Global and regional biomass resources and production potentials

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This paper is based on the presentation given at the CEESA WG meeting at Risø April 16. 2008. The purpose of the meeting and the presentations was to define how the CEESA energy system scenarios should consider the world outside system boundaries.

On potentials

One can distinguish between several biomass potentials as estimates vary according to calculation methodology and assumptions made.

Theoretical potential

The theoretical potential is the potential limited by external factor such as irradiance, CO_2 level in the atmosphere, temperature, area, etc, or by innate qualities such as photosynthetic efficacy or respiration loss.

Technical potential

The technical potential is the potential limited by the availability or absence of technology. Limitations are e.g. agricultural practices, land availability.

Economic potential

The economic potential is the potential that can be utilised with economic profit. A sub-unit of the economic potential is the implementation potential which takes into consideration that the full economic potential may not by utilised immediately due to e.g. physical constraints. The implementation potential is the part of the economic potential that can be realised within a reasonable time frame. Reasonable time frame depends on the scope.

Ecological potential

The ecological potential takes into consideration ecological indicators as loss of biodiversity, erosion, and nutrient mining.

Social potential

One might add an additional potential that could be termed the social potential which take into consideration social indicators such as labourer rights, work safety, indigenous peoples rights, etc. Combining the social, ecological and economical potential could be seen as a sustainable potential using the Brundtland definition of sustainability.

In general the magnitude of different potentials must be considered as:

Theoretical > Technical > Economical > Ecological/Social

Biomass production and appropriation

The global biomass production is huge. Human appropriation of it is very unevenly distributed and, subsequently, so is the unappropriated potential for energy production.

The total production is estimated to 2,090 EJ yr^{-1} [1] on land and 790 $EJyr^{-1}$ [2] in the marine environment, supporting biomass reservoirs of 30 respectively 0.15 ZJ.
Human appropriation of land based production is estimated to 425 $EJyr^{-1}$ divided into 150 $EJyr^{-1}$ for food and 275 $EJyr^{-1}$ for wood and fibre [1]. When the appropriation for food is far higher than the food consumption reported by FAO [3] 27 $EJyr^{-1}$ it is because post harvest losses, crop residues and energy dissipation through meat production is taken into calculation.
Global consumption of biomass for energy purposes (heat and electricity) is estimated to 47 $EJyr^{-1}$ [2] which is about 10 % of the global energy consumption of 455 $EJyr^{-1}$.

Biomass potential in 2000

Current biomass for energy consumption and potential estimated by EUBIA [4] is shown in the table below.

	Consumption (EJ yr^{-1})	Potential (EJ yr^{-1})	Consumption/potential (%)
North America	3.1	19.9	16
Latin America + Caribia	2.6	21.5	12
Asia	23.2	21.4	108
Africa	8.3	21.4	39
Europe	2.0	8.9	22
Former USSR	0.5	10.0	5
Total	39.7	103.1	39

The general picture, that app. 40 % of the potential for bio energy is exploited, covers huge regional differences with very large potentials for increased exploitation is the former USSR, but also the Americas possess a substantial potential.

Biomass potentials in 2050

A study from 2004 [5] has estimated the future potential bio energy resource from agriculture under 4 different agricultural scenarios, all being highly efficient and technology demanding. The estimates are considered sustainable as they support food supply and avoid deforestation. As seen on the figure below somewhere between 273 and 1,471 EJ yr^{-1} can sustainable be produced in 2050, again with huge regional differences.

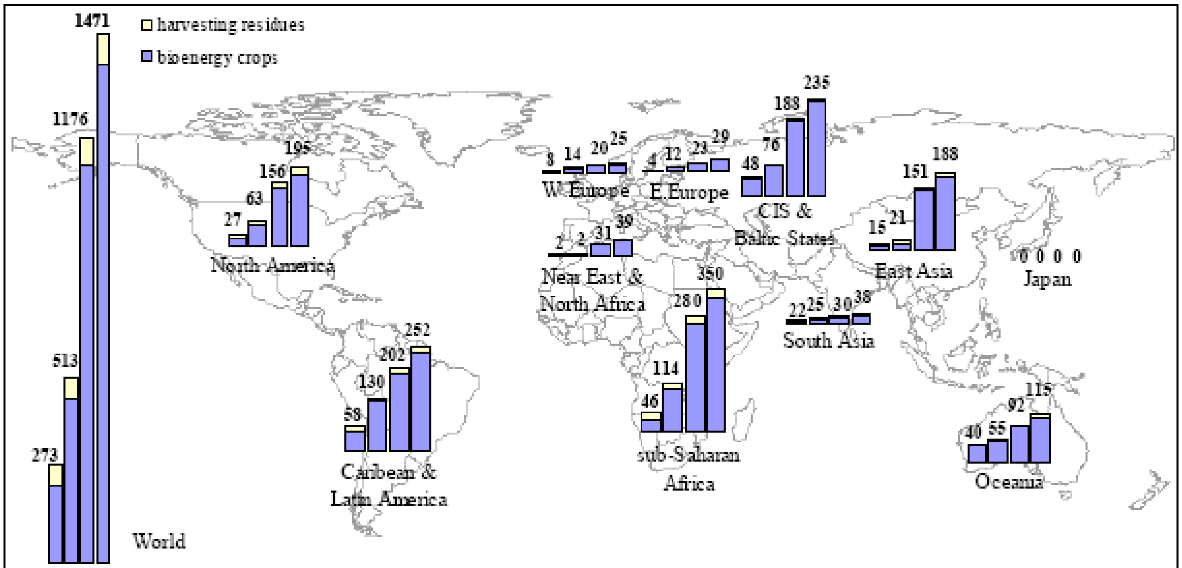


Figure 12. Total bioenergy production potential in 2050 in scenarios 1 to 4 (EJy^{-1}; the left bars is scenario 1, the right bar is scenario 4).

Economic potential of biomass other than wood fuel

The World Energy Council estimates that from a global biomass potential of 2,900 EJ yr-1 only 270 EJ could be considered as available technically and economically [6].

Global potential from forests

The bioenergy potential from existing forests is relatively small with a technical potential of 20 – 38 EJyr^{-1} [5].

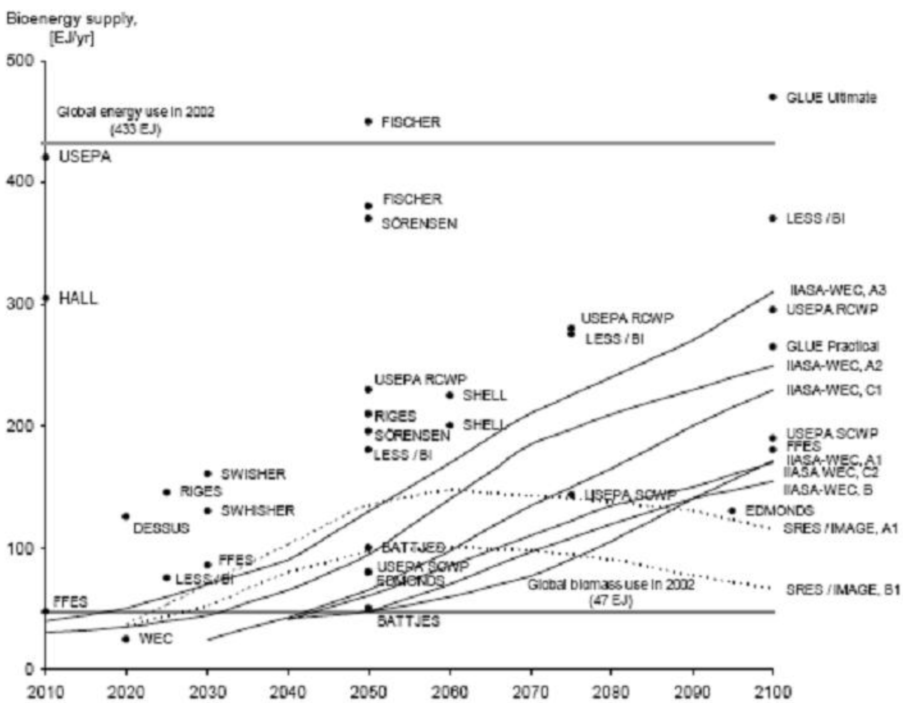
EJ yr^{-1}	Small demand and plantation	Medium demand and plantation	Large demand and plantation
Technical potential	20	29	38
Virgin forest untouched (~ ecological pot.)		8	
Only commercial species exploited (~ economic pot.)		5	
Inaccessible areas left out (~ economic pot.)		1	

European biomass potential

Three different projections on European biomass potentials to 2050 are shown in the table below.

EJ yr^{-1}	2010	2020-2025	2050
EU-27 (BTG, 2004)	7.7	8.8	
EU-25 (EUBIA)		8.4	16.7
EU-25 (Ericsson et al, 2004)	4.4	7.7-9.2	15.7-18.9

Projections on biomass potential
Many studies have tried to project the future potential of biomass for energy leading to very different results. The figure below is from a review of 17 studies [10]. The general trend in projections is that potentials will increase over the coming 90 years, but huge differences appear on the absolute magnitude of future potentials.



Availability of cultivable land
As biomass requires land (we exclude marine biomass in this paper) land availability is a limiting factor. Currently 18 Mkm^2 is of land is under cultivation. This area can potentially be increased to 41

Mkm^2 [11]. Again regional differences are huge. The largest potentials for an increase in cultivable land are found in the northern part of South America and in tropical Africa. Regions to a large part covered with rain forest. This potential does however not take into consideration whether the current land cover is virgin rain forest or other politically sensitive land covers, and must be considered as an estimate of a technical potential.

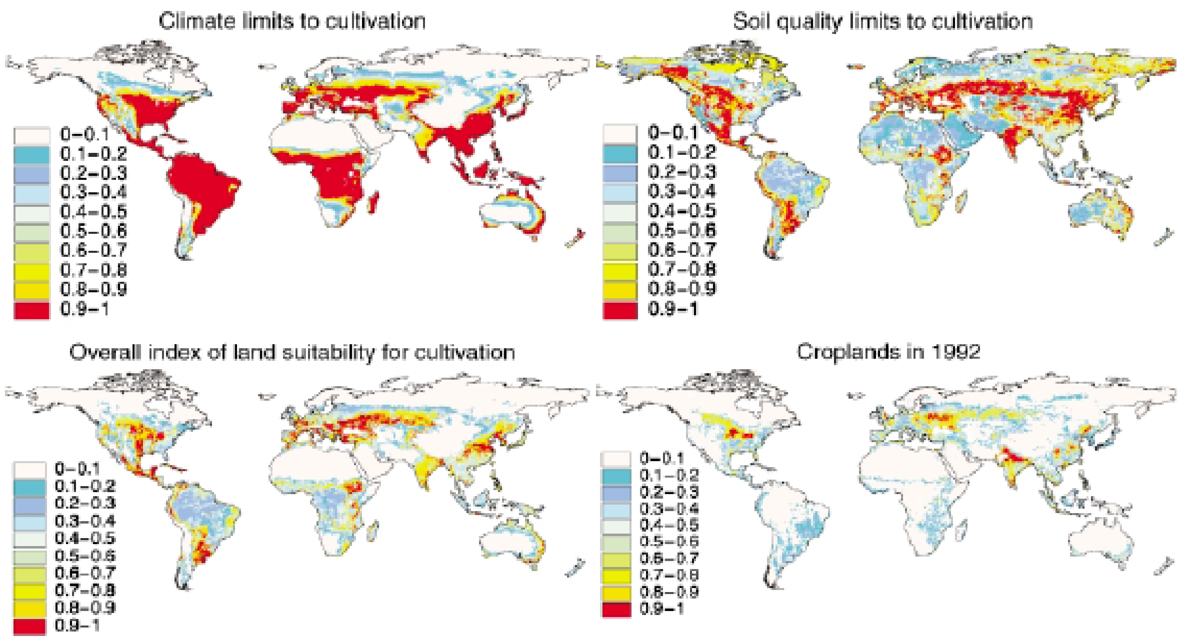


Fig. 4 Top panels: the climatic and soil quality limits to cultivation. The climatic limit is calculated by applying the GDD and moisture functions (Fig. 3) to their respective spatial data (Fig. 1). The soil quality limit is calculated by applying the soil carbon density and soil pH functions (Fig. 2) to their respective spatial data (Fig. 1). Bottom left panel: overall index of land suitability for cultivation derived as a product of the climate and soil quality limits to cultivation. Bottom right panel: the distribution of croplands in 1992, derived from Ramankutty & Foley (1998).

Climate chance

Climate change is expected to induce changes in crop production and land use. Climate change is also expected to change the cultivable area of the world. One estimate is that in general additional 6 Mkm^2 will be cultivable in the period 2070-2099 as compared to 1992. Canada and former USSR will, in this respect, benefit the most from climate change, whereas decreases in cultivable area is estimated to take place in tropical Africa, North Africa, Oceania and central America [11].

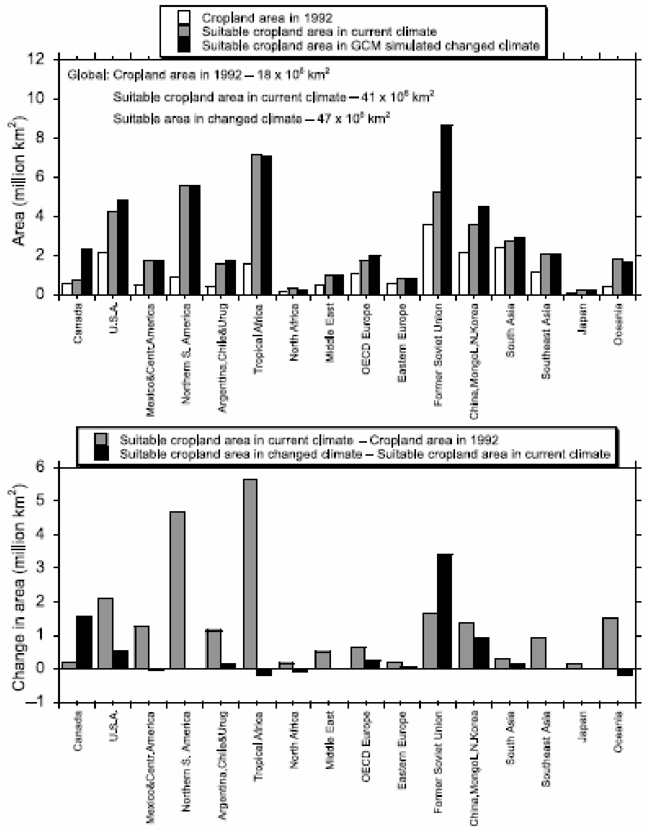
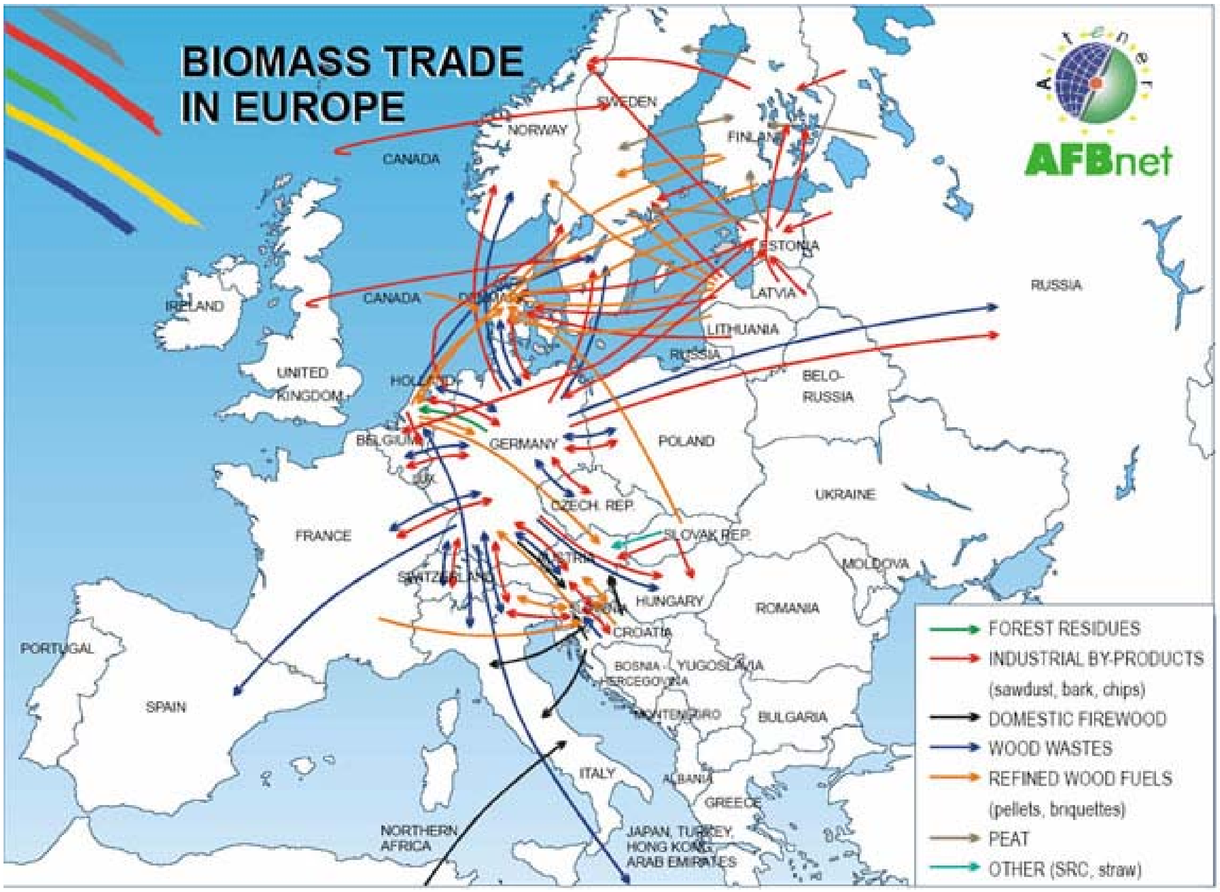


Fig. 8 Top panel: regional averages of current cropland area, suitable cropland area under current climate, and suitable cropland area in a GCM-simulated climate for the 2070–99 period. Bottom panel: differences in areas shown on the top panel indicating the additional potential for cultivation under current climate, and the change in this potential in the event of climate change.

Availability through trade

Trade is a very important part of the economic potential. Traditionally biomass is produced and consumed locally. This comes primarily from storage problems, low value on a weight basis and low energy density. However this is no longer the truth in north-western Europe. See figure below.

In Denmark 11 % of biomass for energy is imported and for wood pellets alone this figure is 77 % [12]



References

1. Imhoff ML et al, Global patterns in human consumption of net primary production. Nature, Vol 429, 2004.
2. Herman WA, Quantifying global exergy resources. Energy 31, 2006.
3. FAO, Statistical Yearbook 2005/2006.
4. kaltscmidt et al, 2001
5. Smeets E, Faaij A, Lewandowski I, 2004: A quickscan of global bio-energy potentials to 2050: analysis of the regional availability of biomass resources for export in relation to underlying factors. Copernicus Institute - Utrecht University.
6. World Energy Council: 2004 Survey of energy resources
7. Biomass Technology Group, Holland, 2004.
8. European Biomass Industry Association.
9. Ericsson K, Nilsson LJ, 2004, Biomass and Bioenergy, Elsevier.
10. Berndes G, Hoogwijk M, vd Broek R, 2003, Biomass and Bioenergy, Elsevier.
11. Ramankutty N, Foley JA, Norman J, McSweeney K, 2002: The global distribution of cultivable lands: current patterns and sensitivity to possible climate chance, Global Ecology & Biogeography, Blackwell Synergy.
12. Energistyrelsen: Energistatistik 2006.