LCA of biodiesel from Jatropha, oil palm and soybean

Nils Rettenmaier

EUROCLIMA Workshop
Campinas, Brazil, 30 November 2011
Who we are - What we do

IFEU - Institute for Energy and Environmental Research Heidelberg, since 1978

• Independent scientific research institute
• organised as a private non profit company with currently about 50 employees
• Research / consulting on environmental aspects of
  - Energy (including Renewable Energy)
  - Transport
  - Waste Management
  - Life Cycle Analyses
  - Environmental Impact Assessment
  - Renewable Resources
  - Environmental Education
Who we are - What we do

TREMOD: Transport Emission Model

• Modelling emissions of road vehicles, trains, ships and airplanes

• Official database of the German Ministries for emission reporting

Life cycle analyses (LCA) and technology impact assessments since 1990:

• Biofuels (all biofuels, all applications)

• Alternative transportation modes

• Renewable Energy
Who we are - What we do

IFEU - Institute for Energy and Environmental Research Heidelberg, since 1978

Our clients (on biofuel studies)
- World Bank
- UNEP, GTZ, etc.
- European Commission
- National and regional Ministries
- Associations (industrial, Life Cycle Analyses)
- Local authorities
- WWF, Greenpeace, etc.
- Companies (DaimlerChrysler, German Telecom, etc.)
- Foundations (German Foundation on Environment, British Foundation on Transport, etc.)
LCA of biodiesel from Jatropha, oil palm and soybean

Nils Rettenmaier

EUROCLIMA Workshop
Campinas, Brazil, 30 November 2011
Outline

• **Introduction**

• **Life cycle assessment (LCA) of biodiesel**
  • LCA methodology
  • Biofuels versus conventional (fossil) fuel
    • Jatropha biodiesel
    • Palm oil biodiesel
    • Soybean biodiesel
  • Biofuels versus biofuels
  • Impact of indirect land use change (iLUC)

• **Conclusions**
Biofuels

Environmental advantages and disadvantages:

+ 
  - CO₂ neutral
  - Save energetic resources
  - Organic waste reduction
  - Less transport
  - etc.

- 
  - Land use
  - Eutrophication of surface water
  - Water pollution by pesticides
  - Energy intensive production
  - etc.

Total:
positive or negative

?
"HEY, I THOUGHT WE WERE WORKING WITH THE SAME DATA..."
Goal and scope definition

Inventory analysis

Impact assessment

Interpretation

ISO 14040 & 14044
LCA: Life cycle comparison

**Fossil fuel**
- Resource extraction
- Raw material production
- Transport
- Processing
- Utilisation

**Biofuel**
- Fertiliser
- Fuel
- Pesticides
- Agriculture
- Co-products

**Credits**
- Fallow maintenance
- Equivalent products

**Raw material production**

**Processing**

**Utilisation**
Life cycle assessment (LCA)

ISO 14040 & 14044

Goal and scope definition

Inventory analysis

Impact assessment

Interpretation
LCA: Inventory analysis

**Inputs**
- e.g.: natural gas, crude oil, brown coal, hard coal, uranium, water

**Outputs**
- e.g.: CO$_2$, SO$_2$, CH$_4$, NO$_X$, NH$_3$, N$_2$O, HCl, CO, C$_6$H$_6$, VOC

-> Starting point: Mass and energy flows
### LCA: Impact assessment

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Parameter</th>
<th>Substances (LCI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource depletion</td>
<td>Sum of depletable primary energy carriers</td>
<td>Crude oil, natural gas, coal, uranium, …</td>
</tr>
<tr>
<td></td>
<td>Mineral resources</td>
<td>Lime, clay, metal ores, salt, pyrite, …</td>
</tr>
<tr>
<td></td>
<td>Water</td>
<td>Water</td>
</tr>
<tr>
<td>Greenhouse effect</td>
<td>CO$_2$ equivalents</td>
<td>Carbon dioxide, dinitrogen monoxide, methane, different CFCs, methyl bromide, …</td>
</tr>
<tr>
<td>Ozone depletion</td>
<td>CFC-11 equivalents</td>
<td>CFC, halons, methyl bromide, dinitrogen monoxide…</td>
</tr>
<tr>
<td>Acidification</td>
<td>SO$_2$ equivalents</td>
<td>Sulphur dioxide, hydrogen chloride, nitrogen oxides, ammonia, …</td>
</tr>
<tr>
<td>Terrestrial &amp; aquatic</td>
<td>PO$_4$ equivalents</td>
<td>Nitrogen oxides, ammonia, phosphate, nitrate</td>
</tr>
<tr>
<td>eutrophication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summer smog</td>
<td>C$_2$H$_4$ equivalent</td>
<td>Hydrocarbons, nitrogen oxides, carbon monoxide, chlorinated hydrocarbons, …</td>
</tr>
</tbody>
</table>

→ Much more comprehensive than RED GHG balances!
Outline

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  • Biofuels versus biofuels
  • Impact of indirect land use change (iLUC)

• Conclusions
Example 1: Jatropha biodiesel (JME)

Characteristics:
Name: Physic nut (*Jatropha curcas*)
Family: Spurge (Euphorbiaceae)
Fruit: Capsule
Yield: ca. 2.3 t capsules / (ha*yr) or 0.4 t Jatropha oil / (ha*yr) on degraded land
Jatropha: Miracle plant?

- **Traditional uses:**
  - Whole plant: enclosure fences, medicine (seeds, leaves, bark, latex)
  - Husks (and shells): fertiliser
  - Oil (toxic): soap, purgative
  - Press cake (toxic): fertiliser

- **Future uses:**
  - Whole plant: erosion control, carbon sequestration
  - Husks (and shells): solid biofuel
  - Oil (toxic): liquid *biofuel* (pure plant oil or biodiesel)
  - Press cake (toxic): solid biofuel or animal feed (detoxified!)

⇒ **Vision:** Low-input biofuel from the “green desert” for the benefit of the rural population
Results: JME versus diesel fuel

Environmental impacts

Advantageous (e.g. energy), disadvantageous (e.g. acidification) and ambiguous results (summer smog)

Source: IFEU 2009
JME: Optimisation potentials

- Jatropha plantation
  - Extraction & refining
    - Jatropha oil
      - Transport
      - Processing
        - Diesel fuel
  - Ancillary products
    - Apiary products
    - Husks
    - De-oiled cake
      - Transport
      - Trans-esterification
        - Glycerine
          - Chemicals
    - Mineral fertiliser
  - Alternative land use
    - Equivalent products
      - Minerals

Results: Optimisation potentials

Greenhouse effect

By-products should be used for bioenergy!

Source: IFEU 2009
Further reading

„Screening Life Cycle Assessment of Jatropha Biodiesel“

Report commissioned by Daimler AG, Stuttgart

Authors:
Guido Reinhardt, Sven Gärtnert, Nils Rettenmaier, Julia Münch, Eva von Falkenstein

Final report:
December 2007
Example 2: Palm oil biodiesel (PME)

Characteristics:
Name: Oil palm (*Elaeis guineensis*)
Family: Palms (Arecaceae)
Fruit: Fresh Fruit Bunches (FFB)
Yield: ca. 20 t FFB / (ha*yr) and 4 t palm oil / (ha*yr), respectively
Oil palm: Green gold?

• **Traditional uses:**
  - Palm oil: cooking oil, margarine, soap, candles
  - Palm kernel oil: frying fat, confectionery, detergents, cosmetics
  - Press cake: animal feed

• **Future uses:**
  - Palm oil: liquid biofuel (PPO or biodiesel)

• **Energy use:**
  - “Only” 5% up to now, but huge potential!

⇒ Threat: Biofuel from highly biodiverse areas to the detriment of the indigenous population
PME: Life cycle comparison

Ancillary products

Oil palm plantation

Extraction & refining

Palm oil

Transport

Press cake

Fibres & Shells

Waste water

Empty fruit bunches

Trans-esterification

Glycerine

Transport

Diesel fuel

Crude oil extraction and pre-treatment

Palm kernel oil

Tensides

Soy meal

Power mix

Power mix

Mineral fertiliser

Alternative land use

PME

Diesel fuel

Product

Process

Reference system
Results: PME versus diesel fuel

Environmental impacts

 ↔ Advant.  Disadvantage →

-100 -50 0 50 100 150 IE / 100 ha

PME

Energy savings
Greenhouse effect
Eutrophication
Acidification
Summer smog*
Summer smog**
Nitrous oxide

→ Mostly disadvantageous results (e.g. greenhouse effect) except for energy and summer smog

Source: IFEU 2009
Typical palm oil production

1. **Oil palm plantation**
   - Fresh fruit bunches

2. **Palm oil mill**
   - Sterilisation, Threshing
     - Empty fruit bunches
     - Fruit digestion, Pressing
       - Fibres
       - Shells
       - Kernels
       - Cracker

3. **Oil clarification**
   - POME

4. **Palm kernel oil mill**
   - Anaerobic waste water treatment
     - Methane
     - Kernels
     - Crude palm kernel oil
     - Press cake

5. **Crude palm oil**
Optimised palm oil production

- Oil palm plantation
  - Fresh fruit bunches
  - Empty fruit bunches

- Mulch

- Sterilisation, Threshing
  - Fruit digestion, Pressing
    - Fibres
    - Shells
    - Kernels
  
- CHP
  
- Oil clarification
  - POME

- Cracker

- Anaerobic waste water treatment
  - Methane

- Surplus power
  - Power

- Palm kernel oil mill
  - Kernels
  
- Crude palm oil
  - Crude palm kernel oil
  - Press cake
Results: Optimisation potentials

Greenhouse effect

Expenditures PME:
- Cultivation
- Land use change
- All transports
- POME CH4
- Production
- Utilisation

Credits PME:
- Biogas
- Power
- Soy meal
- Tensides
- Chemicals

Diesel fuel:
- Production
- Utilisation

CH₄
Typ. practice
Diesel fuel
Good practice

Range

PME
Advantage
Disadvantage

→ Large influence of land use change

→ Palm oil production should be optimised!

Source: IFEU 2009
PME: Direct land use change (dLUC)

- Natural forest *
- Peat forest *
- Tropical fallow

* Including use of hard wood

**Direct Induction of Forest Logging**

1. Tropical producer country: (certified) good practice, production of biomass for export
2. Replaces natural ecosystem, a natural forest

Europe: importing biomass or biofuel

Source: IFEU 2008
Oil palm plantation through cutting of tropical forests
Oil palm plantation on marginal degraded land
Carbon stock changes

Case 1
Natural forest → Plantation
Period 1 → Period 2
Duration 25, 100 or 500 a
Period 2 → Period 3
Carbon

Case 2
Peat forest → Plantation
Continuous use

Case 3
Degraded land → Plantation

Source: IFEU 2006
Results: Direct land use change

Greenhouse effect

Expenditures PME:
- Cultivation
- Land use change
- All transports
- POME CH4
- Production
- Utilisation

Credits PME:
- Soy meal
- Tensides
- Chemicals

Diesel fuel:
- Production
- Utilisation

Natural forest
Peat forest
Tropical fallow
Diesel fuel

Negative GHG balances if natural forests or peat forests are cleared

Source: IFEU 2009
Further reading

„Environmental and Socio-economic Assessment of Stationary and Mobile Energetic Use of Imported Biofuels: The Case of Palm Oil“


Coordinated by Wuppertal Institute

**IFEU contribution:**
„Environmental impacts of palm oil used for power generation and as a transport fuel“ (Chapter V)

**IFEU Authors:**
Guido Reinhardt, Sven Gärtner, Julia Münch & Nils Rettenmaier
Example 3: Soybean biodiesel (SME)

**Characteristics:**
- **Name:** Soybean (*Glycine max*)
- **Family:** Legumes (Fabaceae)
- **Fruit:** Pod
- **Yield:** ca. 0.5 t soybean oil / (ha*yr)
Soybean: Oil for free?

- **Traditional uses:**
  - Main use of soybeans is protein feed
  - 99% GMO soybeans
  - Oil content: 15-20%
  - Production systems mainly large-size

- **Future uses:**
  - Soy oil: liquid biofuel (PPO or biodiesel)

➤ Threat: Biofuel from highly biodiverse areas to the detriment of the indigenous population
SME: Life cycle comparison

Crude oil extraction and pre-treatment

Soybean cultivation

Extraction & refining

Soybean oil

Transport

Trans-esterification

Glycerine

SME

Allocation by energy content instead of substitution (credits)!

Press cake

68.5%

31.5%

5.2%

94.8%

Product

Process

Reference system
Results: SME versus diesel fuel

Greenhouse effect

South of Santa Fe (Venado Tuerto)

North of Bs. As./South of Santa Fe (Pergamino)

South of Cordoba (Rio Cuarto)

\[ \text{t CO}_{2\text{eq}} / (\text{ha} \times \text{yr}) \]

-2,5 -2 -1,5 -1 -0,5 0 0,5 1 1,5

- Yield influences results

Source: IFEU 2011 based on INTA 2011
Results: SME according to RED

**Greenhouse effect**

South of Santa Fe (Venado Tuerto)

North of Bs. As./South of Santa Fe (Pergamino)

South of Cordoba (Rio Cuarto)

Default value

<table>
<thead>
<tr>
<th>g CO₂eq / MJ FAME</th>
<th>Cultivation of Soybeans</th>
<th>Extraction of oil</th>
<th>Esterification</th>
<th>Transport of soybeans</th>
<th>Refining of vegetable oil</th>
<th>Transport of FAME to and from depot</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: IFEU 2011 based on INTA 2011
## Biofuel Resource Demand and Environmental Impact

<table>
<thead>
<tr>
<th>Biofuel</th>
<th>Resource demand</th>
<th>Greenhouse effect</th>
<th>Ozone depletion</th>
<th>Acidification</th>
<th>Eutrophication</th>
<th>Photo smog</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coppice (poplar)</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Willow</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Miscanthus</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Giant reed</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cocksfoot</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>Whole crop wheat</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Biogas (silage corn)</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Biogas (rape seed meal)</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>RME</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>+/–</td>
<td>+/–</td>
</tr>
<tr>
<td>SME</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>+/–</td>
<td>–</td>
<td>+/–</td>
</tr>
<tr>
<td>Rapeseed oil</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>+/–</td>
</tr>
<tr>
<td>EtOH (sugar beet)</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>–</td>
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<tr>
<td>ETBE (sugar beet)</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>+</td>
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<tr>
<td>Biomethanol</td>
<td>+</td>
<td>+</td>
<td>+/–</td>
<td>+</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Bio-DME</td>
<td>+</td>
<td>+</td>
<td>+/–</td>
<td>+</td>
<td>+</td>
<td>–</td>
</tr>
</tbody>
</table>

**Legend:**
- +: Advantage for biofuel
- –: Advantage for fossil fuel
- +/–: Insignificant or ambiguous
Life cycle analysis (LCA)

ISO 14040 & 14044

Goal and scope definition

Inventory analysis

Impact assessment

Interpretation
Results: Biofuels versus fossil fuels

1. All assessed types of biodiesel show environmental advantages as well as disadvantages when compared to conventional diesel fuel.

2. An objective decision for or against a particular fuel cannot be made. However, based on a subjective value system a decision is possible.

3. If, for example, energy saving and greenhouse effect is given the highest priority, biodiesel can outperform conventional diesel fuel but GHG balances can even be negative if land use changes are occurring.

4. The production of biodiesel from Jatropha, oil palm & soybean can be significantly optimised.
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    • Impact of indirect land use change (iLUC)

• Conclusions
GHG balances of biofuels

Source: IFEU 2009

-200 -150 -100 -50 0 50 100 150 200

GJ primary energy / (ha*yr)

Disadvantage for biofuel →

Advantage ←

Sunflower biodiesel
Rapeseed biodiesel
Canola biodiesel

Oil palm biodiesel (natural forest)
Oil palm biodiesel (peat forest)
Oil palm biodiesel (tropical fallow)

Soy bean biodiesel (natural forest)
Soy bean biodiesel (fallow)

Jatropha biodiesel (shrubland)
Jatropha biodiesel (fallow)

Temperate climate

Tropical climate

(Sub)tropical climate

-20 -15 -10 -5 0 5 10 15 20

tonnes CO₂ equiv. / (ha*yr)

Source: IFEU 2009
1. All kinds of biodiesel show advantages with regard to non-renewable energy carriers.

2. Some of them show disadvantages with regard to greenhouse effect which is due to land-use changes occurring prior to cultivation. In this case, energy and GHG balances are decoupled.

3. The results show considerable variations, e.g. depending on the utilisation of co-products.

4. Tropical oil plants have no general advantage over temperate ones (cf. soybean oil biodiesel)
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• **Conclusions**
"Criteria for a Sustainable Use of Bioenergy on a Global Scale"

Report commissioned by the Federal Environment Agency (UBA), Dessau, in cooperation with FSC Germany & K. Lanje

**IFEU Authors:**
Horst Fehrenbach, Jürgen Giegrich & Guido Reinhardt

**Final report:**
January 2008

**Continued by IFEU and Öko-Institute:**
“Development of strategies and sustainability standards for certification of biomass for international trade”
Directive 2009/28/EC on the promotion of the use of energy from renewable sources

The control of European energy consumption and the increased use of energy from renewable sources together with energy savings and increased energy efficiency, continue important parts of the package of measures needed to reduce greenhouse gas emissions and comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCC). The European Commission is committed to reducing the international greenhouse gas emissions that enable reductions in greenhouse gas emissions beyond 2012. These factors also have an important part to play in promoting the security of energy supply, protecting technological development and innovation, and providing opportunities for employment and regional development, especially in rural and isolated areas.

In particular, increasing technological improvements, incentives for the use and separation of public transport, the use of energy efficiency technologies, and the use of renewable energy, have a significant impact on overall transport sector, in which the security of energy supply problem is most acute, and influence the fuel market for transport.

The opportunities for establishing economic growth through innovation and a sustainable, competitive energy policy have been recognised. Production of energy from renewable sources is expected to be a major factor in future energy market development and future energy demand. The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCC) is committed to reducing the international greenhouse gas emissions that enable reductions in greenhouse gas emissions beyond 2012. These factors also have an important part to play in promoting the security of energy supply, protecting technological development and innovation, and providing opportunities for employment and regional development, especially in rural and isolated areas.

In order to reduce greenhouse gas emissions within the Community and reduce its dependence on energy imports, the development of energy from renewable sources should be closely linked to increased energy efficiency.

It is essential to increase the demonstration and commercialisation of these technologies and actions.

→ Europe: RE Directive

Ordinance on requirements for sustainable production of biofuels

The Ordinance on requirements for sustainable production of biofuels (Biokraft-NachV) is an important part of the package of measures needed to reduce greenhouse gas emissions and comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCC). The European Commission is committed to reducing the international greenhouse gas emissions that enable reductions in greenhouse gas emissions beyond 2012.

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It is essential to increase the demonstration and commercialisation of these technologies and actions.

→ Germany: Sustain. ordinance
Sustainability criteria / certification

• Criteria:
  • The greenhouse gas emission saving from the use of biofuels and other bioliquids shall be 35% (50% from 2017)
  • Biofuels and other bioliquids shall not be made from raw material obtained from land with high biodiversity value (e.g. primary forests), high carbon stock (e.g. wetlands) or peatlands.
  • Agricultural raw materials cultivated in the Community and used for the production of biofuels and other bioliquids shall be obtained in accordance with the minimum requirements for good agricultural and environmental condition.

• Open issue:
  • Inclusion of indirect land use change
Indirect land use change (iLUC)

Europe: importing biomass or biofuel

(1) tropical producer country: (certified) good practise production of biomass for export

(2) replaces previously given cultivation on the same acreage

(3) the previous cropping is displaced to an area somewhere else

(4) the area somewhere else is likely to be forest

INDIRECT INDUCTION OF FOREST LOGGING

Source: IFEU 2008
Indirect land use change (iLUC)

Europe: expanding domestic biomass production for biofuel

1. (certified) good practise production of biomass
2. replaces previously given cultivation on the same acreage, e.g. animal food
3. the required area for animal food production is likely to be forest
4. animal food will be imported increasingly, e.g. from tropical countries

Source: IFEU 2008
ILUC report by the Commission

"Report from the Commission on indirect land-use change related to biofuels and bioliquids"


Land-use change in g CO$_{2eq}$/MJ

<table>
<thead>
<tr>
<th>Study</th>
<th>Maize ethanol</th>
<th>Soya biodiesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Searchinger et.al. (2008)</td>
<td>156</td>
<td>165-270</td>
</tr>
<tr>
<td>CARB (2009)</td>
<td>45</td>
<td>63</td>
</tr>
<tr>
<td>EPA (2010)</td>
<td>47</td>
<td>54</td>
</tr>
<tr>
<td>Hertel et.al. (2010)</td>
<td>40</td>
<td>-</td>
</tr>
<tr>
<td>Tyner et.al (2010)</td>
<td>21</td>
<td>-</td>
</tr>
<tr>
<td>IFPRI MIRAGE (2010)</td>
<td>54</td>
<td>75</td>
</tr>
</tbody>
</table>

Default value (RED annex V), without land-use change: 43, 58

⇒ Same order of magnitude!

"[…] The Commission recognises that a number of deficiencies and uncertainties are associated with the modelling […]. Therefore, the Commission will continue to conduct work in this area […]. However, the Commission acknowledges that indirect land-use change can have an impact on greenhouse gas emissions savings associated with biofuels, which could reduce their contribution to the policy goals."
**IFPRI: Hard times for biodiesel?**

<table>
<thead>
<tr>
<th></th>
<th>No change in trade regime</th>
<th>Free trade in biofuels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct savings</td>
<td>LUC emissions</td>
</tr>
<tr>
<td></td>
<td>in grams of CO₂ equivalent</td>
<td>in grams of CO₂ equivalent</td>
</tr>
<tr>
<td><strong>Additional mandate</strong></td>
<td>57</td>
<td>38</td>
</tr>
<tr>
<td><strong>Bioethanol</strong></td>
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<td></td>
</tr>
<tr>
<td>Wheat</td>
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<tr>
<td>Maize</td>
<td>58</td>
<td>10</td>
</tr>
<tr>
<td>Sugar Beet</td>
<td>63</td>
<td>7</td>
</tr>
<tr>
<td>Sugar Cane</td>
<td>70</td>
<td>13</td>
</tr>
<tr>
<td><strong>Biodiesel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm Fruit</td>
<td>58</td>
<td>54</td>
</tr>
<tr>
<td>Soybean</td>
<td>45</td>
<td>56</td>
</tr>
<tr>
<td>Sunflower</td>
<td>58</td>
<td>52</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>50</td>
<td>54</td>
</tr>
</tbody>
</table>

→ Biodiesel has more adverse land use emissions than bioethanol, mainly due to palm extension on peat land.
LUC and life-cycle GHG emissions

Agriculture = 3rd biggest emitter
→ Agriculture = 3rd biggest emitter
→ LULUC together 32%*

*LAND USE
food, fodder+ fibre : bioenergy
= 40 : 1

Others
7%

Power generation
25%

Housing
8%

Industry
14%

Transport
14%

Land use change including deforestation
18%

Agriculture without land use change
14%

Others
7%

Source: Öko 2008
Land use changes: Challenges

- Displacement = generic problem of restricted system boundaries
  - Accounting problem of partial analysis („just“ biofuels, no explicit modelling of agro + forestry sectors)
  - All incremental land-uses imply indirect effects

- Analytical and political implications
  - Analysis: which displacement when & where?
  - Policy: which instruments? Partial certification schemes do not help, but have „spill-over“ effects

- Future global GHG regime with cap for all sectors & countries: no leakage = no indirect effects!

⇒ Any agricultural land use, i.e. also food and feed production, must be included in a certification scheme!

Source: Öko 2008
Outline

- Introduction
- Life cycle assessment (LCA) of biodiesel
  - LCA methodology
  - Biofuels versus conventional (fossil) fuel
    - Jatropha biodiesel
    - Palm oil biodiesel
    - Soybean biodiesel
  - Biofuels versus biofuels
  - Impact of indirect land use change (iLUC)
- Conclusions
Conclusions

1. LCA is a suitable tool for the assessment of a product’s environmental impacts. Moreover, optimisation potentials can be depicted. LCA results can therefore support decision makers.

2. LCA results show that biofuels are associated with both positive and negative environmental impacts. The use of biomass – although renewable – is not environmentally friendly *per se*.

3. Biofuels usually show advantages with regard to non-renewable energy resources and greenhouse gas (GHG) emissions (as long as no land use change is occurring). If only energy and GHG balances are considered, the picture is incomplete as the disadvantages are omitted.
Conclusions

4. Direct and indirect land use changes have a significant impact on GHG balances which can even turn out negative, i.e. biofuels would cause more GHG emissions than fossil fuels. The contribution to climate protection is questionable.

5. Sustainability criteria and certification are a step into the right direction, but have to be extended to solid and gaseous biofuels or – at best – to all kinds of biomass uses.

6. Indirect effects have to be addressed, not only in terms of GHG balances but also regarding biodiversity and food security.
Thank you for your attention!

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