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WISSENSCHAFTLICHER BEIRAT DER BUNDESREGIERUNG
GLOBALE UMWELTVERÄNDERUNGEN

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Göran Berndes:

**Water demand for global bioenergy
production: trends, risks and opportunities**

**Externe Expertise für das WBGU-Hauptgutachten
"Welt im Wandel: Zukunftsfähige Bioenergie und
nachhaltige Landnutzung"**

Berlin 2008

Externe Expertise für das WBGU-Hauptgutachten
"Welt im Wandel: Zukunftsfähige Bioenergie und nachhaltige Landnutzung"
Berlin: WBGU
ISBN 978-3-9396191-21-9
Verfügbar als Volltext im Internet unter http://www.wbgu.de/wbgu_jg2008.html

Autor: Göran Berndes
Titel: Water demand for global bioenergy production: trends, risks and opportunities
Göteborg, Berlin 2008
Veröffentlicht als Volltext im Internet unter http://www.wbgu.de/wbgu_jg2008_ex02.pdf

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Water demand for global bioenergy production: trends, risks and opportunities

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1 Preface

In its 2008 flagship report, the WBGU addresses the question of sustainable land-use and bioenergy use under changing climate conditions. Taking an analysis of global land-use under current and future climate impacts as a starting point, the report aims at finding out what opportunities and risks the global use of bioenergy entails. The goal of the report is to provide information and recommendations for decision-makers on the global sustainable potentials and risks in bioenergy use. The challenge will be to quantify the global niche that a sustainable use of bioenergy could occupy while meeting competing demands in terms of food security, conservation of biodiversity, and infrastructure development.

This report intends to provide a readable global overview on the nexus between water availability and increasing bioenergy production and possible consequences for global bioenergy potentials. One basis for the analyses underlying the report is a number of lead questions provided by WBGU. The primary focus is the water situation in agriculture (i.e., the global food system). However, bioenergy systems based on forest biomass is included in order to account for the total biomass resource base. Furthermore, some of the assessed biomass supply systems qualify as forests and expansion of these therefore takes the form of afforestation/reforestation activities.

The short report format makes it necessary to make the report concise and “straight to the point”, only summarizing background information and context. The reference list is intended to support further studies of the subject treated, in addition to supporting statements made. The report also includes suggestions on research that would advance the scientific knowledge in this field.

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3 Introduction

Freshwater is already scarce in some regions of the world. A growing population and changing dietary trends mean a steeply rising water demand. Under the impact of climate change the population at risk of water stress could increase substantially by the end of the century. In this context, water demand for bioenergy production might place an additional burden on water availability worldwide and induce increased competition over water resources in an increasing number of regions. However, bioenergy demand also leads to new opportunities to develop strategies to *adapt* to climate change in agriculture: a number of crops that are suitable for bioenergy production are drought tolerant and relatively water efficient and by adopting such crops farmers may better cope with a change in precipitation patterns and increased rates of evapotranspiration¹ (ET) due to higher temperature.

The possibility to integrate the cultivation of new types of bioenergy crops within expanded agricultural systems in a modified water resource context presents challenges as well as opportunities in the development of water and land use strategies. This report aims at providing a global overview on the challenges outlined above and to discuss the possible role of bioenergy in a water scarce world. The view on water will include the entire global water resource, i.e. the runoff in rivers, lakes and groundwater aquifers – the blue water flow – and the water flow that supports and is consumed by biomass production – the green water flow, i.e. the water in the root zone of the soil (stemming from precipitation) that controls plant growth.

3.1 Bioenergy may become a human use of photosynthesis that is comparable in scale to that for agriculture or forestry

Before discussing possible effects of bioenergy growth on increasing human water use² – including the possibilities of better land and (green/blue) water resource management to intensify biomass production for food and bioenergy – illustrative quantifications will be presented in order to relate the prospective bioenergy demand to the present major biomass uses in the world.

As can be seen in Figure 1, the quantitative production of fossil resources is much larger than the biomass production in agriculture and forestry. Petroleum is to some extent used for the production of plastics and bulk chemicals, some 10-15 percent of the coal is used in steel

¹ Water is lost to the atmosphere in the process of crop transpiration. Water vapour diffuses from the inside of the leaves to the atmosphere through the stomata, as carbon dioxide diffuses in the opposite direction. Water is also lost to the atmosphere through evaporation from the soil and from the plant leaves. These losses are collectively designated ET losses.

² Water use will in this report refer to the ET that brings water from the possibly plant-available to not available, being water vapour in the atmosphere. Deep percolation may make water unavailable deep in the ground, but focus is here placed on ET.

production, and fossil gas (and to some extent also other fossil resources) are used for the production of synthetic fertilizers. But it is the use of fossil fuels in the energy sector that is the dominating source behind society's exploitation of fossil resources: the decoupling of societal energy use from biological productivity, that took place more than 100 years ago, has now brought us to energy consumption levels that make it difficult to return to a situation where the global society solely relies on biomass for energy. At the same time, global energy consumption is expected to more than double during the 21st century. This means that the requirements of CO₂ neutral energy may have to grow to levels much larger than the present global total fossil fuel use, if we are to reach ambitious stabilization targets³. ***A dramatic increase in the output from agriculture and forestry is required for making biomass an important primary energy source on the global level.***

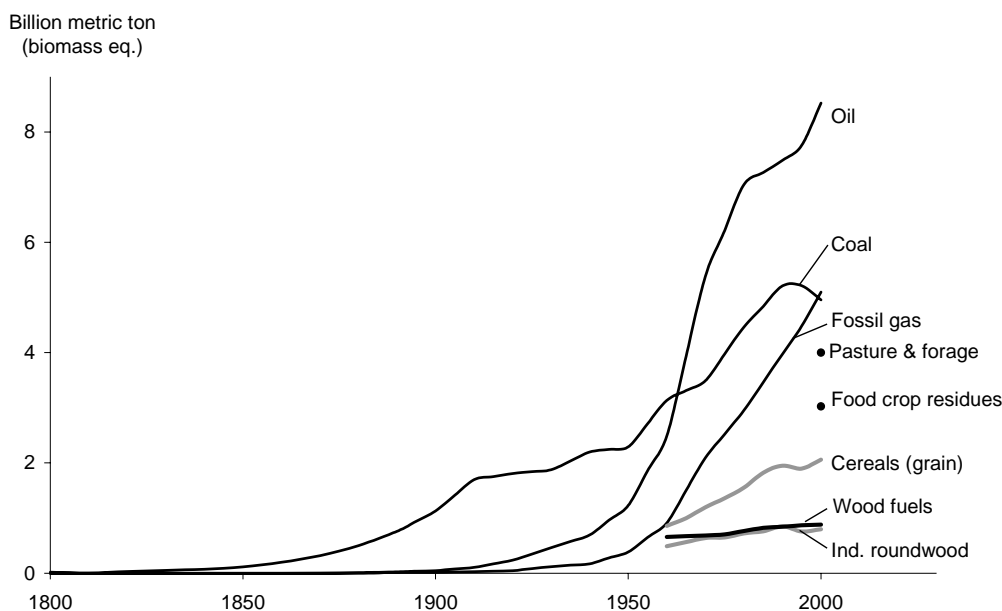


Figure 1. Global annual production of major biomass types in agriculture and forestry, and fossil resources. The fossil resources are given on a biomass equivalent basis (be) in order to facilitate a comparison with the different biomass types (conversion based on 1 ton oil equivalent = 42 GJ; 1 ton be=18 GJ). "Pasture & forage" refers to the part eaten by grazing animals. "Wood fuels" (FAO data) does not include all biomass uses for energy. For example, the FAO "Wood fuels" data for year 2000 corresponds to about 15 EJ, while the global biomass use for energy is estimated at about 35-55 EJ/ year. Based on Berndes (2006).

The conclusion on global level above holds also for most countries. Biomass is presently an important source of energy in developing countries, but this is at a very low level of per

³ Hoffert et al. (1998, 2002) provide readable accounts of the energy implications of future atmospheric CO₂ stabilization levels. Pacala and Socolow (2004) provide some moderation of the technology challenge indicated by Hoffert et al, which is re-emphasized by Pielke et al (2008) arguing that the reference scenarios used by the IPCC's fourth assessment report (AR4) – SRES – seriously underestimates the technological challenge associated with stabilizing greenhouse-gas concentrations.

capita energy use and the biomass use – mainly combustion of wood and agricultural residues – has severe negative impacts. The combustion in confined spaces leads to indoor air pollution to which women and children are primarily exposed. This exposure has severe health consequences, including respiratory illnesses and premature death (WHO 2002). Furthermore, in many instances the biomass use puts large pressure on local natural resources, leading to overexploitation with vegetation and soil degradation. The clear link between access to energy services and poverty alleviation and development is a strong motive to substantially improve and increase the supply of energy services in developing countries (Takada and Porcaro 2005, UNDP 2005).

A few countries with large forest industries are unique in that the residues and by-flows in the forest industry can make up a considerable proportion of the energy supply. This is clearly indicated in Figure 2, in which the industrial wood production gives an indication of the size of the biomass flows in the forest sector in different countries which might be available for energy purposes (the waste product flows are of the same magnitude as the biomass flow in the form of products). Global industrial wood production provides slightly below 16 EJ/year, or about 2.5 GJ/capita/year, which can be compared to the 390 EJ (60 GJ/capita) of fossil fuels that were commercially traded globally in 2005 (BP 2007).

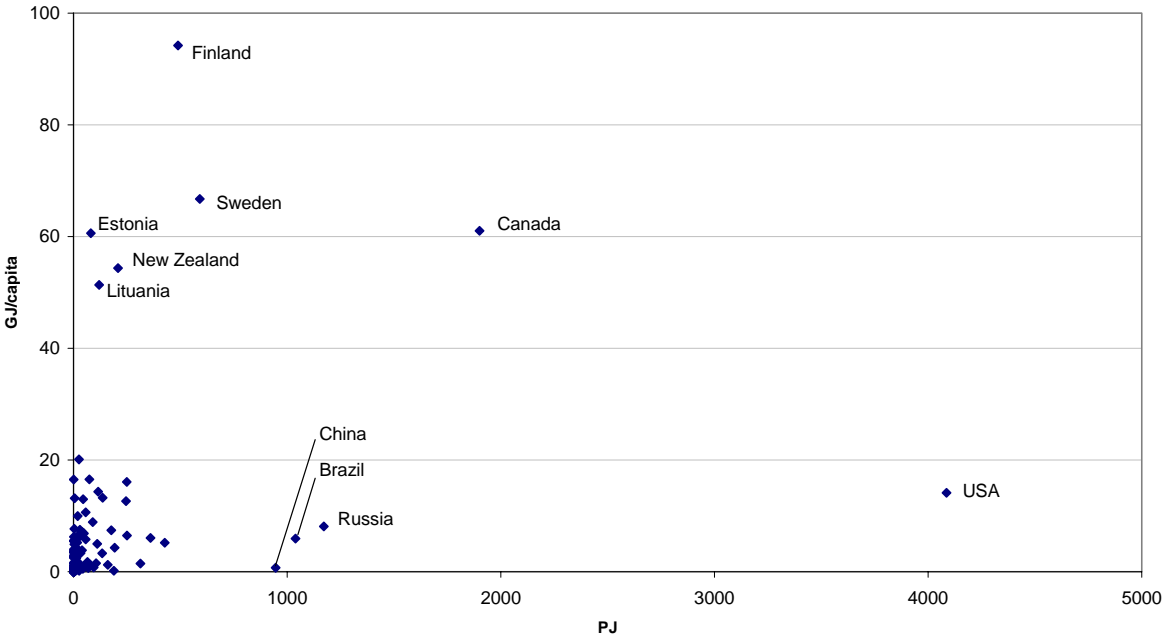


Figure 2. Industrial roundwood production in the countries of the world: average for 2000–2003, converted to energy in the form of biomass based on an assumed energy content of 10 GJ/m³ of wood. The figure shows the dominant industrial wood producers in the world and the production per capita in different countries. Based on data provided by the UN Food and Agriculture Organization, FAO (FAOSTAT 2008).

If we take a closer look at the EU and also compare with current energy use, it is clear that the preconditions vary considerably from one Member State to the next (Figure 3). Sweden

and Finland have the largest forest extraction in EU⁴ and, as can be seen in Figure 3, the extraction is also substantial relative to the domestic energy use. The three Baltic States and a few other MS also have a fairly large forest extraction relative to their own energy use and their extraction relative to forest growth is also less than in Sweden and Finland: countries close to the dotted diagonal have a net annual increment that is approximately twice as large as the extraction. For the entire EU, forest extraction is equal to about half the net annual increment and is, as can be seen from the figure, rather modest compared to the gross energy consumption (about 5 %).

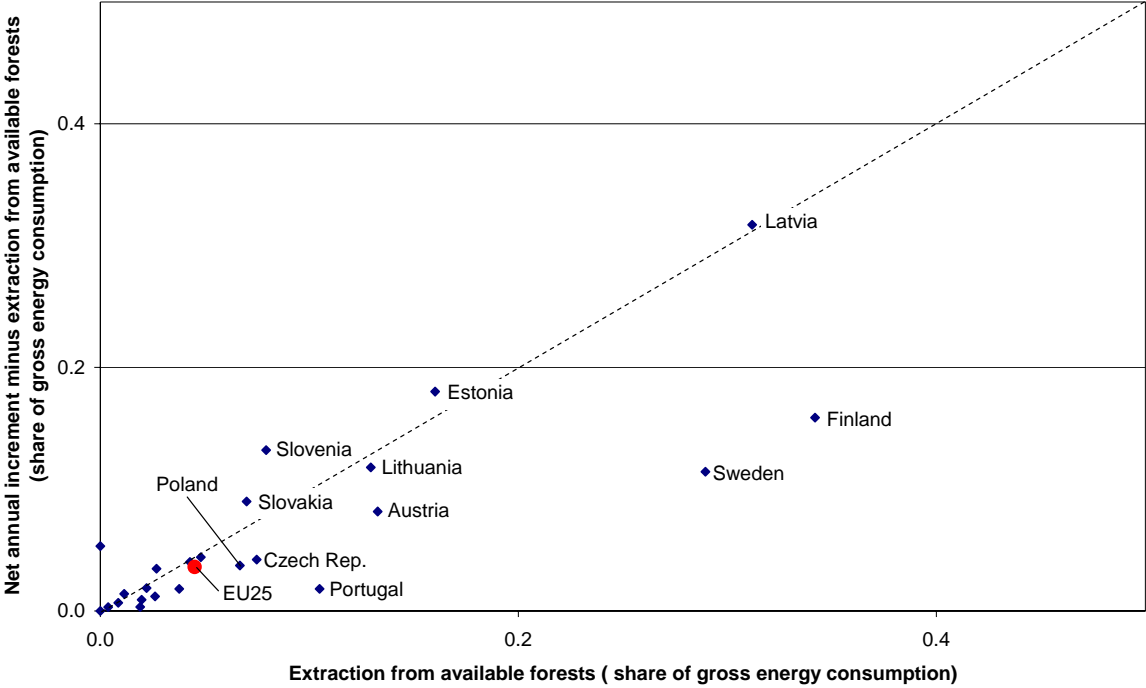


Figure 3. Comparison between gross energy consumption and forest extraction, and the balance between net annual increment and forest extraction in EU Member States. The forest extraction and balance are converted to bioenergy based on assumed energy content of 10 GJ/m³ of wood and then divided by each country's gross energy consumption. The net annual increment applies to parts of a country's forest that is judged available for forest extraction. Data sources: Eurostat statistical database and EC (2006).

Turning to agriculture, Figure 1 clearly showed that considerable biomass flows are generated in this sector. A substantial part (often more than half) of the biomass production above ground consists of residues. Far from all these residues can be used for energy purposes. Some must be left on the fields for soil conversation purposes and some are utilised for other purposes such as feeding and bedding in livestock production. On the other hand, waste

⁴ Corresponding to about 600 and 500 PJ, respectively. Forest wood extraction is also large in France and Germany, but compared to the energy use in these countries it is only a few percent. Forest extraction in Poland is about half the level in Finland and in Austria it is roughly one-third the Finnish level.

products with a possible energy use are also generated when the crops are processed in the food industry and a substantial part of the harvested food products ends up as post consumption waste. Thus, Figure 4 – showing the production of major crop types in the countries of the world – also gives a rough picture of the amount of residues and waste products generated within agriculture. The global production of the major crop types included in Figure 4 corresponds to about 60 EJ (10 GJ/capita). Once again, the global commercial trade in fossil fuels at roughly 390 EJ (60 GJ/capita) provides a relevant comparison.

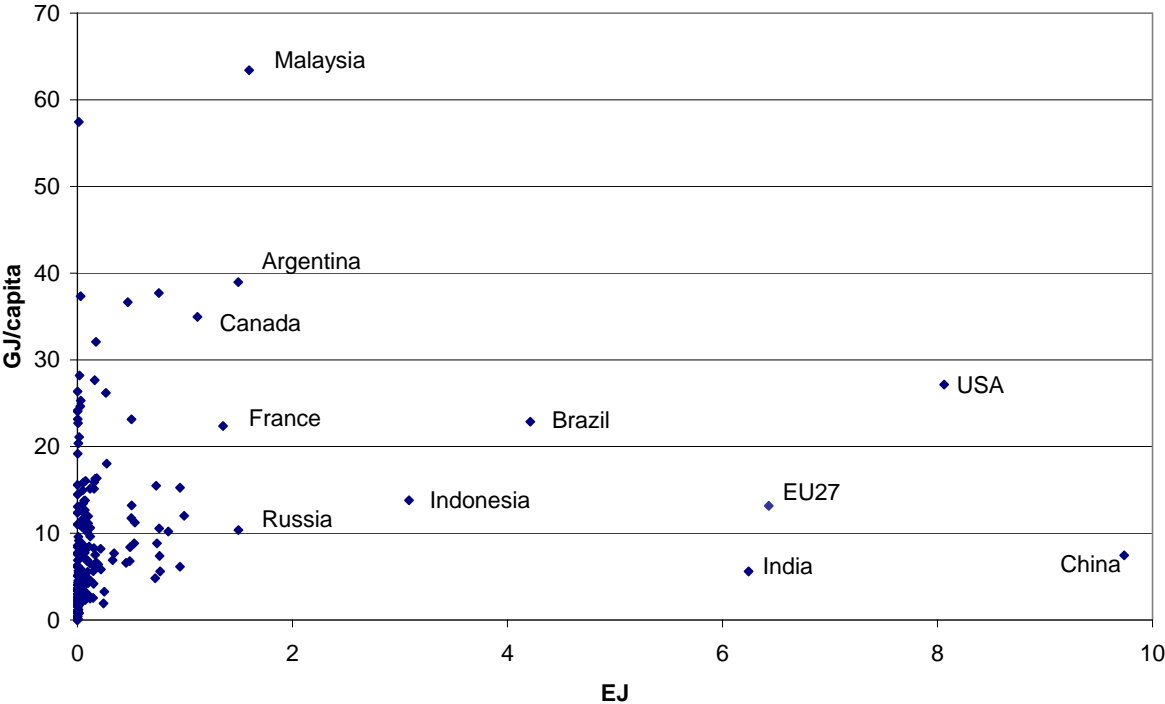


Figure 4. Production of major crop types (cereals, oilcrops, sugar crops, roots & tubers and pulses) in the countries of the world: average for 2002-2006, converted to energy units. The figure shows the dominant producers in the world and the production per capita in different countries. Based on data provided by the UN Food and Agriculture Organization, FAO (FAOSTAT 2008).

3.2 Efficiency increases along the food supply chain and the use of food system by-flows for energy could mitigate the water impacts of increasing demand for food and bioenergy

To the extent that bioenergy feedstocks consist of residues and biomass processing by-flows within the food (and forestry) sectors, water use for human purposes does not increase. The use of such flows improves the water productivity – more utility (e.g., both food and bioenergy) per unit water used – and also mitigates the demand on water for bioenergy, since bioenergy from residues can be produced without an increased pressure on water resources. The water that is used to produce the food and conventional forest products is the same water as will also produce the residues and by-flows potentially available for bioenergy.

