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Biomass for food or fuel:

Is there a dilemma?

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After tens of thousands of years of daily struggle for food, it takes our breath away that today a farmer is able to single-handedly cultivate hundreds of hectares to produce sufficient food to feed thousands of families at the other side of the planet. In spite of a threefold increase in world population since the Second World War, the fastest increase ever in human history, available calories per capita have grown by nearly 25%. This truly remarkable feat is the combined result of academic research, government policy and private investment. It shows that agricultural research has been one of the most rewarding sectors in terms of investment[2].

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We can take a lesson from this: human capacity to innovate is great and allows us to be confident that collectively we are capable of innovation and rapid change.

It is therefore with agriculture that I need to start this lecture, because the future of bio-energy[3] is closely linked to agriculture and food, and in the future of agriculture, bio-energy will play an increasing role[4].

Agriculture

Food demand has always been driven by population growth, income growth and changing diets. Aggregate agricultural output on the other hand is a function of available arable land, agricultural productivity, input prices and commodity prices. World population is still expected to grow, stabilising at around 9 billion in 2050. Future food production will increase by about 1% annually[5] as a result of increased productivity (assuming arable land remains roughly the same)[6]. The most important growth sector within agriculture is the animal production sector with the demand for animal feed, particularly in Asia, driving world market prices. About 40 % of the world's cereal crops are used to feed livestock[7]. We expect the volume of growth of agricultural products to double by 2030 to meet rising demands and shifting dietary patterns. While the agricultural techniques to achieve the required growth already exist, their application is an important challenge and should by no means be taken for granted everywhere.

For the future, hardly any new land is available so all production must come from the natural resource base we currently have available. The only real option for satisfying growing demand is therefore through a process of sustainable intensification, i.e. an increase in the efficiency of the use of land, water and chemicals (fertilizers and pesticides) while avoiding environmental degradation.

We must aim for a second Green Revolution, boosting land, water and labour productivity and enabling greater diversification of diets.

Although the proportion of people in the agricultural sector will decrease overall, many countries, especially in Africa, will remain heavily dependent on agriculture. Seventy percent of the world's poor live in rural areas. For them agriculture will continue to be a main driving force for development. Whatever shape bio-energy takes, it is part of this wider agricultural trend of increased efficiencies in the use of land, water, labour and inputs.

Trends in energy

Since the Second World War, global energy consumption increased more than six fold[8]. In the same period, per capita energy demand has more than doubled from 28 GJ to 68 GJ, with averages for the USA standing at more than ten times those of China. Moreover, with 3.6% growth, 2004 had the fastest energy demand growth rate since 1978, despite record oil prices. Global primary energy demand is expected to grow more than 50% before 2030[9]. By then China and India will account for 30 to 40% of global energy demand[10].
The geopolitical situation in the Near East and the Gazprom confrontation earlier this year have added fuel to the growing concerns about the security of energy supply. Even rumours about energy supply disruptions can cause energy prices to spike virtually overnight. The world economy is **very vulnerable when it comes to physical supply of fossil energy and energy price hikes; moreover, these risks cannot be hedged.** There is widespread agreement,

even in the most oil-addicted countries, that **the best way to mitigate risks is to invest in energy efficiency and accelerate the transition to a diversified energy base with a large share of renewables.** Although the potential for energy efficiency is huge, especially in residential buildings, transport and industry[11], supply side options, including controversial ones such as nuclear energy and exploitation of tar sands, invariably get more attention than options for increasing energy efficiency[12].

On the supply side, in absolute terms, the current proportion of renewables is still very modest; in 2003 it was 13% of global energy supply. The vast majority thereof (11% out of 13%) was biomass of which 90% is so-called traditional biomass, mainly wood fuel used in developing countries[13]. But wind energy is growing by a steady 30% annually, and the solar energy sector realized a growth of over 40 % in 2005. Bio-fuel production has also more than doubled between 2000 and 2005, while oil production increased by only 7% over this period[14]. Overall, the IEA predicts an increase of renewable energy supply by 1.8% annually or an increase of over 60% by 2030[15].

Sustainability

Past economic successes have come at a considerable ecological cost – the images of burnt forests, salt incrusted soils and polluted rivers are all too familiar. While food, feed and energy demands will continue to grow at a faster pace than population, the consensus is that we cannot continue to tax the earth's vital ecological systems at this current rate. This is most clearly reflected in the Millennium Development Goals (MDGs), agreed at the UN Millennium Summit in 2000, which set out concrete targets for future development. However laudable they are, **the MDGs remain vague on the technical side of things, such as what sustainability really means and how we will measure it.** Also, I consider the lack of explicit references to energy and agriculture targets in the MDGs, a great omission.

Since 2000, the private sector and NGOs have done their share in trying to interpret the MDGs in a range of sectors. Many governments have done so as well, with the overall result that we now have a staggering array of ideas, criteria and monitoring systems of sustainability. A running joke is that sustainability is like love: we all know more or less what it is, but nobody is able to define or measure it.
However, it is encouraging that hard environmental metrics are being developed. Similar to financial metrics as 'return on investment' these extra-financial metrics relate net profits to natural resource use[16]. These metrics are increasingly popular in the financial sector because they reflect important company risks and upsides. In addition they also appeal to consumers[17].

Bio-energy

Bio-energy has been hailed as the major way to solve the combined problems of energy diversification, environmental sustainability and agricultural development. Bio-energy refers to the conversion of biomass for energy, whether it is heat, power or transportation (for a definition of bio-energy see end-note[3]). The term biofuels is usually reserved for liquid fuels derived from biomass. Biofuels essentially take two forms: biodiesel, produced through transesterification, for example from rape seed (canola), palm oil or sunflower, and bio-ethanol produced through fermentation of starch or sugars, predominantly from sugar cane or corn, with a minor role for biogas. These biofuels have gained importance in the last decade, promoted by government policy and subsidies. At the same time, some agro-industries such as sugar mills or banana plantations are converting waste into heat and electricity and provide excess electricity to the grid.
Unfortunately, the so-called first generation technologies – fermentation, combustion and transesterification – are relatively inefficient and often expensive. The sustainable use of oil crops, especially canola and corn, must be questioned because of their low net energy yield[18].
Technically, there are two major areas where a break-through is expected. Firstly, the physical and biochemical transformation processes used for converting biomass into

biofuels can be improved: so-called second generation technologies such as biomass gasification followed by catalytic conversion of the syngas into carbohydrates (the so-called Biomass to Liquid or BTL route) and enzymatic hydrolysis, are currently under intense research and should yield far greater efficiencies[19]. Secondly, these new technologies bring into play other sources of biomass, such as cellulose and lignocellulose instead of starch (the main component of edible crops). These are more complex molecules that require special enzymes (cellulases) to break them down and micro-organisms to deal with the residues. One of the most interesting scientific areas today is the biological engineering of *E. coli* and other bacteria to ferment the breakdown products of cellulosic products[20]. Lignins, hemi-cellulose and cellulose together form the most abundant biological material on earth.

The speed of the transition towards improved technology and other sources of carbohydrates depends very much on political decisions on targets for the substitution of fossil fuel (5.75% in the EU by 2010; 30% in the US by 2030), on land availability and on energy prices. **It will be interesting to watch the speed at which major oil companies will react to these new challenges**. According to a recent study of the EEA significant bio-energy production levels are compatible without increasing pressure on existing farmlands, and loss of forest biodiversity, soil degradation and loss of water resources, if the potential is developed in an environmentally friendly way using low pressure bio-energy crops and sustainable forestry principles. As always it all depends on how to do it[21].

Biomass for food or fuel?

Bio-energy has been criticised for competing for land with food crops, directly because products would be destined for energy rather than food, and indirectly because land needed for food production would be diverted to energy crops. But is there really a dilemma? Would investing in bio-energy really be unwise from a social or environmental point of view? Regretfully, there is no simple answer. **Whether and how bio-energy impacts on food security and sustainability depends on many factors**: as is often the case, the devil is in the detail.

To focus first on the question of *food or fuel*: I consider this a misleading dilemma because an immediate and massive displacement of food crops by energy crops seems very unlikely. Nevertheless, there would be a potential conflict if current inefficient biofuel production which exploits crops and land also in use for food and feed. If governments aim at a significant role of biofuels in the near future, this could be questioned as unrealistic if the targets are based on less efficient crops and conversion rates. Under such conditions there is a risk of price induced competition between food and fuel at least in the developed countries. However in food deficit countries substitution of food by fuel crops is unlikely because biomass is not easily traded and local energy needs are still low. In food affluent countries competition can easily be avoided, if government policy promotes efficient conversion routes and use biomass resources that do not infringe on food production.

	Yield l/ha	Yield GJ/ha	Billion hectares	% of arable land
Barley	1100	19,8	2,27	91%
Wheat	2500	45	1,00	40%
Corn	3000	54	0,83	33%
Sugar beet	5000	90	0,50	20%
Sugar cane	5800	104,4	0,43	17%
Soybean	500	9	5,00	200%
Sunflower	900	16,2	2,78	111%
Rapeseed	1100	19,8	2,27	91%
Jatropha	1800	32,4	1,39	56%
Oilpalm	4500	81	0,56	22%

Table 1. Required arable land for 10 different energy crops assuming 10% substitution of current global energy demand (450 EJ/a) or 25% of current oil demand (5000 bn l/a), assuming global arable land is 2.5 bln ha. Crop yields are based on Fulton et al, IEA 2004.

How much land is available for energy farming depends on how much is needed for the production of food and feed. This in turn depends on agricultural productivity and changing dietary patterns (see table 1)[22]. Much depends hence on the crop choice and the energy conversion route. For instance, if 10% of current global energy demand or 25% of current global oil production were to be substituted by biofuels this could require between 17%-200% of total available arable land. The higher percentage would result if biofuel production was based entirely on biodiesel from soybeans whereas the lower percentage refers to a scenario in which sugar cane is used to produce bio-ethanol. Even lower land use ratios could result if the resource base for biofuels was expanded to cellulosic feedstocks such as switch grasses and fast growing trees such as willow or eucalyptus. This scenario presupposes of course the availability of commercial conversion processes for such feedstocks, which is yet 5 to 10 years away.

In any case, **biofuel production from edible crops will soon run up against limits**: converting the entire US corn production would only meet 15% of US gasoline demand. That this would happen is most unlikely. The conversion of annual crops to biodiesel, popular in the EU, is also rather inefficient compared to sugar cane derived bio-ethanol. The entire German production of biodiesel from rape seed (1,9 bn liter in 2005) requires 1,75 mln ha. This highlights the importance of crop choice in using part of the scarce arable land to energy farming. It remains to be seen, therefore whether the EU biofuel targets can be met using indigenous bio-energy resources[23].

Secondly, the dilemma is probably more adequately renamed *feed or fuel*, since the main energy crops – maize, soy bean – are also feed crops and thus present direct competition to the expanding livestock sector, which reflects the shift in dietary patterns in newly developing countries. Whether fuel crops will replace feed crops is largely a matter of price and consumer preferences. **Feed or fuel may well be complementary and allow farmers greater flexibility to switch livestock for bio-energy commodities.**
There may, however, eventually be a *wood or fuel dilemma*, since the second generation conversion of ligno-cellulosic biomass from wood or stalks seems to present great promises in a decade or perhaps earlier. Wood does not compete directly with human food, but that is not to say that this biomass has no use: in developing countries (and some northern hemisphere countries) it serves in a major way as firewood and construction material. Stalks and stubble of course may also have an important local use as ground cover, soil improvement and feed and can make a true difference in poor areas. Typically, after an annual crop the stubble yield is 6-8 t/ha which is not to be ignored[24].

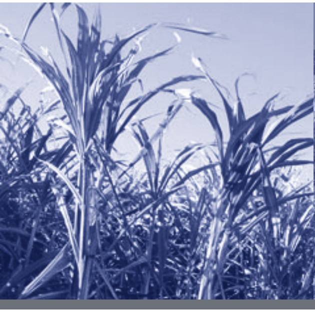
Thirdly, there are promising new plant species that cannot be consumed by humans or animals, such as *Jatropha spp* that are exclusively grown for their energy content. They grow under harsh conditions on soils that are unsuitable for most food or feed crops. Today, these so-called wild species are often very low in yield and major breeding efforts are still needed to increase their productivity. But, in general, the same applies as for any market crop: if these near crops are grown on previously cleared land, especially in a rotation with food crops, they could provide useful cash revenue to farmers and would complement food production rather than displace it. In general one can argue that increased productivity in the food and agricultural sector will boost biomass production and hence free up land for food, feed and fuel production, thereby reducing potential resource conflicts in producing.

Finally, there is another angle to the food or fuel story. Evidence of the effects of the high consumption of sugar and oil palm on chronic health have led to projections of lower demand for these commodities and concern among the major producers[25]. **Bio-energy uses of sugar cane and oil palm may alleviate some of these fears and present new opportunities for the countries concerned.**

Bio-energy and sustainability

The other area of concern is the sustainability of bio-energy. To a very large extent the impact of bio-energy crops is a function of the type of crop or tree and the agro-ecological environment. Much depends on how long the crop covers the soil and how much the soil lies fallow and is exposed to erosion[26]. **Annual crops, such as soy bean, canola or wheat, are generally less favourable than perennial crops such as oil palm, or semi-perennials such as sugar cane, banana, or grasses** such as *Pennisetum spp*. Tree crops do not require ploughing, provide better ground cover in time and space, less soil disturbance and erosion, better carbon fixation and have some positive effects on hydrology. So the balance seems to be in favour of perennials and tree crops[27]. But it is not simply a matter of the crop. If prime forest is cut in order to plant oil palm, the environmental costs may be very high. Not only because of the loss of forest biodiversity and sequestered carbon, but also because of the widespread disruption of the ecosystem due to the heavy machinery and the decrease in biomass. This is exacerbated if forest clearing is combined with widespread burning. On already deforested land, perennial energy crops such as oil palm are more beneficial to the environment than, say, soy bean. Similarly, on infertile or drought-prone land that is unsuitable for annual crops, grasses for biomass may be the only viable alternative to extensive grazing.

Finally, one should look at waste products. The harvesting and processing of palm fruits into oil may cause severe pollution especially if the residue is discarded into the surface waters. The residue itself is of course a source of biomass as well as of plant nutrients.



Two issues remain outstanding. The most difficult technical question is the contribution of bio-energy crops to carbon fixation – the technical data are conflicting and there is a real need for additional research. Any source of biomass contributes to the overall carbon balance of the planet. Hence land use change is an important variable in carbon emission and fixation scenarios. Climate change induced weather changes can also influence biomass production. At this stage, awaiting more systematic scenarios, it is difficult to predict the overall impact of these changes as well as the impact of mitigation policies such as the Kyoto Protocol and its possible successors. Likewise there is evidence that life cycle CO_2 emission reductions of biofuels are much lower than some would contend, depending on land use change, soil type and actual processing conditions[28].

The other issue is the impact of bio-energy plantations on biodiversity. There is no reason to assume that the impact of bio-energy crops is different from any other crops or plantations if these are grown on land that is already cleared. If, on the contrary, natural vegetation would be destroyed for the sole purpose of energy production, this would fall into the same realm as the destruction of rain forests for cattle grazing. **To really unlock the bio energy potential we will have to invest in improving overall agricultural management** of which more rational forms of energy cropping may be a part. This is especially relevant in the vast but currently rather unproductive rural areas in the developing world, in order to avoid further environmental damage due to low productivity. From an ecological point of view, no land use in the humid tropics is more destructive than low yielding annual crops. The savings from avoided oil imports and possible net revenues from energy farming can help to finance and thereby accelerate agricultural productivity improvement.

Bio-energy: Policy and Social Dimensions

Technically, bio-energy should not present a dilemma to safeguard food production or the environment. But, it all depends on what energy feedstock is used, how and where it is grown and how it is processed. In order to be a viable alternative, bio-energy should provide a net energy gain, have environmental benefits compared to fossil fuels, be competitive and be available in large quantities without endangering food supply. Although the energy content of most common biofuels exceeds the energy required to produce them, these requirements can best be achieved by growing tree and forest crops or using agricultural and other waste streams. Since cellulose cannot be digested by humans, these raw materials increase supply but also avoid direct competition with feed and human food.

The importance of a rapid introduction of commercial technologies for conversion of cellulosic materials into biofuels cannot be stressed enough.
I conclude therefore that **bio-energy projects should be judged on a case by case basis taking into account ecological, social and economic criteria**. Also, bio-energy must be part of a broader energy diversification and development policy which includes not only supply side options but also energy demand options and incentive frameworks. Given the huge differences between the various biomass sources and conversion technologies it is of crucial importance that the right priorities are set, nationally and internationally, in supporting bio-energy options. In this respect it is regrettable that the current US and EU biofuel support schemes do not differentiate between net energy gains and the environmental impact of bio-energy alternatives.

Ethical considerations

The discussion about sustainability will not go away in the near future. Producers of biomass would be well advised to document the environmental impact of their production processes in order to comply with consumer pressure for sustainable products. It is not unlikely that biomass traceability will become an issue, both at national level and possibly also under the World Trade Organisation (WTO)[29]. In fact, bio-energy could emerge as an important area of debate in the context of WTO, as part of the talks on support to agriculture. Moreover, **recent evidence from the WTO suggests that environmental concerns will play a greater role in future trade and thus may also affect bio-energy**[30]. It is not unthinkable that countries may refuse market access for bio-energy products on these grounds. This would be all the more reason to develop internationally agreed criteria and monitoring systems as soon as possible.

New technologies require new forms of organization and civilisation. This is a long term transition process of reshaping engrained energy production and consumption patterns. On the supply side we are moving towards more decentralised forms of energy production using a wider variety of resources. Since the transition to a sustainable energy basis entails above all the substitution of the production factor capital for the production factor energy, it will require huge investments. The IEA estimates required investments in the energy infrastructure to be $16 trillion until 2030. In their projection more than 80% of energy supply will then still be based on fossil fuels. Any higher percentage of renewable energy, whether this is based on faster penetration of renewable energy or lower demand growth due to increased energy efficiency, will require higher amounts of investment. Such investments can only be justified by taking a longer term view and by adopting appropriate valuation methods taking into account the avoided external costs and other economic costs inherent to a fossil energy based supply system. It is therefore of crucial importance that governments guarantee a long term stable investment climate that fosters the growth of renewable energy resources and energy efficiency. As all technologies, renewable energy technologies have down sides. The involvement of stakeholders is therefore essential in order to build a broad base for a new way ahead. The rapid agreement reached last year at the Round Table for Sustainable Palm Oil (RSPO) provides a leading example. Although politicians may be slow to follow, there are strong signs of a new global awareness among the citizens of our planet. **Ever better informed and more critical consumers are becoming aware that their purchase decisions can make a difference in reducing environmental impact or preventing social injustice.** This can be a double-edged sword because consumers are sometimes misled by a lack of sound information and even irrational fears. The bio-energy sector ought to learn the lessons from the stand off between the public and private sectors in biotechnology. One lesson that can be learned from this is that we need to be careful in using food cereals, such as wheat, as a feedstock for bio-energy. Not only because it is inefficient compared to other feedstock's but because it may be perceived as socially unacceptable. This may have an adverse effect on public support for bio-energy as a whole. Massive energy crop plantations may also meet with public aversion, even though the environmental problems of monocultures pertain to all monocultures and are not specific to biofuels. This is a matter of scale that can be dealt with by using corridors of uncultivated land. **Biomass has the great advantage of being locally available and thus present new opportunities for rural communities.** Depending on its type it requires a decentralised collection and conversion system this encourages us to rethink the centralised approach we have taken thus far to energy generation. Biomass production would also allow farmers to increase their participation in rural development. If each city had its own bio-energy plants fuelled from local produce and waste this would also promote greater public support and understanding of various energy alternatives

To conclude

Bio-energy, if produced sustainably, can diversify agricultural and forestry activities and attract investments in agricultural production. In the short term there need not be a conflict with food requirements, provided that first generation biofuel production is based on efficient crops, in particular (semi) perennials and uses of municipal and forest waste streams (pellets and other solid biofuels). In the longer term, as second generation technologies come on stream, this conflict seems even more unlikely since this unlocks the far greater cellulosic resource potential.
It is important that environmental problems due to land use change, processing and monoculture are avoided. Development of bio-energy will require the development and broad acceptance of appropriate sustainability criteria and certificating schemes.

Above all the bio-energy revolution could give an impetus to the development of more rational and productive forms of agriculture, especially in developing countries and in marginal areas. In turn this would free up land for food and energy crops. In other words, the dilemma is not food (or feed) or fuel. **A policy that integrates bio-energy farming and food and feed farming can potentially solve both local foods shortages and increase the incomes of the**

world's poorest people. This will only work if governments – and donors - develop coherent policies including bio-energy as part of a broader approach to energy and development. This is all the more important given that the bio-energy sector will, according to IEA projections, absorb 15%, (US$ 2,4 trillion) of total global energy sector investments until 2030. The new popularity of bio-energy in investment and development circles should not lead to isolated projects to the detriment of long term sustainable development.

The two sectors of energy and agriculture may become even more interconnected in the future. Not only because of agriculture's role in bio-energy, but also because plants are far more efficient producers of basic primary inputs for the chemical industry than the oil industry. We need to be aware of these changes now, because of the time-lags of research, investments and regulatory policy.

Although agricultural development is one of the success stories of the modern world, official development assistance in agriculture and rural development has dropped more than 50% in the last twenty years[31]. I do not want to make a plea for more ODA here, but **I would like to emphasize the need for a true partnership between the public and the private sectors to innovate the rural sector through bio-energy**.

Even if the development and application of bio-energy still represents many uncertainties, it is the kind of challenge that throughout its history mankind has learnt to deal with.

… and last but not least

Few of us in this room are able to imagine the acute hunger and widespread misery that was rampant in many countries only a generation ago. Inequality remains the true challenge of our world, when chronic hunger and poverty still affect nearly two billion people. It is unbearable to know that 50,000 of the 400,000 babies born this very day will grow up with food deficiencies affecting their brain development and health making them less productive and less happy citizens. Today, 2.4 billion people who cannot afford to buy imported fossil energy, rely on traditional biomass as their primary source of energy, and 1.6 billion of them do not have access to electricity[32]. The improvement of biomass use in developing countries must be a priority.
If there is a true moral dilemma of our times it is this: that hunger and poverty still exist.

Endnotes

1 I gratefully acknowledge the inputs from Rabobank staff and in particular the 2006 report "Financing and the emerging bio-energy markets, the Rabobank view". Unless otherwise referred to, data are quoted from the Rabobank report. Errors of fact and judgment are, of course, entirely mine. I am especially thankful to Daan Dijk for his assistance in reviewing and collecting data.

2 With rates of return of 40-78% (see U. Lele, 2003. Partnering to promote technology transfers. World Bank, OED, Washington). While the difference in yield between the most productive and least productive areas equaled 1:10 about a century ago, it now stands at 1:500, say the difference between manual cultivation of cereals in the Sahelian countries and intensive wheat production on clay soils in the Netherlands.

3 I follow FAO definitions. **Bioenergy**: energy from *biofuels*. **Biofuel**: fuel produced directly or indirectly from *biomass* such as fuel wood, charcoal, bio-ethanol, biodiesel, biogas, or biohydrogen. **Biomass**: material of biological origin (excluding material embedded in geological formations and transformed to fossil), such as energy crops, agricultural and forestry wastes and by-products, manure or microbial biomass. Bio-energy includes all wood energy and all agro-energy resources. Wood energy resources are fuel wood, charcoal, forestry residues, black liquor and any other energy derived from trees. Agro-energy resources are energy crops, i.e. plants grown for energy such as sugar cane, sugar beet, sweet sorghum, maize, palm oil, seed rape and other oilseeds and various grasses. Other agro-energy resources are agricultural and livestock by-products such as straw, leaves, stalks, husks, shells, manure, droppings and other food and agricultural processing and slaughter by-products. (In: 'introducing the International Bio-energy Platform', FAO, Rome, 2006.)

4 The economic spheres of agriculture and energy have always been interacting. Humans derive energy and materials to sustain their bodies, from food. The energy content of the human diet is currently 2650 kcal per person per day on average (FAO, 2006). This equals about 3 glasses of gasoline per day. Total annual food

consumption is equivalent to about 6% of global energy use. Agricultural production requires about 15% of global energy demand (fertilizers, pesticides, processing, transport). Estimates on the role of agriculture in producing energy range from half to several times current global energy demand. See also: Smeets, Edward M.W, Andre P.C Faaij, Iris, M. Lewandowski and Wim C. Turkenburg,
"A bottom up quickscan and review of global bio-energy potentials to 2050", submitted to: Progression in Energy and Combustion Science; see also Vries, Bert de, Monique Hoogwijk and Detlef van Vuuren, "Renewable Energy sources: their global potential for the first half of the 21st century at a global level: an integrated approach", Forthcoming in Energy Policy 2006. Furthermore, the agricultural sector has a direct interest in energy prices because they determine the costs of direct energy use in agriculture and the costs of energy intensive inputs such as fertilizer, and most importantly because they influence biofuel commodity prices.

5 Source: World Agriculture towards 2020/2050. Interim report on prospects for food, population, agriculture and major commodity groups, FAO, Rome, 2006.

6 The earth's land surface is 13bn ha . Arable land is estimated at 2,50-3 bn ha. Source: Eswaran, H.F. Beinroth and R. Reich, 1999. Global land resources and population supporting capacity. Am. J. Alternative Agric. 14: 129-136.

7 The area of pasture land is about twice the area of crop land.

8 BP statistical review: data series 1965-2005 based on commercially traded fuels only hence excluding renewables and nuclear. This can be used as a good proxy for energy demand growth over this period. The World Watch institute has synthesised time series (for fossil fuels only based on UN, US DOE and IEA data) that go back to 1950, this leads to a multiple of 5.2 over the period 1950-2004. By inference (assuming 6% growth between 1945 and 1950), energy demand over the entire 60 year post-war period has increased by a factor of 6.6.

9 World Energy Outlook, IEA 2006.

10 To be precise, 16% of oil demand (now 10%) ; 5% of natural gas demand (2% now) and 48% of coal demand.

11 Potentials are estimated as follows: residential 10-30 fold reduction, transport 2-4 fold reduction and industry 1,5-2 fold reduction.

12 A notable exception is a recent Pentagon co-sponsored but otherwise independent and peer reviewed report under the title "Winning the Oil end Game" by Amory Lovins of the Rocky Mountains Institute . This report provides a concrete roadmap for eliminating US oil use by 2040 led by business for profit. It outlines how oil can be used twice as efficiently by end use efficiency improvements and how the remaining demand can be supplied by advanced (2nd generation) biofuels.

13 World Energy Outlook, p 82, IEA 2006.

14 ibid.

15 ibid.

16 See for instance the sector reports of the carbon disclosure project (started in 2003) which systematically assesses carbon liabilities and opportunities of the Fortune 500 listed companies (www.cdproject.net). Another ground breaking initiative is the ADVANCE –project, an EU-LIFE Environment programm co-funded initiative of six European research institutes. In their 2006 report they have assessed the environmental performance of 65 European companies from the manufacturing sector by relating Gross Value Added to environmental resource use . Environmental resources considered are: CO_2, NO_x, SO_x emissions, as well as emissions of volatile organic compounds, methane and waste generation and water use. The Advance report 2006 can be found at : www.advance-project.org.

17 See for instance the Swiss Top Ten site which lists consumer goods according to energy costs and environmental impact (www.topten.ch). This initiative is now being rolled out in other EU Member States.

18 It ought to be noted that gasoline crops for biodiesel (sunflower or rape seed) have low energy balances: typically corn for gasoline 1.3-1.8 (output/input), compared to the much more energy efficient sugar cane where the output to input ratio is 8.6.

19 Companies like Shell and Sasol use the Fischer-Tropsh process to convert woody biomass into biodiesel (so-called BTL or Biomass to Liquid plants). The Fischer-Tropsch process (FT-process) is a catalyzed chemical reaction in which carbon monoxide and hydrogen are converted into liquid hydrocarbons of various forms. The FT-process is proven technology and in use since World War II. New is the use of syngas from gasified cellulosic biomass feedstock. The overall high energy and carbon efficiency of this biodiesel route derives form the use of woody biomass resources and the fact that in FT plants biofuel production is combined with electricity production. The ethanol route can also profit from significant efficiency improvements. In 1st generation bio-ethanol production up to 45% energy efficiency improvement is possible simply by blending gasoline with hydrous bio-ethanol instead of anhydrous bio-ethanol

20 See also Nature Biotechnology 24, 777-784 (2006) for an overview. One of the problems seems to be that celluloses yield pentoses rather than hexoses (or glucose) which result from starch.

21 The environmentally compatible primary biomass potential increases from the current level of 70 MTOE (400 PJ) to 190 MTOE in 2010 and 295 MTOE (1700 PJ) in 2030. This is equivalent to 15-16 % of projected primary energy requirements of the EU25 in 2030 (compared to a 4% share of bioenergy in 2003) and could save between 400-600 MT of CO_2. The main drivers for the increasing bioenergy potential are productivity increase and ongoing liberalization in agricultural markets. In the short term the main contribution is expected from waste (100 MTOE). In the longer term high yield bioenergy crops (perennials) and short rotation forestry are becoming more important. The EEA assumes that:

- 30% of agricultural lands is dedicated to "environmentally-oriented farming"
- extensively cultivated agricultural lands (olive groves, dehesas, grasslands) are not transformed into arable land

- 3% of intensively cultivated land is set aside for ecological compensation areas - current forest areas are maintained,
- bio-energy crops with low environmental pressure are used.

European Environment Agency, How much bio-energy can Europe produce without harming the environment?, report nr 7/2006.

22 The US national Agricultural Biotechnology Council estimates that with 10 bn people required arable land for food would be 2.6-1.2 bn ha (low /high yield) whereas available arable land will shrink to 1.1-2.1 bn ha., NABC report 12 (2000).

23 According to a report by the joint research centre of the European commission substantial efforts will be needed by the agricultural sector to achieve the 2% transport fuel target in 2005. Meeting the 5.75 target will however most probably require significant changes in agricultural production patterns in the EU. Implementing such changes might be quite challenging in practice. EU/ERC, Report EUR 21012 EN, 2004.

24 But if it is removed many of the benefits of conservation agriculture, an important technique in countries like Brazil, which aims to maintain continuous ground cover, are lost.

25 FAO/WHO, 2004. Diet, nutrition and the prevention of chronic diseases. Report of a joint export consultation Rome/Geneva.

26 Although sometimes there may be a second season crop, rainfall and temperature permitting.

27 Estimated Green house gas reductions of biofuel feedstock relative to fossil fuels: cellulosic fibers (Myscanthus, Eucalyptus) 70-110%; wastes (waste oil, harvest residues, MSW) 65-100%; sugars (sugar cane-sugar beet) 40-90%; vegetable oils (rapeseed, sunflower, soy) 45-75%; starches (corn wheat) 15-20%; Source: Biofuels for Transportation a report prepared for the German Bündesministerium fur Ernährung, Landwirdtschaft und Verbraucherschütz by the Worldwatch Institute in cooperation with the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), 2006.

28 The maximum amount of avoided CO_2 emissions from substituted mineral oil is about 3.3 ton CO_2 per Ton Oil Equivalent. This is based on the amount of CO_2 released upon combustion of mineral oil (2.9 to CO_2/TOE) with an additonal 10-15% to account for fossil energy use in exploration, refining, transport and distribution. According to Reijnders and Huijbregts in "Palm oil and the emission of carbon-based greenhouse gases" , forthcoming in the *Journal of Cleaner Production*, the life cycle emissions of South Asian Palm oil correspond to 2.8 -19.7 ton CO_2 per ton of palm oil. The higher figure corresponds to plantations on cleared natural forest on peaty soils. Given the fact that the calorific value of palm oil (40 GJ/ton) is comparable to that of mineral oil (41.8 GJ/ton), the lower figure would suggest that emission reductions by palm oil based biodiesel are zero at best. In another article, Reijnders and Huijbregts conclude with respect to starch and sugar based bio-ethanol that in addition to CO_2 emissions linked to life cycle fossil fuel inputs, which are typically about 2.1-3 ton CO_2 per ton of starch derived ethanol, one has to take into account greenhouse gas emissions linked to agricultural practices (e.g. N input related N_2O emissions). These are estimated to be 2-2.5 ton CO_2 equivalent per ton of wheat based ethanol and 0.6-0.9 ton CO_2 for ethanol from sugar beet. The authors add that in the absence of actual processing data on ethanol production from ligno cellulosic crop, no firm conclusions can be drawn regarding how life cycle CO_2-emisssion of ethanol from such crops compare to emissions from starch or sugar derived ethanol. Comparing life cycle emissions of solar energy for automotive purposes and bio-ethanol, the authors conclude that solar cell derived electricity is two orders of magnitude more efficient than sugar cane based ethanol.. "Life cycle greenhouse gas emissions, fossil fuel demand and solar energy conversion efficiency in European bio-ethanol production for automotive purposes", *Journal of Cleaner Production,* 2006 1-7.

29 Certification should be adopted on a wider scale as part of national bio-energy support schemes, in implementing the EU renewable Transport Fuel Obligation or in national duty incentives. That could mean that, in order to qualify as a biofuel under such rules or to meet the fiscal specification for biofuels, a biofuel would need to result in a minimum carbon saving. Practically, that may mean that all biofuels sold in the world need to be carbon-certified

in future. Some EU Member States are already moving in these directions (Belgium, Netherlands, UK). It is essential that the private sector follows suit and organises itself in a "coalition of the willing", committed to truly sustainable biofuels production and trade.

30 With respect to compatibility of such certification schemes with WTO rules on technical barriers to trade it should be noted that decisions of the Appellate Body of the WTO give grounds to expect that environmental regulators can refuse imports of goods based on information on how they were produced. Robert Howes, "The Appellate Body Rulings in the Shrimp/Turtle case: a new legal baseline for the trade and environment debate", Columbia Journal of Environmental law, vol 27, no 2(2002), pp 489-519.

31 Figures from OECD: ODA (official development assistance) dropped from 5.14 B to 2.22 B US$ annually

32 And in Africa 92% of the rural population lives without electricity FAO Committee on Agriculture, 2005. Bio-energy. Report for its 19th session, Rome.