Bioenergy: potentials. limitations

EPS-Summer School
July 17 to 23, 2014

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MPI Biogeochemie, Jena
Color chart Ib (cf. page 176): Global distribution of radiation use efficiency of the vegetation. Energy efficiency, i.e. energy content of net primary production, is expressed as percentage of the global annual photosynthetically active radiation. (After Uchijima and Seino 1987)
Global change = $\Delta$ climate + $\Delta$ Land-use

Additional changes in Industry, commerce, and trade
Bioenergie

Canadell et al. 2007, PNAS
Global Carbon Project, 2013
Focus on Bioenergy
- What can bioenergy do?
- The greenhouse gas balance of Europe
- The situation in forestry
- The situation in agriculture
- Global commerce
- conclusions
Biomass

- Greenhouse Mitigation
- Conservation
- Energy
- Food
- Bioeconomy Products

Canadell and Schulze, in preparation
Zusätzlich zu allen bestehenden Problemen kam die Energiewende: Eine Verdopplung der Anbaufläche ist geplant.
Globale NPP: 60 PgC

Human use: 26 Pg (44%)

Germany: 59% of NPP used

Running, S. Science 337:1458-1459

„Development which satisfied the demands of the present Generation without compromising the chances of future generations“
• The greenhouse gas balance of Europe
A simplified C cycle

- Atmospheric CO₂
- Photosynthesis
- Plant growth
- Respiration
Verification of the budgets (10^6 t y^-1)

<table>
<thead>
<tr>
<th></th>
<th>EU-25 atmosphere-</th>
<th>EU-25 land-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂-flux</td>
<td>-134 ± 303</td>
<td>-124 ± 54</td>
</tr>
<tr>
<td>CH₄-flux</td>
<td>102 ± 40</td>
<td>60 ± 26</td>
</tr>
<tr>
<td>N₂O-flux</td>
<td>58 ± 48</td>
<td>70 ± 35</td>
</tr>
<tr>
<td>NOₓ-flux</td>
<td>8 to 9</td>
<td>9 to 10</td>
</tr>
<tr>
<td>GHG-budget</td>
<td>26 ± 227</td>
<td>6 ± 52</td>
</tr>
</tbody>
</table>

There is no verification for NH₃, NO, wet deposition of N: There is an urgent need for instrument development
Bioenergie

Schulze et al., 2010
IER Stuttgart
at canopy level GPP is very similar
a) Forests [g C m² yr⁻¹]

-1107 (± 55) → -518 (± 67) → -55
589 (± 88)

b) Grasslands [g C m² yr⁻¹]

-1343 (± 269) → -750 (± 150) → -573 (± 172)
593 (± 297)

C: grass > forest
GHG: grass < forest

Schulze et al., 2009
Bioenergie

other GHG
- cropland losses = grass+forest

Schulze et al., 2009
Total CO₂ flux

Land ecosystem CO₂ flux

Schulze et al., 2009
Schulze et al., 2009

**Biological CH₄ sources**

**Biological N₂O sources**

**Sum of all GHG fluxes in CO₂ eq. flux**
Climate Mitigation

Sink/Source Management

Biomass
- Reforestation, deforestation avoidance, improved forest management
- Conservation, delivery of ecosystem services
- Non permanence, saturation, increased water consumption

Soil Carbon
- Reduced- or no-tillage, biochar, improved water management
- Increased fertility and water retention capacity
- Reduced productivity

CH₄ & N
- Improved flood and manure management, precision deliver of fertilizer
- Reduced water pollution
- Reduced productivity

Biomass
- Electricity and heat from forests, annual and perennial crops, and residues
- Industrial and domestic energy
- Low efficiency, ghg balance

Oil & Sugars
- Ethanol and diesel from food crops, first generation biofuels
- Liquid fuel for transport
- Land competition

Waste
- Electricity and heat from industrial processes, manure and landfills
- No land competition
- Promotion of waste production
• The situation in German Forestry
Arguments for a reduced rotation:
- Risk of windthrow increases for age > 60
- Wood industry demands Sapwood
- Prices maximize at 25 cm diameter
- Lower dimensions sold as bioenergy

Arguments against reduced rotation
- No deadwood (Biodiv Hotspot)
- No old trees (Birds)
- Reduced recreation value
- 1 Mill m$^3$: 5% of fossil fuel consumption
- Douglas fir unwanted by NGO’s
<table>
<thead>
<tr>
<th>Number of tree species</th>
<th>Central Europe</th>
<th>NE-America</th>
<th>NE-Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broad leaved</td>
<td>55</td>
<td>203</td>
<td>733</td>
</tr>
<tr>
<td>Coniferous</td>
<td>8</td>
<td>33</td>
<td>94</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>236</td>
<td>827</td>
</tr>
</tbody>
</table>
No Payments for ecosystem services:
- C-sinks, tourism biodiversity
- Subventions instead of payment

keine Beteiligung des Erzeugers an der Produktkette

Nutzholz → Zahlung Produkt → Abriss
Zellstoff → Zahlung Produkt → Recycling
Energieholz → Zahlung Produkt → Hausbrand

Verkauf an Kraftwerk Verbrennung
Ökostrom ist ökologisch nicht vertretbar
High C-osses by Mineralisation
Nitrate in spring water: 25 mg/l (Durka und Schulze, 1992)
Increased N$_2$O by Factor 5 (Papen, Butterbach-Bahl, 1999)
Spread of blackberry
Liming: 250€/ha paid 100% by taxpayer
Struktur der Wärmebereitstellung aus erneuerbaren Energien in Deutschland im Jahr 2011

Gesamt: 138,4 TWh

- biogene Festbrennstoffe (Haushalte): 44,8 %
- biogene Festbrennstoffe (Industrie): 17,5 %
- biogene Festbrennstoffe (HW/HKW): 4,9 %
- biogene flüssige Brennstoffe 1): 5,6 %
- Klärgas: 0,8 %
- Biogas: 11,9 %
- Deponiegas: 0,2 %
- Oberflächennahe Geothermie: 4,3 %
- Tiefe Geothermie: 0,2 %
- Solarthermie: 4,0 %

Biomasanteil 2): 91 %

1) Inklusive Pflanzenöl; 2) Feste und flüssige Biomasse, Biogas, Deponie- und Klärgas, biogener Anteil des Abfalls; 1 TWh = 1 Mrd. kWh;
Quelle: BMU-KI III 1 nach Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat); Abweichungen in den Summen durch Rundungen; Stand: März 2012; Angaben vorläufig.
Abbildung 3-22: Brennholzverbrauch

in Mio. m³ - kumulativ

Quelle: Mantau, 2004; Mantau/ Sörgel, 2006 ; Hick/ Mantau, 2008 ; Mantau 2012b
Tabell 1. Anbefalte utslippsfaktorer for peis og vedovn. 2000

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>PM₁₀</td>
<td>17,3</td>
<td>40</td>
<td>6,2</td>
<td>g/kg</td>
</tr>
<tr>
<td>CO</td>
<td>126</td>
<td>150</td>
<td>50,5</td>
<td>g/kg</td>
</tr>
<tr>
<td>SO₂</td>
<td>0,2</td>
<td>0,2</td>
<td>0,2</td>
<td>g/kg</td>
</tr>
<tr>
<td>NOₓ</td>
<td>1,3</td>
<td>0,97</td>
<td>0,97</td>
<td>g/kg</td>
</tr>
<tr>
<td>N₂O</td>
<td>0,032</td>
<td>0,032</td>
<td>0,032</td>
<td>g/kg</td>
</tr>
<tr>
<td>CH₄</td>
<td>5,8</td>
<td>5,8</td>
<td>5,8</td>
<td>g/kg</td>
</tr>
<tr>
<td>NMVOC</td>
<td>7,0³</td>
<td>6,9</td>
<td>7,0</td>
<td>g/kg</td>
</tr>
<tr>
<td>Cd</td>
<td>0,1</td>
<td>0,1</td>
<td>0,1</td>
<td>g/tonn</td>
</tr>
<tr>
<td>PAH-total</td>
<td>17,4</td>
<td>52,0</td>
<td>0,0226</td>
<td>g/tonn</td>
</tr>
<tr>
<td>PAH-6 (OSPAR)</td>
<td>6,1</td>
<td>8,1</td>
<td>0,045</td>
<td>g/tonn</td>
</tr>
<tr>
<td>PAH-4 (LRTAP)</td>
<td>3,0</td>
<td>2,7</td>
<td>0,025</td>
<td>g/tonn</td>
</tr>
</tbody>
</table>

¹ Dette brukes her synonymt med tradisjonelle vedfyrte lukkede ildsteder.
² Dette brukes her synonymt med rentbrennende vedfyrte lukkede ildsteder
³ Faktoren er egentlig for rentbrennende ovn
We pay twice:
1. The subvention for renewable energy
2. The heating cost for Hartz IV
• Wood is renewable but not unlimitedly available

• Increased environmental concern of people:
  – „people“ pay extra for „green“ electricity,
  – „people“ use wood for construction (mainly conifer), and
  – „people“ heat with logs
  – „people“ object against new species.

• At the same time people demand
  – More area for recreation,
  – More area for Nature Conservation,
  – More deciduous forest
  – More deadwood.

• In reality the desire for living environmentally friendly leads to an increased use of forest products and to a limitation of its supply.

• The „green“ life-style contradicts the additional demands for maintaining diversity and personal recreation in forests

• Pierre Vergniaud: „The Energytransition is like Saturn, it eats its own children“
• The situation in agriculture
**Accounting of Land use according to Artikel 3.4 (December 2006):**

<table>
<thead>
<tr>
<th>Member State</th>
<th>Forest management</th>
<th>Cropland management</th>
<th>Grazing-land management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Not elected</td>
<td>Not elected</td>
<td>Not elected</td>
</tr>
<tr>
<td>Belgium</td>
<td>Not elected</td>
<td>Not elected</td>
<td>Not elected</td>
</tr>
<tr>
<td>Denmark</td>
<td>Elected</td>
<td>Elected</td>
<td>Elected</td>
</tr>
<tr>
<td>Finland</td>
<td>Elected</td>
<td>Not elected</td>
<td>Not elected</td>
</tr>
<tr>
<td>France</td>
<td>Elected</td>
<td>Not elected</td>
<td>Not elected</td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td><strong>Elected</strong></td>
<td><strong>Not elected</strong></td>
<td><strong>Not elected</strong></td>
</tr>
<tr>
<td>Greece *)</td>
<td>Not decided</td>
<td>Not decided</td>
<td>Not decided</td>
</tr>
<tr>
<td>Ireland</td>
<td>Not elected</td>
<td>Not elected</td>
<td>Not elected</td>
</tr>
<tr>
<td>Italy</td>
<td>Elected</td>
<td>Not elected</td>
<td>Not elected</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>Not elected</td>
<td>Not elected</td>
<td>Not elected</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Not elected</td>
<td>Not elected</td>
<td>Not elected</td>
</tr>
<tr>
<td>Portugal</td>
<td>Elected</td>
<td>Elected</td>
<td>Elected</td>
</tr>
<tr>
<td>Spain</td>
<td>Elected</td>
<td>Elected</td>
<td>Not elected</td>
</tr>
<tr>
<td>Sweden</td>
<td>Elected</td>
<td>Not elected</td>
<td>Not elected</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Elected</td>
<td>Not elected</td>
<td>Not elected</td>
</tr>
</tbody>
</table>

**Note:** *) At the time of publishing this report, the election of activities under Article 3(4) was not decided.
Rapdiesel fails the Sustainability Test of the EU: Nature, 9. August 2012
2 to 7% of the organic and inorganic fertilizer-N are emitted as N\textsubscript{2}O (the EU default value is 1%)
– Agriculture causes
  • 50% of European CH4,
  • 70% of European N2O
  • 90% of European NH3
  • 75% of the Global Warming Potentials of GHGs originates from agriculture

– Biological Emissionen are 30% of the GHG balance

No accounting of GHG‘s, since agriculture serves the food supply
(Common Agricultural Practice der EU: CAP)

Schulze et al. Nature Geoscience 2009
Bioenergie

Heimische Biokraftstoffe vermeiden Sojaimporte nach Deutschland
Ohne Koppelprodukte aus heimischer Biokraftstoffproduktion müsste Deutschland fast 50% mehr Soja-Futtermittel importieren.

Hemmerling (2012)
Gefällige Naturwissenschaftler und öffentliche Empörung. Dbk 9/12:4-5

U. Hemmerling ist Vize-Generalsekretär des Deutschen Bauernverbandes

50% werden exportiert

Stand: 5/2012, Quellen: FNR, BMELV, Grunert u. a., eigene Berechnungen

www.unendlich-viel-energie.de
<table>
<thead>
<tr>
<th>Input</th>
<th>TG (Mill t)</th>
<th>C (Mill t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hey</td>
<td>150</td>
<td>75</td>
</tr>
<tr>
<td>Protein-fodder</td>
<td>2.3 (FG)</td>
<td>1.1</td>
</tr>
<tr>
<td>Import</td>
<td>5.1</td>
<td>2.6</td>
</tr>
<tr>
<td>Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biofuel</td>
<td>2.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Meat</td>
<td>8.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Milk</td>
<td>31.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Slurry</td>
<td>200</td>
<td>1.8</td>
</tr>
<tr>
<td>Methan C-eq</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>N₂O C-equ</td>
<td></td>
<td>43</td>
</tr>
</tbody>
</table>
The fertilizer regulations do not consider the use of methane fermentation cake as fertilizer. Thus we have a regional over-fertilization.
## Comparison of bioenergy-crops with fossil fuel

<table>
<thead>
<tr>
<th>Efficiency (gCO2-eq/MJ)</th>
<th>100%</th>
<th>-35% (EU-target 2009)</th>
<th>-50% (EU-target 2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fossil fuel</strong></td>
<td>82.5</td>
<td>53.9</td>
<td>42.1</td>
</tr>
<tr>
<td><strong>Sugarcane</strong> (9 models)</td>
<td>85.9 ± 55</td>
<td>61.0 ± 23</td>
<td></td>
</tr>
<tr>
<td><strong>Wheat</strong> (10 models)</td>
<td>88.3 ± 29</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maize</strong> (12 models)</td>
<td>110.2 ± 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Soja</strong> (8 models)</td>
<td>111.5 ± 66</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rapeseed</strong> (8 models)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DeLucia et al., 2012, Env.Science and Policy
Gesamtläche 110 km²

Running et al., 2013
• Global Commerce
Fossil fuel emissions from the top emitters

Le Quere et al. 2012, Earth System Science Data-D, to be published Dec. 3
Global Carbon Project 2012, online, data to be published Dec. 3
Embedded C in industrial products

Mt CO$_2$/y
2009 Major Pellet Trade Flows

Pellet Trade [PJ]

1
5
7.5
10

IPCC, 2012
Gesamtbiomasse ca. 13 Milliarden Tonnen
• Conclusions
  – Mankind has reached a limit where natural ecosystems collapse (at least locally)
  – 4 to 6°C global temperature rise will make large areas inhabitable by 2050
  – Bioenergy from agriculture enhances this trend

  – There are few options for Mitigation
    • Save Energy (Shut down advertisement)
    • Emittors must pay
    • Reduce Milk and Meat-consumption (unrealistic)
    • Reduce trade of Biomass (unrealistic)
    • Develop new tecnologies to split water
Thanks