their own need” (Brundtland Commission, 1987)

• to be carbon neutral, from the perspective of mitigation of global warming;
• not to affect the quality, quantity and rational use of natural resources as water, air and soil;
• not to have negative social consequences as starvation due to high food price;
• to contribute to the society economic development and equity;
• not to affect biodiversity

LBM (Logic-Based Model) (Edgert et al., 2010)
LCA (Life Cycle Analysis) (Kammen et al., 2008)
multicriteria analysis (Silva Lora et al., 2010) (Delrue F., et al., 2011)
ENVIROMENTAL SUSTAINABILITY

- Integration with the local environment
  - landscape preservation
  - biodiversity
  - land use

- Effect on the local environment
  - waste deposits
  - pollution of air
  - soil preservation

- Effect on the global environment
  - global warming
  - use of non-renewable energy
ECONOMICAL SUSTAINABILITY

- Geographic closeness between feedstock producers and biofuels producers
- Persistency of the feedstock economic viability
- Persistency of the economic viability of the biofuels production

- Competitiveness of the feedstock production
- Competitiveness of the biofuels production
- Competitiveness of the biofuels on fuels retail market
SOCIAL SUSTAINABILITY

- **Social control**
  - Priority to food and feed
  - Respect of the land rights
  - Local control of seeds

- **Working conditions**
  - Comfort of the work process
  - Monitoring of the health and safety of the workers
UNCERTAINTIES OF BIODIESEL SUPPLY CHAIN

- Technology
  - Transesterification process
  - Use of some enzymes
  - Thermal cracking or pyrolysis of triglycerides

- Agricultural productivity of biodiesel feedstock
  - Raw materials acquisition
  - Production yields
  - Lead time constraints

- Transportation and logistics
  - Scheduling
  - Demand and inventory
  - Transportation cost
  - Lack of coordination
  - Delivery constraints

- Total energy balance
  - Energy consumption
  - GHG emissions

- Demand
  - Variations in the quantity
  - Price uncertainty
DEFINITIONS

**equity**

Equitable means fair. What is fair is a normative issue. There is no right or wrong answer from an economic perspective. Opinions can differ.

**efficiency**

According to economists, an allocation of resources is efficient if it is impossible to change the allocation so as to make one or more members of society better off without making any other members worse off.
"The use of vegetable oil as fuel may seem insignificant today, but such oils may become, in course of time, as important as are now oil and products derived from coal."

Rudolf Diesel, inventor of diesel engine, 1912
Second generation biofuels could be the only way in order to reduce waste and create bio-energy.
# BIODIESEL PRODUCTION IN EU


Source: European Biodiesel Board (2009), Statistics, Production by Country.

<table>
<thead>
<tr>
<th>Country</th>
<th>2008</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>3203</td>
<td>3284</td>
</tr>
<tr>
<td>France</td>
<td>2063</td>
<td>991</td>
</tr>
<tr>
<td>Italy</td>
<td>676</td>
<td>413</td>
</tr>
<tr>
<td>Belgium</td>
<td>315</td>
<td>189</td>
</tr>
<tr>
<td>Poland</td>
<td>313</td>
<td>91</td>
</tr>
<tr>
<td>Portugal</td>
<td>305</td>
<td>199</td>
</tr>
<tr>
<td>Denm./Sweden</td>
<td>263</td>
<td>168</td>
</tr>
<tr>
<td>Austria</td>
<td>242</td>
<td>303</td>
</tr>
<tr>
<td>Spain</td>
<td>235</td>
<td>191</td>
</tr>
<tr>
<td>Other</td>
<td>1199</td>
<td>664</td>
</tr>
<tr>
<td><strong>EU 27</strong></td>
<td><strong>8813</strong></td>
<td><strong>6492</strong></td>
</tr>
</tbody>
</table>
The transportation and energy sectors are the major anthropogenic sources, responsible in European Union (EU) for more than 20% and 60% of greenhouse gas (GHG) emissions, respectively.

- "Biofuels Flight path"
- "European Advanced Biofuels Flight path"
CONCLUSIONS

EU has to focus the mounting interest in developing second generation biofuels produced from non-food feedstock such as microalgae, which potentially offer greatest opportunities in the longer term.
CONCLUSIONS

In order to stimulate the biodiesel growth, governments have to support farm subsidies. These include targeted planning and regulation, incentives, industry incubation, and economic risk mitigation both for farmers and users. This kind of detailed, integrated, spatially explicit assessment of the costs, benefits, and trade-offs is useful in all agricultural regions.
THANKS FOR YOUR ATTENTION

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