Sustainability of Bioenergy:

Key Issues

Uwe R. Fritsche
Scientific Director, IINAS
International Institute for Sustainability Analysis and Strategy

presented at the
PhD Symposium 2012: Plants replacing fossil fuels?
ETH Zurich, Nov 8, 2012

research sponsored by

Project Context

- Sustainability criteria for “RED-plus” (IEE)
  www.biomassfutures.eu

- Sustainability criteria for non-food feedstocks (FP7)
  www.crops2industry.eu

- Joint Workshop series focusing on extending the RED to forest bioenergy
  www.iinas.org/Work/Projects/REDEX/redex.html

- Resource-Efficient Bioenergy in EU27 (EEA report – forthcoming)
Consider all Biomass Flows
Sustainable Bioenergy...

- **Key Issues**
  - **resource** efficiency: make the most out of **limited** resource
  - GHG emissions from iLUC (**agricultural** bioenergy) + carbon debt (for **forest** bioenergy)
  - biodiversity: high-biodiverse areas and **management** practice (all cultivation systems, incl. forestry)
  - air, water and soil quality impacts
  - (global) food security, employment, land rights, rural income

- **Coherence for all bioenergy (electricity, heat, transport) and biomaterials needed**
Sustainability Standards

- Principle rules by which sustainable development of biomass systems (crops, residues,…) should play
- Criteria and indicators derived from these standards to “measure” compliance
- Implemented via voluntary or legal systems such as product labelling and certification, and (governmental) support schemes (e.g. subsidies, preferential treatment of products, quota) → preferably mandatory (e.g. RED extension)
Sustainability Certification

- **woody biomass**
  
  FSC + PEFC
  
  Blue Angel for wood chips, pellets (in DE)
  
  activities in BE, CH, NL, UK...

- **liquid biofuels**
  
  ISCC (all); RSB, feedstock-specific BS, RSPO...
  
  (CEN & ISO)

- **biogas**
  
  some (local) initiatives in DE, SE...

→ **all voluntary**
Global Bioenergy Partnership (GBEP)
GBEP Partners and Observers

36 Partners (23 governments – 13 organizations):

- G8 Governments (CA, DE, FR, IT, JP, RU, UK, US) plus AR, BR, CH, CN, CO, ES, FJ, GH, MR, MX, NL, PY, SD, SE, TZ and ECOWAS, EU, FAO, IDB, IEA, UNCTAD, UNDESA, UNDP, UNEP, UNIDO, UNF, WCRE and EUBIA.

32 Observers (22 governments – 11 organizations):

- AO, AT, AU, CL, EG, GM, IN, ID, KY, LA, MA, MG, MY, MZ, NO, PE, RW, SV, TH, TN, ZA, AfDB, ADB, ECLAC, EEA, GEF, IFAD, IRENA, OAS, UEMOA, World Bank, and WBCSD.

Italy and Brazil are currently Chair and co-Chair of the Partnership. The Secretariat is hosted at the FAO in Rome.
24 Sustainability Indicators
agreed by 23 countries & 13 international organizations
involving a total of 45 countries and 23 int. organizations

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Social</th>
<th>Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Life-cycle GHG emissions</td>
<td>9. Allocation and tenure of land for new bioenergy production</td>
<td></td>
</tr>
<tr>
<td>2. Soil quality</td>
<td>10. Price and supply of a national food basket</td>
<td></td>
</tr>
<tr>
<td>3. Harvest levels of wood resources</td>
<td>11. Change in income</td>
<td>17. Productivity</td>
</tr>
<tr>
<td>6. Water quality</td>
<td>14. Bioenergy used to expand access to modern energy services</td>
<td>20. Change in consumption of fossil fuels and traditional use of biomass</td>
</tr>
<tr>
<td>7. Biological diversity in the landscape</td>
<td>15. Change in mortality and burden of disease attributable to indoor smoke</td>
<td>21. Training and re-qualification of the workforce</td>
</tr>
<tr>
<td>8. Land use and land-use change related to bioenergy feedstock production</td>
<td>16. Incidence of occupational injury, illness and fatalities</td>
<td>22. Energy diversity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23. Infrastructure and logistics for distribution of bioenergy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24. Capacity and flexibility of use of bioenergy</td>
</tr>
</tbody>
</table>
## Land-Use of Energy Systems

<table>
<thead>
<tr>
<th>electricity from</th>
<th>land use (\text{m}^2 / \text{GJ}_{\text{el}})</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>el-mix EU27</td>
<td>0.29</td>
<td>Excluding transmission and distribution</td>
</tr>
<tr>
<td>lignite</td>
<td>0.10</td>
<td>Lignite in Germany, new steam-turbine powerplant</td>
</tr>
<tr>
<td>coal</td>
<td>0.06</td>
<td>Import coal (surface mining), new steam-turbine powerplant</td>
</tr>
<tr>
<td>nuclear</td>
<td>0.04</td>
<td>German supply mix, steam-turbine powerplant</td>
</tr>
<tr>
<td>natural gas</td>
<td>0.02</td>
<td>EU supply mix incl. imports, new combined-cycle powerplant</td>
</tr>
<tr>
<td>hydro</td>
<td>0.03</td>
<td>100 MW(_{\text{el}}) run-of-river plant</td>
</tr>
<tr>
<td>wind onshore</td>
<td>0.26</td>
<td>10 x 2 MW(_{\text{el}}) onshore wind park</td>
</tr>
<tr>
<td>solar-PV</td>
<td>2.7</td>
<td>1 kW(_{\text{el}}) (peak) system, full land use</td>
</tr>
<tr>
<td>solar-CSP</td>
<td>1.9</td>
<td>80 MW(_{\text{el}}) concentrating solar power system in Southern Spain</td>
</tr>
<tr>
<td>geothermal</td>
<td>1.2</td>
<td>1 MW(_{\text{el}}) ORC system</td>
</tr>
<tr>
<td>biogas-maize ICE</td>
<td>106</td>
<td>Biogas from maize in internal combustion engine cogeneration plant (energy allocation)</td>
</tr>
<tr>
<td>SRC cogen</td>
<td>112</td>
<td>Woodchips from short-rotation coppice in steam-turbine cogeneration plant (energy allocation)</td>
</tr>
<tr>
<td>bio-SNG SRC cogen</td>
<td>164</td>
<td>Biomethane from short-rotation coppice in gas-turbine cogeneration plant (energy allocation)</td>
</tr>
<tr>
<td>bio-SNG SRC CC</td>
<td>128</td>
<td>Biomethane from SRC in CC powerplant</td>
</tr>
</tbody>
</table>

*Source: own computation with GEMIS 4.8; ORC= organic rankine cycle; ICE = internal combustion engine; SRC = short-rotation coppice; CC = combined-cycle*
Resource Efficiency: a new kid...

<table>
<thead>
<tr>
<th>feedstock (EU production)</th>
<th>bioenergy output</th>
<th>land productivity GJ(_{\text{bio/ha}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>rapeseed</td>
<td>1G biodiesel</td>
<td>87</td>
</tr>
<tr>
<td>short-rotation coppice</td>
<td>2G biodiesel (BtL)</td>
<td>116</td>
</tr>
<tr>
<td>switchgrass</td>
<td>2G biodiesel (BtL)</td>
<td>75</td>
</tr>
<tr>
<td>wheat (grain)</td>
<td>1G EtOH</td>
<td>128</td>
</tr>
<tr>
<td>switchgrass</td>
<td>2G EtOH</td>
<td>80</td>
</tr>
<tr>
<td>short-rotation coppice</td>
<td>pellets</td>
<td>183</td>
</tr>
<tr>
<td>switchgrass</td>
<td>pellets</td>
<td>198</td>
</tr>
<tr>
<td>short-rotation coppice</td>
<td>biomethane</td>
<td>126</td>
</tr>
</tbody>
</table>

**for comparison: non-EU production**

<table>
<thead>
<tr>
<th></th>
<th>bioenergy output</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>sugarcane</td>
<td>1G EtOH</td>
<td>207</td>
</tr>
<tr>
<td>palm</td>
<td>1G biodiesel</td>
<td>154</td>
</tr>
</tbody>
</table>

Source: own computation with GEMIS 4.8; calculated using energy allocation for by- and co-products; 1G = 1\(^{\text{st}}\) generation; 2G = 2\(^{\text{nd}}\) generation; BtL = biomass-to-liquid; EtOH = ethanol
Key Criteria & Indicators

- **Resource efficiency**: land (>100 GJ/ha), residues (> 60%)
- **GHG** (> 60% reduction), include iLUC + consider “C debt” (< 20 years payback time)
- **biodiversity**: more than “no go” areas – require agro-biodiverse cultivation, restrict forest residue extraction
- **soil**: maps of nutrient depletion risk (“go”)
- **water**: buffer zones, restrict agrochemicals
- **social**: global **food** security is key (FAO!)

GHG Emissions and Global Warming
Carbon Neutrality and C Debt

- GHG life-cycle balance is **only one** aspect of climate change – for short-term view (< 100 years), also warming impacts (= radiative forcing) is relevant

- CO₂ balance of bioenergy is **neutral for long-term view**, but warming impacts of forest bioenergy need consideration

- **Not** an issue for agriculture and perennials!

- C debt is a measure for GWP of biogenic CO₂ having longer atmospheric residence time
C Neutrality of Forest Bioenergy

- **RED methodology for GHG balances:**
  - *defines* CO$_2$ from biogenic fuels as C-neutral (i.e. no direct emission)
  - no dynamic warming impacts of C stock changes due to wood harvest, or increased forest residue extraction

- **RED ignores** time delay between biogenic CO$_2$ emissions from fuel use, and CO$_2$ absorption from forest re-growth

- **Warming impact of forest bioenergy can be real!**
Carbon Neutrality and C Debt

Source: Sathre, Gustavsson (2011); baseline = natural decay
C Neutrality of Forest Bioenergy

- Models give 5-20 years of payback time for forest residues = nearly carbon neutral
- Baseline and reference systems are key!
- Differentiation: not all forests are equal
- Long-term: strengthen climate convention to account for CO₂ from all LUC from all sectors in all countries (also for iLUC!)
Sustainable EU Bioenergy Potential

Cost Differences between the Reference and Sustainable Bioenergy Potentials in the EU27 in 2020

Source: Biomass Futures (2012)
Long-term: Cascading!

Biomass crops

Material Use

Residues/wastes

Energy Use

research sponsored by

UNEP

European Environment Agency

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Umwelt Bundes Amt
All reports forthcoming....
Contact: uf@iinas.org