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Neither Climate Protection nor Energy Security: Biofuels for Biofools?

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ABSTRACT

The shift from fossil fuels to bio-based ones is considered to be a strategy to cope with the pressures of the coming peak oil era in oil dependent countries. However, although biomass can be a valuable element of a new energy mix, (i) without a drastic decrease in energy consumption its contribution will remain marginal, and (ii) without structural changes in the energy system (away from its current carbon basis) it poses risks to environmental security, mainly to biodiversity, and food security. This might even lead to significant changes in the relations between developed and developing countries. The prospect that second generation plantations deliver high yields from poor soils without external inputs is unrealistic. A more benign option for of biomass use is for carbon storage, at best realized in soils.

Keywords: Biomass, Biofuels, Biotechnology, Biodiversity, Brazil.

Ne İklim Koruması Ne de Enerji Güvenliği: Biyoyakıtlar Biyoşaşkınlar için mi?

ÖZET

Fosil yakıtlardan biyotemelli yakıtlara geçiş, petrolün tavan yaptığı dönemin petrole bağımlı ülkeler nezdinde yarattığı baskılarla baş etmede kullanılan bir strateji olarak belirmektedir. Buna karşın, biyokütle enerji kompozisyonunun değerli bir unsuru olmasına rağmen, (i) enerji tüketiminde önemli bir düşüş olmadan katkısının son derece sınırlı kalacağı, ile (ii) enerji sisteminde yapısal değişiklikler olmadan (karbon temelinden uzakta) başta biyolojik çeşitlilik olmak kaydıyla çevre güvenliğine ve gıda güvenliğine riskler yüklediği hususları göz önünde bulundurulmalıdır. Bu durum gelişmiş ve gelişmekte olan ülkeler arasındaki ilişkilerde önemli değişikliklere dahi yol açabilir. İkinci nesil ekimlerin fakir topraklardan dış girdi olmadan yüksek verim sağladığı hususu gerçekçi değildir. Karbon birikimi açısından biyokütlenin daha akılcıl kullanımı en iyi toprak içinde gerçekleşmektedir.

Anahtar Kelimeler: Biyokütle, Biyoyakıt, Biyoteknoloji, Biyoçeşitlilik, Brezilya.

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Introduction: The Supply Potential is Limited

The current global energy consumption of about 11 billion tons oil equivalent (BTOE) in 2004 consists of about 80 percent fossil fuels (oil 35 percent, gas 21 percent and coal 23 percent), about ten percent biomass and five percent each hydropower and nuclear energy.[1] The reserves are estimated to last for 40, 60 and 170 years, respectively (optimistic for coal); this implies that under current consumption levels these will be completely depleted within 82 years. Assuming that all humans consume at the current OECD average level (and ignoring world population growth), such a situation would be reached already within 27 years.[2] Even taking the speculative resources into account, the end of the fossil age will still be within this century, and if we burn all those resources, we will experience a greenhouse situation characterized by permanent catastrophes. Thus we cannot but admit and realize that:

(i) The fossil resources are indeed coming to an end. Alternative sources for energy, fuels, and chemicals are needed.

(ii) It is completely unclear how we will store, transport and use the energy we might produce in the future.

(iii) Ultimately, fuel and organic chemical production will have to use the atmosphere as the key source of carbon, producing them from CO_2 and H_2O without fossil fuels available for the endothermic process.

Many proposals have been made how to deal with this situation, but all too often the dramatic challenge caused by the combined developments of peak oil and climate change (let alone social tensions and economic crises) is grossly underestimated. Biomass has been suggested as a replacement for fossil fuels. But can it fulfill these expectations, physically, socially and economically? And if so, would it come timely enough for climate protection, i.e. within a decade - the time left to turn the tide according to the IPCC?[3] Current cars cannot run on 100 percent biofuels, and the average life time of a car is 12 to 14 years, thus, the demand side is limited for the foreseeable future.

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1 J.H. Spangenberg, "Biomass or Biomess The Promises and Limits of Bioenergy", Frano Barbir and Sergio Ulgiati (Eds.), *Sustainable Energy Production and Consumption?*, Brussels, Springer, 2008, p. 55.

2 O. Metzger and A. Hüttermann, "Beyond Oil and Gas: Vorschläge für eine künftige Energiewirtschaft", *Mitteilungen Umweltchemie und Ökotoxikologie,* Vol. 12, No 3, 2006, p. 71–73.

3 IPCC Intergovernmental Panel on Climate Change, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Summary for Policy Makers. Working Group II Contribution to the IPCC Fourth Assessment Report,* Geneva, IPCC, 2007.

The total volume of fossil fuels burnt per year worldwide, about nine BTOE, is the result of geochemical transformations of biomass containing 4.4 x 10^{19} g carbon (C), more than 400 times the net primary production of the Earth today.[4] Substituting biomass for fossil fuels with constant use efficiency would result in a tenfold increase in biomass demand to ten BTOE, equivalent to about ten kg of dry wood consumption per day per capita of the world population.[5] Today, the one BTOE biomass use stems mostly from non-commercial use in countries with low per capita energy consumption, and from ethanol production in Brasil, with commercial biomass use rapidly increasing in the EU and the USA. While biofuel production is on the rise, energy demand has been sky rocketing until taking a temporary dip due to the economic recession. With demand in China and India continuing to grow, no end to the increase in demand is in sight. According to the IEA (International Energy Agency), its estimate of 147 million t biofuel production until 2030 is not sufficient to supply the increase of fuel consumption[6] – although this may change if a prolonged recession dampens global fuel demand.[7]

The German government's Scientific Advisory Council for Global Environmental Problems (WBGU) estimates that in a sustainable land use scheme with 10-20 percent protected areas, no conversion of ecosystems of high nature conservation relevance for bioenergy production, and with primacy given to food over bioenergy production, at best three percent of the global land area could be used for bioenergy production. The total domestic consumption of fossil fuels in the EU was 1.4 billion tons, while the domestic consumption of biomass including food, feed, energy carriers, construction materials etc. was 1.5 billion tons[8]; they also provide a country specific analysis), with a caloric value half as high as oil (18.0 GJ/t for grasses and cereals, and 18.4 GJ/t for wood as compared to 36 GJ/t for oil). Thus, substituting fossil fuels for biomass use is *a priori* limited to marginal quantities – reducing their suitability for achieving policy objectives like (i) reducing the dependency on fossil fuels, (ii) energy supply security, or (iii) energy source diversity.

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4 See, Spangenberg, "Biomass or Biomess", p. 56 and G. Monbiot, "Das Ringen mit uns selbst", *Natur & Kultur,* Vol. 7, No 1,2006, p. 119–128.

5 J. Schindler and W. Zittel, "Peak oil: Der Strukturbruch Konventioneler Energieerzeugung", *Natur & Kultur* Vol. 7, No 1, 2006, p. 23–41; op. cit. in Spangenberg, "Biomass or Biomess", p. 57.

6 Monbiot, "Das Ringen mit uns selbst".

7 See, Spangenberg, "Biomass or Biomess", p. 56.

8 H. Weisz et al. "The physical Economy of the European Union: Cross-country Comparison and Determinants of Material Consumption", *Ecological Economics,* Vol. 58, No 4, 2006, p. 676-698.

Current Use is Unsustainable

Biomass can be used for a diversity of purposes – the question is not if, but how to use it for a future-proof strategy, balancing food, feed, biodiversity, climate and energy demands.

Competing Demands in the North

Competing demands for land and water arise from food provision, feed/fodder production, biodiversity conservation, chemical and construction industry demands, the raw material needs of the pulp and paper industry, and the opportunities for terrestrial carbon sequestration, each of them with different – and partly unrealistic – capital and labor demands. These diverse interests are not only competing for these resources, but also for the hegemony on setting land use criteria. On the one hand, the main objective for CO_2 sequestration and biomass production is a maximum yield of dry biomass per hectare (for energy use, industrial and construction materials). On the other, for biodiversity conservation (including agro-biodiversity) on a landscape as well as a site scale and for sustainable food production, the dominant objective is extensification (including organic agriculture) and maintenance or reestablishment of traditional land use patterns. [9] This also reduces environmental impacts, contributes to the protection of soil and its fertility, guarantees clean ground water etc. The former (biomass orientation) calls for permanent increase, needs no local contextualization and is in a process of being organized in large, multi-national business coalitions, whereas the latter accepts if not requires limits to yield increases, uses small scale technologies, needs to be embedded in local socio-environmental development strategies and mainly benefits local/rural actors.[10]

Obviously, the question is not about a 1:1 substitution, but the role of bioenergy in a new, less energy squandering economic system, as part of a new socio-ecological regime. The quantitative size of the challenge is illustrated in table 1; the structural challenge is described by Krausmann et al by analyzing the historical development trajectory from an agrarian to an industrial socio-ecological regime.[11] By comparative historical analysis the authors show the changing role of agriculture from the main factor of societal production to a one-sided supply function for the dominating non-agricultural production in the

9 M. Kleyer, et.al., "Mosaic Cycles in Agricultural Landscapes of Northwest Europe", *Basic and Applied Ecology*, Vol. 8, 2007, p. 295-309.

10 See, M. Bilgin, "Significance of Indigenous Locality for Global Sustainable Development", Rabindra Nath Pati and Odile Schwarz-Herion (Eds), *Sustainable Development: Issues and Perspectives*, New Delhi, D.K. Printworld, November 2007, p. 445–465.

11 F. Krausmann, et al., "Socio-ecological Regime Transitions in Austria and the United Kingdom", *Ecological Economics,* Vol. 65, No. 1, 2008, p. 187-201.

intermediate "coal phase" (significant flows from agriculture to non-agricultural population and production, with hardly any return flow) to the current situation of an agricultural system which is decoupled from human labor and depends heavily on massive energy subsidies, allowing for the tremendous increase in agricultural output. "In this new regime the relation between the agricultural and the non-agricultural production system is reversed. The non-agricultural system fuels agricultural production."[12] In order to make agriculture a net source of energy, a new transition establishing a new but re-reversed relation of agricultural and non-agricultural production is a necessary condition for making agriculture a net source of energy.

Table 1: Resource Consumption under Different Socio-ecological Regimes, *Source: (Krausmann et al., 2008)*

Countries (UN classification) Parameter	Agrarian	Least Developed	Developing	Newly industrialised & Transition economies	Industrialised
Domestic energy consumption DEC/cap [GJ/cap*yr]	40-70	37	49	95	294
Share of biomass in DEC [%of total]	>95	93	57	37	21
Coal consumption [kg/cap*yr]	<100	3	143	672	1603
Cereal yield [kg/ha*yr]	<2000	1346	2040	2782	4002

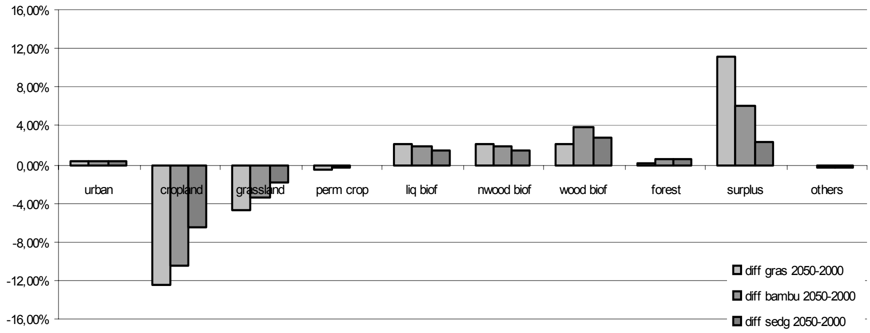
Model calculations by Reginster et al. from within the ALARM project which assumed an annual productivity increase of two percent, have shown that areas for biomass production only increase at a very low rate (while still causing significant problems for biodiversity).[13] Assuming a primacy for domestic food supply imposed by trade restrictions or new agricultural subsidies leads to limited imports, but does not lead to significant biofuel areas.[14] Even fewer biofuel areas are to be expected under the conditions of sustainable development (SEDG). In the free trade scenario (GRAS), the land use for agrofuels in Europe remains rather marginal: the demand is met by imports as Third World exports are cheaper than domestic production (see Figure 1).

12 Ibid, p. 190.

13 See, I. Reginster et al., "The effect of alternative socio-economic and political strategies on European land use from 2006 to 2080", *Land Use Policy,* in print, J. Settele et al.,"ALARM: Assessing LArge-scale environmental Risks for biodiversity with tested Methods", *GAIA*, Vol. 14, No. 1, 2005, p. 69–72 and www.alarmproject.net.

14 For BAMBU scenario, See, J.H. Spangenberg, "Integrated scenarios for assessing biodiversity risks", *Sustainable Development,* Vol. 15, No. 6, 2007, p. 343–356.

Figure 1: Comparison of percentage of land use changes in Europe from 2000 to 2050 under three scenarios. Source: Reginster et.al. (in print)



Global Impacts

The ambitious targets for biomass use, in particular for biofuels, set in the EU and the USA cannot be met by domestic production. The US government objective of 35 billion gallons of biofuels equals converting 100 percent of the maize and soya harvest. Although the cost of animal feed (previously maize now refined to ethanol) has vastly increased, adding US$ one billion to the cost of beef production, the US congress missed the opportunity to reduce the target in October 2008, and the new administration promised to keep subsidizing agrofuel production.[15]

The EU targets of 20 percent renewable energy in 2020 (including 10 percent transport fuels from biomass) would require 70 percent of the EU agricultural area if produced domestically. Thus the European Commission calls for a "balanced mix" of domestic production and imports, but this would mean to increase the EU's long standing net "land import"[16] significantly[17], namely up to 50%.[18] Even the 2010 objective of 5.75 percent biofuels causes trouble and is disputed as it would require 18 million ha (of a total of 100 million ha in the EU-

[15] M. Anslow, "Biofuels-facts and fiction", *The Ecologist,* No. 19, February 2007, http://www.theecologist.org/pages/archive_detail.asp?content_id=755, (Accessed on 24 November 2008).

[16] J. H. Spangenberg, *Towards Sustainable Europe. A Study from the Wuppertal Institute for Friends of the Earth Europe*, Nottingham, UK, Russel Press, 1995.

[17] The total area of land outside Europe permanently used to supply the EU (net balance average).

[18] The more so the larger the share of imports is, see, T. Kaphengst, "Nachhaltige Biomassenutzung in Europa", *GAIA,* Vol. 16, No. 2, 2007, p. 93-07.

27, at a current annual productivity of one TOE/ha), leading to competition with the food industry. Price increases and supply problems in the food sector have already been caused by agrofuel production.[19] Thus from the outset such policies rely on imports from Third World countries, at a time when the IPCC forecasts predict significant reductions of agricultural yields e.g. in Africa, and temporary increases in Europe and the USA.[20] Furthermore, limits to imports cannot be set politically, as unlike the agricultural markets, the fuel sector is fully liberalized, making measures to restrict imports illegal under the WTO trade regime.

This applies to plans for using the Sahara as solar energy source for Europe as much as to the global sourcing of agroenergy. He emphasizes that the refusal to rethink basic structures is essentially a power conflict: the problem is not the question of energy security for all, but how 25 percent of the world population (1/5 to ¼ thereof in the South) can uphold their privileged, oil based life style and consumption patterns.

The Case of Brazil: Social and Environmental Impacts of Agrofuel Production

A number of Third World countries see this as an opportunity not to be missed. Brazil planned to increase its 19 billion liter ethanol production (comparable to the US ethanol production from maize) by another 25 billion liters by 2016, doubling the land area planted with sugar cane to 14 million ha.[21] In addition to the seven million ha used for sugar cane today (more than the combined area of the UK and the BeNeLux countries), another 20 million ha have been declared 'suitable'. These have been regarded as being of 'minor value', and were opened for commercial development leading to the destruction of riparian forests with severe impacts on biodiversity. Areas now declared opened include parts of the Mata Atlantica (the coastal forest harbors more biodiversity than the Amazon), the Pantanal (the world's most important wetland) and the Cerrado. This activity is probably the biggest assault ever on biodiversity.

According to past experience, the people replaced here would migrate to the Amazon, increasing the already heavy losses of currently 325,000 ha per year and further accelerating biodiversity losses. They would be replaced by short-term migrant workers from other parts of Brazil, often employed by gang-leaders,

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19 CEC European Commission, "Es regt sich was in Sachen Biokraftstoffe", *FTE Info, Magazin für europäische Forschung*, No. 50, 2006, p. 30–33.

20 IPCC Intergovernmental Panel on Climate Change, *Fourth Assessment Synthesis Report Report*, Geneva, IPCC, 2007.

21 L.A. Martinelli and S. Filoso, "Expansion of sugarcane ethanol production in Brazil: environmental and social challenges", *Ecological Applications,* Vol. 18, No. 4, 2008, p. 885–898.

having long working days, low pay and a high death rate, with little protection from labor legislation. And rural jobs in general become scarce: whereas 200 ha of land in average provide jobs for about 70 people in tropical countries, it is 20 in palm oil and sugar cane plantations, four for eucalyptus plantations, and one for soya (economies of scale will further worsen the relation).

Beyond the threat to biodiversity and the social disruptions, this development also represents a huge environmental challenge. Martinelli and Filoso list as environmental factors to be taken into account the impacts of the current practice of intensive sugar cane agriculture:[22]

- heavy use of nitrogen fertilizers leading to eutrophication of coastal water and estuaries,
- erosion and compaction leading to soil degradation, reducing the soil's water retention and filtering capabilities, and
- the use of banned agro-chemicals such as organochlorides (found in fish and sediment).

The sugar cane processing leads to additional environmental problems, such as depleting oxygen in water systems by resulting waste water (12 liter of a red acid fluid with an extremely high oxygen demand in waste water treatment, called 'bagasse' or 'vinasse', are a side product of 1 liter of ethanol produced), and air pollution caused by sugar cane straw incineration. The impacts will be felt far beyond the plantations, for instance through the deterioration of wetlands, streams, rivers and reservoirs by silt and sediment, loaded with polluting chemicals.[23]

To become a "world supplier of food and energy", providing 10%of the world's fuel demand,[24] besides extended sugar cane plantations, another 12 million ha are foreseen for the production of bio-diesel from soybeans, beyond the 1.2 million t converted to fuel in 2007 (whereas sugar cane requires a period of low rainfall in its growing cycle and is thus grown mainly in the South-East of the country, soybeans can be grown more easily under tropical conditions). Serving mainly for fodder export so far, the current soybean area of 23 million ha is already much larger than the one used for sugar cane. Castor oil is investigated as another agrofuel to be produced in the poor North-East of the country.[25] In

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22 Ibid.

23 Ibid.

24 E. Holt-Giménez, Sprit vom Acker, "Fünf Mythen vom Übergang zu Biokraftstoffen", *Le Monde diplomatique*, Vol. 2007, No. 8, June 2007, p. 12–13.

25 N. Glaser, "Die neuen Scheichs. Brasilien möchte die Welt mit Biosprit versorgen", *Frankfurter Rundschau,* Vol. 2006, No. 18, July 2006, p. 10.

total, the agricultural area is foreseen to grow by half until 2020 as part of a plan to become "the World's prime supplier of food and biofuels", driven by an agribusiness which contributes more than ¼ to the US$ 800 billion GDP and more than ⅓ to the export earnings.[26] Its domestic market has been established and is still strongly supported by the government, although official subsidies for ethanol have been phased out in the mid-1990s. Personal diesel-engined vehicles have been banned to encourage the uptake of ethanol burning models, despite the formers better fuel efficiency, and new 'flex-fuel' cars (running on both petrol and ethanol) are subsidized by reduced VAT rates.

However, such ambitious plans currently suffer from the economic downturn and the falling oil price. Across the world investment in "green energy" is massively scaled back, and while firms selling technology earning a quick return (e.g. through enhanced energy efficiency) are proving rather resilient, capital-intensive businesses such as ethanol distilleries are suffering. One of the biggest US ethanol producers, VeraSun Energy, already had to file for bankruptcy protection. These general problems are even more severe in Brazil, where the debts are in US dollars, whereas the revenues come in depreciating reais.[27] However, so far no official scaling back of the ambitious plans has been announced, but with wind and solar energy thriving on collapsing ore prices, it remains to be seen if bioethanol remains the talk of the town, even in Brazil.

Not only Brazil

A similar development takes place in South-East Asia (in particular Indonesia and Malaysia which plan to cover 20 percent of the EU diesel demand), where palm oil plantations (as the best available diesel source) have been growing rapidly at the expense of virgin forests. Indonesia is tripling its plantation area – and in the course of the process will loose 98 percent of its forests (hence the nickname "deforestation diesel".[28] Production sites and refineries are mushrooming in Malaysia, Singapore, but also in Europe (Rotterdam), with capital from all over the world. Despite its rapid spread, this trend does not at all contribute to reducing the global CO_2 emissions, to the contrary: in a life cycle perspective, including emissions from felling, draining, planting, fertilizing, harvesting, processing and transporting, in particular the emissions from underground stocks in the case of clear felling of forests, and from subsoil biomass degradation in the

26 Ibid.

27 The Economist, "Gathering Clouds: Clean technology in the downturn", *The Economist*, Vol. 2008, No. 8 November 2008, pp. 67-68.

28 The Ecologist, "Scrap biofuels target, say Friends of the Earth and OECD", *The Ecologist,* Vol. 2007, No. 11, September 2007, http://www.theecologist.org/pages/archive_detail.asp?content_id =1064, (Accessed on 25 November 2008).

case of wetland draining, the production of palm oil causes 33 tons of CO_2 emissions for each ton of oil, ten times as much as the production from crude oil. In this case, accelerated biodiversity loss and enhanced climate change problems go hand in hand.

Another problem of the agrofuel strategy is the high water demand. Besides the water used in agriculture, modern maize based refineries produce 13 liters of waste water for one liter of ethanol[29] and the nitrogen applied as fertilizer (now 45 million t/a), which has not only doubled the natural volume of the nitrogen cycle, but also evaporates in particular from tropical agriculture as N_2O, a greenhouse gas 300 times as effective as CO_2. Within a recent analysis Crutzen et al. conclude that the additional N_2O releases due to the production of commonly used agrofuels, such as biodiesel from rape seed and ethanol from maize, depending on nitrogen fertilizer uptake efficiency by the plants, can compensate or overcompensate the reduction of warming by fuel savings (grasses and woody coppice species exhibit the same effect, but to a lower degree).[30] Maize and soybeans, used for biofuels, also accelerate erosion, leading to annual soil losses up to 6.6 t/ha in the USA, and 12 t/ha in Argentina.[31]

Hunger for Fuel – A New Substitution

When energy prices were sky rocketing, food prices have been soaring. Now (November 2008), with energy prices down to about a third of their 2008 summer peak, and with non-oil commodities down 40 percent since July 2008, food prices are also down again. Falling food prices helped driving down the cost of living in particular for the poor in North and South. However, this may be a mere temporary relaxation, as most of the driving forces behind the price hike still persist, if dampened by the recession: pre-refining oil costs continue increasing (the age of easy oil is over, as Chevron advertisements point out), demand in emerging economies grows (albeit with temporarily reduced speed), and fuel consumption in the USA, while taking a ten percent dip this year, is expected to be on the rise again in the future. The prices of fertilizers and pesticides are still bound to rise with the energy price. The panic buying by grain importers may be over, but a whole lot of money from hedge funds looking for new markets as the housing bubble has burst (the latter also applies to the minerals markets) is still in the market, now speculating on falling instead on rising prices. Thus the current price may be too low, as much as it was too high in July to be explained by supply and demand. As usual with speculation, these influences can change

29 Anslow, "Biofuels-facts and fiction".

30 P.J. Crutzen, "N2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels", *Atmos. Chem. Phys,* Vol. 8, No. 2008, 2008, p. 389-395.

31 Monbiot, "Das Ringen" .

abruptly, and so some experts expect the next oil price hike for early 2009. That may be underestimating the recession, but most experts reckon that the price of oil, and thus of the means of food production, is bound for a regular increase in the medium and long term.

On top of that comes the direct competition of agrofuel production for the same plants. For instance, the US government handed out US$ 5.1 to US$ 6.8 billion in ethanol subsidies in 2006, in payments to farmers, tax breaks to refiners and payments made under the carbon reduction programs.[32] The vast majority of the payments, however, ends up not with the farmers but with large biofuel manufacturers, accounting for 28 percent of the ethanol industry in 2006.[33]

The conversion of maize to ethanol in the USA, now making up for 5%of the fuel volume sold in the country, has been a catastrophe for the poor who already spend 50 to 80%of their household income on food. By driving up crop prices it led to hunger and public protests in Mexico (where maize tortillas are a staple food), an OECD country. In El Salvador, the poor were eating only half as much food as they were a year earlier. Afghans spent half their income on food, up from a tenth in 2006.

Today, just over one billion people live on US$ one a day, and additional 1.5 billion on one to two US$. Josette Sheeran, head of the UN's World Food Program, describes the impacts of food inflation affecting also people usually not hit by famines: "For the middle classes, it means cutting out medical care. For those on US$ 2 a day, it means cutting out meat and taking the children out of school. For those on US$ 1 a day, it means cutting out meat and vegetables and eating only cereals. And for those on 50 US cents a day, it means total disaster."[34] As with one percent increase of food prices, in average the nutrition of 16 million people becomes precarious, the 2007/08 trends – If reemerging – would lead to 1.2 billion people in starvation, twice as much as estimated earlier and quite the opposite of the Millennium Development Goals.[35] According to cautious estimates of the World Bank, food inflation could force at least 100 million people into poverty, wiping out all the gains the poorest billion have made during almost a decade of economic growth.[36]

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32 D.N. Koplow, *Biofuels, at what Cost? Government Support for Ethanol and Biodiesel in the United States,* International Institute for Sustainable Development, Winnipeg, Canada, 2006.

33 See, D. Pimentel and T.W. Patzek, "Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower", *Natural Resources Research,* Vol. 14, No. 1, 2005, p. 65-76; Anslow, "Biofuels-facts and fiction".

34 The Economist, "The new face of hunger", *The Economist,* Vol. 2008, No. 19, April, 2008, p. 31.

35 C.F. Runge and B. Senauer, "How Biofuels Could Starve the Poor", *Foreign Affairs*, Vol. 86, No. 3, 2007, p. 41–53.

36 The Economist, "The new face of hunger" .

No Hope from the Second Generation

As (i) current bio-refineries are economically not viable (i.e. subsidy dependent), (ii) their energy balance is at best positive but disappointing, (iii) the direct (fuel from food) and indirect (fuel plants instead of food plants) effects of agrofuel production on food prices and world hunger have caused so much public protest, and (iv) the only current alternative – using land not previously used for agriculture – poses severe threats to biodiversity, the current recession is an opportunity to rethink policies. Biofuel protagonists admit the problems encountered, but suggest not giving up on large scale plans but claim that with the second generation of agrofuels and agro-refineries the problems could be overcome. But could they? The challenge is enormous, given an energy density of ca. 10 W/m^2 for biomass and 10^3 to 10^4 W/m^2 for fossil fuels.[37]

Second generation systems come in two varieties. Either, they are (i) based upon collecting organic waste material from industry (paper, wood and food), agriculture (straw), households and green land (agro, forest, reserves) management, or (ii) they are planned to achieve a higher efficiency by using full plants (not only parts thereof) of high yielding varieties either by enzymatic processes setting the sugars free from the cellulose, or to degrade the biomass to synthesize gas, a mixture of hydrogen and carbon monoxide (BtL, Biomass to Liquids, a process not yet fully developed), and to stepwise synthesize chemicals from this raw material.[38] Methanol, as a first step, could be used as a fuel, and much better so than hydrogen for fuel cell cars, as it could be distributed using the existing infrastructure[39] – a claim fiercely refuted by other authors due to the corrosive effects of organic solvents on the infrastructure.[40] Hydrogen cars are now off the agenda, a costly and time consuming illusion of a technical fix for an essentially unchanged system.[41]

In the first case, the negative environmental impacts may be minimized, but despite its significant potential (in Europe the highest one available in the short run,[42] the prospects remain bleak, due to the high transport energy consumption

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37 The energy intensity of energy consumption in cities is ~ 10^2 W/m^2. See, M. Giampeto, "Energy system analysis - the case of biofuels", *Paper presented at the international workshop of the Rosa-Luxemburg-Foundation: Sozialökologischer Umbau als zentrale Herausforderung für alternative wirtschaftspolitische Konzepte und Strategien*, Berlin, 30 June-1 July 2007.

38 CEC European Commission, "Es regt sich was in Sachen Biokraftstoffe".

39 Metzger and Hüttermann, "Beyond Oil and Gas".

40 Anslow, "Biofuels-facts and fiction".

41 The Economist, "The car of the perpetual future", *The Economist*, No. 6, September 2008, p. 27-28.

42 EEA European Environment Agency, *How much Bioenergy can Europe Produce without Harming the Environment?* EEA Reports, 7/2006, Copenhagen, EEA, 2006.

acting as a limiting factor to raw material collection, cost wise and regarding the energy balance (the EROI energy return on investment is all too often poor to negative). Here, economies of scale bite: small scale facilities may have a good energy balance, but they tend to be uneconomic, and profitable ones (> 200,000 t/a methanol) need to be fed from a forest area of about 35,000 ha, producing about 500,000 t of wood per year, with the equivalent of one lorry load of wood processed every ten minutes.[43] That suggests refineries in the midst of biomass plantations, but not small scale waste processing plants. Even for waste use, new refineries may not be the optimal option from a climate perspective: Marmo argues that – provided certain standards for organic waste quality are met – such remains (crop residues, farmyard manure, compost and sewage sludge) spread on agricultural land could provide a direct route for carbon to the soil, with a potential of two to 20 million t CO_2/a in Europe.[44]

Thus the trend seems to be towards the second option, where the hope rests on breeding special grasses and fast growing trees which are expected to grow on low quality soils (i.e. not competing with food production, but probably with biodiversity), without fertilization and irrigation.[45] However, there are limits to this strategy: plant biomass (99 percent of all biomass on earth) contains about tow to four percent nitrogen, which on poor soils must be replaced if the biomass is extracted; nitrogen fixing bacteria associated with plant roots can contribute, but do not replace fertilizer in high yielding plantations. Besides nitrogen, phosphorus, sulphur, potash, calcium and magnesium are essential for plant growth, plus a number of trace elements. On poor soils, these elements are missing, and they as well must be provided by fertilization. Water supply is another problem: even if more efficient C4 plants are used (usually of tropical origin, as opposed to C3 plants: their optimal growth temperature is between 30 and 45°C, as compared to 15 to 25 °C for C3 plants), they still need 230 to 250 liters of water per 1 kg of dry biomass produced – either from rain, from ground water, or from irrigation (C3 plant needing twice to three times as much water).[46] Additional water demand comes from the refining process, waste and waste water treatment, the distributions system and so on.

As a result, this option enhances rather than reduces the environmental impacts, as these high yielding plants, in order to realize their potentials, are dependent on intensive, large-scale, mostly monoculture agriculture or forestry,

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43 Metzger and Hüttermann, "Beyond Oil and Gas".

44 L. Marmo, "EU Strategies and Policies on Soil and Waste Management to Offset Greenhouse Gas Emissions", *Waste Management,* Vol. 28, No. 4, 2008, p. 685-689.

45 F. Frick, "Biosprit II: Stroh statt Soja", *Bild der Wissenschaft,* Vol. 2008, No. 8, 2008, p. 92–102.

46 In both C3 and C4 plants, photosynthesis follows the formula $12\ H_2O + 6\ CO_2 \rightarrow C_6H_{12}O_6 + 6\ O_2\uparrow + 6\ H_2O$ which clearly shows the water demand of the photosynthesis: for every molecule of carbon dioxide fixed one molecule of water is inevitably consumed.

with significant consumption of water, nitrogen and minerals, and the resulting environmental impacts known from industrialized agriculture: a threat (not only) to agro-biodiversity, when it is most needed to manage the adaptation to climate change.[47]

Another proposal for technical optimization is based on genetic engineering. On the one hand, modified plants are suggested (trees, fast growing grasses), but besides being dependent on the intensive cropping systems described above, once deliberately released, they can hardly be contained (due to long-range pollen transport) and will inevitably lead to genetic contamination and additional biodiversity loss. If liability regulations along the polluter pays principle were introduced, insurance costs would make such approaches most likely economically unviable. The same holds true for the long-standing attempt to modify GMOs to degrade lignin, cellulose and hemi-cellulose to industrially usable sugars. Research has been going on for 20 years, progress is scarce, and the risk of unintentional releases significant (similarly as for plants fixing their own nitrogen with fungi genes). These are rather high risks given the fact that even if successful such technologies could only deliver a fraction of the global fuel demand.

As it is the system, not the plant causing the damages, using "wild" or "natural" plants within the same cropping system as it has been suggested to reduce environmental impacts, would not make a difference. Outside agriculture, but within the same management approach, large scale aforestation, in particular with fast growing trees leads to homogenization of forest areas and thus to loss of biodiversity. Other large-scale plans, based on the same philosophy, like flooding low-laying parts of the Sahara desert and using it for the production of marine algae as a biomass source suffer from the same problem of causing unforeseen detrimental side effects which may well overcompensate the initial gains (in this case by changing the global albedo, enhancing the water vapor content of the atmosphere, an effective greenhouses gas, and by destroying local cultures and biodiversity). Each of these proposals implies large transport systems with high energy losses (today ¼ to $^1/_3$), stabilizes unsustainable transport and use structures, and is associated with severe collateral damages to the environment (climate change, erosion, eutrophication, etc); soil carbon stocks are released rather than increased. Large scale biofuel production is clearly a strategy with high costs and low benefits for the public good (although certain private interests may gain significantly from it, illustrating the divergence of public and private goods). The option of large scale biofuel production as a substitute for fossil fuels is thus economically, socially and environmentally unsustainable. It maybe supported by vested interests' lobbying, but only biofools could support large scale biofuels.

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47 J. Kotschi, "Agricultural Biodiversity is Essential for Adapting to Climate Change", *GAIA,* Vol. 16, No. 2, 2007, p. 98-101.

An Alternative: Soil Biomass as Carbon Sink

The technical potentials for CO_2 sequestration, according to estimates by the German Federal Government (despite technical efficiencies of about 90%) is realistically at a maximum of about $^1/_3$ of the global emissions from coal fired power plants, i.e. 1.8 billion t CO_2 The potential from soil biomass production has been estimated to be ten times as high, if instead of using biomass as energy source, it would be used as carbon sink (as foreseen as one option in the compensation mechanisms under the Kyoto Protocol and many "carbon neutral project/city/company" initiatives).[48]

Recultivation of abandoned land and its aforestation would provide trees offering a local source of energy and construction material, and a carbon free one (as only soil carbon was counted for the 18 bio t sequestration potential, this is no double counting). Energetically, this is the most efficient land use option with aforestation yielding up to 200 GJ/ha, sugar beet about 100, potato 80, maize 50 and wheat 40 (the latter with a negative life cycle energy balance due to the inputs required). Providing energy and raw materials, and improving soil fertility and water retention capacities, it offers opportunities for rural development in 3rd World countries. Finally, it is an economically attractive option, as aforestation is significantly cheaper than technological carbon sequestration.[49]

Subsoil Sequestration

If the intention is to store atmospheric carbon for a long time, biomass production cannot be the final step (unless trees are left standing for centuries). Instead carbon storage should take place in the soil as a long term deposit providing additional benefits to ecosystems and anthropogenic land use. This happens by the growth of root matter, e.g. from perennial grasses, or by the sub-surface carbon transport of trees. The breakdown of the organic matter and its transformation by soil bacteria, fungi and earthworms releases a faction of the carbon, but stores most of it in soil organic matter or humus.[50]

As this kind of biological carbon sequestration –unlike low carbon fuels– at least in principle offers the opportunity not only to limit net CO_2 emissions, but even to reduce the atmospheric CO_2 content, it is an option not to be neglected when discussing the use of biomass. Thus soil could be an important long term sink for atmospheric CO_2, and strategies to increase carbon storage in soil could play a major role in cost-efficient mitigation strategies.

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48 GDCh Fachgesellschaft Deutscher Chemiker, "A propos ... CO_2 Emissionen", *Mitteilungen der Fachgruppe Umweltchemie und Ökotoxikologie,* Vol. 10, No. 1, 2004, p. 76–77.

49 Metzger and Hüttermann, "Beyond Oil and Gas".

50 Marmo, "EU strategies and policies".

Realizing the sequestration potential of 18 billion t CO_2 which could be activated by using biomass as a sink would require turning some trends: The current sequestration potential of about 7 billion tons is nearly compensated by forest destruction, causing about 6 billion t CO_2 emissions, a trend which would need to be reversed.[51] Similarly, erosion prone plants and land management and agricultural practices would have to be replaced by soil preserving ones (enhancing food security and drinking water quality as collaterals). A trend change is also needed for grasslands; recent research indicates that the ongoing loss of plant biodiversity might undermine the capabilities to use soil as a carbon sink there. Fornara and Tilman have shown that, compared to monocultures, high diversity mixtures of perennial grassland species increased soil carbon deposition up to five times, and soil nitrogen up to six times (the mix included Rhizobium hosting legumes) –a huge gain for climate protection, and for soil quality.[52]

However, if the primacy of food production is to be upheld and biodiversity, in particular pristine forests but also traditional cultural landscapes, to be protected, where is the land for soil carbon storage? It is available if not only existing productive area is foreseen as location, but in particular the re-planting of desertification areas were targeted, providing *en passant* an overdue push to efforts to combat desertification. This would require significant investments, but would also provide –*á la longue* significant– positive side effects: the carbon fixed in human soil components is stored for a long time, providing water storing capacity and improving soil quality.

Little wonder then, that already in 2003 the first European Climate Change Program identified a potential of 60 to 70 million t CO_2 to be captured in agricultural soils alone.[53] Unfortunately, this is neither addressing the full potential, nor has it led to a targeted subsoil sequestration strategy, despite its environmental and economic superiority.

Under economic criteria, bio-sequestration is an attractive option, too. Costs in Germany are estimated to be between two and five € per ton CO_2 stored in the soil (containing $^{9}/_{10}$ of the biomass in European forests); two € for fast growing trees and five € for forests with local species in sustainable forestry, whereas in the South the cost would be below one €/ton.[54] This is an attractive solution given estimated costs of 18-60 €/ton CO_2 for sequestration plus additional 10-24 €/ton CO_2 for transport.

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51 Chemiker, "A propos".

52 D.A. Fornara and D. Tilman, "Plant functional composition influences rates of soil formation and nitrogen accumulation", *Journal of Ecology,* No. 96, 2008, p. 314-322.

53 ECCP European Climate Change Program, *Sinks Related to Agricultural Soils*. EECP I 2003 Report. http://ec.europa.eu/environment/climat/pdf/execsummary_agricsoils.pdf, (Accessed on 23 November 2008).

54 Chemiker, "A Propos".

Discussion and Conclusions

Bioenergy is no silver bullet – but it may play a part in an integrated system of future energy supply. However, it is no bulk substitute: given the current consumption levels, bioenergy will not be able to deliver any meaningful contribution unless the reduction of total primary energy use of $^4/_5$ up to $^9/_{10}$ becomes reality (as recommended by the IPCC for industrialized countries). In other words: the contribution of biomass as a future energy source is relevant, but limited (and in scenarios never fully exploited). A maximum exploitation of the technical potential might have serious environmental impacts, thus regulatory frameworks are needed defending environmental and social standards in biomass use.

On the other hand, if used intelligently, biomass has an important niche to fill. For instance, Haeseldonckx and D'haeseleer found that small scale (< 400 MW_e) decentralized electricity generation from biomass close to the consumer could have the most positive impact amongst technologies currently available for decentralized electricity generation on emissions reduction, if operated in the combined heat and power generation CHP mode.[55]

Confronted with a competition for land and water, choices have to be made between producing (i) food, (ii) industrial chemicals (starch, oil, sugars,…) and fibers, (iii) construction materials (wood, straw), (iv) energy, or (v) conservation of biodiversity or (vi) CO_2 sequestration.[56]

In terms of contributing to climate change mitigation, the most effective and cost-efficient use of biomass seems to be carbon sequestration by biological fixation in the soils and stocks, e.g. by regeneration, aforestation and establishment of protected areas (depending on the detailed implementation both also potentially beneficial for biodiversity conservation).

The second-best option in terms of climate impact (and probably the best one in economic terms, limited by the low energy density of the biomass available) is the use of bio-waste as a relevant source of local energy needs, in particular in agricultural areas. Using biomass from landscape and biotope management can even enhance the economic viability of biodiversity conservation measures.[57]

For reasons of conversion efficiency, to maximize climate protection and minimize other environmental impacts, energy generation should focus on heat,

55 Between 400 and 2000 MW_e local wind turbines turned out to be the best solution – hydropower did not play a role as the study was conducted for Belgium. See, D. Haeseldonckx and W. D'haeseleer, "The environmental impact of decentralized generation in an overall system context", *Renewable and Sustainable Energy Reviews,* Vol. 12, No. 2, 2008, p. 437-454.

56 Kaphengst, "Nachhaltige Biomassenutzung in Europa".

57 Kleyer, et.al., "Mosaic Cycles in Agricultural Landscapes of Northwest Europe", *Basic and Applied Ecology*, Vol. 8, 2007, p. 295-309.

electricity and biogas, and not on biofuels. Technically, the former are typically produced in small scale plants for regional markets, whereas the latter tends to be a large-scale industry with high local impacts and limited local benefits, at least in the medium and long term.

If any, some small scale bio-diesel production for regional use, based on multi-annual plants, can be part of an integrated land management and sustainable production pattern, avoiding high intensity agriculture, with its annual plants (maize, rape), enhanced vulnerability to erosion, soil compaction, pollutant emission (pesticides, fertilizers), and reduced suitability for species survival. Making biofuel production supportive to local communities requires improved governance on all levels, including integrated land management systems based on local ownership, implying – in particular in many 3rd World countries – agrarian ownership reforms (in Brazil, the agro-business is in the hands of only four families who amongst them share the entire sugarcane production).

Instead of setting ambitious targets for biofuel use in Europe, transport policy must aim at reducing fuel demands (otherwise one international dependency is replaced by another), set standards (e.g. FSC-like socio-environmental certification) as mandatory for imported biofuels (accepted under the WTO regime – or the regime must be changed)[58]

Thus exploiting the potential of biomass for energy generation needs to be constrained by externally set environmental and social limits, and must be adapted to the specifics of the local situation (i.e. deliver local supply for local demand, e.g. biogas, electricity, maybe some plant oil if needed) if it is to be a part of the solution, and not the source of new problems. Without such restrictions, it would probably become – even at use levels significantly below the possible environmentally justifiable maximum – a serious source of increased pressures on the environment in general and on biodiversity in particular.[59]

In any case it must be clear that bio-sequestration, and even more so bioenergy production, are no catch-all solutions. To avoid developing into new technological lock-ins as hard to overcome as the current fossil fuel fix, biomass use should always be embedded into an overall sustainable development strategy, with technology assessments for all applications and sustainability assessments for all projects, plans, and policies, evaluating them against economic, social, institutional and environmental sustainability criteria. Such a strategy, to be convincing, also needs an explicit discussion on what should be sustained, for whom and at whose expense.

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58 M. Verdonk et al., "Governance of the Emerging Bio-energy Markets", *Energy Policy,* Vol. 35, No. 7, 2007, p. 3909-3924.

59 EEA European Environment Agency, *Estimating the Environmentally Compatible Bioenergy Potential from Agriculture,* EEA Technical Report 12/2007, Copenhagen, EEA, 2007.

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