Bioenergy, Climate and Development: Linkages, Synergies and Conflicts

Transport, Communication and Sustainable Development
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Overview of Presentation

- Definitions of biomass and bioenergy
- Current use, future potential
- Conversion Options/platforms
- Traditional vs. modern bioenergy
- Biofuels for transport
- Examples: eucalyptus, sugar cane, sweet sorghum, jatropha
- Economics and Markets
- Food-Feed-Fuel: linkages/synergies/conflicts
- Energy balance, land use, GHG emissions
- Sustainability and biofuels policies
What is Biomass? – living matter from plants and animals: 

**Biomass ≠ Bio-energy!**

Many inter-connected and critical functions/services:

- The 4Fs: Food, Feed, Fibre, and Fuel.........
- .......and still more Fs: Fertiliser, Feedstocks, Flora, Fauna
- Shelter, housing, household materials
- Livelihoods, entrepreneurship, local business opportunities
- Maintenance of Biodiversity
- Ecosystem functions and integrity
- Nutrient cycles and functional synergies
- Water quality, erosion control, watershed maintenance
- Recreation, peacefulness, tranquillity, wildlife observation
- Contribution to human dignity and equality
- Shaping the role of citizens and communities as caretakers
- Resource Base for Future Generations
Energy-Environment-Development driving forces

- Rural development - creation of sustainable livelihoods
- Relieving resource pressures and stresses
- Socioeconomics of urbanisation and migration
- Energy security: local – regional – global
- Rural health issues - indoor air
- Urban health issues – lead, air quality
- future competitiveness of agro-industries
- Kyoto Annex 1 countries seeking carbon credits
- Developing countries looking for foreign investment through Clean Development Mechanism (CDM)
- Dependence on fossil fuels in increasingly volatile market
- Reduced vulnerability of poor farmers through diversification
Shares of different fuels in the global energy mix over time

Sources: Grübler, 2004; IEA, 2011
Total Primary Energy Supply (TPES) by fuel

1973 and 2012 fuel shares of TPES

1973
- Coal: 24.6%
- Natural gas: 16.0%
- Oil: 46.1%
- Nuclear: 0.9%
- Biofuels and waste: 10.5%
- Hydro: 1.8%
- Other: 0.1%
- Total: 6106 Mtoe

2012
- Coal: 29.0%
- Natural gas: 21.3%
- Oil: 31.4%
- Nuclear: 4.8%
- Biofuels and waste: 10.0%
- Hydro: 2.4%
- Other: 1.1%
- Total: 13371 Mtoe

*World includes international aviation and international marine bunkers.
**In these graphs, peat and oil shale are aggregated with coal.
***Includes geothermal, solar, wind, heat, etc.
Sub-Saharan Africa energy consumption

Excluding South Africa

- Oil: 13%
- Gas: 3%
- Combustible renewables and waste: 71%
- Hydro: 2%
- Nuclear: 0%
- Coal: 11%

Including South Africa

- Oil: 13%
- Gas: 3%
- Combustible renewables and waste: 61%
- Hydro: 1%
- Nuclear: 0%
- Coal: 21%

Source: IEA and UNDP
2.5 billion people depend on traditional biomass for cooking
Per capita bioenergy use in developing and developed countries

Sources: Grubler (2004); IEA (2011)
Bioenergy for traditional and modern applications

Primary supply (55 EJ)

Traditional use (31.4 EJ)
- domestic, industrial (31.4 EJ)

Modern use (23.6 EJ)
- Transformation losses (7.1 EJ)
  - Heat (12.7 EJ)
  - Biofuels (2.6 EJ)
  - Electricity (1.2 EJ)

16.5 EJ = final use modern bioenergy

Source: Goldemberg, 2013
Socio-economic impacts and health impacts of traditional biomass

- Biomass for cooking contributes to Indoor air pollution (IAP), which contributes in some areas to more deaths annually than HIV or Malaria
- Deforestation and greenhouse gas (GHG) emissions
- Time cost and safety risk for women and girls gathering fuelwood
- Low quality energy source compared to modern fuels
- Reliance on traditional biomass use as an energy-environment-development problem
Both the complete & incomplete combustion of biomass has health and environmental impacts

- **Particulate Matter (PM)**
- **Other gases** *
  - Carbon dioxide ($\text{CO}_2$)
  - * Products of incomplete combustion (PICs): Carbon monoxide (CO), Methane ($\text{CH}_4$), Volatile organic compounds (VOCs)
- **Indoor air pollution**
- **Outdoor air pollution** (smog, ozone, poor visibility)
- **Climate change**
Different forms of biomass energy

- Fuelwood: 67%
- Agriculture: 10%
- Charcoal: 7%
- Black Liquor: 1%
- Forest Residues: 1%
- Wood Industry Residues: 5%
- Recovered Wood: 6%
- Animal By-Products: 3%
- Agricultural By-Products: 4%
- Energy Crops: 3%
- MSW and Landfill Gas: 3%
Covering a charcoal kiln
Charcoal bag distribution by truck
(note the driver having a nap underneath it)
Towards sustainable charcoal supply chains

Wood production

Transport

Wholesaling, Retailing

Consumption

Charcoal production
The Role of modern bioenergy

Modern bioenergy will play a leading role in the global transition to clean and sustainable energy due to two decisive advantages over other renewables:

1) Biomass is stored energy. Like fossil fuels, it can be drawn on at any time, in sharp contrast to daily or seasonally intermittent solar, wind, and small hydro sources, whose contributions are all constrained by the high costs of energy storage.

2) Biomass can produce all forms of energy, i.e. energy carriers, for modern economies: electricity, gas, liquid fuels, and heat. Solar, wind, wave and hydro are limited to electricity and in some cases heat.

Modern bioenergy has several other advantages over other energy resources:

• provides rural jobs and income to people who grow or harvest the bioenergy resources; bioenergy is more labour-intensive than other energy resources;
• increases profitability in the agriculture, food-processing and forestry sectors. Biomass residues and wastes—often with substantial disposal costs—can instead be converted to energy for sale or for internal use to reduce energy bills;
• helps to restore degraded lands. Growing trees, shrubs or grasses can reverse damage to soils, with energy production and sales as a valuable bonus;
## Different types and sources of biomass used for energy (yellow = agricultural)

<table>
<thead>
<tr>
<th>Biomass type/source</th>
<th>Woody biomass</th>
<th>Herbaceous biomass</th>
<th>Biomass from fruits or seeds</th>
<th>Others (including mixtures)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dedicated Feedstocks or extraction</strong></td>
<td>Extraction from native forests, Forest plantations</td>
<td>Cereals (e.g. maize, wheat) Energy grasses (e.g. sugarcane, miscanthus)</td>
<td>Oilseed crops (e.g. jatropha, sunflower) Oil fruits (e.g. oil palm)</td>
<td>(mixed biomass sources can be used for some applications)</td>
</tr>
<tr>
<td><strong>Residues (Direct)</strong></td>
<td>Logging by-products Thinning by-products</td>
<td>Straw, Bagasse, husks shells and husks, fruit bunches</td>
<td></td>
<td>Animal dung, Landscape management by-products</td>
</tr>
<tr>
<td><strong>Residues (Indirect)</strong></td>
<td>Sawmill wastes, Black liquor (from pulp/paper production)</td>
<td>Fibre crop processing wastes, Recycled fibre products Food processing by-products Waste oils</td>
<td></td>
<td>Bio-sludge, Slaughterhouse by-products, Municipal solid waste (MSW)</td>
</tr>
</tbody>
</table>
Biomass feedstocks arising from residues and energy crops
Schematic view of commercial (solid lines) and developing bioenergy routes (dotted lines) from biomass feedstock through therm-chemical, chemical, biochemical and biological conversion routes to heat, power, CHP and liquid or gaseous fuels. Commercial products are marked with an asterisk (IPCC, 2014)
Recent development in biofuels markets (production)

Source: BP, 2011
Ethanol for cooking stoves
Charcoal stove (left) and Clean cooking stove (below) in Addis Ababa, Ethiopia
(Photo: Gaia)
Micro-distilleries in Nigeria

Cassava
Sweet potato
Banana
Sugar cane
Coffee residues
Sweet sorghum

Small rural communities

Micro-plants
1,000 - 2,000 lt/day
5 - 10 t crop/day
< 1 ha crop/day

Central Plant (dehydration)

Ethanol (99.5%)

Transport

Ethanol (95%)
### Characteristics of selected relevant agro-energy crops

<table>
<thead>
<tr>
<th></th>
<th>Latitude Range</th>
<th>Drought tolerance</th>
<th>Rainfall Requirement</th>
<th>Approximate biofuel yield (litres/ha)</th>
<th>GHG reduction (excludes land use change)</th>
<th>direct competition with food production</th>
<th>potential synergies with food production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sugar crops</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugarcane</td>
<td>37°N – 31°S</td>
<td>poor</td>
<td>high</td>
<td>4000-8000</td>
<td>70-90%</td>
<td>minimal</td>
<td>some</td>
</tr>
<tr>
<td>Sweet Sorghum</td>
<td>adapted widely</td>
<td>excellent</td>
<td>low</td>
<td>3000-6000</td>
<td>50-80%</td>
<td>minimal</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Starch crops</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava</td>
<td>30°N – 30°S</td>
<td>good</td>
<td>moderate</td>
<td>2000-3000</td>
<td>20-50%</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Maize grain</td>
<td>adapted widely</td>
<td>poor-moderate</td>
<td>moderate</td>
<td>3000-5000</td>
<td>30-60%</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Oil crops</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jatropha</td>
<td>tropical</td>
<td>excellent</td>
<td>moderate</td>
<td>2000-3000</td>
<td>40-60%</td>
<td>no</td>
<td>some</td>
</tr>
<tr>
<td>Oil palm</td>
<td>10°N – 10°S</td>
<td>poor-moderate</td>
<td>very high</td>
<td>3000-7000</td>
<td>35-70%</td>
<td>yes</td>
<td>some</td>
</tr>
<tr>
<td>Soya bean</td>
<td>adapted widely</td>
<td>poor-moderate</td>
<td>moderate</td>
<td>400-1000</td>
<td>25-50%</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Lignocellulosic (Second Generation)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize cellulosic</td>
<td>adapted widely</td>
<td>poor-moderate</td>
<td>moderate</td>
<td>5000-8000</td>
<td>80-110%</td>
<td>minimal</td>
<td>yes</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td>adapted widely</td>
<td>good</td>
<td>moderate</td>
<td>6000-18000</td>
<td>90-110%</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>adapted widely</td>
<td>good</td>
<td>moderate</td>
<td>4000-10000</td>
<td>80-100%</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Miscanthus</td>
<td>adapted widely</td>
<td>good</td>
<td>moderate</td>
<td>5000-15000</td>
<td>90-110%</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

Crescentino, Italy: Second Generation (lignocellulosic ethanol plant (2G ethanol)

- Capacity: 75 million litres/year
- Beta Renewables + Novozymes
- Lower capital due to less biomass handling, simplified flows, no special equipment;
- fermentable sugars: ~22 ¢/kg;
- Cost of ethanol <$ 0.40/L;
- Cost-effective at modest scale;
- short supply chains;
- Feedstock-independent: agro-wastes, arundo donax, other
- Deployable worldwide;
- Pure lignin by-product provides power for plant;
The Future Bio-economy

Moving the Factory into the Fields
# Estimates/assumptions for physical bioenergy potential in 2050

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential of Residues and Wastes</td>
<td>50-100 EJ</td>
<td>50 EJ</td>
<td>119-135 EJ</td>
<td>80 EJ</td>
<td>100 EJ</td>
<td></td>
</tr>
<tr>
<td>Potential from dedicated bioenergy systems</td>
<td>311-657</td>
<td>215-1272</td>
<td>34-120 EJ</td>
<td>160-270 EJ</td>
<td>65-300 EJ</td>
<td>26-174 EJ</td>
</tr>
<tr>
<td>Share of IEA (2010) forecast total energy</td>
<td>30% - 65%</td>
<td>25% - 130%</td>
<td>8% - 17%</td>
<td>27% - 40%</td>
<td>14% - 38%</td>
<td>13% - 27%</td>
</tr>
<tr>
<td>Key land use assumptions</td>
<td>Use of abandoned agricultural lands</td>
<td>Significant improvements in yields and reductions in pasturelands</td>
<td>Competition with land for food and feed; water scarcity; weak institutions</td>
<td>Ecological constraints</td>
<td>Competition for land</td>
<td>Modest yield improvements; impacts of climate change and water scarcity</td>
</tr>
</tbody>
</table>
Bioenergy Contribution: 2050 Low-Carbon Energy Scenarios (DRAFT)

Average: 131 EJ

IEA 2DS
- Absolute (EJ): 150
- Percent: 25

GEA Efficiency
- Absolute (EJ): 80
- Percent: 10

IPCC Special Report on RE
- Absolute (EJ): 118 to 190
- Percent: 20 to 32

WWF Ecofys
- Absolute (EJ): 180
- Percent: 36

Greenpeace Energy Revolution
- Absolute (EJ): 90
- Percent: 19

Average: 20%

Percent (primary except where otherwise noted)
Land area per capita by type and major countries or regions

Source: FAOSTAT, 2008
Bio-energy production potential in 2050 for different scenarios

Potential in Oceania is 4-6 times projected primary energy use

Source: E. Smeets, A. Faaij, I. Lewandowski – March 2004
Potential market context for bioenergy and development: flow of bioenergy commodities, technology transfer, investment.
International Trade in key bioenergy products: Africa has largely been bypassed thus far.

**TRADE creates new investment opportunities that cannot be obtained through AID.**

Source: Hoffman et al, 2013
## Towards a Green Economy – job creation

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Jobs per TWh output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>75</td>
</tr>
<tr>
<td>Small hydro</td>
<td>120</td>
</tr>
<tr>
<td>Natural gas</td>
<td>250</td>
</tr>
<tr>
<td>Big hydro</td>
<td>250</td>
</tr>
<tr>
<td>Oil</td>
<td>260</td>
</tr>
<tr>
<td>Oil offshore</td>
<td>265</td>
</tr>
<tr>
<td>Coal</td>
<td>370</td>
</tr>
<tr>
<td>Traditional biomass (wood)</td>
<td>733 - 1.067</td>
</tr>
<tr>
<td>Wind</td>
<td>918 - 2.400</td>
</tr>
<tr>
<td>Ethanol (in Brazil)</td>
<td>3.711 - 5.392</td>
</tr>
<tr>
<td>Solar</td>
<td>2.958 – 10.700</td>
</tr>
</tbody>
</table>

Source: Delcio, 2007
Bioenergy Development Options - Scale matters

Large Scale
1. Sugarcane to EtOH
2. Palm / Soy Biodiesel

Mill-owned estate
Very competitive globally

Small-holder led
Higher cost base
Less globally competitive

Lower Value Added to Local Communities
*lowest risk
Export potential

Higher Value Added to Local Communities
*moderate risk
Export potential

Small Scale
1. Sweet Sorghum – micro-distillery
2. Woodlot gasification elec.

Multi-product or multi-crop
e.g. sweet sorghum
Economics Uncertain
Complex-Value Added to Local Communities
*high risk
Local Markets Social Issues Crop not well characterised

Value Added to Local Communities
*high risk
Complex food-fuel-cash-crop interactions

Palm oil in Indonesia: small-scale ownership, large-scale production (refining)
Jatropha plants/shoots in Zambia
Jatropha production: small-scale options
Eucalyptus plantation in Brazil
Harvesting of eucalyptus trees for wood products (~85%) and energy (~15%)
Sugar Cane: large-scale monocrop system
Semi-mechanical Sugar Cane Harvesting
Burning prior to harvest still common in Africa (to remove pests and extraneous matter)
Up in smoke: more than 50% of the available biomass energy is lost when sugarcane is burned before harvesting

(More than 90% of sugarcane is burned before harvest in Africa)
Assessing Land Suitability for specific energy crops: an example for sugarcane in 4 African countries

<table>
<thead>
<tr>
<th></th>
<th>Malawi</th>
<th>Mozambique</th>
<th>Tanzania</th>
<th>Zambia</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated suitable/available land (1000 ha)</td>
<td>206</td>
<td>2338</td>
<td>124</td>
<td>1178</td>
<td>3856</td>
</tr>
<tr>
<td>Estimated suitable/available land (%)</td>
<td>2.2</td>
<td>3.0</td>
<td>0.2</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Ratio of maximum to current production</td>
<td>10</td>
<td>585</td>
<td>5</td>
<td>69</td>
<td>61</td>
</tr>
</tbody>
</table>

- Potential small, medium and large scale areas (rain fed & irrigated) suitable and available for sugarcane in **Malawi, Mozambique, Tanzania, and Zambia**

Source: UKwZN 2007, South Africa
rapid growth of sweet sorghum (3-4 months)
Average fuel consumption new Swedish cars 2010: 8.3 l/100km
Average fuel consumption new EU cars 2010: 6.5 l/100km
1925: first tests with alcohol in engines in Brazil
Ethanol Production Cost Reductions over time in Brazil

![Ethanol Learning Curve Graph](source: COPERSUCAR - MME - 2005)
Price of ethanol (alcool) and blended petrol (gasolina) in Sao Paulo, Brazil
Competition over land

land currently available and suitable for biofuels is constrained by low efficiency of agriculture in some world regions

Most severe land use competition is in Asia due to high population density
Intensity of agricultural cultivation remains low in most world regions
Water Use per unit biomass

Source: SASRI, 2007
Water use intensity of selected biofuels (litres of water evaporated per litre of biofuel produced)

Source: Hoogeveen et al. (2009)
Fertiliser use: kg/ha (equivalence)
GHG emissions due to various types of land use change

Source: EP 2011 (PE 451.495)
FOSSIL ENERGY BALANCE
Energy output per unit of fossil fuel input

Source: Various, compiled by World Watch Institute, 2006.
GHG and energy yield estimates for biofuels (per MJ fuel) under different assumptions; Source: Hoefnagels et al, 2010

- Jatropha, electricity from residues, glycerine co-produced
- Soy beans, soy bean meal and glycerine co-products
- Rapeseed, rape meal and glycerine co-products
- Palm fruit, incl CH4 emissions from POME
- Sugar cane, excess bagasse for fuel (heat)
- Sweet sorghum, heat from bagasse
- Sugar beet, pulp to fodder
- Wheat, heat from CHP straw
- Wheat, heat from lignite CHP
- Wheat, heat from NGCHP
- Wheat, heat from NG boiler
- Maize (corn), heat from NGCHP

Legend:
- EU approach
  - Cultivation
  - Processing
  - Logistics
  - Energy allocation
  - Mass allocation
  - Market value allocation
  - System expansion
Ethanol and Biodiesel GHG emission reduction for selected paths – Renewable Energy Directive default values (land use change emissions are not included).

<table>
<thead>
<tr>
<th>Biofuel and path</th>
<th>GHG emission reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar beet ethanol</td>
<td>52</td>
</tr>
<tr>
<td>Wheat ethanol (process not specified)</td>
<td>16</td>
</tr>
<tr>
<td>Wheat ethanol (natural gas in CHP plant)</td>
<td>47</td>
</tr>
<tr>
<td>Wheat ethanol (straw as fuel in CHP plant)</td>
<td>69</td>
</tr>
<tr>
<td>Corn ethanol (natural gas in CHP plant)</td>
<td>49</td>
</tr>
<tr>
<td>Sugarcane ethanol</td>
<td>71¹</td>
</tr>
<tr>
<td>Rape seed biodiesel</td>
<td>38</td>
</tr>
<tr>
<td>Sunflower biodiesel</td>
<td>51</td>
</tr>
<tr>
<td>Soybean biodiesel</td>
<td>31</td>
</tr>
<tr>
<td>Palm oil biodiesel (process not specified)</td>
<td>19</td>
</tr>
<tr>
<td>Palm oil biodiesel (with methane capture at oil mill)</td>
<td>56</td>
</tr>
<tr>
<td>Hydro-treated vegetable oil from rape seed</td>
<td>47</td>
</tr>
<tr>
<td>Lignocellulosic ethanol</td>
<td>70 – 85²</td>
</tr>
<tr>
<td>Fischer-Tropsch diesel</td>
<td>93 - 95²</td>
</tr>
</tbody>
</table>

Notes: 1. Includes transport emissions from Brazil to EU;
2. Range for different feedstocks.
Source: (EC, 2009).
## 2G ethanol - potential

<table>
<thead>
<tr>
<th>Agricultural Residues</th>
<th>Energy Security</th>
<th>Growth</th>
<th>Jobs</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>China 221 mio dry ton</td>
<td>China could displace up to 37% of its gasoline consumption in 2030</td>
<td>779 bn USD</td>
<td>2.87 million man years</td>
<td>29%</td>
</tr>
<tr>
<td>US 180 mio dry ton</td>
<td>The US could displace up to 16% of its gasoline consumption in 2030</td>
<td>663bn USD</td>
<td>1.37 million man years</td>
<td>11%</td>
</tr>
<tr>
<td>Brazil 177 mio dry ton</td>
<td>Brazil could displace 83% of gasoline consumption in 2030. This is on top of sugarcane ethanol</td>
<td>622 bn USD</td>
<td>1.25 million man years</td>
<td>67%</td>
</tr>
<tr>
<td>India 110 mio dry ton</td>
<td>India could displace up to 100% of its gasoline consumption in 2030 and still produce 4bn litres for export</td>
<td>329 bn USD</td>
<td>0.91 million man years</td>
<td>80%</td>
</tr>
<tr>
<td>Europe 151 mio dry ton</td>
<td>The EU27 could displace 68% of its gasoline consumption in 2030</td>
<td>532 bn USD</td>
<td>1.18 million man years</td>
<td>54%</td>
</tr>
<tr>
<td>Argentina 39 mio dry ton</td>
<td>Argentina could replace up to 100% of its gasoline consumption by 2030 and potentially export ethanol</td>
<td>65 bn USD</td>
<td>0.30 million man years</td>
<td>80%</td>
</tr>
<tr>
<td>Australia 16 mio dry ton</td>
<td>Australia could replace up to 19% of its gasoline consumption by 2030</td>
<td>58 bn USD</td>
<td>0.12 million man years</td>
<td>17%</td>
</tr>
<tr>
<td>Mexico 20 mio dry ton</td>
<td>Mexico could displace up to 7% of its gasoline consumption in 2030,</td>
<td>70 bn USD</td>
<td>0.15 million man years</td>
<td>5%</td>
</tr>
</tbody>
</table>

Source: Bloomberg new Energy Finance 2012
## Potential of bioenergy on degraded lands

<table>
<thead>
<tr>
<th>Source</th>
<th>Lands included</th>
<th>Area (million ha)</th>
<th>Biomass yield (t/ha/year)</th>
<th>Bioenergy Potential (EJ/year)</th>
<th>Ratio to projected EU Biofuels consumption in 2020</th>
<th>Ratio to projected Global Biofuels consumption in 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Van Vuuren et al, 2009</td>
<td>Global degraded lands not in use as forest, cropland, pastoral land or urban.</td>
<td>n/a</td>
<td>2.5 - 33</td>
<td>31</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>Hoogwijk et al, 2003</td>
<td>Abandoned agricultural land and degraded grassland systems</td>
<td>430-580</td>
<td>1 - 10</td>
<td>8 - 110</td>
<td>4-54</td>
<td>1-15</td>
</tr>
<tr>
<td>Tilman et al, 2006</td>
<td>Agriculturally abandoned and degraded lands</td>
<td>500</td>
<td>4.74</td>
<td>45</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>Field et al, 2008</td>
<td>Abandoned pastoral lands and croplands not in use as urban or forest</td>
<td>386</td>
<td>3.55</td>
<td>27</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Campbell, 2008</td>
<td>Abandoned pastoral lands and croplands not in use as urban or forest</td>
<td>385-472</td>
<td>4.3</td>
<td>32-41</td>
<td>16-20</td>
<td>4-6</td>
</tr>
<tr>
<td>Nijsen et al (2011)</td>
<td>Based on downscaling of lands classified in GLASOD database</td>
<td>1836</td>
<td>2.2 – 10.1</td>
<td>344</td>
<td>169</td>
<td>48</td>
</tr>
<tr>
<td>Wicke et al, 2011</td>
<td>Salt-affected soils (suitable for woody biomass)</td>
<td>971</td>
<td>3.1</td>
<td>56</td>
<td>28</td>
<td>8</td>
</tr>
</tbody>
</table>
Landscape ecology: multi-use, multi-product systems

Landscape management vision to more fully integrate economic, environmental, and social aspects of agriculture into integrated systems to produce food, feed, fiber, and fuel sustainably; Source: INEL, 2009
Integrated Food Energy Systems: Example

**Farmers’ Ethanol LLC**
Unique Integrated Process

- **Corn** → **Ethanol Plant**
  - Corn Germ = Oil
  - Renewable Solid Fuels
  - Offset Facility Electricity (Boiler fuels)
  - Renewable "Green" Grid Electricity
  - Waste and solubles
    - Ethanol (Fuel Grade)
    - Carbon Dioxide
    - DDG Export (Dried Distillers Grain)
    - Anaerobic Digester
      - Waste
      - Water
      - Waste
  - Water
  - Nitrogen BioFertilizers as N-P-K
  - Internal Animal Feeds

- **Dairy Facility** → **Milk**
  - Beef Facility → **Beef**
Concluding Comments

- SCALE: multi-scale rather than scale *per se*
- SCOPE: multi-use, multi-product, multi-service, multi-landscape systems
- TIMEFRAME: energy/resource transitions take time – decades or centuries
- COMMODITISATION: to improve efficiency and facilitate trade
- LAND USE GOVERNANCE: across all sectors and uses, cannot analyse bioenergy separately
- CARBON MANAGEMENT: carbon storage, ecosystem function

*Cannot afford the risks of doing bioenergy badly, but also cannot afford to forego the benefits of doing bioenergy well*
Thanks for your attention

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