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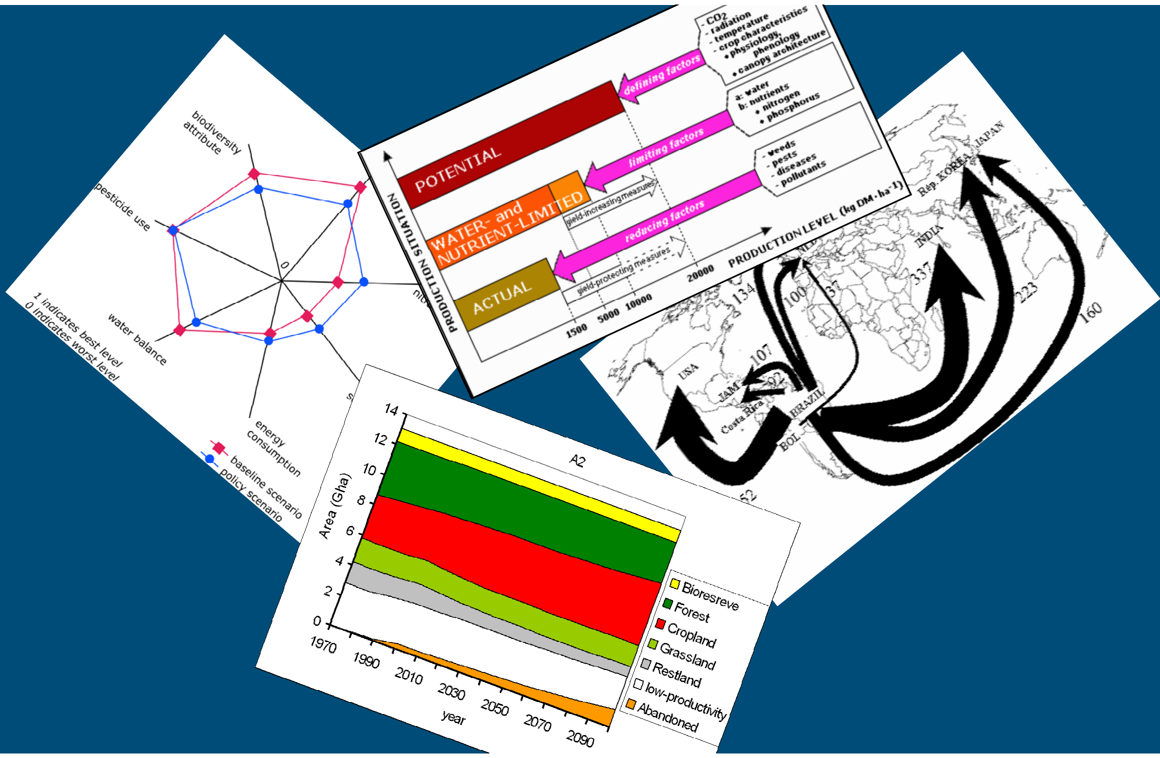

Report 142

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Editorial

In the coming four decades a doubling of the global food and feed production is foreseen. This will further increase the demand for natural resources. Government directives, incited by high oil prices, global climatic change, finite energy resources and geo-political tensions, promote partial replacement of fossil fuel by biofuels. This will further increase the demand for land, water and minerals.

Any component of organic material can, theoretically, be converted into energy for use in transport or as electricity. Food grade sugars starch and vegetable oil are presently, used as feedstock for energy production, through so called first generation technologies and other technical industrial applications. Second generation technologies must yield greater efficiencies and allow the use of (ligno)cellulose from woody material and from current agricultural wastes, for both energy and technical applications. Although presently some second generation plants are being built, it is expected it will still take a number of years to develop these technologies into economically viable pathways.

No matter the feedstock for the production of biofuel from either 1st or 2nd generation technologies, any biomass source will require similar resources and will put a claim on land and other resources. Presently several millions of hectares are dedicated to biofuel production especially in Brazil and the United States where sugar cane and corn starch are converted into alcohol for mandatory mixing with petrol. Similar directives of the European Union increase the demand for biofuels and consequently for land and other resources. Prices and availability of certain commodities such as sugar, corn, palm oil and canola are becoming affected by the demand for bioenergy.

Many implications of this additional demand for feedstock for biofuel on the resource base, economic power structures, price development of foodstuff and social changes are unknown. There are gaps in our knowledge regarding the potential global capacity of feedstock production for biofuels resources such as land, water and nutrients. There also is a need to base future efforts on facts rather than emotion.

To this end, Wageningen UR organized a seminar, supported by the Ministry of Agriculture, Nature and Food quality and two major global industries Unilever and Shell with the following aims:
I. to review the most recent scientific insights in potential global feedstock production for large scale biofuel production, the claims on natural resources and the competition between food and fuel
II. to identify gaps in knowledge regarding sustainable production of feed stock.
III. to inform policy and industry about current insights in these issues

The agenda addressed the long-term sustainability by optimal use of the resources, including ex-ante evaluation of competing claims of resource use for the various needs of people, and scientifically underpins sound sustainability indicators, monitoring and certification systems.

Questions that the participants addressed in the afternoon sessions were:

- What are the relevant issues considering present and future feedstock for bioenergy?
- Which future technological developments do you expect?
- How will they affect geographical claims on land, water and fertilizers?
- What will the implications be on pro poor developments and global energy use?
- What (Dutch and European) policies are required to avoid pitfalls?
- What knowledge gaps need to be addressed?
- What are the opportunities for (Dutch and European) industries?

Participants, 80 persons, represent the food and non-food industry, EU and Dutch policy makers, NGO's and scientific institutions. During the afternoon workshops each participant completed a form by enumerating opportunities and threats of biomass production and of measures needed to realise the opportunities and to avoid the threats. These lists, and added to them points that were raised during the workshop and plenary sessions, are represented in these proceedings. As editorial team we decided not to interpret and rank the remarks - but just to group them in related topics - as we trust that they best guide the reader in their original state.

Anton Haverkort
Prem Bindraban
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Organizers and Editors

Food, Feed, Forest or Fuel? Summing up of consensus and debate

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The symposium sponsored by Shell, Unilever, Wageningen UR and the Ministry of Agriculture, Nature and Food quality was a meeting of minds. The excellent introductions and the constructive and stimulating discussions made clear that there are many points where consensus is reached, a few that have clear differences of opinions and many where further research was needed.
These points will be given below, but it should be mentioned that the organizers have done a wonderful job by bringing so many excellent presenters and specialists together. They should be thanked for that initiative.
Consensus was reached at least five crucial points:

1. From fossil to flow. At present more than 80% of energy is from stocks or fossil sources. In the coming decades that has to change. The solar energy which is far more than the present human energy use should replace the fossil sources through direct capture of solar light or indirect flows such as wind or tidal movements. This transition will, depending on investments or political will, take at least 50 or 100 years.
2. The need for change should be based on the right arguments, right for the right reasons. It is questionable whether, for example, the geopolitical reasons are sufficient to justify the enormous change in policy. It is also questionable whether the envisaged contributions to reduction in CO_2-emission are feasible. It is the role of honest and unbiased scientists to develop the basic data that are not dictated by vested interests of companies, policy makers or NGOs.
3. In the transition to flow energy, based on direct or indirect ways to capture solar energy, biomass may play a role on a limited scale. The use of biomass should be based on clear and explicit feasibility studies and not on policy decisions based on unjustified claims or anxiety and geopolitics. As feedstock for chemicals and materials, biomass may play a more prominent role.
4. To promote the ultimate aim of more solar energy, various methodologies and approaches to reach more solar energy harvesting possibilities should be developed. That long term aim requires substantial investment both public and private, now!
5. For the short term there is no one single bullet and mixtures of various ways to make use of biomass should be considered, but most of all efficiency- and efficacy increase should be promoted, and last but not least energy neutral systems such as for example glasshouses and buildings should be stimulated.

Points that differ in the opinions of the participants in the discussion:

1. The criteria that should be used to assess the sustainability of producing, transporting and importing various forms of biomass, are still under debate. Certification is indispensable, but how that should be done is still not generally accepted.
2. The context of various countries and regions may be very different and that explains also the differences in expectations and possibilities of these countries to contribute substantially to biomass production for energy.
3. There are a lot of ill perceived ideas and unjustified prejudices of biomass for energy in various areas for example in the EU. This needs much more study and debate in order to prevent overestimation of potential on one hand and unjustified criticism on the other.
4. Many interventions in energy production (first, second and especially third generation) require new institutional arrangements and appropriate governance. This requires institutional innovations.
5. The present forms of LCAs apparently need further elaboration and upgrading with regard to amount and precision of data upon which they are based. It should be ascertained when comparing studies that similar systems boundaries are used.

Biofuels: views of the European Union and of a politician

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Politicians need to design the energy strategy, and not just on a national level. The energy question imposes enhanced European cooperation – although I do not believe that energy and climate change may even create the same impetus for European integration as the Cold War did, or the need to avoid new wars between European nations. The threats by climate change and the inevitable end of fossil fuels seem too remote, too far away, and too many people still don't feel the urgency acutely enough.
For the moment, the run on biofuels has some ironic consequences. Just read last Mondays Financial Times. The price of barley is rising rapidly. This is because of the strong demand for bio-fuel feedstocks such as corn, soybeans and rapeseed. Farmers feel encouraged to plant these crops instead of barley. Barley, as you all know, is the main raw material for beer. So, bio-fuels may be more than good news for environmentalists, and for farmers. But for the world's beer drinkers it could be a sad story. There is only one possibility that prices will remain reasonable. The main ingredient of beer is water.

Current issues

I would like to share some sobering thoughts on biofuels with you, of course without becoming pessimistic. Politicians have the moral obligation to spread optimism. Here follow the main issues.

- First generation bio-energy may not be the most effective solution on the long term, but we will not be able to develop the second generation without working ourselves through the first, in order to develop the necessary new technologies.
- First generation biofuels may lead to an increase of food prices and this has to be addressed, in particular in poor countries, where one should rather opt for the second generation whenever possible.
- It will be necessary to change existing legislation on animal feed and on manure, in order to stimulate investments in biogas installations.
- Europe should invest courageously in the development of new solar panels, and this will prove to be the best available method to capture and convert solar energy, far more efficient than the first and second generation of bio-energy, however useful they will be.

Of course, the combined effects of high prices of fossil fuels, the need to curb climate change, and geopolitical instability and unreliability of some major gas and oil producing countries have spurred intense interest in alternative fuels, especially from renewable energy sources.

Global warming, but also contamination of air and soil and the related health issues, are important environmental problems caused by fossil fuel combustion.

So far, hybrid cars are still a rare phenomenon on our roads. European car makers have mainly focused on using more first-generation biofuels, such as biodiesel and bio-ethanol. The European goal of 5,75% biofuels in energy used for transport by 2010 is feasable, and should be reached even if we are lagging behind schedule right now. But there is still a great number of questions that have to be answered. Let me just enumerate some of them.

Are first-generation biofuels really that much greener than traditional fossil fuels? In order to reach its biofuels targets, Europe will have to rely on imports of ethanol from Brazil, where the Amazon is being burned to plant more sugar and soybeans, and from Indonesia where rainforest land is being cleared to house palm oil plantations. An eco-certificate for imported and European biofuels may help, and it needs to be introduced quickly. But certification will not entirely solve this problem, as we have had to conclude after the certification of tropical wood.

Can first-generation biofuels contribute to reducing greenhouse gas emissions? In principle, yes. With smart production techniques they can reduce carbon dioxide emissions by around 60% compared to fossil fuels.

But some studies show that in the worst and inefficient case biofuels can even produce more Greenhouse Gasses (GHG) than conventional fuels, if one includes the emissions from agriculture, transport and processing involved in their production.

For the American administration, this is not a problem: their main concern is to diminish the US dependence on uncertain oil suppliers abroad. For Europe, the equation should be different. The question of GHG should always be addressed in an integral manner, taking into account the whole production chain.

Step by step: there is no second without first

An increasing number of voices are calling on the EU to focus its attention on 2nd generation biofuels, as they offer important advantages: a more favourable GHG balance compared to most current biofuels, at competitive prices, in particular if low-cost biomass is used. They are able to use a wider range of biomass feedstocks - thereby they do not compete that much with food production. They also offer a better fuel quality than first-generation biofuels.

Indeed, at the level of the European Union we should concentrate on facilitating steps towards second-generation biofuels. This will mean a gradual shift of the main source of raw materials for energy from arable land to other sources like forests, shrubs and peat bogs.

It is absolutely essential to realize that we can achieve these steps gradually only. The development of the whole chain of the first generation of biofuels is unavoidable and necessary for researchers, for the industry, for society, and for farmers, as a first phase of the 'European sustainable energy strategy'. It is vital to develop efficient bio-ethanol plants, based on sugar beets to start with, but they should be modular and flexible, so as to be able to incorporate novel techniques and different raw materials in a later stage. The Cosun project for an ethanol plant in Groningen is a good and promising example of such a modular and future-oriented approach.

Oil for the rich, instead of food for the poor?

The other question is the consequence of the run on biofuels for food prices. Biodiesel production has significantly increased the consumption of rapeseed within the EU, driving the price of edible oils to record levels within a few years. A recent OECD study suggests these price hikes may become permanent. The production and consumption of ethanol will increase the price of sugar and some other products.

This is also true for the rest of the world. If we are chopping down huge areas of rainforest in order to grow palm oil, this is a disaster for the world's biodiversity – on which we depend. Demand for agricultural and other commodity feedstocks for first-generation bioenergy production is already causing irreversable damage to environment. It is also driving up food prices. Mexicans are protesting against high corn prices – and they will be followed by many others.

The market responds in its own way to the high price of oil. Investors flock to alternative fuels, including investments in cellulosic ethanol research and development. Important parts of regions with warm climates are in fact perfect for shrubs that do not need much water, like *Jatropha cursas*, and these do not have to grow on arable land used for food production. Poor countries should therefore be encouraged to develop this kind of shrubs, instead of palm oil.

But that demands immediate transfer of available knowledge. We all know Wageningen is very active in this area of cooperation with poor countries, but Europe could do more.

Biogas installations need changes in legislation, and legislation should facilitate innovation

Roughly, 500 Bio-gas installations of around 2 Megawatt each spare one new 1000 Megawatt nuclear or coal energy plant. They deserve to be developed throughout Europe, producing heat for households as well as electricity, and creating far more jobs than any nuclear plant, on the countryside as well as in industry. But this will require active policy.

First, planning in rural development will have to incorporate bio-energy and biogas installations.

Second, a rapid reform of legislation on animal feed content is also needed – as heavy metals like copper can no longer be allowed. Otherwise, rest products of biogas installations cannot be put on farmland, and replace fertilizers – and that would be such an interesting and cost-efficient goal to achieve. One has to get rid of the residues, and why not by using them. This will, by the way, probably also need a slight reform of manure legislation within criteria of sustainability – I am currently working on it in the European parliament.

These developments of biogas installations offer an important new source of income to farmers.

Governments can limit themselves to the role of facilitators. Subsidies are not needed, as bio-energy will largely finance itself – perhaps, some financing schemes are needed for those who do not get loans easily. The recent intervention by Eurocommissioner Marian Fischer-Boel, to raise the limit of state aid to farmers from 3000 to 200.000 euros was a welcome step, too.
Legislation should set ambitious goals and thereby create new markets for sustainable energy, for instance by imposing innovation on construction building. New housing lots should no longer have to rely on fossil fuels for their heating. Old houses should gradually change their heating systems to a sustainable source. New industrial building projects could also rely on heating from greenhouses. Near Schiphol airport, an immense greenhouse will provide the heating to an equally immense new logistics facilities for the goods that arrive at the airport and have to be shipped throughout Europe.

Develop new solar panels within ten years

The European Union should without any doubt support the biofuels development but in an open-minded way for all the novel and reliable technologies, in respect of the EU sustainable development policies, and without limited focus on the common agricultural policy which must not lead the strategic choices concerning biofuels. It should be the other way round. The need for sustainable energy will impose further changes in the Common Agricultural Policy, and will bring the next reform nearby, as farmers find new markets. They will, one day, be proud to farm without income subsidies – honestly paid for the many green and blue services they deliver to society.

To be freed from the risks linked to the oil dependency, some Member States are launching national measures aimed at developing renewable energy use for heating, for electricity production and biofuels for transports. These initiatives must be greeted. Nevertheless, we observe the quick development of non concerted and unbalanced measures, which lead to competition between the different channels of renewable energies, not on a relevant environmental efficiency standard but on rentability standards influenced by subsidies. Thus, for example the production of biogas is often constrained at an economic level, because there are no subsidies for it in many Members States, whereas electricity production is strongly supported. This situation can lead to the frustration of the biogas market (at least as a fuel for vehicles).

And after all, biogas is the cleanest and most efficient of all biofuels, second-generation biofuels included and when produced from municipal or industrial waste, it can even be carbon negative.

But even more promising is the recent development of an entirely different type of technology, still based on solar energy. The next generation of flexible solar panels – such as the Helianthos solar cells - will be cheap and energy-efficient, and will change our lives drastically. This deserves massive public investments in research and development. Europe should invest in solar panels in the next ten years – and the 7th Framework Program has the necessary budget. This will undoubtedly bring the expected result. The European Commission and the European parliament are setting ambitious goals for sustainable energy. Some member states are still hesitating – in order to protect their car industry, for instance. This makes no sense. The European Union is a perfect tool for ambitious programs combating climate change and making the right choices for a sustainable society. It just demands willpower, and persuasion by committed European citizens.

Conventional and advanced technologies for the conversion of biomass into secondary energy carriers and/or chemicals

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On January 10, 2007 the EU has presented its new energy-related policy goals in the so called ‘Energy Package’. Within this package, 20% greenhouse gas reduction in 2020 compared to 1990 is defined as main goal to be met by the member states. Biomass is expected to play a major role, being part of the subgoals i) 20% renewable energy in 2020 and ii) 10% biofuels for transport in 2020. On the longer-term an even larger contribution is expected to come from biomass. The EU Technology Platform Biofuels for example has developed a Vision that in 2030 25% of the transportation fuels used have to be bio-based.

Introduction

In the Netherlands the Platform Bio-based Raw materials has developed a Vision that 30% of the fossil-based raw materials and fuels have to be substituted by biomass-derived raw materials and fuels in 2030. Assuming a total primary energy input in the Dutch economy in 2030 of about 3000 PJ_{th} (scenario based on strong energy savings), 30% substitution means about 850 PJ_{th} avoided fossil fuel input.
The following sectorial bio-based substitution percentages are foreseen: transport sector 60% (324 PJ_{th}), industry (chemicals/materials): 25% (140 PJ_{th}), power: 25% (203 PJ_{th}), and heat: 17% (185 PJ_{th}). These substitution percentages, however, only seem to be realistic in case a) the Dutch harbours become the Bioports for Europe, importing biomass, bio-based intermediates and/or end-products for both domestic use and export to the European neighbour countries (biofuels for transport), b) a significant RD&D programme is set-up and implemented (chemicals), c) coal-fired power production capacity is replaced by biomass-fired capacity (power), and d) biomass-derived Substitute Natural Gas (SNG) production capacity is implemented in the market (heat).

850 PJ_{th} avoided use of fossil fuels and raw materials corresponds to a raw biomass demand of about 1200 PJ_{th} or about 80 million tonnes dry basis (d.b.). This is about twice the gross national biomass production (i.e. [import – export] + production) in 2000: (742 PJ_{th} or 42.3 million tonnes dry basis), of which only a small part was available for non-food applications. Projections concerning the domestic biomass availability for non-food applications in 2030 show the following results: 6 Mt d.b. primary by-products (100 PJ_{th}), 12 Mt d.b. secondary by-products (200 PJ_{th}), and 0 – 9 Mt d.b. energy crops (0 – 150 PJ_{th}). In 2030 a total domestic biomass availability of about 18 – 27 Mt d.b. or 300 – 450 PJ_{th} is expected. In spite of the fact that the cultivation of aquatic biomass (i.e. micro algae and/or macro algae / sea weeds) potentially could significantly increase the domestic availability of biomass, the larger part of the biomass request in 2030 has to be met by the import of raw materials, biomass-derived intermediates and/or final products from in and outside the EU.

Current use of biomass within the Dutch (energy) infrastructure

In the current Dutch energy infrastructure biomass is mainly used for direct and indirect cofiring in conventional coal-fired power plants, and combustion in domestic waste combustion facilities (‘AVI’s’). The total biomass contribution in 2005 amounted to about 60 PJ_{th} avoided fossil fuel use (about 2% of the total primary energy consumption) [Statusdocument Bioenergie, 2005, SenterNovem]. The maximally achievable biomass-based contribution to the Dutch energy infrastructure in 2010 is calculated as about 120 PJ_{th} avoided fossil fuel use or about 3-4% of the total primary energy consumption [Ecofys, 2004]. The main contributions in 2010 are expected to come from direct/indirect cofiring (47%), domestic waste combustion facilities (15%), landfill gas (1%), CHP production by digestion (4%), CHP production by combustion/gasification (14%) and biofuels for transport (19%).

Technology and product transition pathways (examples)

To meet the future market demand for bio-based products it is expected that both conventional and advanced conversion technologies will be applied. For the substitution of conventional diesel, for example, both conventional biodiesel, next generation biodiesel, Fisch-Tropsch diesel (Figure 1) will be used and even bioethanol and biobutanol may be used. The provisioned substitution pathways of gasoline are shown in Figure 2. At what time and to which extent the different bio-based alternatives will be implemented into the market is still unsure, and mainly determined by the industrial stakeholders concerned.

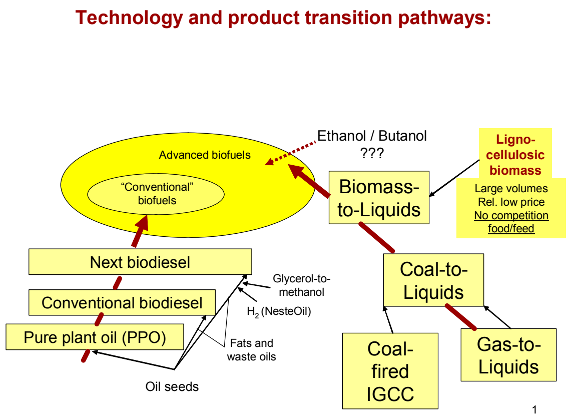

Figure 1. *Fossil diesel substitution (example).*

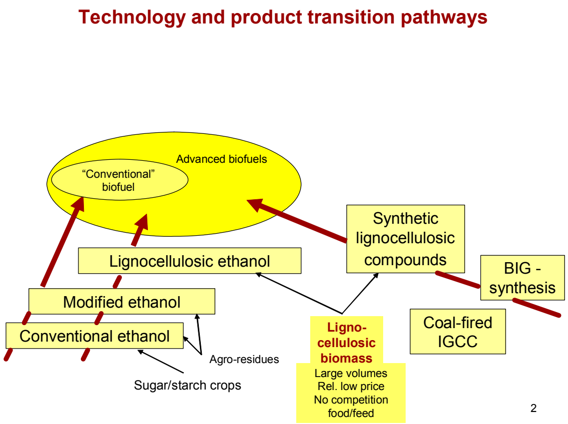

Figure 2. *Fossil petrol substitution (example).*

Biorefinery

Biorefineries (Figure 3), co-producing a portfolio of chemicals, materials, transportation fuels, gaseous energy carriers (SNG/H_2), power and/or heat from a variety of biomass resources (agroresidues, arable crops, marine crops, …), in high-efficient integrated processes, with minimal negative environmental emissions, are generally believed to be the optimal solution to convert the relatively scarce raw materials to the variety of products required on the longer-term. The scientific biorefinery network working towards this goal in the Netherlands is shown in Figure 4.

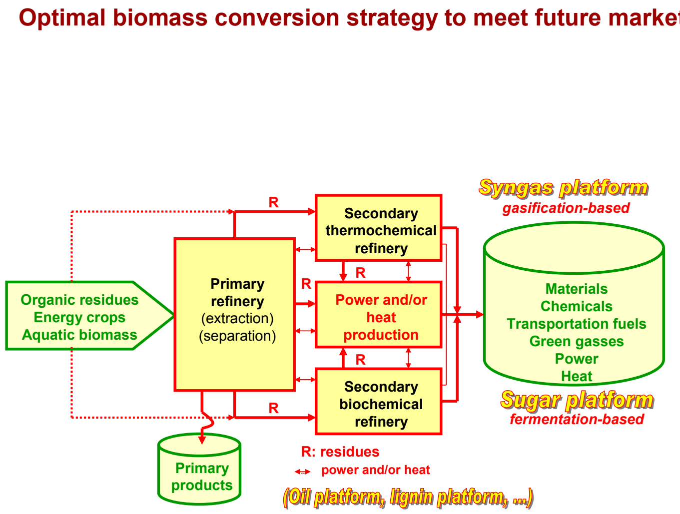

Figure 3. *Schematic representation of biorefinery. A biorefinery is an integrated facility for efficient co-production of materials, chemicals, transportation fuels, gaseous energy carriers, power and/or heat from biomass (analogous to today's petroleum refineries)*

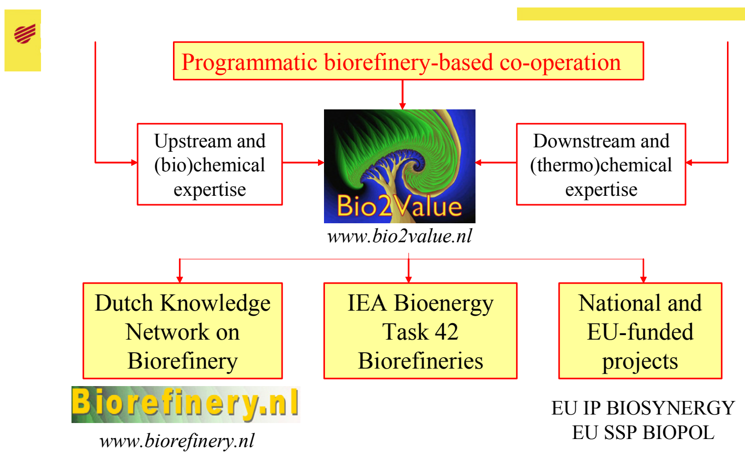

Figure 4. *Programmatic biorefinery based co-operation in the Netherlands.*

Conclusions

1. It is expected that biomass and biomass-derived intermediates will play a dominating role in the transition to – and the realisation of – a more sustainable Dutch economy. Biomass will be applied in almost all future market sectors.
2. Because of contractibility and financial economic issues it is expected that biomass will be applied on the longer-term preferably for: food, feed, materials, chemicals, transportation fuels, gaseous energy carriers, power and finally heat.
3. The domestic available biomass in the Netherlands – i.e. agricultural residues, wood residues, forest residues, and specific grown arable crops – will not be enough to meet the longer term market demand. Synergistic co-operations to make full use of this domestic potential should, however, be supported, especially for the short and midterm. Aquatic biomass potentially could contribute significantly to the future domestic biomass demand.
4. Biorefinery processes are expected to become major players in the future Bio-based Economy (high-efficiency, low environmental impact, broad product portfolio).

Biomass resource potentials; where are they?

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Background

Global energy demand is growing rapidly. Total current primary energy use, the sum of fossil fuels, nuclear and renewables amounts 440 EJ. About 80% of this demand is covered by fossil fuels. Demand is expected to at least double and perhaps triple during this century. At the same time, concentrations of greenhouse gases in the atmosphere are rising rapidly, with fossil-fuel-bound CO_2 emissions being the most important contributor. In order to stabilize related global warming and climate change impacts, GHG emissions must be reduced drastically to about half the global emission levels of 1990. In addition, security of energy supply is a global issue. Supplies of conventional oil and gas reserves are increasingly concentrated in politically unstable regions and increasing the diversity in energy supplies is important for many nations to secure a reliable and constant supply of energy. In this context, biomass use for energy can play a pivotal role. Biomass, when produced in a sustainable manner, can drastically reduce GHG emissions compared to fossil fuels. Most countries have various biomass resources available or could develop a resource potential, making biomass a more evenly spread energy supply option across the globe. It is also a versatile energy source, that can be used for producing power, heat, liquid and gaseous fuels and also serve as, carbon neutral, feedstock for materials and chemical industry.

Current use of biomass

Current energy supplies in the world are dominated by fossil fuels (some 80% of the total use of about 440 EJ per year). Nevertheless, about 10-15% (or 45 $\pm$ 10 EJ) of the energy demand is covered by biomass resources, making biomass by far the most important renewable energy source used to date. On average, in the industrialized countries, biomass contributes some 9-13% to the total energy supplies, but in developing countries the proportion is as high as 20 to 35%. In quite a number of countries biomass covers even over 50 to 90% of the total energy demand. A considerable part of this biomass use is, however, non-commercial and used for cooking and space heating, generally by the poorer part of the population. Part of this use is commercial though, i.e. the household fuel wood in industrialized countries and charcoal and firewood in developing countries. An estimated 9 $\pm$ 6 EJ is covered by this category.

Growth of modern bio-energy

Modern bio-energy (commercial energy production from biomass for industry, power generation or transport fuels) makes a lower but still very significant contribution (some 7 EJ/yr in 2000) to the energy requirement and this share is growing. Figure 1. shows for instance the absolute increase of bio-ethanol flows in four years time, in 2004 globally 32 billion liters were produced of which 3 billion liters were traded. Biomass combustion is responsible for over 90% of the current production of secondary energy carriers from biomass. Combustion for domestic use (heating, cooking), waste incineration, use of process residues in industries and state-of-art furnace and boiler designs for efficient power generation all play their role in specific contexts and markets. Total production of biofuels (mainly ethanol produced from sugar cane and surpluses of corn and cereals and to a far lesser extent bio-diesel from oil-seed crops) currently represent a modest 1.5 EJ (about 1.5%) of transport fuel use worldwide. It is especially in this field that global interest is growing, in Europe, Brazil, North Amercia and Asia (most notably Japan, China and India). [Turkenburg *et al.*, 2000; IEA/WEO]. Global ethanol production has more than doubled since 2000, while production of biodiesel, starting from a much smaller base, has expanded nearly threefold. In contrast, oil production has increased by only 7% since 2000.

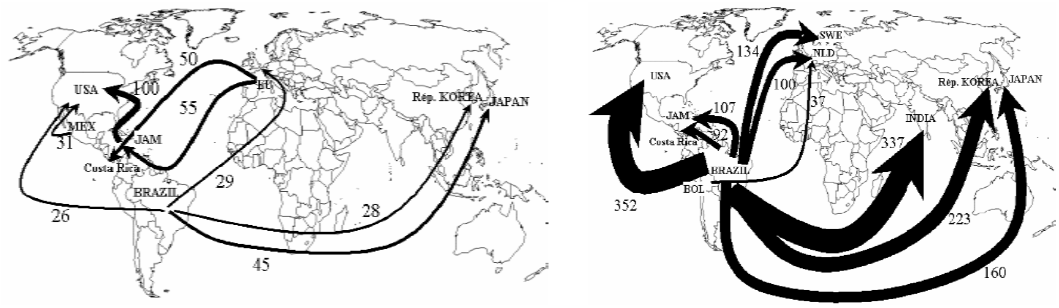

Figure 1. Bioethanol flows (kton) in 2000 (left) and 2004 (right) Zarrilli, 2006.

Market developments

Especially due to high prices for fossil fuels (particularly petrol but also natural gas and to a lesser extent coal) the competition for biomass use has improved considerably over time. In addition, the development of CO_2 markets (emission trading), as well as ongoing learning and subsequent cost reductions for biomass and bioenergy systems, have strengthened the economic drivers for increasing biomass use, production and trade. Biomass and bioenergy is nowadays a key option in energy policies to secure supply, to develop an alternative source for mineral oil and to reduce carbon emissions. Targets and expectations for bioenergy in many national policies and long term energy scenario's are ambitious, reaching 20-30% of total energy demand in various countries, as well as worldwide

Sufficient biomass resources (e.g. through energy crops) and a well functioning biomass market that can assure reliable, sustainable and lasting biomass supplies, is a crucial precondition to realize such ambitions. To date, various countries have considerable experience with building biomass markets and linking available resources with market demand. Examples are found a.o. in Brazil, Europe and Canada. Recently, international trade of biomass resources has become part of the portfolio of market parties and volumes traded worldwide increase at a very rapid pace with an estimated doubling of volumes in several markets over the past few years. The fact that those markets are growing, means that more and more resources are becoming available from regions were biomass use was low or absent so far, and risks for biomass users have reduced due to increased diversity and reliability of supplies. Biomass resource availability and their sustainable production are vital to the future possibilities for bio-energy though.

Biomass resource potentials

Various biomass resource categories can be considered: residues from forestry and agriculture, various organic waste streams and, most important, the possibilities for active biomass production on various land categories, including grass production on pasture land, wood plantations and sugar cane on arable land and low productivity forestation schemes for marginal and degraded lands.
Clearly, active biomass production requires land. The potential for energy crops therefore largely depends on land availability, considering that worldwide a growing demand for food has to be met, combined with nature protection, sustainable management of soils and water reserves and a variety of other sustainability criteria. Given that a major part of the future biomass resource availability for energy and materials depends on these (intertwined, uncertain and partially policy dependent) factors, it is not possible to present the future biomass potential in one simple figure. Table 1 (based on: [Berndes *et al.*, 2003], [Smeets *et al.*, 2006] and [Hoogwijk *et al.*, 2005]) provides a synthesis of a range of analyses that have assessed the longer term potential of biomass resource availability on a global scale. Issues that require further research and especially more regional demonstrations and experience with biomass production are:

a. Competition for Water Resources
Although the analyses mentioned above generally exclude irrigation for biomass production, in some countries this could lead to further worsening of the already stressed water situation. But there are also countries where such

impacts are less likely to occur. More region specific knowledge is needed in order to asses the question to what extent competing demand for water resources is a constraint for biomass production.

b. Availability of Fertilizers and Pest Control

Better agricultural management and higher productivities imply availability of fertilisers and pest control methods. Their use needs to be within sound limits. Sound agricultural methods (agroforestry, precision farming, biological pest control, etc.) exist that can achieve major increases in productivity with neutral or even positive environmental impacts. Such practices must, however, be secured by sufficient knowledge, funds and human capacity.

c. Land-Use Planning Taking Biodiversity and Soil Quality Into Account

- Lower costs (< 2 €/GJ)
- Planted for 15-25 years
- Low(er) intensity
    - Can restore soil carbon and structure
    - Suited for marginal/degraded lands
    - Requires less inputs (well below key threshold values)
- Earlier development stage
    - Large scale and diverse experience needed
    - Learning curve to be exploited
- Wide portfolio of species
    - Possibilities for enhancing (bio-) diversity
    - Adaptable to local circumstances (water, indigenous species)
    - Potential for improvement

Figure 2. Perennial crops versus annual crops.

Further intensification of agriculture and large scale production of biomass energy crops may affect biodiversity, compared to current land-use. Biodiversity standards are to be interconnected with biomass production when changes in land-use are considered. Fact is that perennial crops (Figure 2.) - which are the preferred category of crops for energy production - have a
(much) better ecological profile than annual crops. Benefits with respect to biodiversity can be achieved when annual crops are displaced by perennials. However, insights in how biodiversity effects can be optimized (and improved compared to current land-use) when sound landscape planning is introduced are limited. Also here, more regional efforts, experience and specific solutions are needed.

Table 1. Overview of the global potential bio-energy supply on the long term for a number of categories and the main pre-conditions and assumptions that determine these potentials.

Biomass category	Main assumptions and remarks	Potential bio-energy supply up to 2050
Energy farming on current agricultural land	Potential land surplus: 0-4 Gha (higher average: 1-2 Gha). A large surplus requires structural adaptation of intensive agricultural production systems. When this is not feasible, the bio-energy potential could be reduced to zero as well On average higher yields are likely because of better soil quality: 8-12 dry ton/ha/yr is assumed. (*)	0 – 700 EJ (more average development: 100 – 300 EJ)
Biomass production on marginal lands	On a global scale a maximum land surface of 1.7 Gha could be involved. Low productivity of 2-5 dry ton/ha/yr. (*) The supply could be low or zero due to poor economics or competition with food production.	(0) 60 – 150 EJ
Residues from agriculture	Estimates from various studies. Potential depends on yield/product ratio's and the total agricultural land area as well as type of production system: Extensive production systems require re-use of residues for maintaining soil fertility. Intensive systems allow for higher utilization rates of residues.	Approx. 15 – 70 EJ
Forest residues	The (sustainable) energy potential of the world's forests is unclear. Part is natural forest (reserves). Range is based on literature data. Low value: figure for sustainable forest management. High value: technical potential. Figures include processing residues.	30 - 150 EJ
Dung	Use of dried dung. Low estimate based on global current use. High estimate: technical potential. Utilization (collection) on longer term is uncertain.	5 – 55 EJ
Organic wastes	Estimate on basis of literature values. Strongly dependent on economic development, consumption and the use of bio-materials. Figures include the organic fraction of MSW and waste wood. Higher values possible by more intensive use of bio-materials.	5 – 50 EJ
Total	Most pessimistic scenario: no land available for energy farming; only utilization of residues. Most optimistic scenario: intensive agriculture concentrated on the better quality soils. (between brackets: more average potential in a world aiming for large scale utilization of bio-energy).	40 – 1100 EJ (250 - 500 EJ)

(*) Heating value: 19 GJ/tonne dry matter.

d. The Use and Conversion of Pasture Land Connected to More Intensive Methods of Cattle Raising

A key land category in making more efficient use of land used for food production, is the worlds grasslands currently used for grazing. The analyses that were discussed here show that much land can be released when production of meat and dairy products is done in more intensive (partly land-less in closed stables) schemes. Grasslands could then be used for the production of energy grasses or partly converted to woodlands. The impacts of such changes should be closely evaluated.

e. Socio-Economic Impacts

Large scale production of modern biofuels, partly for the export market, could provide a major opportunity of many rural regions around the world to generate major economic activity, income and employment. Given the size of the global market for transport fuels, the benefits that can be achieved by reducing oil imports and possibly net exports of bio-energy are vast. Nevertheless, it is not a given that those benefits end up with the rural population and the farmers that need those benefits most.

f. Macro-Economic Impacts of Changes in Land-Use Patterns

Although the analyses discussed indicate that both worlds' food demand and additional biomass production *can* (under relevant pre-conditions) be achieved (Figure 3.), more intensive land-use and additional land-use for biomass production may lead to macro-economic effects on land and food prices. Although this is not necessarily a bad mechanism (it could be vital for farmers to enable investment in new production methods), the possible implications on macro-economic level are poorly understood. More analyses are needed that can highlight with what speed of implementation and change undesired economic effects can be avoided.

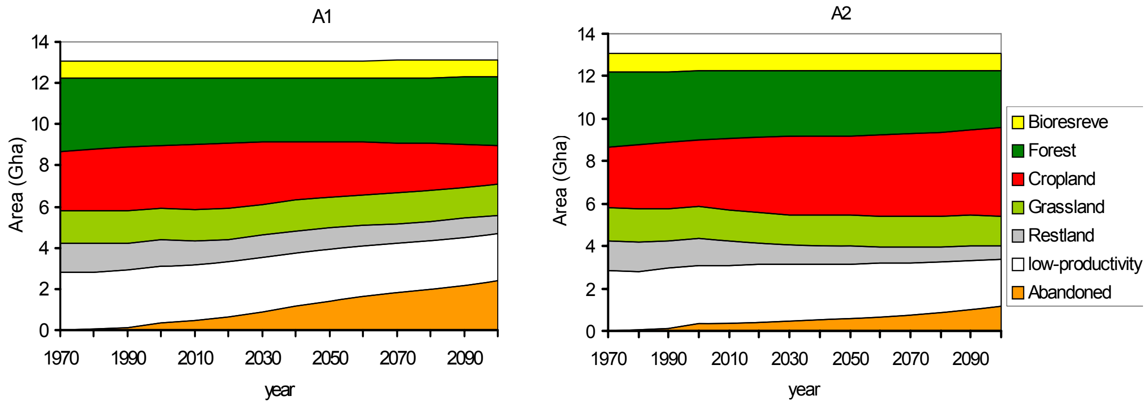

Figure 3. *Potential land-use pattern changes, A1: intensified land use, A2: current technology application. Hoogwijk, Faaij et al., 2006).*

Outlook

In theory, energy farming on current agricultural (arable and pasture) land could, with projected technological progress, contribute over 800 EJ, without jeopardizing the future world's food supply. Latin America, Sub-Saharan Africa, Eastern Europe and Oceania clearly are promising regions. These analyses also show that a significant part of the technical potential (around 200 EJ in 2050) for biomass production may be developed at low production costs in the range of 2 U$/GJ [Hoogwijk, 2004], [Rogner *et al.*, 2000] assuming this land is used for perennial crops. Another 100 EJ of biomass could be produced with lower productivity and higher costs at marginal and degraded lands. Regenerating such lands requires more upfront investment, but competition with other land-use is less of an issue and other benefits (such as soil restoration, improved retention functions) may be obtained, which could partly compensate biomass production costs.

Organic wastes and residues could possibly supply another 40-170 EJ, with uncertain contributions from forest residues and potentially a very significant role for organic waste, especially when bio-materials are used on a larger scale. This is a very important potential resource category once 2nd generation biofuel conversion technology becomes available. It should be noted though, that parts of this potential are used for production of power and heat as well. In total, the bio-energy potential could be over 400 EJ (per year) during this century. This is comparable to the total *current* global energy use of about 440 EJ.

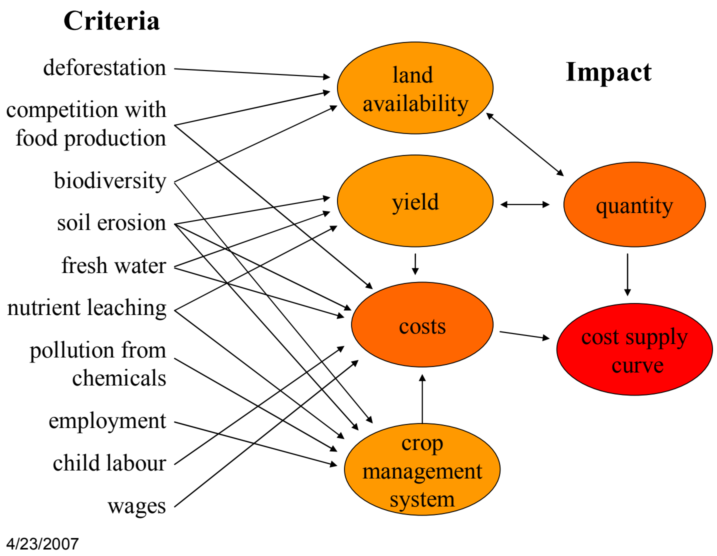

Figure 4. *Sustainability criteria made operational (Smeets et al., 2005).*

Key to the introduction of biomass production at the suggested orders of magnitude is the rationalization of agriculture, especially in developing countries. There is room for considerably higher land-use efficiencies that can more than compensate for the growing demand for food.
Major transitions are however required to exploit this bio-energy potential. Especially improving agricultural efficiency in developing countries (i.e. increasing crop yields per hectare) is a key factor. It is still uncertain to what extent and how fast such transitions can be realized in different regions. In developing countries (e.g. sub-Saharan Africa) very large improvements can be made in agricultural productivity given the current agricultural methods deployed (often subsistence farming), but better and more efficient agricultural methods will not be implemented without investments and proper capacity building and infrastructural improvements. Such schemes, in which the introduction of bio-energy can play a pivotal role, can create more income for rural regions by additional bio-energy production. Financial resources generated could then accelerate investments in conventional agriculture and infrastructure and also lead to improved management of agricultural land taking into account the implementation of sustainability criteria (Figure 4.).

Finally, technological developments (in conversion, as well as market development) as well as high prices for fossil fuels (most notably petrol) can dramatically improve competitiveness and efficiency of bio-energy. Increased competitiveness is logically a driver to develop the production potentials of bio-energy.

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Impact of an increased biomass use on agricultural prices, markets and food security

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Agricultural prices have always been affected by energy prices. Hitherto, this price link was limited to the impacts of energy prices on the prices of agricultural inputs, i.e. on fertilizer, pesticides, diesel, etc. Higher input prices often resulted in a rationalisation of production and thus lower output. This has changed. With rapidly rising energy prices and improved bioenergy conversion technologies, higher energy prices are also affecting agricultural *output* prices. As prices for fossil energy reach or exceed the energy equivalent of agricultural products, the energy market creates demand for agricultural products. Where demand from the energy sector is large/elastic and agricultural feedstocks are competitive in the energy market, a *floor price effect* for agricultural products results. The output price effect creates incentives to produce more rather than less.

How big is demand from the energy sector?

A crucial precondition for an effective floor price mechanism is that demand from the energy sector is sufficiently large. In theory, the volume of global demand for energy is indeed large compared with the energy that bioenergy production from agricultural crop cultivation can deliver. This means that demand for agricultural feedstocks should be elastic as long as biomass energy can be sold at prices that ensure coverage of total costs. In practice, the effectiveness of the mechanism strongly depends on the volumes of agricultural output/feedstocks that can be absorbed in the fuel market.

What crops are competitive at what energy price ...?

The point where total costs for biomass based energy production are covered by revenues from sales of bioenergy (ethanol, biodiesel, etc.) is referred to as the parity price of a given feedstock. This is the point, where the costs (feedstock, upstream and downstream transport, conversion, wages, capital) of producing a unit of the bioenergy (ethanol, biodiesel) are equal to the costs of producing the same energy unit from fossil energy (petrol, diesel). Differently put, this is the point where bioenergy producers break even on total costs. Figure 1 depicts parity prices for a selection of agricultural feedstocks, farming systems and fuels (ethanol, diesel, BTL). The blue diagonal reflects a parity price line for the conversion from crude oil to petrol which allows mapping feedstock parity prices for crude oil into feedstock parity prices for refined petrol.

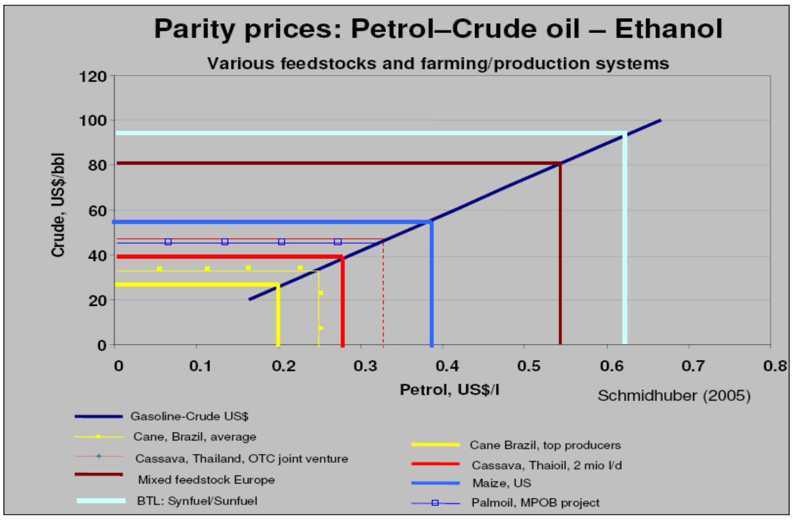

Figure 1. *Parity prices for a selection of agricultural feedstock.*

... and are there integrated bioenergy markets?

The only integrated biofuel market in practice is Brazil's cane-based ethanol market. In this ethanol/electricity co-generation system, sugar cane becomes a competitive energy provider at petrol prices of about US$ 35/barrel. As of this price level, Brazilian sugar millers can produce ethanol (cum electricity) without subsidies. This also means that as of this threshold, prices for sugar should move in sync with petrol prices. Figure 2 one corroborates this co-movement of sugar and oil prices above an oil price level of US$35/bbl.

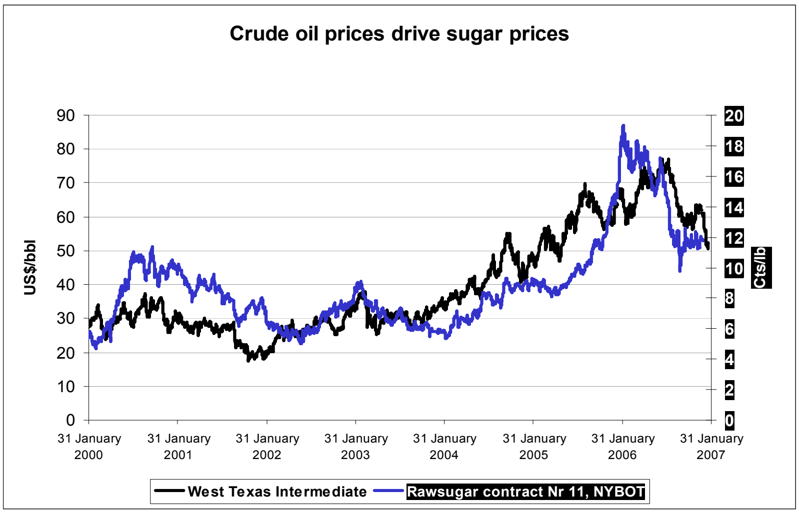

Figure 2. *Co-movement of oil and sugar.*

Fossil fuel prices also create a ceiling for agricultural prices

Energy prices cannot not only create a lower limit for agricultural prices, they will also eventually create an upper bound. Agricultural feedstocks are the most important cost component for most forms of bioenergy and price increases for agricultural feedstocks can therefore crucially circumscribe the economic viability of bioenergy. Barring the effects of major subsidies or other policy interventions, agricultural prices should therefore not rise faster than energy prices in the long-run. If they do, and not withstanding that they do so in the short run, agricultural feedstocks prices themselves out of the energy market. Floor and ceiling prices together can thus create a price corridor for agricultural products, in which price fluctuations are (co-)determined by their energy equivalents and the current energy price. Figure 3 shows the ceiling price that can be paid by a cassava based ethanol plant in Thailand. If cassava prices move e.g. above 1200 baht/t as they did in the late 1990s, only very high oil prices of US$70/bbl and above, would keep cassava in the ethanol market. If cassava prices rise above this level, the feedstock loses its competitiveness for the bioenergy market, demand for it will fall or cease altogether and prices will decline again. Figure 4 illustrates how additional payments/benefits (clean development mechanism: CDM) can alter the parity price levels and affect the ceiling price effect.

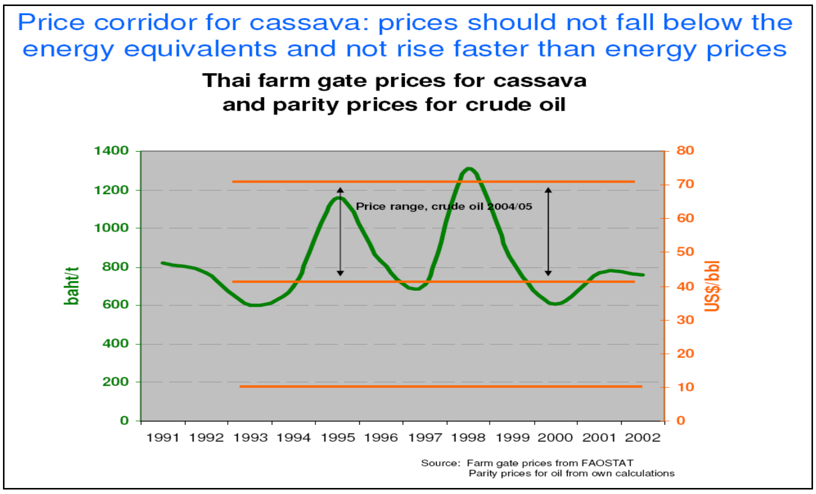

Figure 3. Ceiling price that can be paid by a cassava based ethanol plant in Thailand (Schmidhuber, 2006).

Differential price impacts across agricultural markets

The co-movement of prices, however, is not a universal feature across all agricultural markets. In general, prices for energy-rich crops (sugar, starch-rich crops or woody biomass) stand to benefit from the added energy demand, while those for protein-rich commodities and those for by-products of the bioenergy conversion process are likely to decline. Table 1 summarises the effects that the use of various bioenergy scenarios can have on energy and protein prices.

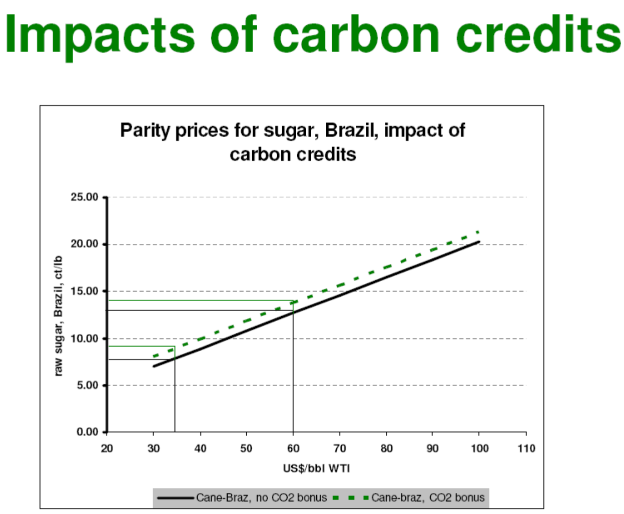

Figure 4. Effect of additional payments /benefits (CDM) on parity levels and ceiling price effect.

Table 1. Effect of bioenergy scenarios on prices of energy and protein.

	An additional 10 million tonnes of ...				
	Sugar	Maize	Sugar and Maize	Soybeans and Maize	Sugar, Maize and Soybeans
Corresponding energy [biofuels]	0.195 EJ	0.087 EJ	0.282 EJ	0.167 EJ	0.349 EJ
Commodity	... used for biofuels would change international prices (percent) in the long-run by :				
Sugar	+9.8	+1.1	+11.3	+2.3	+13.8
Maize	+0.4	+2.8	+3.4	+4.0	+4.2
Vegetable oils	+0.3	+0.2	+0.2	+7.6	+7.8
Protein	+0.4	-1.2	-1.2	-8.1	-7.6
Wheat	+0.4	+0.6	+0.9	+1.8	+2.0
Rice	+0.5	+1.0	+1.2	+1.1	+1.4
Beef	+0.0	+0.2	+0.2	+0.4	+0.4
Poultry	+0.0	-0.4	-0.4	-2.1	-2.0

Source: @2030 simulation results

Impacts on food security

Food security comprises four dimensions of food supplies: *availability*, *stability, access and utilization.* (Figure 5.).

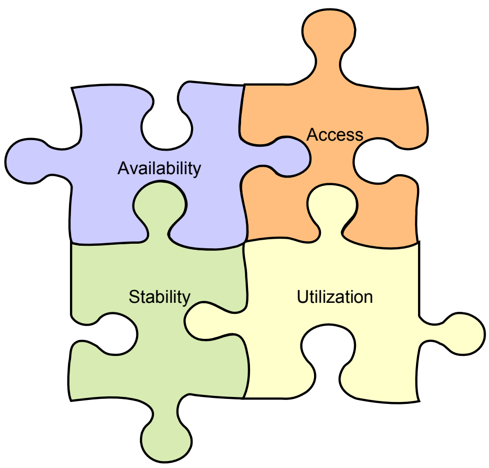

Figure 5. Bioenergy affects all four dimensions of food security.

Access to food

The key factors that affect changes in the access to food are real incomes and real prices for food. A greater role of bioenergy could affect both. Rising demand for bioenergy is likely to raise food prices; but growing demand for bioenergy feedstocks should also raise incomes in agriculture and rural areas, particularly in developing countries. The effects on prices and incomes will be discussed separately.

Price effect:

Increased bioenergy use should result in higher prices; crucial for food security is to understand that the ceiling price effect will ***not*** allow food prices to rise faster than energy prices. This means that neo-Malthusian scenarios would only be warranted if energy prices were to continue to rise and remain at high levels.

Income effects:

- Bioenergy production should boost overall revenues in agriculture through higher prices and increased volume of products that farmers can sell on the markets (straw, crop residues, etc.). Higher farm incomes typically have positive knock-on effects on rural areas and can result in more jobs and higher rural wages. Higher wages in rural areas and more employment should increased overall rural incomes (trickle down effect). The know-on effects can be particularly positive where bioenergy is labour-intensive. Conversely, where bioenergy is capital-intensive and labour-saving, impacts on incomes and thus access to food could be small or outright negative. With 75% of the poor living in rural area, higher rural incomes are particularly important to improve food security.
- While rural areas stand to benefit, urban households will face higher prices for food. Important here is to recall that food prices and energy prices rise in tandem and that the strength of the link between the two increases with rising energy prices. For net buyers of food and energy, this would be particularly negative.
- The co-movement of food and energy prices and the growing link of them with higher energy prices can not only create differential food security impacts with a country, but also across countries. It will hit those countries particularly hard that are dependent on both, food and energy imports.

Food availability

- Food availability is the net effect of changes in production, imports, exports and stocks.
- Food production is likely to decline as competition with energy crops rises; the corollary is that exports will fall.
- Imports are likely to rise, but the extent depends on the real income (magnitude and distribution of income strata) and real price effects as well as the responsiveness (elasticity) of demand.
- The extent in change of food availability also depends on the type of feedstock. Where bioenergy is waste/ residue/wood based, impacts on food availability are likely to be small.
- Changes in stocks are irrelevant for food supplies in the long-run.

Impacts on the stability of food supplies

- A priori, a rising non-food demand should reduce the size of the food market and make this smaller market more susceptible to exogenous shocks. In addition, demand for energy can be very inelastic in the short-run, particularly in rich industrial countries. This could mean that food consumers in poor countries are being 'priced-out' of the food market by energy consumers in rich countries.
- The magnitude of possible short-term price peaks will depend on the share of variable costs in total costs. Where this share is high/low, short term fluctuations are likely to be small/high.
- The magnitude of possible short-term price peaks will also depend on the extent of short-term substitutability in using feedstocks for food and non-food uses. If substitutability is high, this would enlarge the overall market volumes and make prices c.p. less variable. Brazil's sugar-based ethanol production is a case for high substitutability and an enlarged market volume.

Impacts on food utilization

a. Food utilization effects will be determined by real income effects in the long-run and should thus in tandem with access to food.

Conclusions, Outlook

a. Potential: differentiate between theoretical, technical and economic potential
    - Energy markets are 'large' compared with agricultural markets; create (perfectly) elastic demand for competitive agricultural produce.
    - Energy markets *drive* agricultural markets but not vice versa.

b. Price effects

- Rising fossil fuel prices have made a number of agricultural feedstocks economically viable sources of energy; demand from the energy sector has created a *floor price* for agricultural produce; bioenergy demand as a new intervention system.
- The price links between agriculture and energy markets rises with rising energy prices, as more feedstocks become competitive energy sources.
- However, agricultural prices will not rise faster than energy prices. *Ceiling price* effect.
- Not all commodities are affected in the same way and to the same extent:
  - Protein/energy differential
  - Differences for the same feedstock across countries (sugar from Brazil to Japan)
  - Differences for the same country across feedstocks (Thailand cassava vs. sugar vs. palm oil)
- Paradigm shift possible with an end to falling real prices, but neo-Malthusian scenarios are unwarranted.

c. Impacts on food security

- Winners and losers depending on the trade balance and net effects on energy and food prices; lose-lose situation for food and energy importers, impacts rise more than linearly with rising energy prices.
- Food availability likely to decline, access to food to improve; rural-urban shift in food security.
- Improvements depend on land ownership, institutional support, creation of rural employment, land and labour intensity of bioenergy use and technologies.
- Policy challenge: harness benefits for agriculture (renaissance) without harming food security.

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Environmental impacts of various options of biofuels for transportation

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The institute, IFEU, is an independent scientific research institute with currently about forty employees. It does research and consulting on environmental aspects of energy, including renewable energy, transport, waste management, life cycle analysis, environmental impact assessment, renewable resources and environmental education. The institute among others works for the World Bank, UNEP, EU, NGOs and private companies. Life cycle analysis of fossil fuel and biofuels (Figure 1) are part of the institute's activities

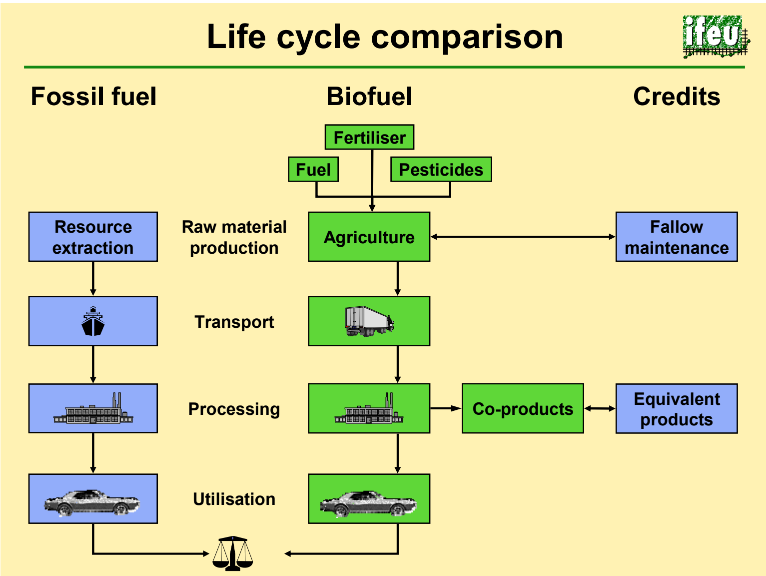

Figure 1. Life cycle comparison of fossil fuel and biofuel.

Comparing fuels

Early comprehensive life cycle assessments (LCAs) that compared biofuels with fossil fuels already appeared in the beginning of the nineties. Since then the public, scientific and political interest in biofuels has continuously grown and also the number of biofuels and assessed parameters has increased and the methodology for assessment has improved. The presentation gives an overview about the state of the art concerning the environmental implications associated with the production and use of biofuels for transportation in the context of LCA discussions. Figures 2 and 3 give examples of results comparing biofuels versus their fossil counterpart taking into account full life cycle comparisons.

Advantages and disadvantages

The results given are based on the results of life cycle comparisons. These comparisons are made on numerous assumptions. Although scientifically reliable results can be derived, these results and the resulting interpretations cannot be generalized because other assumptions, system boundaries etc. lead to different results. Therefore the results must be explicitly discussed considering the underlying assumptions. On the other hand, the evaluated results from the so called LCI and LCIA (life cycle inventory and impact assessment) are very reliable because data that are not reliable at all are excluded from the final assessment and other uncertain data have been examined by sensitivity analyses.

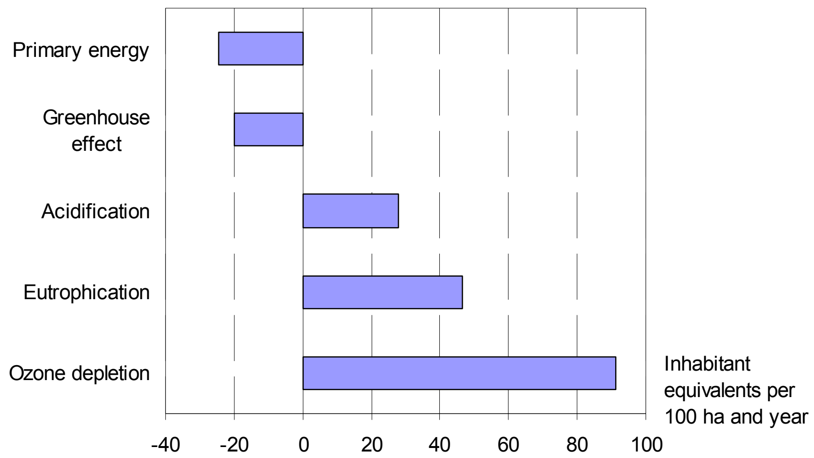

Figure 2. *Exemplification of environmental impacts of RME compared to conventional diesel fuel. (Source: Own calculations and updates based on [IFEU 2003])*

The main result is, that the energy and greenhouse gas balances of the biofuels considered are mostly favourable as compared to fossil fuels. Since most biofuels, however, also have disadvantage in other environmental impact categories (see figure for RME) an objective decision in favour of one or another fuel can only be undertaken if energy savings of fossil resources as well as greenhouse gases are given the highest ecological importance In this case almost all investigated biofuels compare favourably to their fossil alternatives.

The following additional conclusions can be made from the presented results:

- *High variability of the results.* An examination of various studies in energy and greenhouse gas balances of biofuels shows a high level of variability in the findings. A direct comparison between the different biofuel options is not always possible. The high level of variability arises from the favourable or unfavourable assumptions taken on the external factors, e.g. those related to the cultivation, the conversion or valuation of the co-products. In order to make direct comparison among different biofuel options, the system boundaries must be determined exactly.
- *A ranking of biofuels can be undertaken for some examples:*
    - Regarding the area-related consideration for biofuels from agriculture, ETBE shows advantages compared to all other biofuels.
    - Bioethanol scores better or worse in dependency on resource basis than biodiesel and vegetable oil.
    - Biodiesel shows advantages compared to vegetable oil, when the same system boundaries are assumed.
    - Biodiesel from palm oil shows a huge bandwidth and can even lead to disadvantages compared to fossil fuel.
    - BTL shows higher advantages - again: if looked at area related - compared to biodiesel and to ethanol, if ethanol is produced with conventional technologies from wheat, maize or potato. However, ethanol shows advantageous results compared to BTL if produced from sugar cane.
- *Geographically specific advantages.* The advantages of a few biofuels are not found in all geographical areas. For example, the bioethanol production from sugar-cane is only limited to the tropical climatic conditions while the cultivation of sugar-beets in the temperate regions is only found on particularly fertile soils.

Nevertheless, it has finally to be concluded, that there is a great potential for biofuels for transportation which should be developed in accordance with other goals towards a sustainable development including alternative use of biomass for electricity and heat generation, and for industry and chemistry.

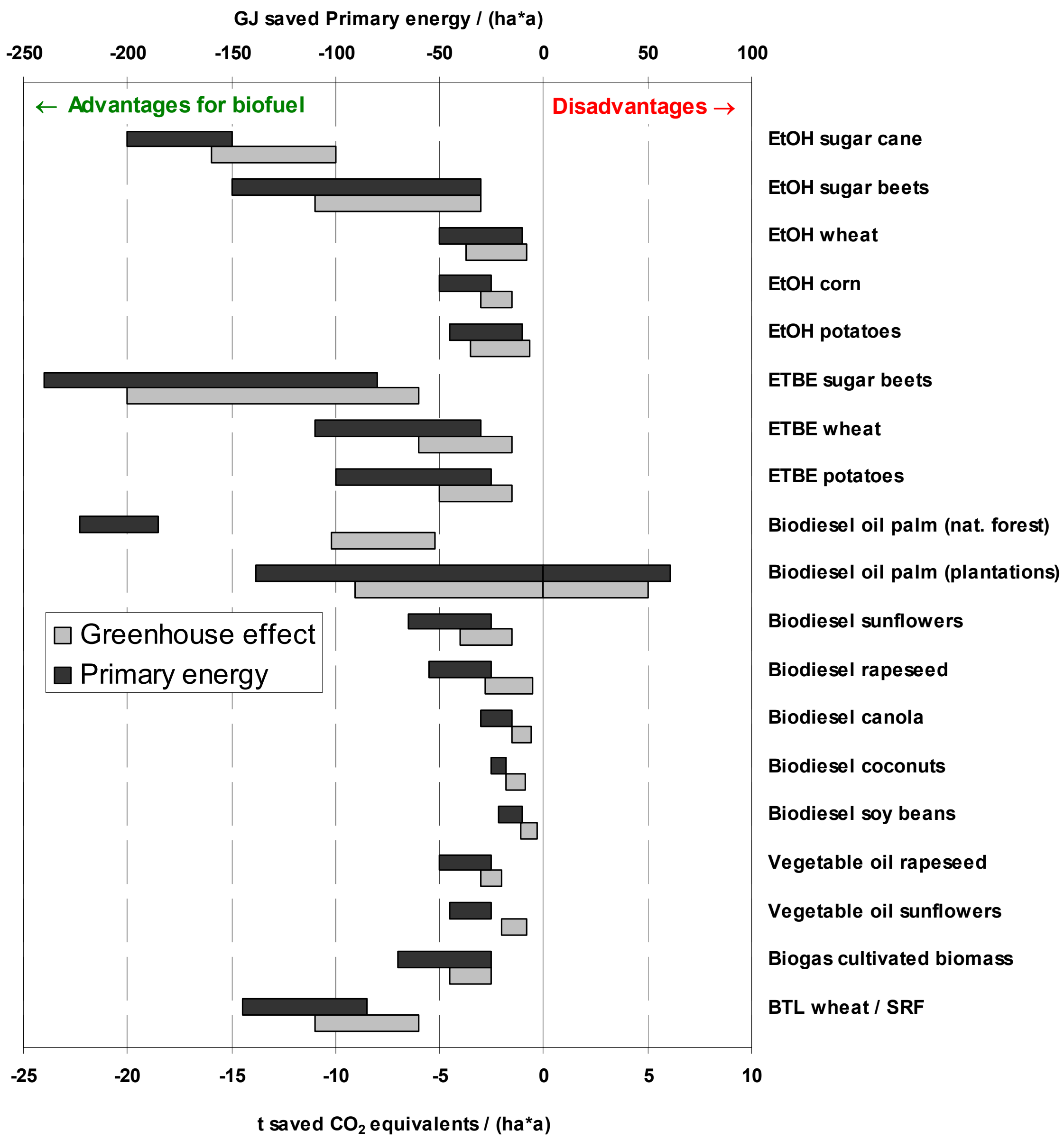

Figure 3. *Advantages and disadvantages for greenhouse gases and primary energy for biofuels from agriculture compared to their fossil counterpart.*
(Source: [IFEU 2004], [IFEU & WI 2006], [IFEU 2006])

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Land, water and nutrient requirements for sustainable biomass production

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Background

Biomass already contributes for 10% to the global energy demand, primarily as fuel-wood and charcoal in world's poorest nations. The demand for bio-energy has abruptly increased over the past years because of compulsory blending of transport fuel and subsidies for producing bio-energy. Recent analyses show substantial global production capacity of biomass for bio-energy. These analyses take land availability as the prime limiting factor, while little to no attention is paid to the requirement of other inputs for plant production such as water and nutrients. In this paper we argue why and how to incorporate these production factors in estimating production potential of biomass, present some preliminary results on input requirements, viz., land, water and nutrients, and reflect on ecological sustainability.

A production ecological approach

For calculating biomass production, we take production ecological principles as the fundamental basis. This approach follows eco-physiological pathways in plants and soils to calculate processes like transpiration and photosynthesis, as a function of weather, soil and crop characteristics. The level of crop production and input requirements are therefore interlinked and respond to environmental conditions. Also, associated environmental side-effects can simultaneously be calculated. A soil nitrogen balance, for instance, relates fertilizer application, uptake by plants and losses to the environment in a functional way and therefore allows analysis of the sustainability of biomass production in a wider context. Despite the strength of this eco-physiologically approach, it has been used little in global studies for estimating feedstock production potentials (see e.g. Wolf *et al.*, 2003).

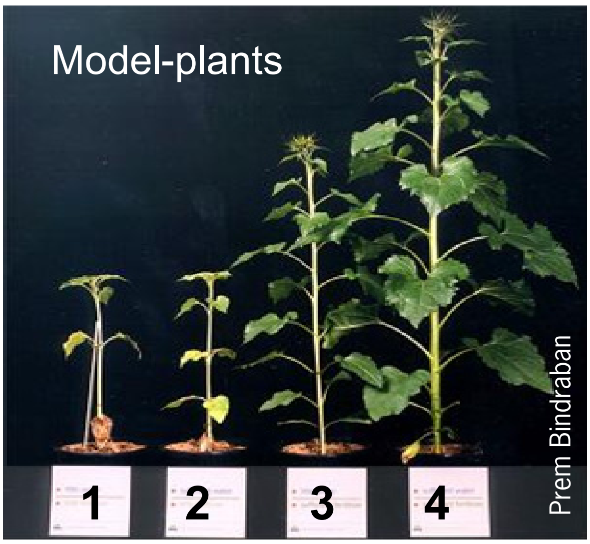

Figure 1. *The effect of water and nutrients on plant growth (Own experiments P.S. Bindraban).*

Pursuing a production ecological approach is essential because of the strong interactions between production factors. Plant 1 in Figure 1 is grown in a poor unfertilized soil with little water and remains small. Adding water would be expected to improve growth which is not the case as the poor soil fertility puts a stronger limit to its growth (plant 2). Adding fertilizers rather than water does enhance growth indicating that the strongest limiting production factor (i.e. nutrients) was eliminated (plant 3). At the same time this third plant shows that water is used more efficiently under these fertilized conditions as the same amount of water was applied as in plant 1. Adding both nutrients and water boosts growth to a level where neither of these factors is limiting but where other factors, like radiation, set a ceiling to growth (plant 4).

The difference in agricultural performance between Sub-Saharan Africa and Europe for instance can be explained by the same basic principle. In Sub-Saharan African hardly any fertilizer is applied and yields over the past 4 decades have remained stagnant. In Europe, yields have gone up, simply because of the use of inputs. Not only fertilizers, but also other inputs and overall management have improved in Europe (Figure 2).

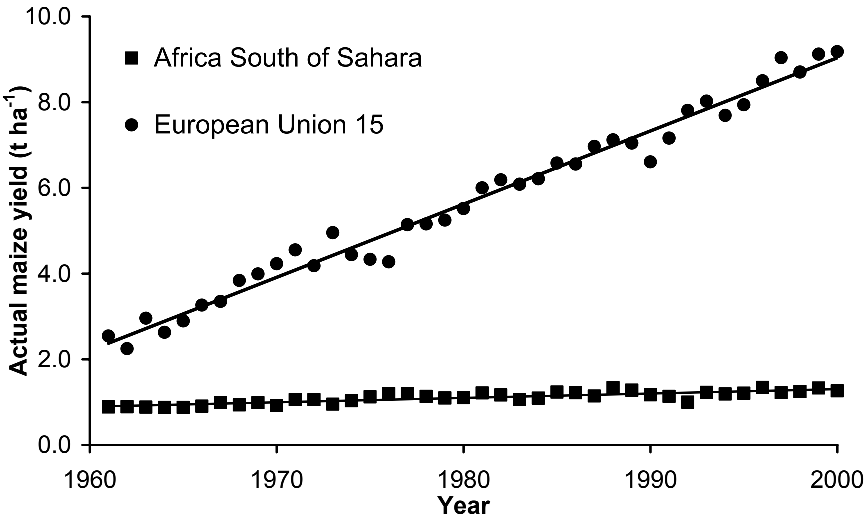

Figure 2. Development of maize yields in Europe and Africa (based on FAOstat, 2006).

Quantification – Crop scale

For illustration, the amount of nitrogen and water needed for the production of sugar beet at a sandy soil in the Netherlands is given in Figure 3 using the simulation model E-CROP. Biomass production is simulated as function of climate, soil and plant characteristics and depends on the level of applied agricultural inputs. Sustainable biomass production equals nil if no inputs are applied to the field

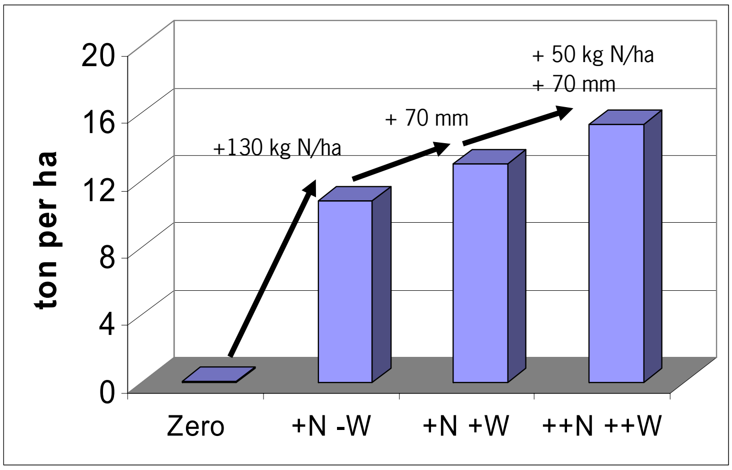

Figure 3. *The effect of water and nutrients on crop growth*

(Zero). Nutrient application increases the amount of biomass produced up to a level where water availability limits growth (+N-W). Here rainfall is the only source for water (410 mm during the growing period). Adding (irrigation) water further increases production (+N+W). Finally, more nutrients and irrigation pushes production up to potential levels (++N++W), i.e. a level that is determined by weather and plant genetic characteristics.

E-CROP further calculates net energy yield and net reduction in greenhouse gas (GHG) emission of different bio-energy production chains. All steps in a chain from seeding to end-use of bio-energy are evaluated in terms of energy and GHG emission. Net balances are calculated and expressed as amount of fossil energy replaced and amount of GHG emission avoided per hectare, but can also be calculated relative to other inputs such as per liter water or per kg nitrogen applied. E-CROP allows a consistent evaluation of various options of bio-energy chains based on different crops (Conijn *et al.*).

Quantification – Continental/global

A simulation model based on the production ecological principles was applied in a study to estimate the global production potential of food, including feed (WRR, 1995). Modified versions have been used e.g. for defining indicators for the productivity of land of the African continent as the approach integrates soil characteristics with plant traits and local weather conditions (Bindraban *et al.*, 1999; 2000). The agricultural production potential for the African continent is large if we take land availability, solar radiation and temperature as the only driving factors, but declines dramatically when water availability and native soil fertility is considered (Figure 4.)

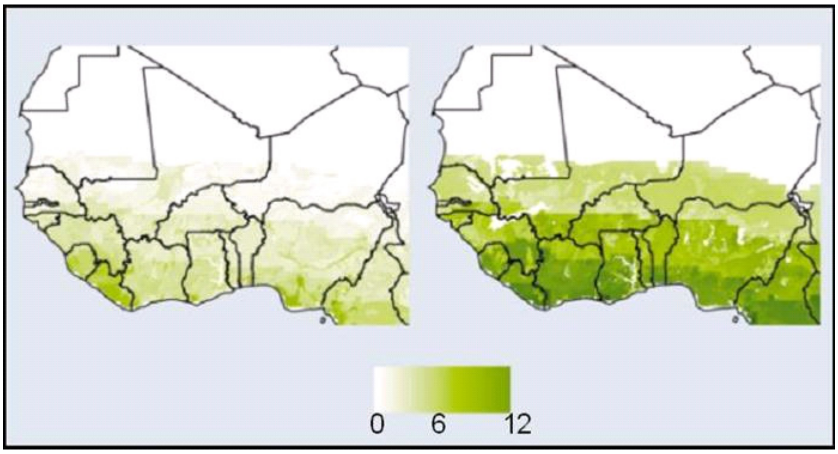

Figure 4. *Yield (in ton grain equivalents per hectare) under natural soil fertility (left) and under rainfed conditions with adequate fertilization (right) in West Africa.*

The global production potential of biomass for bio-energy (Table 1) was estimated by Wolf and colleagues (2003) based on the study of the WRR (1995). These estimates do account for ecological production factors, but the associated water or nutrient requirements could not be estimated accurately nor geographically specified by Wolf, because their estimates were derived from aggregated data of the WRR study. For illustration only, we estimated nitrogen and phosphorus requirements associated with these production potentials. The land area remaining for production of biomass for energy depends on the global population, the diet they consume and the agricultural production system that is used. The amount of energy that could be produced globally depends on these scenarios and on the conversion efficiencies applied. Allocating all nitrogen and phosphorus fertilizers currently being used in agriculture would allow a net energy production equivalent to 45-70 EJ. This range rather than a fixed value results from a number of uncertainties, such as the recovery of nutrient input in harvested biomass.

Table 1. *Estimated global energy production potential and associated nutrient requirement[1] (based on Wolf et al., 2003).*

	Agricultural production[2]	Land use	Biomass	Gross energy[5]	Net energy[6]	Nitrogen[7]	Phosphorus[8]
			Billion ton y^{-1}	EJ	EJ	Million ton N	Million ton P_2O_5
Vegetarian diet	Low input	Agric. Land[3]	10.8	194	77	81	18
		Total land[4]	22.1	397	159	166	37
	High input	Agric. land	29.1	523	209	218	49
		Total land	49.8	896	358	373	84
Moderate diet	Low input	Agric. land	3.3	59	24	25	6
		Total land	14.3	257	103	107	24
	High input	Agric. land	23.2	418	167	174	39
		Total land	43.9	790	316	329	74
Affluent diet	Low input	Agric. land	0	0.0	0	0	0
		Total land	1.5	27	11	11	2
	High input	Agric. land	13.5	243	97	101	23
		Total land	34.1	614	245	256	58
Current chemical fertilizer use (2003)						85	35

[1] *Medium population growth (9.4 billion people in 2050).*
[2] *Without (low) and with (high) input of agro-chemicals.*
[3] *Current agricultural land (4.9 billion hectare).*
[4] *Current total suitable land, including cleared forest land (7.8 billion hectare).*
[5] *Biomass * 18 MJ/kg.*
[6] *Assuming 40% conversion efficiency.*
[7] *Nitrogen content in biomass (assuming 0.75% N).*
[8] *Phosphate content in biomass (assuming N:P = 10:1).*

Availability of inputs

The availability of nitrogen fertilizer might not become a major problem as the energy cost of producing nitrogen fertilizers approximates 2% of the energy content in biomass and ample source material for N-fertilizer production is available. The increased level of (re-)active nitrogen might however pose problems in the long term (e.g. on ozone depletion). Phosphorus will pose a major problem, if not recycled efficiently. Current available sources are estimated to deplete in less than 150 years. As fertilization of crops for energy production has not been considered in these estimates, an accelerated depletion can be expected of this finite resource. Depletion of organic matter from soils leads to decreased productivity through land degradation and soil erosion. For maintaining sufficient soil organic matter not all produced biomass should be removed for conversion into bio-energy. The current looming water crisis is likely to be exacerbated by the increased competition resulting from biomass production for energy. Water reservoirs, such as deep water aquifers are being depleted already, water quality is deteriorating because of poor handling, and the variability of precipitation is increasing with more frequent floods and droughts. With adequate handling, efficient utilization following the production ecological approach (third plant in first picture), part of the current water shortage for food could be resolved. However, the implications of large-scale biomass production for energy on water use are unknown.

Reflection on sustainability

To avoid competition for land (food versus fuel) large amounts of land should be(come) available for bio-energy production apart from the amount already required for food, feed, fibre, etc. Some analyses assume that these acreages can be found in current degraded/marginal lands and by increasing agricultural productivity. Degraded/marginal lands need substantial inputs of nutrients and sometimes water before sufficient biomass production is possible and soil fertility can be improved. However, land degradation will occur if removed carbon and nutrients are not replenished. Second, agriculture has developed due to economic incentives, technological advances and institutional support resulting in overall doubling of yields per hectare during the past five decades. In the same period crop land area has increased by 12% to secure food availability. These past decades reveal that agricultural productivity increase has to be intensified even further to keep up with food/feed demand and at the same time to alleviate land areas for energy crops, even against the background of contemporary problems of soil degradation, water pollution and depletion, and slowed gains in crop improvement.

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Competing Claims on Natural Resources: Food, Fuel, Feed, Fibre or Forest?

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Of course, the title is wrong! Demand increases for agricultural products for food, feed, fibre and now also fuel, while pressure is maintained for global conservation of biodiversity and nature. Decisions have been made already concerning biofuels - the big question is how to produce them and satisfy all other demands on land, including the prerogative for conservation. Maintenance of biodiversity and nature is a condition not an option. Political decisions have been made to reduce dependence on fossil energy through greater investment in biofuels. So the question is how to meet the demand for food, fuel, feed and fibre, *and* at the same time address the prerogative for biodiversity and nature – referred to in the title (for the sake of alliteration) as 'forest'. Defined in this way, the current debate on biofuels shares many relationships with earlier debates on the relative advantages of 'extensification' versus 'intensification' that have been discussed in previous analyses of land use for agriculture or nature (e.g. the Ground for Choices, 1992 WRR report).

Analysis of the future scope for biofuel production is often based on potential yields

Analyses on the future scope for biofuel production can be done from several different perspectives. Most past, and current approaches look at 'potential' (usually water limited) production in response to climate and soil conditions, based on the principles of production ecology (see for example Bindraban, this seminar; Figure 1). Factors affecting crop production may be divided schematically into three broad categories: defining factors; limiting factors and reducing factors. The actual production is the common situation for the majority of the world's agricultural production systems, yet most explorations of the scope for biofuel production use either the potential production, or water-limited production as the starting point. See http://www.dpw.wageningen-ur.nl/pdmm/ for further information. It is likely that this results in serious overestimates of how much biofuel and food can be produced.

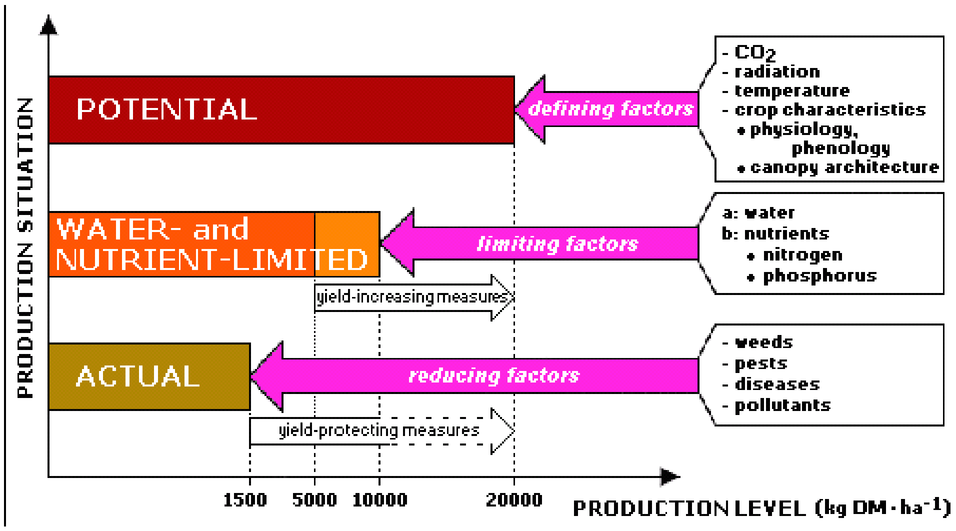


Figure 1. Factors affecting crop production.

From reviewing the current literature, we conclude that current evaluations of biofuel probably overestimate their likely scope. More realistic analyses should be developed based on 'feasible' production scenarios that take into account the likely constraints both of using production technologies in practice, and the infrastructure and policy constraints that may hamper their use.

Interacting hierarchical forces restrict production potentials

Within the key international research theme for Wageningen University and Research Centre entitled 'Competing Claims on Natural Resources' we focus on the impacts of global and international policy and global change on rural people in developing countries. A particular focus is on forms of alternative or adaptive land management for rural people, and their role in deciding on such options. The space for innovation or change at the local level depends on the local resources, and opportunities are constrained or enabled by policies and governance at local, national, regional and international to global levels (Figure 2). A key aim of the analysis is to identify enabling policies that can create a greater space for local innovative responses, and strengthen local communities' influence at higher levels (from Giller *et al.*, 2005). All sorts of (conflicting) global treaties (forms of policies) are declared which intend to control/regulate what happens at local level. Other (often unintended) factors have strong influence (such as migration, labour markets), then at local level infrastructure is often restricting and causes extra costs, and corruption at many levels means that even good policies may become twisted. But effects of all policies affecting land use are experienced at local level, often with little feedback to higher levels in terms of influence. Most analyses treat land use as a single hierarchical level and ignore the many layers of influence above.

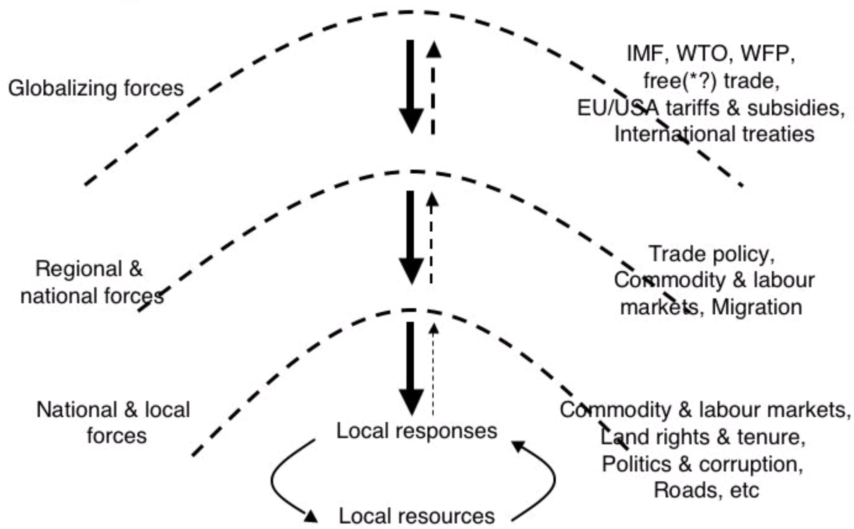


Figure 2. *Global and national policies structure the space within which local responses can be generated (see text for further explanation).*

Although global drivers are generally the same, local resources and local responses greatly differ. As a result, production opportunities and constraints will be very region specific. So, the question is where to produce, for which purpose, what biofuels to produce (first or second generation?), and how (under what form of cropping management or intensity)?

Many claims have been made that areas of land that are marginal for agriculture should be used for biofuel production. But where in the world are marginal areas without people? Perhaps biofuel represents an opportunity for investment in marginal environments? But such areas usually owe their 'marginality' to both their poor production environments with low potentials and in terms of their remoteness from markets. Remoteness means that local conversion into energy is necessary or else the net gains in energy disappear.

Choice of commodity

Then what to produce? There is much current interest in the production of jatropha (*Jatropha curcas*) for oil in marginal areas, but the potential production of oil is relatively poor, with annual yields often only 0.5 - 1 t ha^{-1} of oil annually (Figure 3). Thus for a given oil production a large area of land is required. The danger of proposing wide scale production of jatropha is that large areas of land in semi-arid environments would be required – which are also often areas of pastoralism or have high conservation value for wildlife.

Jatropha curcas

- Yields up to 1.5 t ha^{-1} oil under optimal conditions
- Needs plenty of cheap labour
- Less yield under marginal conditions (<0.5 t ha^{-1} oil)
- Many examples of spectacular failure (e.g. no seed set, hollow seed)

Figure 3. *Marginal areas, marginal yields? Although there is widespread excitement in the use of jatropha for biofuels many projects in India are reporting yield failures.*

By contrast, potential production of oil palm which is grown under humid climates is much greater – up to 12 t ha^{-1} of oil. Expansion of oil palm cultivation is taking place in areas of rainforest on peat soils causing huge C losses that compromise the gains in oil production. Although there is much current debate on oil palm in relation to rainforest clearance, the primary causes for clearance of forest are often for timber extraction, with oil palm production following after. There is great potential for increasing oil production in existing plantations of oil palm (Table 1). Up to 25% of current oil palm is produced by smallholder production of palm oil. In theory, feasible yields, based on advice on current best commercial practice, can double the current average yield, and some companies are achieving these high yields on large plantations currently. Doubling the production per unit area would halve the area of land needed for production. Whether this would have direct effects on reducing logging and forest clearance remains to be seen, as it is highly questionable whether oil palm production and rainforest clearance are directly linked.

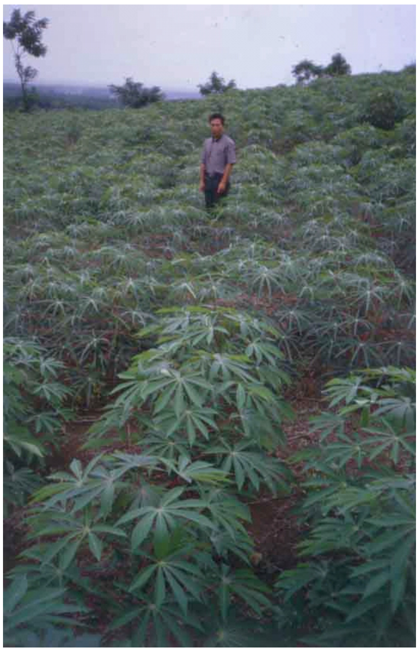
Table 1. *The yield gap between current and feasible production of oil palm in South-east Asia. Much greater attention should be given to increasing the yield of palm on current plantations rather than clearance of new forest areas.*

Country	Current yield[1]		Feasible[1] yield	Yield gap	
	t ha^{-1} bunches	t ha^{-1} oil	t ha^{-1} oil	t ha^{-1} oil	%
Indonesia	18	3.7	5.5	1.8	47
Malaysia	21	4.4	5	0.6	14
Papua New Guinea	15	3.1	6	2.9	93
Thailand	15	3.2	4.5	1.3	39

[1] *Based on statistics from FAO (2005) and advice on current best commercial practice.*

Other crops that have good potential for biofuel production, such as cassava (Figure 4) for bioethanol, offer new opportunities for smallholders. In South-east Asia, analyses by the Centro Internacional de Agricultura Tropical (CIAT) group led by Rod Lefroy indicate that cassava can provide a route to sustainable intensification. The advantages that such a crop offers are its multiple uses: for food or for conversion into bioethanol, with the residues from fuel production providing a useful feed for livestock. Another route for biofuel production by smallholders is the use of by-products such as rice straw, although analyses need to be made on how much straw can be removed without having negative effects on

sustainability of farming systems by causing reductions in soil organic matter. Figure 5 shows that the amounts of organic resources (maize straw or farmyard manure) required to maintain soil C are large. If all of the maize straw is removed for lignocellulose for biofuel production, the soil organic matter will decline to critical levels. Other techniques such as zero-tillage or fertilizer addition have little impact on soil C contents if all of the crop residues are removed.



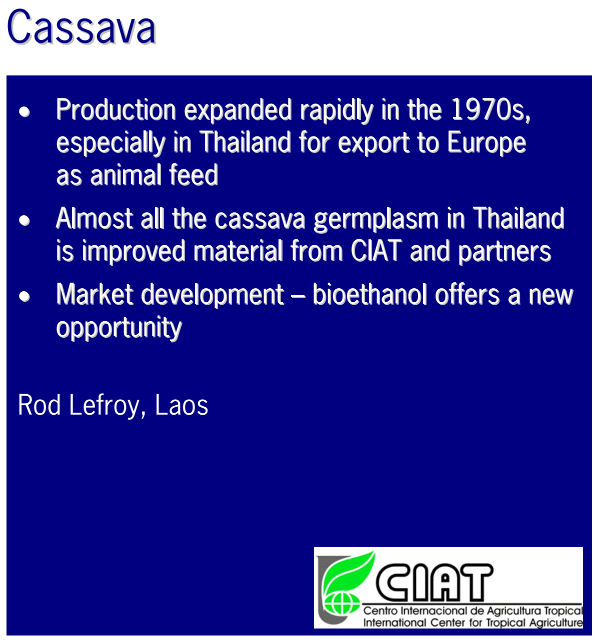


Figure 4. Cassava is a potential biofuel crop with multiple uses for food, fuel and the by-products of processing for bioethanol are an excellent feed for pigs and other livestock.

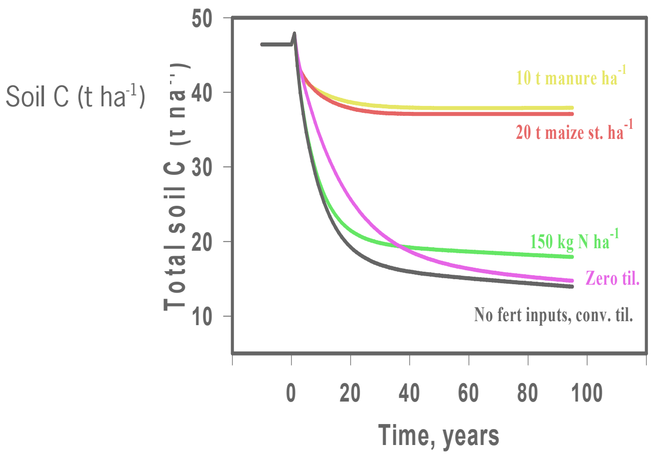


Figure 5. How much crop residue is needed to sustain soil fertility? (Zingore et al., 2005).

Unexpected opportunities for smallholder farmers in developing countries could be created, for example through the increased use of maize for bioethanol in the USA. Although there has been an outcry against the increased price of maize in Mexico, resulting from this change in policy in the USA, this may represent an opportunity for farmers in Latin America and Africa in the future. The decrease in dumping of subsidized maize into the world market could allow smallholders in developing countries to produce maize profitably for food, although this will have implications on food prices for the urban poor.

Integrated analysis across scales

Integrated analyses can play in guiding choices that must be made on when, where and how to invest in biofuel production, in relation to the equity of the effects on small and large scale producers. For this type of analysis tools are required that can examine links and feedbacks between different scales from the plot to the farm, from the farm to the region and from the region to the world. One such tool is SEAMLESS (**S**ystem for **E**nvironmental and **A**gricultural **M**odelling; **L**inking **E**uropean **S**cience and **S**ociety) (see http://www.seamless-ip.org/). Scenarios studies allow *ex ante* judgement of various biofuel options in countries or regions, and various indicators can be weighed against each other (for an example see Figure 6).

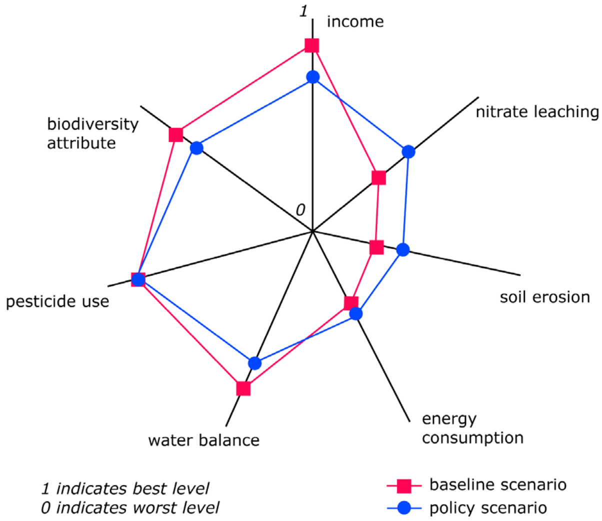


Figure 6. *Scenario studies by the European research consortium using SEAMLESS (**S**ystem for **E**nvironmental and **A**gricultural **M**odelling; **L**inking **E**uropean **S**cience and **S**ociety).*

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Biofuels and the development in the EU as related to world agricultural markets

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World-wide production of biofuels is rapidly growing. In the European Union in 2004, about 0.4% of the EU cereal and 0.8% of the EU sugar beet production was used for bioethanol, and more than 20% of the oilseed production was processed into biodiesel. The growth rate over the previous two years (2002-2004) was 27% and 70% for bioethanol and biodiesel, respectively. As in the EU the main drivers for increased biofuel demand in the USA are high energy prices and incentives provided by the Energy Policy Act of 2005. The EPACT05 requires a minimum of 7.5 billion gallons (approx. 28.7 billion litres) of renewable fuels (bioethanol and biodiesel) to be used in the nation's motor fuel by 2012. Apart from the EU and the USA other countries like Canada, Brazil, Australia, India and China also implemented targets for biofuels volumes and market shares.

Driving forces of growth in biofuel production

The driver for biofuel production in the EU, the USA and Canada is mainly political, including tax exemptions, investment subsidies and obligatory blending of biofuels with fuels derived from mineral oil, while high energy prices further enhance biofuel production and consumption in other countries and regions. In general, one can identify two levels of drivers steering biofuels production. On one side exogenous drivers, where patterns are not likely to change, such as population growth, macro-economic patterns, consumer preferences, agri-technology and environmental conditions. On the other side one can identify endogenous drivers, where changes are easier to achieve, e.g. agricultural, structural and/or environmental policies together with WTO and other international commitments.

Increasing biofuel production either due to 'pure' market forces and/or 'policy' has significant impacts on agricultural markets, including the trade in agricultural raw materials. Linkages between food and energy production include the competition for land, but also for other production inputs. The increasing supply of by-products of biofuel production, such as oil cake and gluten feed, also affects animal production, for instance.

Projections of future biofuel production in Europe

In the prospective study Scenar2020, first results of an analysis of the EU biofuel directive have been presented. Scenar2020 aims at identifying future trends and driving forces, that will be the framework for the European agricultural and rural economy on the horizon of 2020. The study provides a systematic review of primary variables that rural and agricultural policies have to take into account, such as rural demographic patterns, agricultural technology, agricultural markets, and the natural and social constraints on land use that are likely to exist in 2020.

The method used is to build a reference scenario ('baseline') that is based on an analysis of past trends projected forward to 2020. The relative importance between various policy frameworks is understood by comparing two scenarios ('liberalization' and 'regionalization') to the reference scenario. While the baseline scenario establishes a possible and reasonable perspective of what might happen until 2020 from today's perspective, this scenario is contrasted by two alternative scenarios representing two possible but extreme policy choices. The regionalization scenario assumes that the WTO negotiations would not conclude and bilateral trade agreements would become more important. Under the liberalization scenario a complete withdrawal of price and income support to farmers is assumed. It should be mentioned that the EU biofuel directive is only implemented in the regionalization scenario.

The results of Scenar2020 indicate that crop production for biofuel purposes (including cereals, sugar and oilseeds) will increase in the coming 15 years in the EU even without the implementation of the mandatory blending obligation imposed by the EU biofuel directive (Baseline scenario in Figure 1). Under the baseline scenario crop production expands in all regions of the EU and contributes 3.6 percent of total fuel consumption for transportation. Different levels of support to farmers does not alter the outcomes significantly, such as high support under the regionalization scenario vs. low support under the liberalization scenario.

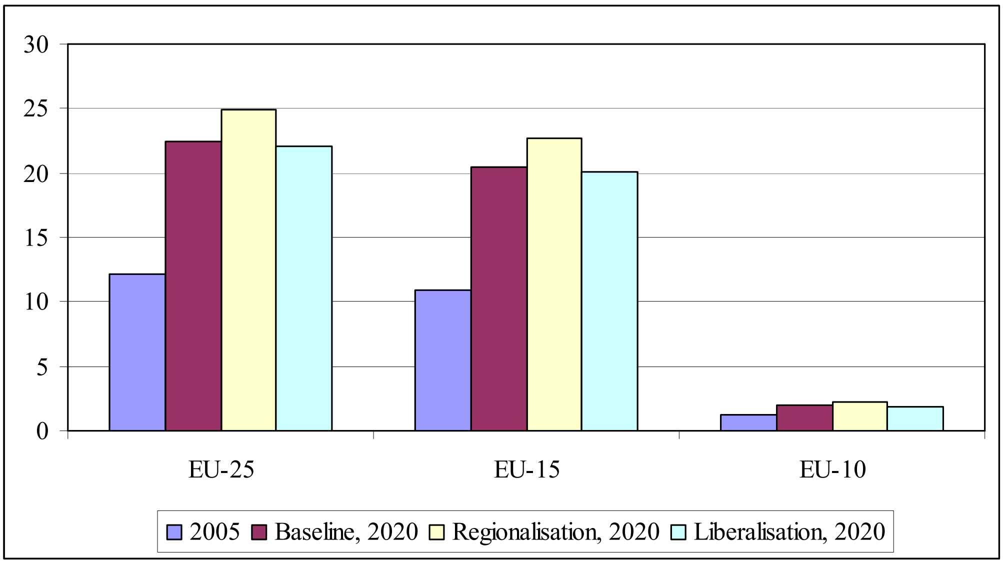

Figure 1. *Production of crops for energy under different scenarios in the EU, 2005 and 2020, in million tons. Source: Results from the Scenar2020 Study.*

The major uncertainty with regard to all conclusions concerning the future of biofuels is the tightness of oil/energy markets. Therefore any scenario result depends on the assumption made on the future development of crude oil price. For this study an increase of crude oil price by 1.5% p.a. has been assumed. Therefore, the impact of biofuels on European agriculture may be under-estimated: Meeting 10% of EU's energy requirements for transport in 2010 could take up 43% of current land use for cereals, oilseeds, set aside and sugar beet, if all feedstocks for biofuel production are grown domestically.

The Scenar2020 study shows, that the 5.75% objective for 2010 in itself will require 15.03 mio tonnes of biofuels. If the feedstocks are all grown domestically, this would be equivalent to 12.02m ha, or 9.4% of EU-25 agricultural land demand. It is projected, however, that in 2010 there will be only 6.98 million ha of agricultural land used to produce biofuels feedstocks, which is equivalent to (a) 8.74 million tonnes of biofuels, (b) 58% of total biofuels used and (c) 5.5% of total agricultural land demand.

A corollary of the increased demand for biofuels is the increased resort to biobased materials (partially motivated to replace plastics, a petroleum derivative); the conjunction between the demand for biofuels and the demand for biobased materials is likely to create competition with other demands for agricultural commodities.

The demand for biofuels derived from agricultural commodities could be rapidly offset by biomass, using second-generation bio-energy production technology, as a substitution feedstock for the bio-ethanol fraction that would be fully operational on an industrial scale as early as 2015. The second generation of biofuels is currently considered to be more beneficial because the reduction of greenhouse gas emissions is larger and it is (perhaps) less land intensive.

The Scenar2020 study clearly shows how non-food demand of agricultural products (e.g. energy) competes with food demand. This implies first, increasing food prices with possible adverse effects on food importing (developing) countries; and second, a land expansion with implications for the environment. A trade-off exists between lower greenhouse gas emissions and adverse effects of this expansion and intensification in terms of for example biodiversity.

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Scenar 2020 – Scenario study on agriculture and the rural world. Published under the following web-site: http://ec.europa.eu/agriculture/publi/reports/scenar2020/index_en.htm

Biomass production for bioenergy: opportunities, threats and required actions

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The participants were divided into four groups with about 15 attendees each.
Before exchanging views and entering into discussions they were asked to complete forms in which the following questions were asked:

- Which opportunities and threats do you see regarding the projected increasing demand of biomass for non-food purposes?
- Which measures are needed to benefit from the opportunities and to avoid the threats?

The moderators – mentioned above – grouped in two reported on the discussion per workshop and compiled the completed forms. In the box below, the main opportunities, threats and measures are shown, based on how often they were mentioned thereby lumping similar remarks in a single statement. The box is followed by individual statements mentioned on paper or in the discussion. Many overlapping or closely similar statements were lumped. Not all participants agreed on all statements as there was not always consensus during the discussion nor were all written statements discussed at the plenary session per workshop. If readers are interested in who produced a particular statement, editors may establish contact.

Major outcome of workshops

Main opportunities

- Reduced greenhouse gas emission
- Diversified energy sources secures supply
- Increased income for farmers and industry
- Boosted scientific and technological development
- Chances for developing countries as energy producers

Main threats

- Competition with food security
- Neglected energy saving and alternative energy sources
- Reduced availability of resources and biodiversity
- Uncertain livelihood in rural areas of developing countries
- Decisions based on wrong quantitative assumptions

Measures to benefit from opportunities and avoid threats

- Reflect on proper route rather than following the hype
- Establish sustainability indicators, certification systems and acknowledged LCAs
- Stimulate research on resource use efficiency in agriculture
- Invest more in second generation biofuels
- Develop bio-refinery pathways to add value at all levels
- Carry out ex-ante socio-economic research
- Improve governance to enable opportunities
- Develop markets that assure level playing fields for people and nations
- Develop clear policies that assure sustainability in terms of people, planet and profit
- Development aid re bioenergy needs a pro-poor low-tech labour intensive focus
- Start pilots and learn by doing

Recorded statements on paper and in discussions

Biomass production offers opportunities

Opportunities for climate change

- Contributes to a decrease of GHG emission globally
- Reduces of ecological footprint of countries when criteria of sustainability are fulfilled

Opportunities for society

- Spreads energy security risks through diversification of energy sources
- Makes societies independent of imports of fossil fuel
- Reduces conflicts/implications associated with conventional fuels
- Offers agricultural and industrial development opportunities
- Improves food security by uplifting agricultural production especially in poor countries
- Synergy between food and biofuel production yields an overall improved agricultural production system
- Combination of food and fuels within regions makes them more independent
- More regional production of biofuels, so no longer needed to import from developing countries
- Biofuel production will organise the next agricultural revolution
- Food production will also benefit from biomass innovations
- Lowers the cost of mitigating the effects of climate change
- Increases agricultural production yielding a surplus (of food and land) for biofuels
- Leads to redistribution of wealth
- Increases the importance of plants in our life
- Creates jobs
- Changes our lifestyle

Opportunities for economics

- Capital investments in a production of raw material for non-food use have a high return
- The new non food bio-industry embraces the complete chain from generating raw material to final applications with values added at each link
- Totally new industry for biofuel production increases economic activity
- The radical changes give opportunities new industrialisation period
- Profit for farmers worldwide will rise.
- Bio-energy provides new economic perspectives for Eastern Europe.
- Much set aside land in Europe will become productive
- It will let farmers work without dependence on subsidies
- Optimization of usage of local wastes increases profitability of commodities
- Economic changes for countries growing crops for food and energy
- Yields profits from side-streams and waste
- Increases efficiency of agriculture when waste is used
- Offers opportunity for companies take the lead in biofuel chain orchestration
- Offers opportunities for companies regarding certification of sustainability
- Requires new biofuel crop species and varieties (intellectual property development)
- Requires production and distribution of propagation material (including non-food GM crops)
- Offers chances for vital sectors: agrofood, transport/logistics, chemical industry
- Benefit the three discriminate strengths: agro, harbours and chemical industries
- Increases dynamics between agri on one side and chemistry/fuels on other side leading to more dynamism, more ‘elan’

Opportunities for technological innovations

- Leads to a boost in the development of second generation fuels/technology
- The pressure on increased food, feed and fuel production boosts agricultural innovation
- Breeding and propagation of raw material crops differs from food crop improvement
- Leads to novel technologies to recover nutrients from waste streams
- Leads to small scale processing at farm level.
- Developments in biogas, pyrolysis and biorefinery make efficient use of all biomass without excessive transportation
- Biofuel production leads to a boost of R&D activities
- Makes it possible to produce a full range of chemical products form agriculture
- Bio-refinery enables the use of almost all components of plants at their highest values
- Optimizes food and fuel production efficiency over the whole chain

Opportunities for trade

- Stops the economic drive to dump of excess food in developing countries
- Increases the opportunities for local rural economies to develop because they are no longer out competed at local markets by low dump pricing
- Improved energy security diversifies global trade
- Gives chances for developing countries to trade in energy (fuel not raw material/biomass)
- Increased maize price gives small holders in Africa access to the world market
- Gives chances for regional economies to link with the global economy
- May rebalance subsidy disturbed agricultural markets
- Improves market efficiency and helps trade barriers to disappear

Opportunities for development

- Farmers have new chances of earning a living on the basis of small scale bioenergy production;
- Improved rural economics reduce migration to cities and slow down urbanisation
- Exporting fuel – not biomass gives DC a chance to keep most of the value of the chain
- Leads to new economic impulses, especially when local processing is developed.
- Making bioethanol and biodiesel at location of production of biomass stimulates rural economy and reduces bulky transport
- Locally produced and supplied cheaper energy stimulates growth
- Gives opportunities for agriculture based economies.
- Poor rural areas can now step on the energy ladder
- Biofuel production underpins Millennium Development Goals
- Revitalizes rural areas, stops depopulation.
- Gives raise to new business coalitions and roles for public and private sector
- Leads to more rural food security because of higher farm income
- Adds value to low value products when energy is exported, not biomass

Opportunities for sustainability

- Because markets for biofuels are still very much government regulated - e.g. through subsidies on green energy - governments can control the definition of criteria for sustainable production and use of biofuels
- Leads to improved land management, modernization and enhanced sustainability of agriculture
- Introduces more rapidly the introduction of sustainability indicators in agriculture
- Makes society truly sustainable
- Gives agriculture value again
- Enhances resource use efficiency through the use of by products
- Triggers an increased awareness by consumers that sustainability is a key issue
- Giving LCA outcome there is clear opportunity for sustainable production

- Improves degraded land by amending organic matter, nitrogen and soil structure
- increases biodiversity with the introduction of new perennial crops

Recorded statements on paper and in discussions

Biomass production represents threats

Threats to food security

- Higher prices for food and feed. Coupled with too fast implementation of biomass for energy creates a risk for the most poor people, also because markets lack the flexibility of reacting fast enough; additional risk: instead of fossil oil, biomass energy resources may be used by owners as a strategic asset
- Causing short term distortions of food markets that will lead to (locally and temporarily limited) absolute food shortage. Even if limited such shortages will be devastating in poor or subsistence farming areas
- Food availability and security are at stake
- Risk of different sustainability criteria for food feed and fuel
- Development presently too fast
- More people will starve due to high food prices
- Excuse of competition to further raise food prices

Threats to biodiversity

- Negative effect on biodiversity, however also new chances with perennial crops;
- Increased land use area
- Deforestation
- Degradation of soils
- Some crops – like oil palm - are extended at the expense of rain forest or other ecologically sensible areas
- Negative impact on esthetical aspects of the landscape
- Landscape changes due to monocultures of large companies
- Monocultures, gentech industry and pesticide threaten nature

Threats to natural resources and environment

- When new farmland is developed, risk of 'burning up' carbon stored in soil during first phase of cultivation leading to a lower than anticipated reduction of CO2-emission
- Removal of all produce (including crop residues) leads top decline in productivity, coupled with diminishing soil organic matter does not help reduced CO2 production
- Biobased crop production will be carried out on better soils and not on marginal soils competing for inputs
- Unbalanced certification systems aim at biomass and not on food production
- Too high pressure on land use
- Especially competition for water (and phosphorus)
- Further distortion of mineral balances, when large amounts of biomass are transported (compare situation of feed transport)
- Pooling too quickly the demand for first generation biofuels does not leave room for careful sustainable development of production resources
- Increased pollution of soil, water and air due to more intensive agriculture
- Reduced concern with energy conservation
- Large transfer of minerals from developing countries to Europe causing depletion and excess
- DDG (by-products from bio-ethanol, used for feed) is new phenomenon. It is high in protein (thus: N) causing increased N emissions from livestock production
- Lack of fertilizers, especially phosphate in the long term

Threats to people

- Social dimension in PPP is not well included in scenario studies, debate
- Price margins captured by large scale producers rather than small scale production
- Redistribution of value may lead to social unrest
- Oppression of small holders, corrupt land acquirement
- No communication per option, too technical for people to understand
- No profit for the poor, getting poorer
- People fear the long term effects when only first steps have to be set
- Large scale production will reduce employment in rural areas
- Raise awareness about real benefit of going green on energy supply
- Big farmers take over from small ones who become jobless
- False claims lead to public disappointment (loss of credit)
- Dominance of a few commercial parties
- Risk of over-asking for 'perfect' solutions, not taking time to learn
- Displacement of local people; Current agro-production: small scale; bioenergy crops: large scale
- Risk of going too fast at the expense of conventional economic and cultural values
- Current developments result from the perversity of the current ethanol subsidies. However, we already have a perverse system (ie subsidizing farmers to limit production while millions are malnourished)

Threats to trade

- Biomass will become a strategic resource
- More volatility in agrimarket prices.
- New round of non-tariff trade barriers. agricultural subsidies coming up undermining WTO and creating of market access
- Unequal subsidies in different countries hinder the optimal use of biomass
- Lose-lose situation for energy and food importing countries
- Tariffs and subsidies in developed countries
- Market distortion due to subsidies and fuel mixture directives

Threats to governance

- Because global governance is weak and it is a fact that is difficult to optimize various policy goals at the same time, there is a risk that developments will be unguided and therefore chaotic and resulting in unwanted side effects
- Displacement of 'indigenous' people
- Abrupt policy changes
- Lack of governance quality required to steer sustainable management and production and lack of policy quality to achieve multiple objectives
- Stalemate on consensus on applying sustainability criteria
- Biomass production in developing countries: no link to development perspective of the country, nor poverty reduction
- Imprecise decisions due to lobby of oil producers and automobile industry
- The decisions are based on the short term; will the transition needed for the long term come in time?
- Secure ownership of the land before embarking on large scale production

Threats to policies

- As policies are unilaterally made, further gap in wealth distribution between North and South
- Biofuel production now is a matter of politics, not of market needs. Compulsory targets may also trigger wrong technological developments
- Tendency to protect local crops are inefficient from market point of view

- Current subsidies exaggerate certain biofuel activities that are not economically and ecologically sustainable in the long (subsidy free) term
- Governments and legalization helps large industry and not small enterprises with innovative technology and products
- We are forgetting better alternatives (sun, nuclear, wind, water)

Threats to alternatives

- By overlooking energy production from municipal waste
- Such as water, wind, nuclear and solar energy
- Taking away much needed resources form other GHG mitigation options. Resources include R&D funding, subsidies, land, biomass and include opportunity cost for alternative strategies
- Certification of biofuels is not there yet
- The world economy becomes more dependent on global climate change
- Diversion of more simple solutions (such as energy saving techniques)

Threats because of miscalculations

- Because of wrong or incomplete assumptions regarding CO_2-reduction potential of various biomass and biofuel chains
- Assuming that second generation is much more efficient that present fuel use of food grade raw material the rush to produce it will lead to an increased claim on natural resources than decreased because it will be economically much more interesting to produce this more efficient biomass
- As equity is not guaranteed
- If not done by good management biomass production may produce more green house gases than replaced from fossil substitution
- Regarding CO_2 emissions from cultivation on peat soils
- Overestimation of harvests/profits
- Revenues are more and more dependent on unstable oil prices
- Overestimation of the development of the 2nd generation of biofuels, technology, logistics, investments
- Policy and money drive development that is not based on sound analyses
- Misleading LCA studies by wrong assumptions of LCA input or interpretation of output
- Unclear unproven technologies (second generation, GMO,..)
- Unavailability of quantitative and reliable data on biomass demand and supply
- Some projects not delivering life cycle CO_2 benefits
- Biofuel production is not a solution for climate change

<u>Recorded statements on paper and in discussions</u>

Biomass production for biofuels requires actions

Act to reflect before embarking

- Make sure that right routes are chosen that really lead to CO_2 reduction
- Rather invest in wind and other energies
- Make sure that environmental and social costs are included in bioenergy production
- Subsidise energy saving not biofuel
- Listen to the needs of the South, not to multinationals
- Do not allow food grade raw material in support programmes if there are alternatives to avoid GHG emissions
- Forget about policy making, the markets will decide (focus on the very poor)
- Define goals before starting a policy
- Do not follow a hype but reflect on desired route
- Focus more on institutional solutions than technical ones

- Make sure that only biomass with highest GHG benefit is used
- Animal producers are moving closer to bio-ethanol factories (in US: back from south to Chicago region). Net sustainable effect is not easily determined
- Governments distinguish between biofuels with respect to the level of emission reduction they realise (focus on CO_2 instead of litres of fuel)
- C Produce an environmental impact assessment of the EU for policies to be based on
- Carry out LCA's as decision support tool for biofuel production
- Create a sustainable society: walk away from the CO_2 caricature and strive for sustainability everywhere
- Think globally
- Think locally

Act to establish sustainability indicators and certification systems

- Certification of agricultural production (in order to ensure sustainability) for food, feed and biomass production requires an International Agricultural Certification Agency
- Committee like the Cramer-committee is needed at the global level
- International agency for certification of Food, Feed and Fuel production based on sustainability criteria; like ISO-certification on a voluntary basis, with possible government incentives when certificate is available.
- Set standards for GHG reduction per unit of energy and of land
- Develop international criteria on sustainable production of feedstocks for bioenergy
- There is a need for a legal and institutional and complementary voluntary partnership schemes (certification) to safeguard sustainability issues and level playing fields
- Develop instruments and mechanisms that internalize environmental and social costs of unsustainable biofuel production
- Apply ecolabeling to prevent negative GHG balances like the famous example of palm oil in Indonesia
- Train farmers on meeting sustainable agriculture indicator values
- Develop global standards for sustainable sourcing of feedstock
- Unify and standardise (accreditation?) LCA methods

Act to stimulate research

- Stimulate research on the potentials and threats of biomass for energy (ecologically and economically sound
- Update the maximal global biomass production capacity
- Fill in the gap in knowledge on plant genetics, physiology and agronomy
- Do research on producing biomass in saline conditions (sea)
- Direct all research efforts to enhance current biomass production before embarking on second generation: first generation benefits both food and fuel
- Restart the discussion on GMO in Europe
- Support research agenda towards bio-refinery
- Promote infant industry related research, but avoid wasting resources on current ethanol industry
- Keep knowledge base updated, invest in fundamental and applied research
- Beside research on biomass and conversion also research needed for customer side (car engine) and logistics
- Develop production systems on marginal lands for integrated food, feed and fuel production
- Development of conversion processes for second generation biofuels
- Biorefinery roadmap should lead to major governmental investment (FES)
- R&D for high-tech solutions (biorefinery)
- Competing claims concept must be developed to link levels and actors for more sound decision making
- Modeling and scenario studies (agro-ecological and socio-economic)
- Develop local for local systems (self-subsistence at e.g. city level), not global
- Invest in dedicated agricultural and technological solutions to enable small scale production of energy carriers (multiplication models)
- Increase efficiency of agriculture to alleviate pressure on land for nature and biodiversity
- Enhance the development of small scale technology

- Domesticate wild species to make new crops
- Develop complete and concrete concepts of crops, land use management systems, agricultural rationalization and start pilots
- Start pilots on sustainability indicators (actual and desired levels) monitoring, tracing and tracking
- Specifically develop crops, varieties and propagation material for developing countries
- Develop highly efficient processing e.g. pre-treatment of lignocelluloses and hydrolysis
- Develop ecosystems based land management

Act to improve governance

- Negotiate policies: meaning that stakeholders of an certain region discuss various policies for their region and come to an agreement for the best course to be taken. Dilemmas here are: what are the boundaries of the region for which a negotiation result should be obtained.
- Formulate effective criteria to reduce external costs of agricultural production (food, feed and biomass for energy)
- Experiment with participatory governance models: multistakeholder platforms This idea looks like that of negotiated policies.
- Set up governance models/organizations
- Establish a Global stewardship Board that assures good governance
- Develop integrated policy strategies needed at country level, intersectoral and international
- United Nations intervene for arbitrage when countries offer unsustainable biofuels

Act to regulate markets

- Link market for bio-energy to agricultural development
- Mineral balances' tax on mineral content of imported raw biomass or otherwise discourage import of raw biomass
- Stop perverse trade subsidies and policies to create a level playing field for all countries
- Adapt the WTO treaty for biofuels
- Reduce tariffs and NTBs
- Upgrade CO_2 trading rights, this is most cost effective way to reduce emission
- If GHG is principle goal, market mechanism should steer the way of saving GHG
- Do away with all trade barriers and subsidies
- Develop mechanisms for 'biodiversity-offsetting' (e.g. a kind of biodiversity credit trading similar to CO_2-credit)

Act to develop policies

- Grant each individual a fixed CO_2 budget?
- Always integrate electricity and heat production
- Make institutional arrangements for cooperation between producers and local industries and trade
- Develop economic incentives for sustainable production
- The European Union stops with one sided policy making. Policy is destructive for sustainable production
- Policy measures ensure that biomass production takes place on marginal soils only
- Strong policy support for energy conservation
- Policy only supports biofuels with a GHG benefit of over 50 %
- Do not reward destructive behaviour by very politically stretched targets like 5.75 % in the EU
- Involve all stakeholders in public-private cooperation and policy development
- GHG balance: governments develop a helicopter view to invest in energy options
- Develop stable and clear government policies on medium and long term
- From policy market to real market (unsubsidized, no targets set by policy
- Have policies in place that ensure profits reach primary producers. Do and listen to sound economic analyses
- Governments work out policies built by the various platforms of energy transition
- Continue the liberalization of EU agricultural policies

- Set clear limits to land use in European countries (e.g. % grassland)
- Continue energy consumption reduction policies
- Slow down policy goals, give markets more room to develop themselves
- Support other types of sustainable energy (e.g. wind, solar)
- Make bioenergy pro-poor focus on labour intensive forums of bio-energy, residues based, low tech
- Forbid that land dedicated to food production is used for biomass production
- Provide subsidies in relation to CO2-reduction only, including whole chain analysis and assuring level playing fields
- Support financially and organizationally new developments with higher efficiency and more environmentally friendly
- Increase tax on inefficient cars
- Make main ports attractive for role in biofuels
- Invest more in agriculture worldwide because of the additional claim (energy)
- Dare to exclude some commodities (e.g. palmoil)
- Do not exclude some commodities (e.g. palmoil) as it is impossible
- Go upstream in cooperation with countries that grow biomass
- Create platforms for information exchange
- Increase the speed of development and implementation of biorefinery, fermentation and gasification
- Mineral balances' tax on mineral content of imported raw biomass or otherwise discourage import of raw biomass
- Give incentives for most efficient GHG-gas reduction (per hectare)
- Carry out intersectoral policy scenario analysis to show options decision support
- Increasing productivity of agricultural production to decrease pressure on land use
- Start up some good examples and take the disbelievers on the luggage carriers

Act to aid development

- Appeal on the corporate responsibility of major players
- Multinationals do philanthropical investment in developing countries
- Fund capacity building in developing countries
- Create opportunity to export knowledge conversion technologies + biorefinery & capacity building in the South for developments of local economies (no import of crude biomass if it can be processes in country of origin. This can stimulate local economy and generate jobs
- Building knowledge in developing countries (biomass processing and refinery; agricultural intensification)
- Stimulate biofuel production in developing countries, start pilots
- Create platforms for technology transfer to developing countries
- Capacity building and transfer of knowledge
- Develop a 'fair trade' system for bio-energy
- Setup large scale demonstration and research programmes to show that synergy is possible between biomass for energy production and rural development and improvement of the biodiversity situation
- Distinguish bio-ethanol production at large plantations versus biodiesel production in small scale agriculture
- Small scale production: stimulation of small scale production of bioenergy in Europe on a level playing field with subsidies. Also stimulating small scale production in developing countries

Programme Seminar Food, Fuel or Forest? March 2, 2007

08:45	Welcome drink and registration Wageningen International Conference Centre	
09:15	Opening address by the chair	Rudy Rabbinge Wageningen UR/Senate Wageningen, The Hague
09:20	Drivers for bioenergy: governmental directives driven by geopolitics, greenhouse effect and autarky	Thijs Berman EU parliament, Brussels
09:40	Conventional and advanced technologies for the conversion of biomass into secondary energy carriers and/or chemicals	René van Ree ECN, Petten
10:00	Developing global biomass potentials in a sustainable way	André Faaij Copernicus Institute, Utrecht
10:20	Impact of an increased biomass use on agricultural prices, markets and food security	Josef Schmidhuber FAO, Rome
10:40	Nutritional break	
11:10	Environmental impacts of various options of biofuel for transportation	Guido Reinhardt FEU, Heidelberg
11:30	Land, water and nutrient requirements for biomass production	Prem Bindraban Wageningen UR, Wageningen
11:50	Competing claims on Natural Resources: Food, Fuel, Feed, Fibre or Forest	Ken Giller Wageningen UR, Wageningen
12:10	Biofuels and the development of world agricultural markets	Hans van Meijl Wageningen UR, The Hague
12:20	Lunch	
13:30	Plenary session: workshops procedures	Harriëtte Bos Wageningen UR
13:40	Four parallel workshops	
15:20	Plenary reporting of workshops and discussion	Raoul Bino Wageningen UR
16:00	Report of PhD-students' round table of March 1	Steven de Bie Wageningen UR
16:45	Closure	Rudy Rabbinge
17:00	Drinks and farewell	

<u>Advisory committee</u>

- Irene Mouthaan, Ministry of Agriculture
- Iris Lewandowski, Shell
- Willem Jan Laan, Unilever

List of participants of the Seminar

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• Weber Amaral	Brazilian Center for Biofuels
• Fred Klein	Central Arable Farming Marketing Board (HPA)
• Geert Bergsma	CE-Transform
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• Dee Timmermans	Cordaid
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