Biobased Raw Materials Platform

The Biobased Book

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Biobased raw materials could provide a real and extremely important contribution to solving our world's energy problems. The long-term applications of biobased raw materials or biomass are considerable: use of these materials does not contribute to worldwide CO_2 emissions, as whatever is emitted today is stored in new biomass tomorrow (except the energy input for cultivated crops). Terrestrial and aquatic crops currently offer one of the few immediately available means to bind CO_2, thereby removing it from the atmosphere.

However, there is still a need to develop a quality mark, including sustainability criteria for biomass, as the use of biobased raw materials for energy purposes may also have a negative impact on food provision and the environment. Sustainability is seen across the entire chain: from source to use. The use of residual materials and surpluses from agriculture and the food industry for use as raw materials and/or energy sources is not included in this debate, however, there should be provisions where crops are being explicitly cultivated for energy to ensure energy biodiversity is not affected and food supply is not hindered. However, where there is sufficient agricultural land available, the link to new non-food markets may deliver additional income to the farmer, providing rural development a much needed boost. This applies in particular to situations where there is too much dependence on a single crop. Proper interchange of crops not only ensures that biomass crops deliver additional income, but that food crops also deliver improved yields.

Whether a biomass source can be sustainable may vary from country to country and region to region, products that are scarce in one country may be available in surplus in another. The guide has to be that only surpluses of crops which have been destined for food across generations should be employed for large-scale use as raw materials and energy sources. We should avoid impacting the already scarce biodiversity any further through sacrificing more natural, arable land to cultivating crops for food, raw materials or energy. One country should not be tempting another into supplying products which threaten the cultivation of food crops and biodiversity. A judgment about whether this is the case needs to be conducted in collaboration with local interest groups.

Biobased raw materials passing the above mentioned test are or will be widely available. The potential for energy supply is considerable, yet the production of chemicals and materials could also be tailored to using a green template. This additional potential of biobased raw materials lies in the use of the total biomass production and not in the use of only parts of a plant for, for instance, consumption, energy or cattle feed. Residual materials can be exploited in countless ways, often yielding higher added value than traditional applications. New technologies, such as fermentation and biorefinery, which have already demonstrated opportunities within the fine chemistry and biotechnology industries, may also serve to supply biobased raw materials for (new) materials and energy supply.

Biobased raw materials do not need “rocket science” to become the basis for more than a third of all raw materials we use in the Netherlands. The technologies and methods required are sometimes remarkably simple and have often been available for a long period of time. We could already start to use biobased raw materials tomorrow, or to put it more forcefully: we have already started to use them, and every day we move another step forwards in this process. An important breakthrough in the technology – the so-called second generation technologies – is expected to be available within the next ten years: this will enable us to utilise the full potential of biobased raw materials.

Biobased raw materials will deliver a very significant contribution to the transformation of our energy supply in the coming decades by reducing CO_2 and greenhouse gas emissions, until that time when we will be truly able to directly convert sunlight into energy cheaply and on a large scale. Until that time we can reduce dependence on fossil resources (coal, oil and gas), which are becoming scarcer, by utilising biobased raw materials.

The Biobased Raw Materials Platform (Platform Groene Grondstoffen, PGG), created by the Interdepartmental Programme Management Energy Transition (Interdepartmentale Projectdirectie EnergieTransitie) has formulated its vision in a number of scientific reports, which this book is based on. The Platform’s ambition is that 30% of energy and material use in the Netherlands is to be based on biobased raw materials before 2030, leading to a positive impact on the environment, society and economy. This book details how fundamentally realistic this ambition really is.

Mr. Paul L.A. Hamm
Chair Biobased Raw Materials Platform

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Energy Transition

Why use biobased raw materials?

Why use biobased raw materials?

Energy transition imperative

Energy is one of the most urgent dilemmas in the world. There is a close relationship between energy use and climate change, and because the oil market is shrinking energy has become a potential source of international conflicts.

Eighty percent of the world's energy supply is based on fossil resources: natural oil, natural gas and coal. As welfare improves so does energy demand, not just in industrialised countries, but also in developing economies, such as China and India. However, stocks of fossil fuels will eventually run dry. The oil market is shrinking and the effects of disruptions to it are immediately felt, such as, for instance, the war in Iraq and hurricane Katrina, which submerged New Orleans under water and destroyed drilling platforms in the Gulf of Mexico. The import of oil and gas in Europe and the USA, which have too little of their own stocks to satisfy energy demands, is becoming less certain. Countries with large energy stocks will start using them to play a greater role in world politics.

The use of fossil fuels releases large quantities of CO_2, the most important cause of the greenhouse effect. This leads to additional warming of the earth and thereby climate change. There have been agreements by industrialised nations to limit their CO_2 emissions in order to counteract this effect. The first deadline (according to the Kyoto treaty) is in 2012. Further targets may subsequently be agreed, at least, this is what countries serious in their intentions to combat the greenhouse effect, including the European Union, intend to do.

A global approach in all sectors of energy supply is required to tackle these problems: electricity production, heating provision, transport and industry. This means less energy waste through better cars, houses and factories. We will be generating our energy from alternative sources: less gas, oil and coal, and more sun and wind.





Biobased raw materials will also play an important role in the transition period for energy supply and as a sustainable basis as feedstock for the chemical industry. This will affect all aspects of society: from housing and industry to mobility, telecommunication and agriculture. Changes in energy supply will affect everybody. This kind of change is referred to as a transition. The energy transition will take decades. All of this demands a long-term pathway to the future, which will have to be followed in concrete steps from today.

Threat and opportunity

The energy transition is necessary to tackle the threats facing us. However, energy transition is at the same time also an opportunity to explore new raw materials, apply new technologies and develop even better technologies, and to get new commercial ventures off the ground. For the Netherlands there is not only the necessity of venturing down new roads (particularly due to the depleting natural gas deposits and the strive to guarantee supply), but also, in particular, the possibility of embracing new opportunities.

The Netherlands is unique in its approach to limited space: virtually nowhere in the world have urbanisation, traffic, intensive agriculture and energy production been combined so efficiently. The Netherlands is a world leader in separating and recycling of waste streams. The Netherlands has a unique gas infrastructure. Its scientific and technical knowledge of energy, biomass and chemistry is at the international forefront. And within the Dutch energy sector there are many active companies with commercial awareness taking an innovative approach. If Dutch commerce were to embrace the opportunities today, it could achieve global competitive advantages with new energy technology through good timing and efficient production.

Platforms and the Energy Transition Task Force

Dutch energy policy is focused on bringing about the energy transition. An ambitious, long-term vision has been developed, which, although not a blueprint covering all industries, forms a guide to sustainable energy provision.

Energy will have to be used much more efficiently. A large part of the energy used in 2050 should originate from sustainable sources: sun, wind and biobased raw materials. CO_2 emissions must have been cut back to half the levels in 1990 and the Dutch commercial position will have to be strengthened.

Platforms have been created for six core themes, consisting of representatives from commerce, research institutes, public organisations and the government. These platforms and their objectives are as follows:

- Biobased raw materials: in 2030 30% of our energy will be derived from biobased raw materials; conversion of biomass into electricity, heat, chemicals and materials.

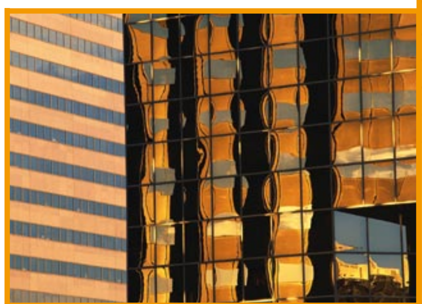
- Sustainable mobility: greenhouse gas emissions by new vehicles will have been reduced by a factor of 2 in 2015 and greenhouse gas emissions for all vehicles will have been reduced by a factor of 3 in 2035 by using alternative transport fuels, new vehicle technology and the optimisation of traffic behaviour.

- Chain efficiency: the Netherlands will be the most energy efficient economy in the world due to intelligent organisation of production chains from factory to consumer; in 2030 a saving in product and production chains of 150-180 PJ will be realised.

- New gas, clean fossil fuels: the Netherlands will be the most efficient and innovative gas economy in the world due to efficient applications of natural gas, biogas and hydrogen and through the capture and storage of CO_2 where possible.

- Sustainable electricity: the Netherlands will have a CO_2-free energy supply through use of wind energy, solar energy and biomass and through greenification of traditional electricity production and infrastructure.

- Built environment: an energy neutral built environment, where housing and buildings collectively have sufficient sustainable energy on balance through a drastic reduction in energy consumption for heating, cooling and equipment.






In addition, the Dutch Cabinet has also created an Energy Transition Task Force, which will be responsible for publicising the platforms' overarching message. Commerce, research, public organisations and the government are also represented in this group.

The international dimension is extremely important to all of this: the Netherlands wants to be the frontrunner in the global transition to a sustainable energy supply. This means, for instance, taking a leading role in global multilateral collaborations, such as in international treaties relating to climate, energy and environment. It will mean active collaboration in the European Union and with the Commission and likeminded countries. It will mean seeking collaborations with European industry and inviting foreign companies to explore energy innovation in the Netherlands. Finally, this international dimension will take shape in the development of world markets, full of opportunities for innovative Dutch businesses and knowledge enterprises.

Transition paths

Each of the platforms has a number of "transition paths" (development in energy supply offering multiple opportunities), which should contribute to the actualisation of the objectives. Each transition path will also involve commerce and the objective is not to just modify the course of the energy system towards a favourable direction, but also to contribute to the competitive strength of the Dutch economy.

The transition paths relate to a wide variety of activities: the development of products and services, changing consumer behaviour, starting up new enterprises. The Transition Action Plan currently consists of 26 transition paths, collectively covering a broad spectrum. This portfolio has not been set in stone and paths may be removed or others added, for instance when new technologies become available.

Since both the government and commerce are participating in this process, they also each provide their own contributions. The government has been tasked with charting a favourable, stable policy, for instance, through removing obstacles, whether they be financial, or statutory rules and regulations.

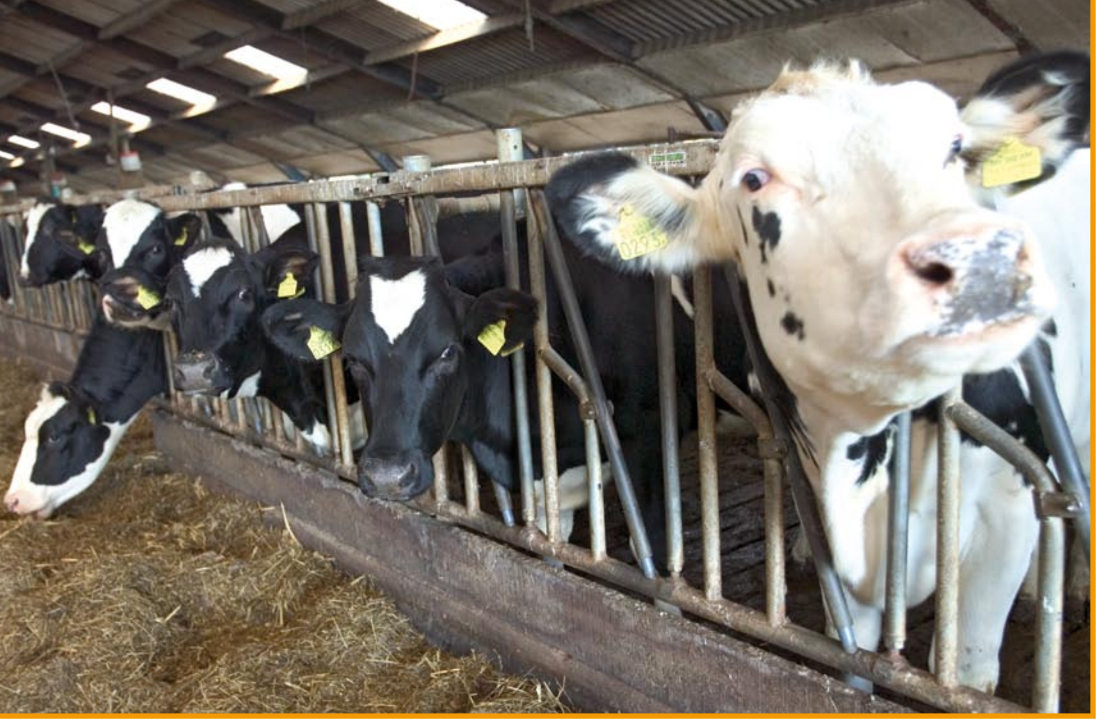
Examples of transition paths

Micro and mini heat and power cogeneration systems

This transition path is directed at a drastic improvement in yield in electricity and heat generation by generating them collectively through a home power plant. The combined production prevents heat loss in electricity production and loss of exergy (capacity to generate electricity) in heat production. Transport losses are avoided by generating this close to a house or in a home. The technology for this based on gas boilers is already available. In the future fuel cells will take over this function, but these are still in development. All home power plants can function collectively in a single linked system, such as a virtual electricity station, allowing heat to be effectively buffered.

Sustainable paper chain

The energy efficiency of the production chain for paper and cardboard from raw material to end use could be improved considerably by introducing process and product improvements across the entire chain, as well as recycling residual products and optimalising logistics. The paper and cardboard industry is responsible for 4 to 5% of primary energy consumption in the Dutch process industry, although there are opportunities for considerable reductions (down to 50%) in energy consumption. The question of how these conditions can be created to realise the actual transition is a central question in the sustainable paper chain. The target is to halve energy consumption per end product by the year 2020.



A stall at the dairy farm Zijlstra in Hallum, Friesland

The government is also encouraging projects in energy transition, for instance through subsidies or making the addition of biofuels compulsory, thereby making it increasingly interesting for companies to invest in projects contributing to the transition paths.

Biobased raw materials

Processes which have been developed in nature over millions of years offer a potential solution. The sun radiates three hundred times as much energy onto the earth as used by humans. An important part of this energy is captured and stored by plants, both on land, as well as in large quantities at sea (in the form of algae). This gives rise to "biobased raw materials", which is also referred to as biomass. Animal products, such as manure, are also included in the definition of biomass.

In the creation of biobased raw materials CO_2 is removed from the atmosphere and becomes bound in the photosynthesis process. Therefore the use of biobased raw materials is, in principle, CO_2 neutral. CO_2 is of course emitted in this process, but this quantity is firstly bound in the form of plant material (the so-called short cycle). It is only the use of cultivated crops where this cycle is not CO_2 neutral, due to an input of fossil fuels, primarily in the form of artificial fertiliser and diesel oil for tractors. However, across the globe 95% of all biobased materials have been created without fossil inputs such as these.

Biobased raw materials are derivatives of solar energy and may therefore be able to provide a significant contribution to a sustainable energy supply. They represent an enormous potential: half of the world's population could benefit from biobased raw materials for its energy supply. Their current contribution to the global energy supply is roughly 10%. In the Netherlands biobased raw materials could also start to play an important role, and may also start to be used as raw materials for many (chemical) products currently produced from natural oil and gas.

The competition between food supply and the use of biobased raw materials for energy and chemicals is an important concern. Responsible use is only possible if agricultural efficiency is improved across the entire globe, which is certainly possible with a lot of effort, requiring a political will to achieve this objective. Energy and food supply could also co-exist in combined crops through the use of residual streams in agriculture for production of fuels. Furthermore, cultivation of energy crops is possible on marginal and arid grounds, as well as in saline areas where ordinary agriculture has become impossible; this avoids competition within agriculture and creates a new source of income for the farmer. Biobased raw materials may also be cultivated at sea. We will also see that rapid development of the so-called second generation technologies is of huge importance for the future of biobased raw materials; these will allow valuable products to be created from the lignocellulose fraction of biomass which is unsuitable for food.

The wood oven developed by Philips for use in developing countries

As well as energy savings and solar and wind energy, biobased raw materials provide an opportunity to develop new commercial activities, often on the basis of new, clean technologies. In the Netherlands, biobased raw materials offer an excellent economic opportunity, as the necessary know-how would link up with the existing strengths of the Dutch agro- and chemical industries. Agriculture and the chemical industry are exactly two fields where Dutch industry has earned its spurs.

Therefore, in order to develop a strong position in the field of biobased raw materials, nothing more (or less) is needed than that these sectors and the associated research institutes partly transfer their attention to this new, promising field.

Ambition and transition paths

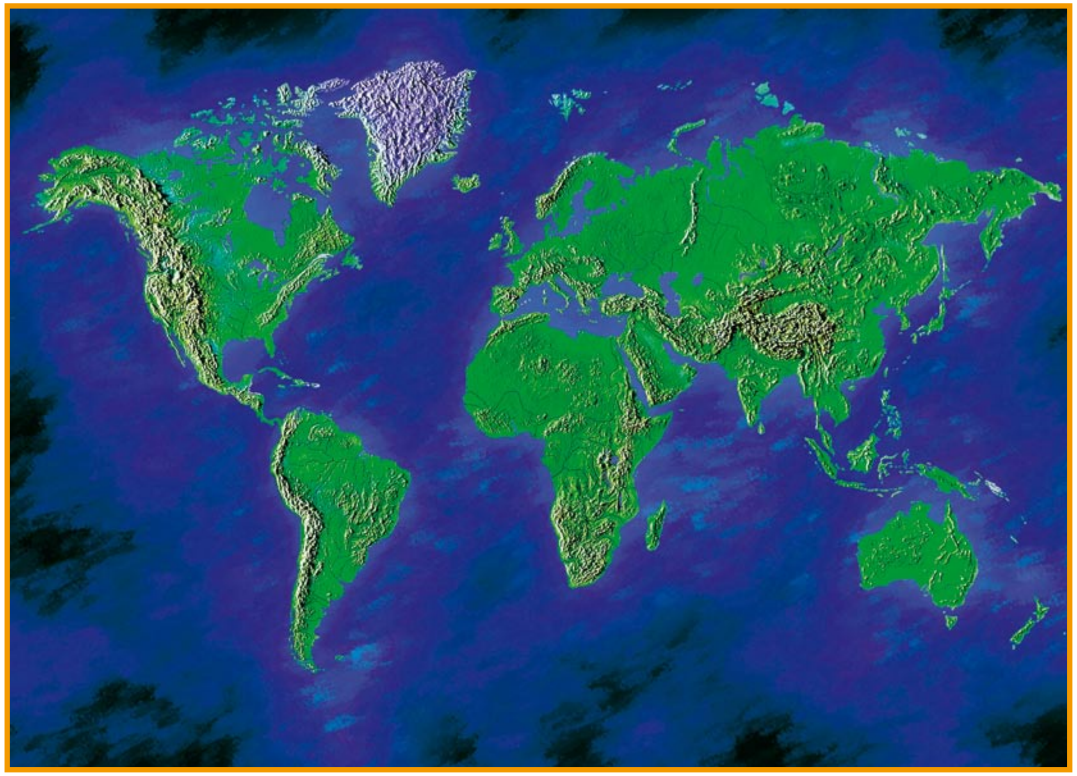
The ambition of the Biobased Raw Materials Platform is to replace 30% of fossil resources in the Dutch energy supply by biobased raw materials by 2030. The Platform is assuming here that energy consumption in 2030 will be equivalent to that in 2000, that is 3000 PJ. Therefore energy savings are critical to this vision. In addition, the Platform is assuming that biomass will primarily have to be imported, as there will be insufficient quantities of biomass available in the Netherlands (residual streams and own production) to achieve the ambitions. The projected year of 2030 has been chosen deliberately. That year is sufficiently distant to allow the opportunities and potential of biobased raw materials to be developed across the whole spectrum, but is also sufficiently close to allow conscious choices to be made now in the transition paths and to initiate the application of biobased raw materials.

The field of biobased raw materials is extraordinarily wide and a considerable number of activities full of potential could be thought up. The Platform has formulated five transition paths in order to introduce some focus. The first two relate to the production of biobased raw materials, the last three to their conversion.

Transition path 1:

Sustainable production and development of biomass

An inventory has been created detailing which biomass should be developed, produced and imported based on the desired end applications (electricity, heat, transport fuels and chemicals). This transition path strives for a considerable contribution from domestic residual streams. In addition, there are prospects in the improvement and optimised production of agricultural crops and harvestable crops cultivated in salt or fresh water (aquatic biomass).



Transition path 2:

Sustainable import chains

There is a considerable potential for profitable biomass production in regions such as southern Africa, Eastern Europe and Latin America. There needs to be a guarantee for the import of these products that this will not be at the expense of food supply, the environment and working conditions in the export countries. Dutch companies could play an important role in areas such as international logistics and trade, certification and commercial service provision.

Photograph and copyright: IdéActive BV, Sittard, NL

Transition path 3:

Co-production of chemicals, transport fuels, electricity and heat

A large number of technologies are available for the conversion of biobased materials, which can be roughly divided into biorefinery (separation of valuable parts of the plant), fermentation (processes regulated by enzymes and live organisms) and thermo-chemical conversion (gasification, pyrolysis, co-firing). The choice of technology will be dependent on the applications of biobased raw materials.

Transition path 4:

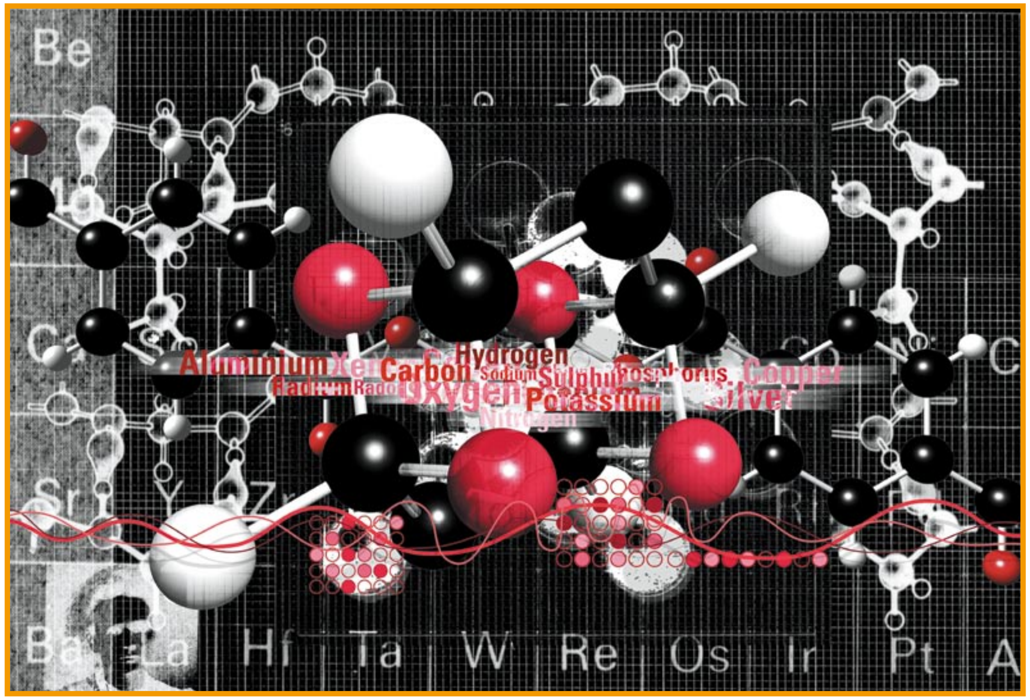
Production of SNG (synthetic natural gas) for the natural gas infrastructure

The heating needs of households may become sustainable by use of SNG (synthetic natural gas) from biomass. In terms of composition SNG differs somewhat from Groningen natural gas, but has the same calorific value, which means that it can be easily consumed within the existing infrastructure. Currently the Netherlands has pole position in the area of SNG through research undertaken by ECN and the involvement of Gasunie. The expectation is that the entire conversion chain of biomass material to SNG could be commercially viable within 10 years.

Transition path 5:

Innovative use of biobased raw materials and increasing the share of sustainable products and processes in the chemical industry

In the Netherlands, the chemical industry is the largest industrial user of fossil resources, using approximately 20% of the total, of which 8% is used for energy and 12% in the form of feedstock. The transfer to biobased raw materials has already been in process for around 10 years, giving the Netherlands a leading role through a strong position in fermentation technology. Unique opportunities are being created for more efficient and more environmentally friendly processes and the development of new, sustainable materials and products using a combination of new chemical building blocks and intelligent biorefinery. Reduction of waste and emissions of hazardous materials are part of these developments.



Structure of this book

The Platform's ambitions are described and detailed in the following chapters.

In Chapter 2 we will provide an overview of the ways in which biobased materials can be used.

In Chapters 3, 4 and 5 we will discuss the sources from which biobased materials can be obtained: residual streams and surpluses, crops, import. There will also be a discussion of the objections often raised against the use of biobased raw materials.

In Chapters 6 and 7 we will discuss the technologies which can convert biomass: technologies for energy production in Chapter 6 and technologies for the production of chemicals and materials in Chapter 7.

Chapter 8 will provide an overview of how widely the use of biobased materials can vary depending on purpose, and concluding provisionally that many options should be left open.

Finally, **in Chapter 9** we will attempt to pull together a lot of the pieces of the puzzle and to formulate a strategy for biobased raw materials.

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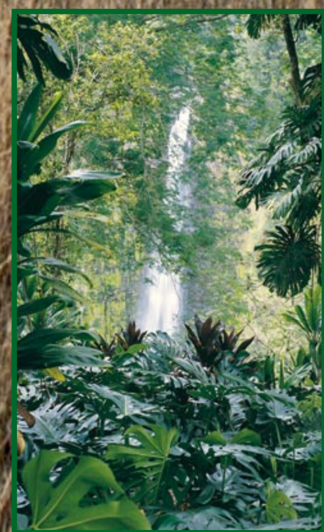
Which biobased raw materials should be used where?

Which biobased raw materials should be used where?



The Biobased Raw Materials Platform has set an ambitious target: to provide 30% of Dutch energy requirements with biobased raw materials by 2030. This will partly be made possible through conditions specific to the Netherlands, with many residual streams of biomass, good import opportunities through large ports and limited opportunities for other forms of sustainable energy, namely hydropower and solar energy.

If the use of biobased raw materials reaches this ambitious level in other countries, then the yield for agriculture will have to be improved on a global scale to avoid competition with food supply as much as possible. To reiterate: energy savings are crucial, as otherwise a too large demand will be placed on valuable resources. We will firstly provide a description of the biomass available in the Netherlands and then the ways in which this can be exploited, in order to explain the Platform's ambitions.

The Platform views four sources of biomass: primary by-products, secondary and tertiary by-products, crops and import. We will firstly consider the types of biomass and their applications. The volumes of biomass will be reviewed in Chapters 3, 4 and 5: is there enough biomass available?

Primary by-products consist of by-products from agriculture and forestry, such as beet leaves, grain straw, verge grass and wood derived from felling and pruning. Owners are often interested in selling products in a responsible and in a preferably financially attractive way. For instance, crop residuals left behind on the land are easily flushed out, leading to eutrophication of surface water. Crop residuals are often ploughed back to improve the soil, but in terms of soil quality this is usually only required in a limited number of cases.

The Reinders sugar beet field in Emmen

Secondary by-products are released through the processing of agricultural products, for instance, steamed potato silage, brewer's grains and beet pulp. ***Tertiary by-products*** are released after use of agricultural products; examples include manure, scrap wood, vegetable, fruit and garden waste (VFG) and meat and meat by-products. These products should be disposed of responsibly. The existing markets for this have been already in movement for the last couple of years. There are prohibitions on the continuing designation of some by-products as feed due to certain feed incidents (BSE, hormones). Animal diseases, such as swine fever and bird flu, have led to the accumulation of by-products, which has led to significant costs. Therefore there is a need for new sales channels; energy generation is one opportunity.

The cultivation of energy crops has limited opportunities in the Netherlands and is only slowly coming to fruition, as it is only profitable with subsidies. The environmental yield is still limited with current crops and technologies. There are initiatives for the use of rapeseed for biodiesel (Groningen, Achterhoek and Limburg), wheat for ethanol production (Zeeland) and corn for fermentation. Changes to subsidy regulations for sugar beets would allow cultivation of these crops to be primarily directed towards energy production.

Another possibility is multifunctional energy cultivation, where cultivation of energy crops is combined with other agricultural functions. The need for alternative sales channels for grass may also arise due to the planned reduction of livestock, rationalisation of commerce and management measures in peat areas, which will lead to more lower quality "managed grass" becoming available. All developments in this area are highly dependent on European agricultural policy.

Import of biomass will have to cover a large part of the requirements for the Netherlands. Studies have demonstrated that there is sufficient potential for this. The main challenge is to create a responsible supply. For instance, considerable discussions have arisen around the use of palm oil for combustion in power stations. Palm oil is produced in countries such as Indonesia and Malaysia on large plantations, often created through the decimation of rain forests. In addition, palm oil is also suitable for human consumption, which may affect food supply in those countries. The main problem is therefore generating a responsible supply and associated price. This is discussed in more detail in Chapter 5.

The next question is where, and in which sectors, biobased raw materials will be applied. The Platform has drawn a distinction between four significant applications of fossil resources in order to answer this question: transport fuels, heat, electricity, and chemicals and materials. A potential contribution of biobased materials has been formulated for 2030 for each application:

- ***60% replacement of transport fuels***
- ***25% replacement in the production of chemicals and materials***
- ***17% replacement in heat use***
- ***25% replacement in electricity use***

We will consider the structure of Dutch energy housekeeping in further detail in order to explore the role biobased raw materials could play in these sectors.

We will use a study carried out by the Energieonderzoek Centrum Nederland (ECN, Energy Research Centre of the Netherlands) and Wageningen University and Research Centre (WUR) on behalf of the Platform: L.P.L.M. Rabou and E.P. Deurwaarder (ECN), H.W. Elbersen and E.L. Scott (WUR), “Biomass in the Dutch Energy Infrastructure in 2030”, (referenced as ECN/WUR).

The Dutch energy housekeeping

In 2000, 3065 PJ were used in the Netherlands, distributed across sectors as demonstrated in Figure 1.

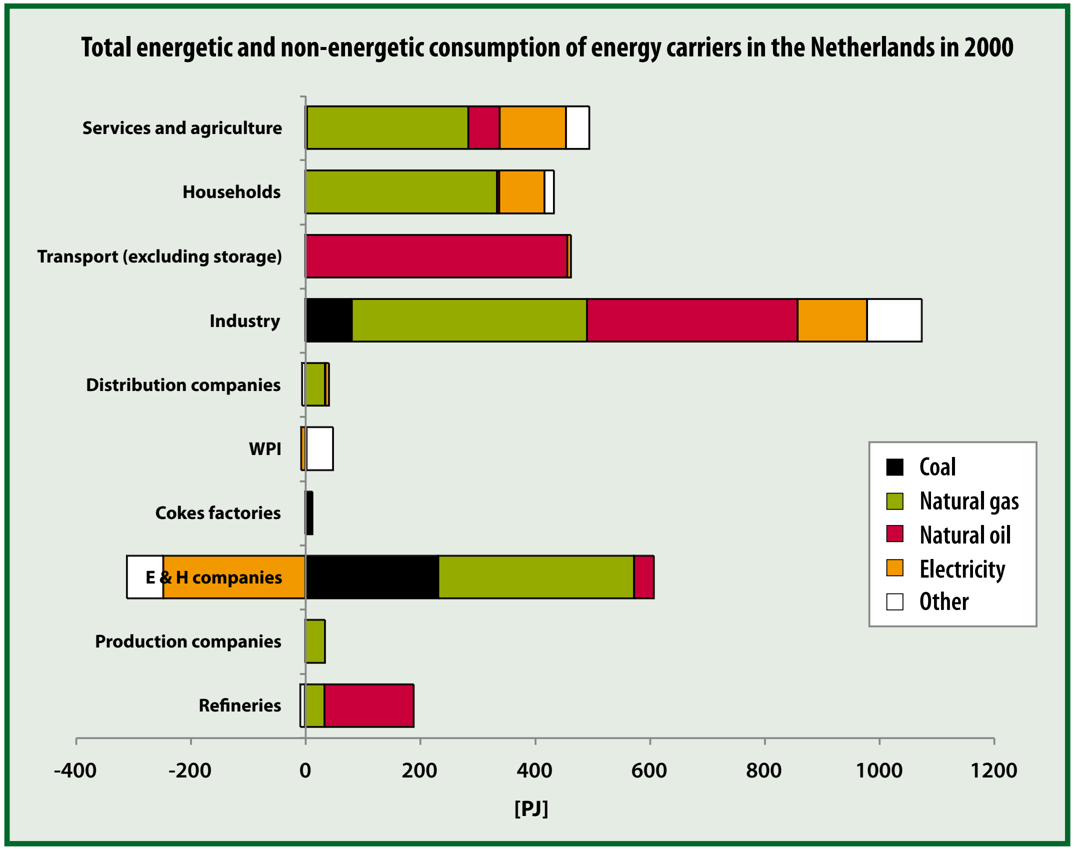


Figure 1. Energy consumption in the Netherlands by sector, 2000 (source: Biomass in the Dutch Energy Infrastructure in 2030, ECN/WUR, 2006)

Another way of expressing these results is in the form of pie charts: see Figure 2.

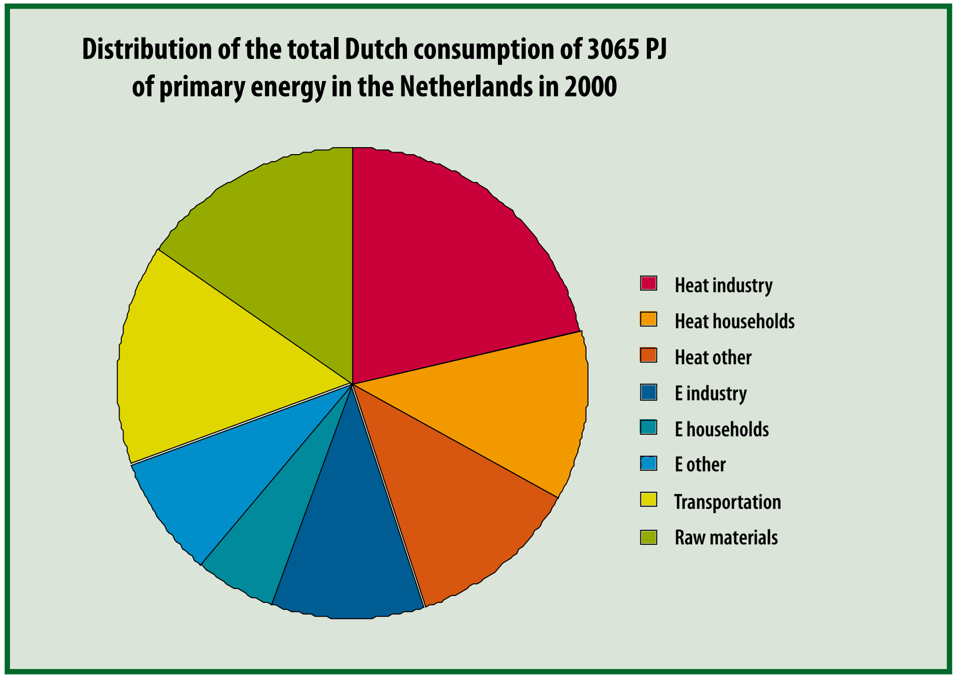


Figure 2. Energy consumption in the Netherlands by application and users, 2000 (source: Biomass in the Dutch Energy Infrastructure in 2030, ECN/WUR, 2006)

Energy statistics is a complicated field, as many decisions have to be taken about the designations of various usages. For instance: should conversion losses in electricity production be calculated within energy consumption by the power stations or transferred across to electricity consumers? And what should happen when these conversion losses are used efficiently in the form of heat in industry or for heating a city? Should conversion losses in refineries be recorded as industrial energy consumption or transferred across to the users of petrol and diesel?

There has to be a continuous attention to detail in the statistics when recording the energy effects of various measures. For instance, it is quite possible to replace fish oil, a raw material for the feed and silage industry, with oils from cultivating algae. This would mean that less fish has to be caught. Should the savings in diesel oil from the fishing boats be recorded as a "benefit" of this measure? And if amino acids, such as lysine, are isolated from plant material, should the prevention in energy use from the synthesis of natural oil be recorded as an energy benefit? Benefits like this have not included in calculations for the savings as represented in this book.

The Netherlands has a very large sector of energy intensive industries, such as refineries, heavy chemicals producers and artificial fertiliser factories in comparison with other countries. Production in these sectors is considerably greater than use in the Netherlands, and an important share of these products is exported. Therefore, the assessments of the Netherlands are not particularly applicable to other countries. The distribution of energy consumption across industrial sectors in the Netherlands is represented in Figure 3.

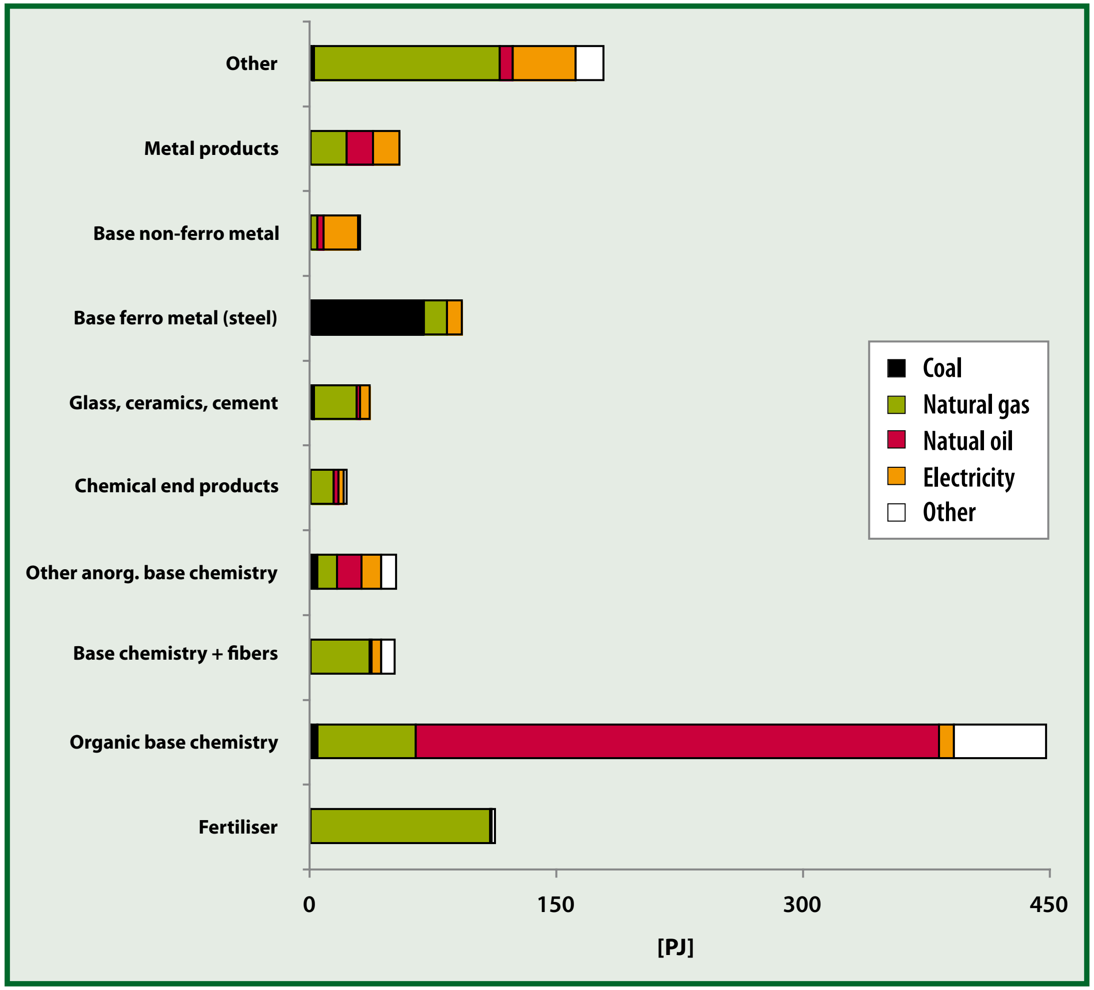


Figure 3. Energy consumption in the Dutch industry, 2000 (source: Biomass in the Dutch Energy Infrastructure in 2030, ECN/WUR, 2006)

Furthermore, the fact that part of fossil resources, particularly natural oil and gas, is used as feedstock should also be taken into consideration. Natural gas is for instance used as a feedstock for the production of artificial fertiliser, since hydrogen is generated from natural gas, which is subsequently bound with nitrogen to form ammonia, which is the basis for nitrogen-based artificial fertiliser. We have summarised the use of fossil resources as feedstock in Figure 4.

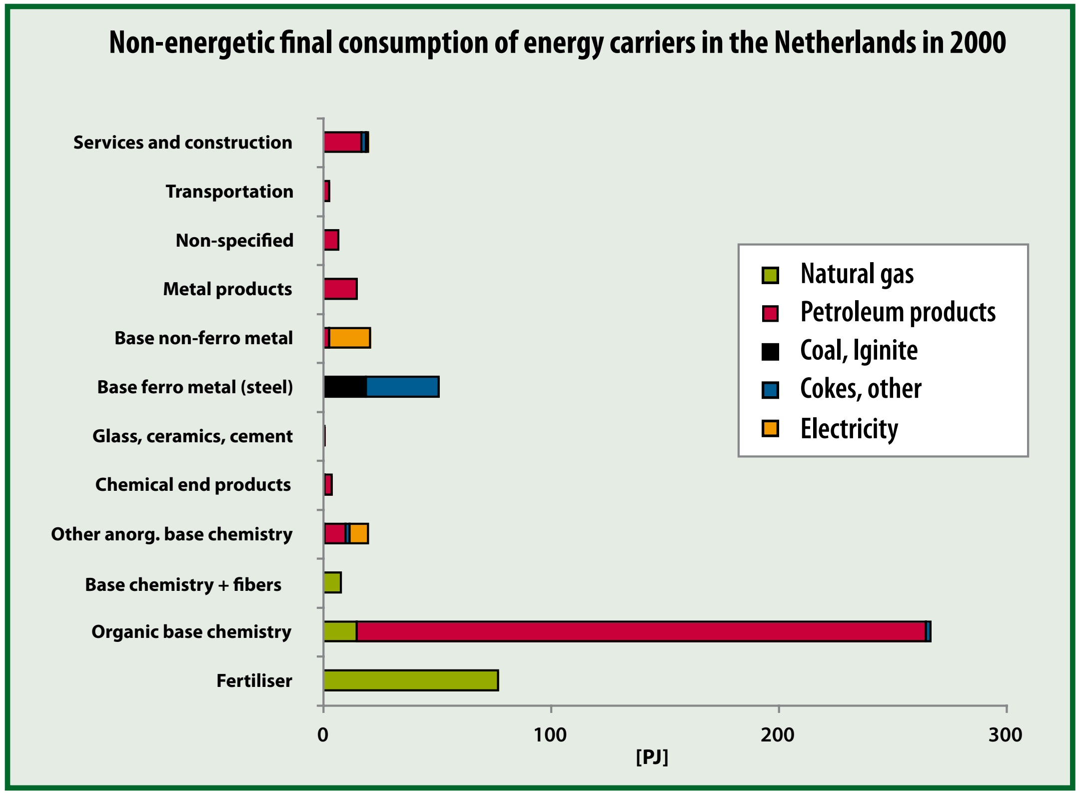


Figure 4. Non-energetic final consumption of energy carriers in the Netherlands, 2000 (source: Biomass in the Dutch Energy Infrastructure in 2030, ECN/WUR, 2006)

The Netherlands in 2030

The question is: what will the expected energy consumption look like in these sectors in 2030? The assumption for this study has been that the total energy consumption in the Netherlands in 2030 will be at the same level as 2000, that is: approx. 3000 PJ. Considerable efforts will only be required for the stabilisation of energy consumption, given that this has been rising in the Netherlands by 2 to 3% per year for a long period of time. In 2005 energy consumption was higher again than in 2000, namely approx. 3200 PJ. However, autonomous developments may start to lend a helping hand here, as 2005 was also the first year after the Second World War in which energy consumption reduced slightly.

Given the state of technology, reasonable predictions can be made about the way in which energy consumption will develop per sector. Taken together this will provide an image of Dutch energy supplies in 2030.

Households. The population is increasing and the number of houses is increasing even more rapidly, however, in contrast to this, houses will be better isolated. Heat will be supplied via solar panels and heat pumps. Electricity consumption will increase, but this will be broadly compensated through reductions in the use of natural gas for heating.

Services. The same developments as for households, however, the reduction in use of natural gas consumption for heating will be even greater. Electricity consumption will also increase slightly here.

Agriculture and horticulture. Greenhouse farming is the greatest energy consumer. Despite increases in acreage, heat use will also reduce here while electricity consumption will increase slightly.

Transport. Despite cleaner cars it is anticipated that consumption of transport fuels will increase. Railways will use more electricity through the use of new lines and higher speeds.

Refineries. Predictions to 2030 are difficult. We are assuming that capacity will not increase rapidly, whereby individual consumption will remain largely static.

Industry. This is very dependent of the development of the world economy and the extent to which production will move across to low-wage countries. The assumption here is that growth will still take place, however, that this will scarcely lead to a greater demand for energy, particularly through energy savings for heat production.

Electricity and heat production. The increasing demand for electricity leads to an increasing demand for fuel for power stations, even where there is a significant building programme for wind energy at sea. There will be an increase in heat provided through co-generation in industry, agriculture and services.

This will lead to changes in energy consumption per sector. The expected distribution for 2030 is displayed on pie charts in Figure 5.

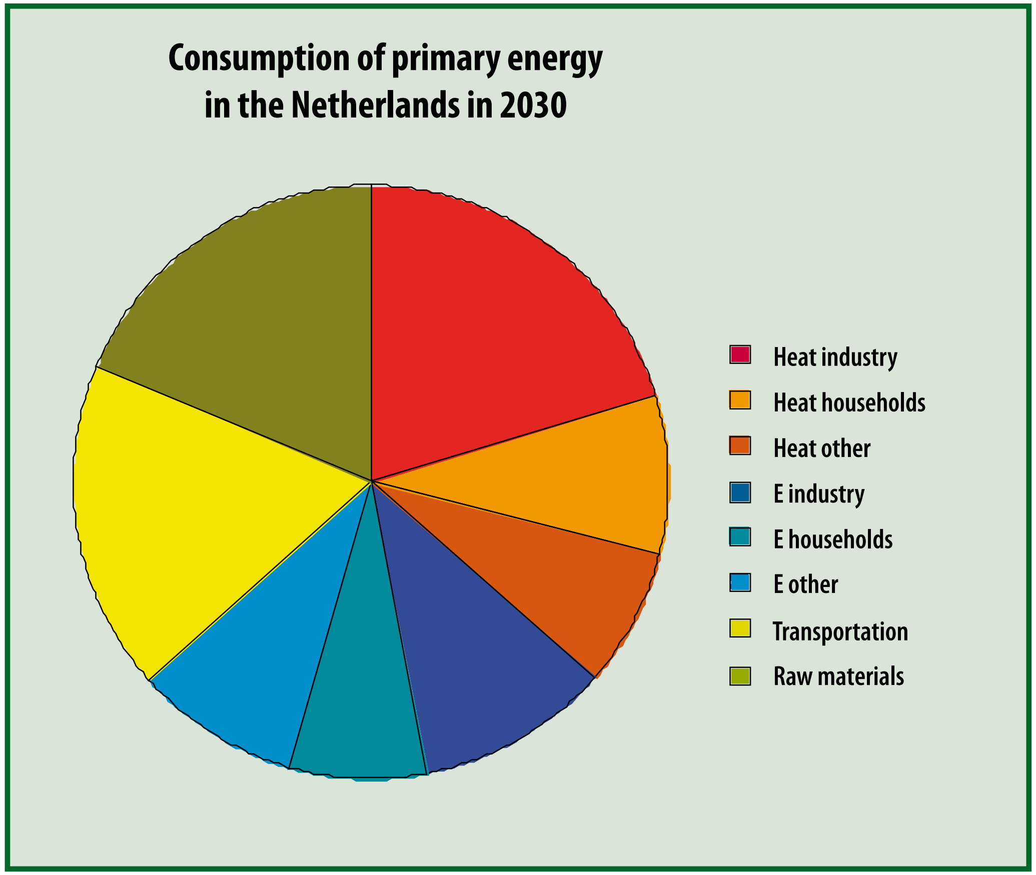


Figure 5. Expected primary energy consumption in the Netherlands by sector, 2030
(source: Biomass in the Dutch Energy Infrastructure in 2030, ECN/WUR, 2006)

The contribution of biomass

How will the multiple forms of biomass contribute to the four applications in 2030 namely: heat, electricity, transport fuels and chemicals/materials? (The various technologies for converting biomass will be discussed in further detail in Chapters 6 and 7).

Heat. Biomass can be converted directly into heat through combustion. In practice there will often be objections to this due to the emissions of small particles and acid gases, particularly at small-scale installations. Therefore the conversion of biomass into methane is a more attractive option through fermentation (small-scale) or gasification (large-scale). Gasification is a suitable technology for the production of synthetic natural gas (SNG) on a large scale (yield approx. 70%), which can be distributed via the natural gas infrastructure.

Electricity. Dry biomass is currently also being co-fired in coal power stations for electricity production. The share of biomass is restricted to 20% for environmental reasons, but this could perhaps be increased to 30%. Specific power stations for combustion of biomass could be an alternative.

The considerable quantity of wind capacity to the net should be taken into consideration in the electricity supply in 2030, although production is dependent on weather conditions. This requires that the remaining capacity is properly regulated. The existing coal power stations, where biomass is being co-fired in the form of wood pellets, are not suitable for this purpose.

This requirement for regulation does exist in natural gas power stations, where liquid fuels from biomass can also be used. At this moment in time pure plant oils are being used for this, but in the future these may be replaced by pyrolysis oil. Plans for flexible power stations also exist, where coal and biomass can be converted into electricity, SNG and heat through gasification, according to requirements.

Transport. The expectation is that many cars will still be powered on diesel and petrol by 2030. Both car fuels can be replaced to a large extent by biological products. ***Biodiesel*** is created from plant oils such as rapeseed oil, but pure plant oils can be adapted for use in engines as well. In the future, as the demand for biodiesel increases, this will also be created synthetically via the Fischer-Tropsch process.

Bio-ethanol through fermentation of sugar beet, amongst other things, is used in the mixture for petrol. At the moment, ethanol can only be used in limited quantities with existing cars along with petrol, but once engines are adapted (as has happened on a large scale in Brazil) ethanol levels can rise to 85%.

The use of biodiesel and bio-ethanol is being strongly encouraged by bio-fuel guidelines from the EU, which have set a target of 5.75% for transport fuels from biological sources by 2010.

** The Biobased Raw Materials Platform will conduct a further study towards the end of 2008 to provide a supplementary report about its ambitions concerning the proportion of biobased raw materials in transport fuels by 2030.*

The European Commission proposal was for an 8% contribution in 2020, however, research by the Commission revealed that 10% (EU target for biofuel addition in 2020*) is achievable. A limiting factor to this is the relative inflexibility of existing refineries. These produce petrol and diesel in a fixed ratio, which means that for each alternative for diesel there has to be a corresponding percentage replacement of petrol. Additionally, refineries also produce many products for the chemical industry, meaning that biological alternatives will have to be developed for these materials as well. All in all, the transport sector offers good prospects for large-scale biomass use.

Chemicals/materials. In principle, there are a great number of opportunities available to replace the use of fossil resources in the production of chemicals and materials with biobased resources, however, a great deal of these processes are still in the research stage and many promising ideas are still on the drawing board.

One direct application is the replacement of coal by charcoal in steel production; it appears that 50% replacement is technically possible. Heavy chemicals in the organic chemical industry are primarily produced from natural oil, such as olefins (ethylene, propylene, butadiene) and aromatics (benzene, toluene, ethylbenzene, xylenes). However, the development of biobased raw materials as the basis for the chemical industry may lead to the discovery of very different heavy chemicals. This will be explored in Chapter 7.

There are in principle four routes where suitable raw materials may be extracted from biomass:

1. Small-scale biomass (pre-)conversion near the source (land). Biomass becomes available in numerous locations in various quantities and with differing compositions. There are large advantages in local processing to an intermediary product that is more easily transportable and has a longer shelf-life in combination with the return of the fractions required back to the land.

2. Improvements in use of existing residual streams from the agro-food industry through biorefinery and further conversion.

3. Co-production of fuels and chemicals alongside electricity (and heat) in large-scale co-gasification installations for coal and biomass.

4. The production of the so-called second generation of transport fuels and other products from lignocellulose and agrarian residuals through fermentation and thermochemical conversion.

The conclusion of this overview per end application is that the adaptation of biobased raw materials is certainly possible within the energy supply in the Netherlands. It is only in electricity production and transport where these ambitious targets might meet problems due to the potential limited availability of raw materials and inertia in the existing infrastructure.

Priorities

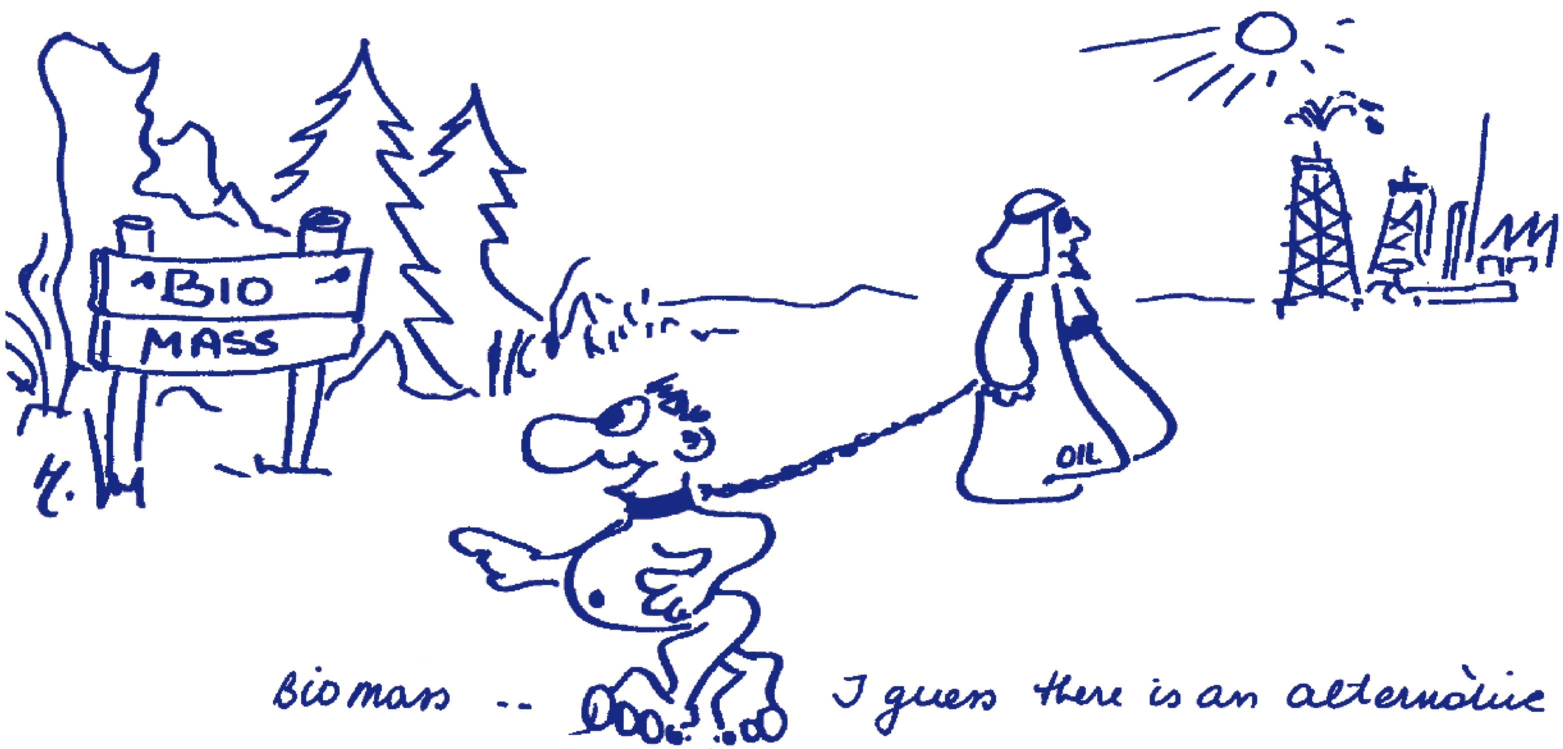
Priorities will need to be set either sooner or later for the development of biobased raw materials. Should oils and residual fats, such as frying fat and offal, be used for electricity production, which will primarily conserve natural gas, or would these be better used as raw materials for biodiesel, which will lead to savings in natural oil? Should agricultural residues be fermented to methane for small-scale use in co-generation units or collected centrally for gasification and conversion to biodiesel? Should there be a primary emphasis on energy production or refining and processing to heavy chemicals? Should the priority be on CO_2 emissions or on producing as much added value as possible?

The Platform is of the opinion that the first priority should be on replacing natural oil. It is scarcer than natural gas (and definitely scarcer than coal) and the market for natural oil is tighter. For the Platform, the replacement of natural oil has priority over the replacement of natural gas and coal. This priority is strengthened further by the consideration that coal is used on a large scale, in particular in electricity power stations, where eventually thorough CO_2 capture will be possible, while natural oil products are distributed widely and capture of CO_2 is not possible.
Therefore, it is certain that in the initial phase a lot of focus will have to be directed at the production of transport fuels and chemicals from biobased raw materials.

Residual fats and oils should therefore be processed to biofuel and not be used in electricity power stations. It is preferable that the remaining residuals and by-products are converted to pyrolysis oil.

A second priority arises from economic considerations. There are large differences in terms of yield between the four sectors where fossil resources could be replaced by biomass. Use of raw materials for heat production provides the lowest yield, currently approx. € 3/GJ; electricity production delivers € 6/GJ, transport fuels € 8/GJ, and for the production of bulk chemicals raw materials have an average value of € 30/GJ. From an economic perspective it therefore also makes sense to utilise the various biomass streams in the sector providing the highest yield.
Once again the production of chemicals and transport fuels heads the priority list, followed by electricity production, while heat production is the application for residual streams which cannot be utilised elsewhere.

The last priority follows from the need to prevent competition with food supply. The following years, transport fuels will be primarily produced from biomass from food crops, such as rapeseed, corn and wheat, and competition with food will be fierce if there is a massive transfer. It will be possible to convert lignocellulose, which is not suitable for food, into transport fuels using second generation technologies (Fischer-Tropsch process and fermentation, detailed in Chapter 6). It is therefore extremely important that these technologies are developed for large-scale applications of biobased raw materials.



Creative Energy

Energy Transition

Potential, residuals and surplusses

Potential, residuals and surpluses

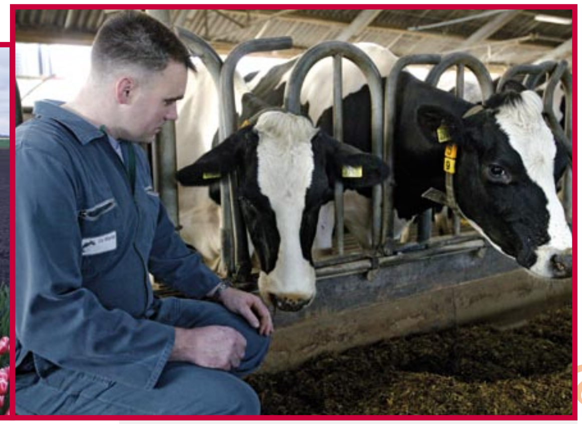
Many people are sceptical when hearing for the first time of the potential large role that biobased raw materials may play in energy supply and ask themselves whether this will happen at the expense of food supply and the environment. This concern is justified, however, under favourable conditions it is possible that abuses will only arise incidentally. One condition of the large-scale use of biobased raw materials is that global agricultural efficiency increases. Furthermore, proper organisation and supervision of delivery of agreements are essential ingredients for a responsible use of biomass.

The potential of biomass

Half of the world's population is entirely dependent on biomass for its energy supply. Biomass contributes to 10% of the global energy supply and it is an attractive proposition, even in the Netherlands. The standard of living enjoyed in the Netherlands is high, and energy intensive industries and little surface area are unfavourable conditions for a large domestic share of biobased raw materials. Researchers from WUR and ECN estimate that in the Netherlands biobased raw materials generated ***domestically*** would provide a tenth of the energy supply without specific cultivation of energy crops, therefore making exclusive use of residual materials, such as felled wood, VFG, residues from agriculture and forestry, manure, etc, The Biobased Raw Materials Platform is aiming for a systematic use of these residual materials by 2030, whereby a third of these targets have already been achieved.

Even higher figures appear when we compare the global potential of biobased raw materials with the global energy demand. The last figure currently amounts to approx. 400 EJ, which will probably stabilise at approx. 1000 EJ in thirty years time, along with a growing world population, an increasing standard of living and a much greater efficiency in energy supply. The stream of residual materials from agriculture and forestry across the globe represents an energy value of 100 EJ.



Experimental farm de Marke in Hengelo, Gelderland

Another 100 EJ may be obtained from the cultivation of energy crops on land which is (or has become) unsuitable for agriculture: marginal and fallow land, saline and arid areas, and eroded land where reafforestation could be the first step towards cultivation. We have not yet included futuristic concepts such as the cultivation of seaweed at sea. Finally, if agricultural efficiency increases, lands may be released which are not required for food production, which will provide another 200 EJ of biobased raw materials by the middle of this century. All of the figures described here are "mean estimates": pessimistic researchers have produced much lower estimates, whereas figures are a lot higher for the optimists.

This can also be expressed as follows: The Platform has calculated which additional area would be necessary if 30% of the energy supply in the Netherlands is from biobased raw materials, assuming a given improvement in agricultural efficiency. The Platform estimates this to be 3.5 million hectares, while the Netherlands only consists of 3.3 million hectares.

The Netherlands will therefore have to make use of foreign agricultural land. It should also not be forgotten that the Netherlands is a densely populated country, which has always relied to a certain extent on the import of food and raw materials for food on foreign production land. What would happen if the Dutch standard of living and use of biobased material were to be found world-wide? Approximately 0.3% of the world's population resides in the Netherlands. If the entire world population were to require the same amount of land for the production of biobased raw materials we estimate that this would amount to a billion hectares, or 7% of the total surface area of our planet – an extremely high, but not impossible claim on land use.

Therefore biobased raw materials provide a significant potential on a macro-economic scale. Would this potential also be possible in practice? In order to investigate this, we looked at the biomass sources in succession: residuals streams, crops (both within the Netherlands) and import. This will include not only the opportunities, but also the risks associated with the use of biomass.

"Calculations concerning the potential of biobased raw materials continuously use assumptions that are too conservative. There is no consideration of the rapid improvements produced by biotechnology. Incremental improvements to crops using biotechnology have alone lead to annual increases of 2% in agricultural yields. For instance, the corn yield per hectare has increased enormously through the right choice of cultivation. We have succeeded in reducing communication between plants significantly. Therefore plants can now be planted much closer together. And that 2% per year excludes breakthroughs that are taking place as well."

Johan Vanhemelrijck, member of the Biobased Raw Materials Platform

Residual streams

In the Netherlands, biomass streams are primarily released from domestic production processes: cultivation of plants and trees. The maximum yield for sustainable use of the Dutch soil (in other words, without the degradation of agricultural land) has been estimated by the researchers at ECN and WUR at 527 PJ in energy terms; this excludes cultivation at sea. This figure is equivalent to 17% of the energy use in the Netherlands in 2000 and consists of all biomass production, therefore including food production as well.

However, in the Netherlands biomass is not just retrieved from Dutch soil, but also imported and exported on a large scale. In 2000 the Netherlands imported 52 million tonnes of biomass, while 43 million tonnes were exported (based on “dry mass”). The following are taken to be biomass: all organic materials, therefore products such as paper, flour, plant oils and seeds and grains containing oils, as well as fruit, meat, fish and livestock. The most important import and export streams are displayed in Figure 6. All biomass has been expressed in terms of energetic value (PJ) in order to allow comparison with previous results.

The statistics demonstrated that for 2000 import figures exceeded export by 9 million tonnes or 215 PJ. There are two categories which are prominent in the import balance: wood and pulp (for building and paper manufacture), and foodstuffs, such as “grains” and “seeds containing oil” (raw materials for silage and the bio-industry, amongst others). In contrast to this there are export surpluses for plants and livestock, meat, fish and dairy produce, and products

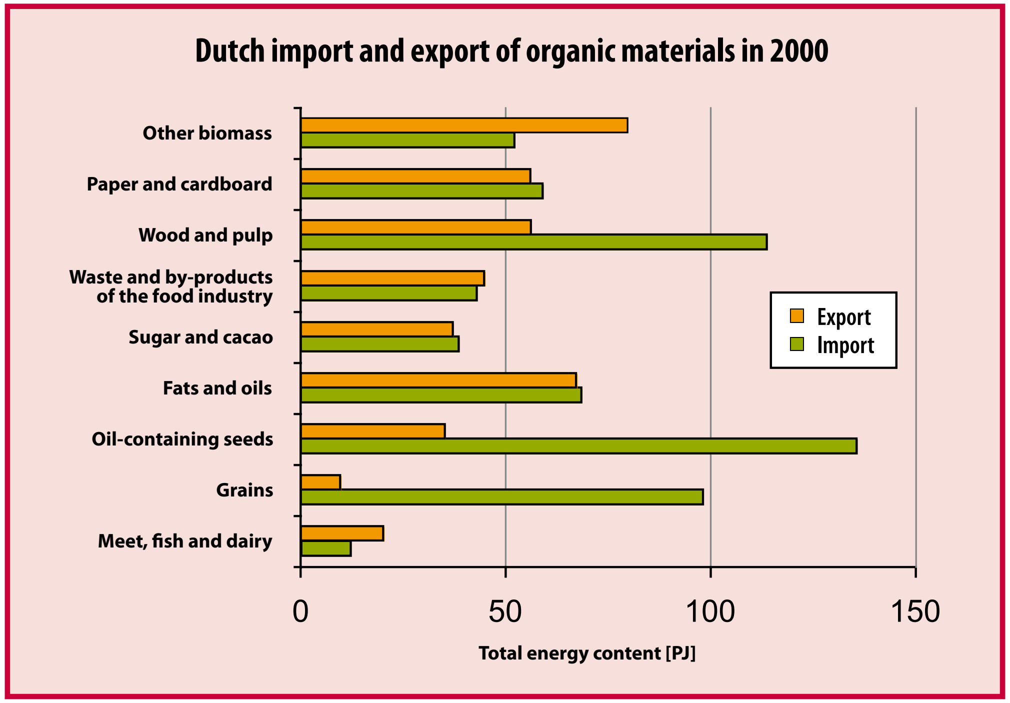


Figure 6. Import and export of organic materials (biomass) in the Netherlands 2000 (source: Biomass in the Dutch Energy Infrastructure in 2030, ECN/WUR, 2006)

from the flour industry. Therefore, a significant proportion of imported biomass is converted into more valuable products in the Netherlands.

Domestic applications of biomass start with the collation of residual streams. The Netherlands, partly because of the import surplus, has the largest use of biomass in the world, calculated per hectare. This use amounts annually to 42 million tonnes, of which 21 million is derived from import of food, silage and agricultural residues, 10 million from grass production, 7 million from farming and horticulture and 5 million from import and domestic production of wood and paper.

This amounts to a flux of 13 tonnes per hectare per year on 3.3 million hectares. In comparison with this, the figures for France and Germany are 5 tonnes, USA 2.5 tonnes and the global average 1.5 tonnes.

Residual stream is a euphemism for waste and this immediately leads to a problem, as there are stringent rules for protecting human health and the environment for processing of waste. However, there is an urgent need for markets to be developed to process biomass in order to use biobased raw materials. This will have an impact, for instance, on the export of waste. European legislation plays an important role here, and the experience with European collaboration in this field has not been good up to now.

Markets already exist for tertiary streams, such as frying fat and offal. These will create approx. 10 PJ of transport fuels annually in the Netherlands. Once this processing is in place, hay could also be offered for this purpose, providing a yield of another 2 PJ per year.

VFG (vegetable, fruit and garden waste) are collected separately in many districts. In 2002, 1.4 million VFG was collected, or 88 kilograms per person per year. However, this is only 52% of the total quantity of household VFG; another 1.3 million became residual waste. If the separately collected VFG fraction were to be used for energy production, for instance through fermentation, this would provide an annual yield of 9 PJ.

Manure constitutes a very large residual stream. From 1 January 2006, new regulations are applicable in the Netherlands regarding manure, which are intended to encourage processing of manure at so-called co-fermentation plants (installations which process both manure and plant waste). In 2006 there were tens of these fermentation plants and about one hundred of initiatives in the Netherlands. These fermentation plants have been encouraged through an MEP (Electricity Generation for Environmental Quality) subsidy from the government until the end of 2006, when these subsidies were largely stopped. In Germany the situation is better, where the government has provided its full support for sustainable energy, which is not only expressed in a greater proportion of wind energy, but also in many more fermentation plants: currently there are already around 1000.

The primary by-products will also be offered on the market, depending on the processing capacities developed.

This involves products such as beet leaves and verge grass, which are often left on the land and thereby cause problems with nitrates washing out into the surface water. In the Netherlands an annual average of 3.5 tonnes of biomass material is produced per hectare in forests and the countryside, but this produce is not used extensively. The removal of wood from forests in the Netherlands only contributes to half of the annual new tree growth.

Straw from grains is only partially collected for sale in bales and is also left behind to be ploughed back in the land. However, not all straw is required for carbon contributions and manure.

New sales opportunities are also of interest to farmers.

For instance, green fertiliser crops, such as radish, are an attractive source of biomass material. These crops are sowed later in the season after the main crop, such as wheat. They bind to nitrogen and therefore, once ploughed back in, function as nitrogen fertilisers. However, they may also be harvested and fermented (with energy production), after which the nitrogen contribution may also be used as a digestate (residue from fermentation).

The Platform employs the following inventory for the expected biomass supply in the Netherlands in 2010.				
No.	**Type of Biomass**	**Supply in the Netherlands [ktonnes/year]**	**Energy contents [GJ/tonnes]**	**Energy contents [PJ/year]**
1a	Fresh residue wood, wood blocks	500	10,2	5,1
1b	Fresh residue wood, shredded	540	10,2	5,5
2	Energy crops	2	2	-
3a	Clean residue wood (sawdust/curls)	270	15,6	4,2
3b	Wood pellets	100	17,5	1,8
3c	Clean residue wood, wood cuttings	250	15,6	3,9
4	Separate collected wood of type A quality	500	15,4	7,7
5	Separate collected wood of type B quality	700	15,4	10,8
6	Separate collected wood of type C quality	50	15,4	0,8
7	Grains	-	17	-
8	Grain straw	-	13,3	-
9	Verge grass	450	5,3	2,4
10	Grass hay	140	12,7	1,8
11	Hemp, flax	5	11,3	-
12	Energy crop (Miscanthus)	0,5	13,2	-
13	Vegetable oil	4	38	-
14	Straw	15	13,6	-
15a	Peals	100	16,5	1,7
15b	Oil seed residues	100	15	1,5
16a	Discarded frying oil	60	38	2,3
16b	Residues from oil hardening/hydrogenation	12	10	-
16c	Fatty acids	60	38	2,3
16d	Residue greases	-	30	-

The Platform employs the following inventory for the expected biomass supply in the Netherlands in 2010.				
No.	**Type of Biomass**	**Supply in the Netherlands [ktonnes/year]**	**Energy contents [GJ/tonnes]**	**Energy contents [PJ/year]**
16e	Dry food processing residues	100	18	1,8
16f	Bone meal	50	22	1,1
17	Swill	215	-	-
18	VFG / organic household waste	2.280	3,4	7,8
19	Waste	6.800	9	27,5
20	Used paper and cardboard	-	-	-
21	Textile	-	-	-
22	Shredded waste	-	-	-
23	Municipal wastes	-	-	-
24	Chicken manure	1.000	6,6	6,6
25	Cow and pig manure	15.000	-	-
26	Silt from Sewage Treatment Plants	1.400	1,5	2,1
27	Compost fraction	50	10,2	0,5
28	Assorted wood from waste streams	500	15,4	7,7
29	Paper sludge	1.000	1,6	1,6
30	Paper/plastic pellets (SRF)	1.400	18	18,9
Total		**34 Mtonnes**		**132,3**
Primary by-product (directly from the field)				**4,2**
Secundary and tertiary (by-product or waste)				**126,3**
Crops				**-**
Import				**1,8**

Table 1. Expected supply of biomass in 2010 (after Koppejan 2005, adjusted by Rabou et al (source: Biomass in the Dutch Energy Infrastructure in 2030, ECN/WUR, 2006))

The situation in 2030 will be different again from now. The residual streams will be greater due to increasing agricultural productivity and industrial growth. In addition, technologies will also be available to convert the difficult to use waste, for instance, cattle and pig manure; these have not been included in the energy production in Table 1. The Platform estimates that in 2030, 100 PJ will be available for use from primary residual streams and another 200 PJ from secondary and tertiary residual streams.

Further developments of residual streams

Many interesting developments could be initiated after 2010 with the residual streams described here. The Platform has provided various examples.

The food & drinks industry annually produces large quantities of residual products. An important part of this becomes silage. However, there are by-products which are less suitable for this, estimated by the Platform to be 5.5 million tonnes per year corresponding to an energy content of 44 PJ. However, the technologies required to convert these residual streams into chemicals and transport fuels are still in development (see Chapters 6 and 7).

Another development concerns the optimisation of the roughage chains. These are focused on better use of grass. Avébé has already developed a technology for biorefinery of grass, which can be adapted for this. This involves grass being converted into silage, as well as into raw materials for chemicals, electricity and transport fuels. The economy of the refinery technology will determine whether biorefinery like this can be applied commercially. If half of the current grass land acreage were to be cultivated for this purpose, then the estimated yield would be 7.5 million tonnes, of which 2.5 million tonnes would be used for silage (sufficient for the expected levels of livestock in 2030) and 5 million tonnes would be available for non-food.

A stall at the dairy farm Zijlstra in Hallum, Friesland

Proteins, where not used in silage, could be used in the chemical industry. Fibres could be used for electricity production. Sugars and organic acids can be used as a source of valuable chemicals. And minerals could be used as fertiliser. The yield for this route is estimated by the Platform to be 65 PJ per year.

Large quantities of imported rapeseed and wheat are expected in European harbours, particularly in Rotterdam, as a result of EU guidelines on car fuels. Ethanol can be produced from wheat starch with existing technologies. The remaining proteins can be used in silage. Biodiesel can be produced from rapeseed oil, the residual product glycerol can be used as the basis for various chemicals.

A protein fraction also remains from this process. The final stage results in a large cellulose fraction which can be used for the production of electricity and heat, until more intelligent technologies become available.

A final example: household waste can currently be used in various ways. A significant amount of household waste is currently being used for electricity production, as this is more hygienic than sorting into plastic, glass, paper, wood, metals, etc. However, household waste can be pre-treated at 160 °C and separated more easily and hygienically. Plastic, metal and biomass can be separated particularly easily. Biomass can for instance be used for fermentation (biogas). The plastic fraction can be utilised as raw material for diesel oil, a technology which is currently only available on a small scale. This treatment of household waste delivers much more energy than direct incineration, where yields do not exceed 25%. The reason for this is that the waste gases contain corrosive HCl. Waste gases have to be purified at a lower temperature, which has a significant impact on the yield.

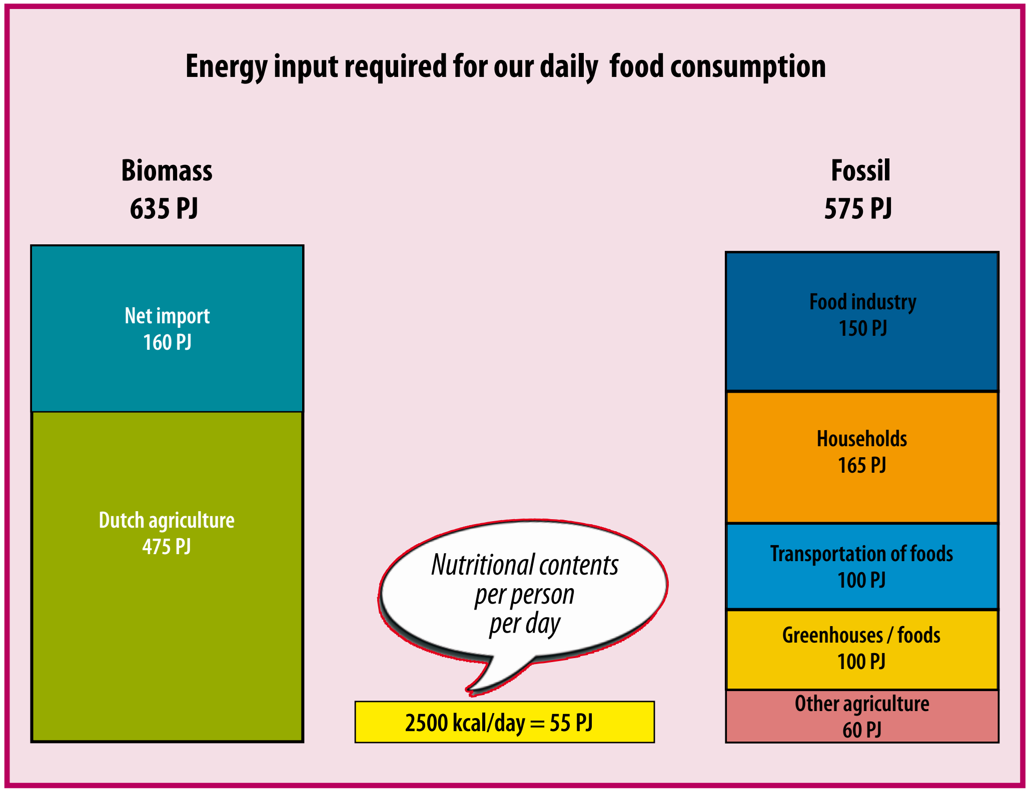


Figure 7. Energy input required for daily food consumption in the Netherlands (source: Sustainable production and development of biomass, both in the Netherlands as well as abroad; final report study group transition path 1 of the Biobased Raw Materials Platform, 2006)

Creative Energy

Energy Transition

Cultivation

Cultivation

The notion that new domestic sources of biomass will be provided by cultivation of energy crops fits within the ambitions of the Biobased Raw Materials Platform. We distinguish between two opportunities for these crops: dry cultivation on existing agricultural land or grasslands, and wet cultivation on land outside of dykes, at sea or in specially created basins.

Cultivation on existing agricultural land

Cultivation of energy crops on existing farmland and pastures will not necessarily be at the expense of food production. It is possible to cultivate crops for more than one purpose through choice of cultivation and improvements in agricultural technologies: for both food production as well as energy and chemicals production. This means that cultivation of biobased raw materials does not replace food production, but is in addition to it. A number of crops appear to lend themselves very well for combined crops like this. We will express yields in terms of energy in order to describe the potential of this concept. This will facilitate a comparison between different opportunities.

Sugar beet belongs to one the domestic crops with currently the highest yield per hectare. Following extraction of sugars and fermentation sugar beets deliver 123 GJ per hectare, which leaves a net amount of 66 GJ/ha once 57 GJ/ha (input) has been deducted. In addition to this sugar beets also produce a significant yield of primary and secondary residual materials (beet heads and leaves, respectively pulp). The added yield after fermentation amounts to 91 GJ/ha in the form of biogas.

The same applies for potatoes to a lesser extent. The net yield for potatoes is 61 GJ/ha. The potato plant has considerably fewer leaves. Fermentation of this and the residual pulp remaining after starch and protein have been extracted provides an additional 12 GJ/ha.

Photograph and copyright: Webletters, Anna Groot

Rapeseed produces a considerably lower yield. A crop yield of 3.3 tonnes/hectare has a net energy yield from the biodiesel generated by the rapeseed of 15 GJ/hectare, partly due to the high energy demand in the production of biodiesel (14 GJ/tonnes). Fermentation of straw and pulp may increase the energy yield to 57 GJ/hectare. Therefore, in respect of energy efficiency, the production of biodiesel from rapeseed is currently not a very attractive process. If plant oil could be used in diesel motors, the yield from rapeseed crops would provide a more attractive option in energy terms, as savings could then be made to the process energy for biodiesel production.

Grasses (including grains) provide a very interesting raw material: Grass consists of 30% fibres, 20% proteins, 10% minerals, and in addition a large number of interesting building blocks, such as polysaccharides, mono- and disaccharides and organic acids. We also include wheat, corn, barley, oats, etc. as grasses.

A crop yield of 14 tonnes of grass (dry matter) per hectare provides an average net energy yield of approx. 125 GJ/hectare. The yield of corn is potentially even higher in the presence of sufficient water. New types of grass, such as switchgrass and miscanthus, can also be considered as energy crops. These have very high yields, however, trial projects will need to be conducted for cultivation methods and options required in the Netherlands.

Farmers will only transfer to the cultivation of crops for the production of energy and chemicals if these lead to higher incomes. This could, for instance, be achieved through alternative cultivation systems, such as the use of crops with longer growth periods, whereby a larger proportion of the incoming light could be utilised. An example of this concept is the increase of the corn yield from 14 to 20 tonnes/hectare by extending the growing season to the end of October.

Additional yields may also be obtained through the production of heavy chemicals from plants, such as alcohols, organic acids and amino acids. The technology required for this is still in development and the market is still in its starting-up phase. Given the variety of crops and market for sales of bio-energy the demand would need to be in the region of a hundred thousand tonnes per year. A proportion of the additional yield will have to be derived from the added value of residual materials, such as foliage. Fermentation to methane is the most readily achievable in the short run, but in the future proteins and amino acids may be extracted first for additional income.

The Platform has produced calculations to investigate which crops the farmer could rely on for additional income. The assumption for this has been that by 2030 all European agricultural subsidies will have been stopped. Potatoes will then be discarded as energy crops, as yields will be too low. Sugar beet still has a great potential, particularly as the total biomass of pulp, leaves and root residues are greater than for the potato. If all residual streams were to be used for energy production, the farmer would have an income of just € 600 per hectare, which would be considered as a minimum for an agrarian company. However, beet only becomes really attractive when chemicals can be extracted through amino acid separation from the biobased raw materials. It also applies to grass that intensive energy cultivation only delivers sufficient income if valuable components can be separated out. The production of rapeseed has too low yields in the Netherlands; this will only change if the crop yields were to be doubled.

The Platform expects that all food crops will slowly, but surely, come to have a dual function in the Netherlands by 2030: for food and for the production of energy and chemicals, by making use of the continuing increases in yields from agricultural crops. The limits to this development will primarily be determined by the need for water, even in a moderate climate as in the Netherlands, as agriculture will require more water in proportion to the intensity with which it is being exploited. Limits will also be imposed by the need for carbon deposits in the soil, when crops residues are not being ploughed back again into the soil, but systematically removed.

Since agricultural production is continuing to rise, it is likely that the surface exclusively allocated for food production will decrease and that the land released by this process is allocated for the development of nature areas and tourism, as has happened in the mountainous regions of Europe. This would perhaps combine very well with energy generation, but this concept still needs to be developed.

Wet cultivation

Wet cultivation provides a very interesting opportunity for domestic production of biomass. In general terms there are four opportunities available: use of plant growth in ditches and canals for energy generation, biosaline biomass, cultivation of micro-algae in special basins and cultivation of seaweed at sea.

Water plants. The Netherlands enjoys, proportionally speaking, a territory which is water rich. Water plants are a presence in all ditches, waterways, marshes and lakes and maintenance is required in order to prevent silting: plant growth both in and along the water has to be mown. Only a small proportion of the yield is currently usefully employed (composting). The majority is ploughed back in or remains on the land.

The problem here lies with organising the removal of plant residuals after harvest often from areas which are hard to reach. In addition to this, fermentation plants or other processing installations will need to be constructed.

A trial project, including water companies and installation suppliers, will be set up from 2006. The potential of this biomass source in 2030 is estimated to be approx. 20 PJ per year.

Biosaline biomass. The Netherlands enjoys a large amount of farming land (125,000 hectares) on saline soil (outside the dykes), where cultivation of energy crops could take place with little damage to the environment and without space conflicts with, for instance, industry and housing. Saline soil is of importance due to its international dimension: silting is being increasingly recognised worldwide as a serious problem due to large areas of saline soil, both in arid areas (Middle East), as well as in river deltas. An example of one of the deltas is the Colorado river delta in the north of Mexico. Once, the Colorado was a powerful river with a beautiful delta, but many dams in American states have meant that only 2 to 5% of the debit arrives in the delta.

Cultivation of micro-algae (source: AquaPhyto)

The ocean is now encroaching in-land and the environment is becoming saltier, which has meant that the basis of the local economy has disappeared. Cultivation of crops on saline land would mean that this land could be cultivated again. A Dutch initiative has led to the first trial plantation in this delta in 2006.

A form of mixed farming has been developed in the Netherlands on silted ground, where the production of fish, shellfish and crustaceans, algae, seaweed and silt plants are all combined, creating an enterprise with closed material streams, producing sustainable production with high added value. The plants to be cultivated should naturally have a high level of salt tolerance. Existing crops such as barley, spelt or beet are suitable for this, as well as new crops, such as spartina grass or sea poa.

Micro-algae. Micro-algae are plant micro-organisms which exploit sunlight and inorganic food matter, particularly CO_2, nitrogen bindings and phosphate, for growth. Cultivation of these crops takes place in so-called photo-bio reactors, which could take the form of open or closed ponds. These can be placed on marginal grounds or land that is (or has become) unsuitable for agriculture. Productivity of algaes is very high (in terms of the quantity of biomass per hectare). Currently in the Netherlands 30 tonnes per hectare per year is already feasible, and in the future perhaps 50 tonnes per hectare is achievable (in comparison with a maximum of 20 tonnes per hectare for corn).

Biomass derived from micro-algae forms a multi-faceted raw material for producing feedstock for energy and chemicals. There are more than 30,000 types of micro-algae and the choice of algae, mode of cultivation and processing, which is partly dependent on climate and demand for products, is currently in full development. Some types of micro-algae produce oils with many unsaturated fatty acids, which can be applied directly in the food industry to replace fish oils, or for the production of biodiesel instead of rapeseed oil.

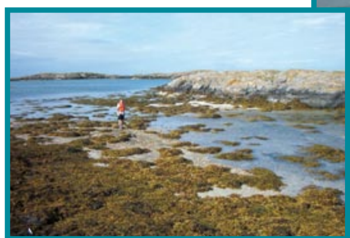
Other kinds of micro-algae can be used for the production of soil-improving fertilisers, which will both stimulate plant growth and counteract mould. Interesting compounds can be isolated from the crops, such as omega fatty acids, dyes, polysaccharides with particular properties or pharmaceutically interesting chemicals such as anti-oxidants.

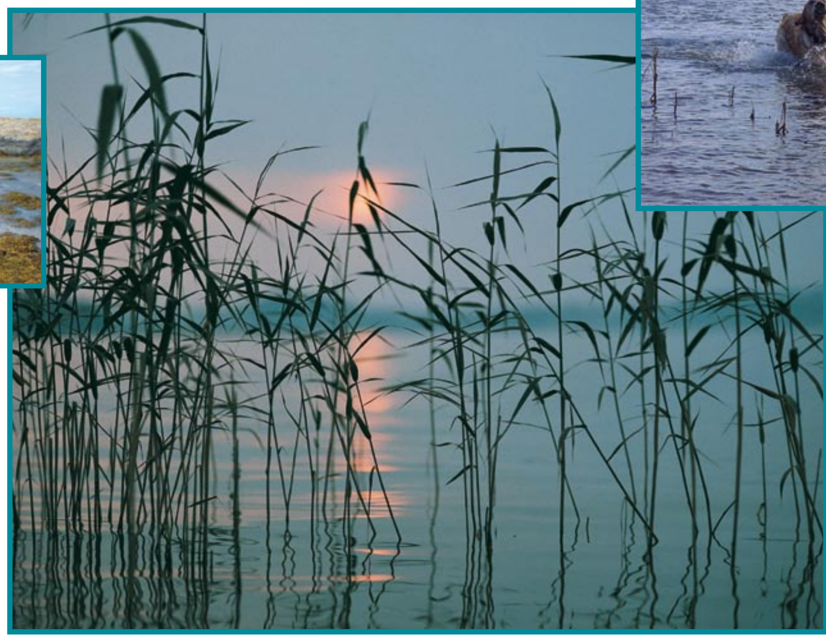
The extractable quantities of these particular materials are small, but their production could contribute significantly to the economic feasibility of micro-algae cultivation. An alternative is to use the entire yield as a food source for cultivating fishes in aqua-culture, or as a supplement to silage. Fermentation to biogas is always an alternative use.

The Platform expects that in the Netherlands a significant acreage of 20,000 hectares will be used by 2030 for the cultivation of micro-algae. The yield from this would amount to approximately 16 PJ per year, expressed in energy terms.

Seaweeds. Seaweeds, or macro-algae, form a highly diverse plant group. They can reach lengths ranging between a few centrimetres to tens of metres. Various seaweed species have already been harvested worldwide, partly from the sea and partly through cultivation, amounting to a total of approx. 10 million tonnes or 2 million tonnes of dry matter per year. Seaweed is used in the production of food for human consumption (food supplements), fertilisers, cosmetics and pharmaceutical products. Seaweed can definitely be used in the production of energy and chemicals.

Seaweed cultivation can easily be combined with wind turbine parks at sea. Wind turbine parks will not be accessible in order to reduce the risks to shipping, so that the relevant ground could be used for other purposes. The turbine masts can be used to anchor the crop installation. The negative impact on the fishing industry would be minimal, as the proportion of the North Sea owned by the Netherlands amounts to 57 million hectares, of which only a small percentage would need to be employed by wind parks in order to provide the entire Netherlands with electricity.





Source: Floris Boogaard (Tauw)

Rather, it is anticipated that this would have a positive effect on fish stocks, as turbine parks could start to serve as breeding grounds and shelter for fish, particularly when intensive cultivation of algae is initiated.

In the first instance, all existing markets could be supplied from the cultivation of seaweeds, including products for personal care and animal feed. Seaweeds contain high levels of polysaccharides (60%) and have a very low lignin content, which means they are highly suitable for fermentation (to methane or ethanol). Heavy chemicals, such as lactic acid, propandiol and biopolymers, can also be extracted from seaweed, as well as proteins, mannitol, fatty acids and dyes. Seaweeds have a high mineral content from which iodine, bromide and fertilisers can be extracted. Processing can be undertaken entirely at sea or partially on land. Given the high water content from the harvest (85-90%), a desiccation process would be required at sea in order to limit transport costs.

If seaweed cultivation takes place entirely at sea in wind parks, then the potential energy contribution would be linked to the quantity of wind energy that can be derived at sea. If by 2030 the Dutch section of the North Sea is populated by 20 wind turbine parks, each of 100,000 hectares, or a total of 2 million hectares, then the cultivation of seaweed would provide a yield of 126 PJ per year. This crop offers enormous potential, but is at yet surrounded by large economic and technical uncertainties.

Plant breeding

The application of biobased raw materials will increase in relation to higher agricultural productivity. Higher productivity will mean increases in agricultural surpluses in some regions (such as Western Europe). The alternative is to use land for other purposes, for instance the cultivation of crops for energy and chemical production. Plant breeding will be required for this increasing productivity. Other properties, beneficial to the production of energy or chemicals, could primarily be strengthened through plant breeding. Existing crops are the product of centuries old selection and breeding directed at improving food production. Generally, these differ markedly from their natural predecessors through the increased production of, for instance, starch (grains, potatoes) or fruits. Other demands are now being placed on the productivity of crops through the use of biobased raw materials for the production of energy crops or chemicals.

Sugar beet is a good example here. It is an interesting crop for the production of energy and chemicals. Sugar beets are exceptionally well-suited for the production of chemicals containing oxygen and nitrogen, such as organic acids and amino acids. In the current methods of sugar production the presence of amino- and organic acids is undesirable, as they reduce the yield of crystal sugar, but this should be contrasted to instances where the primary aim is to produce ethanol where they do contribute to the yield. An even better idea is to isolate and separately sell off amino acids.

This does not increase the yield in GJ per hectare, but does increase the farmer's income. If this becomes (part) of the goal of sugar beet cultivation, then it should be possible to double the contents of amino acids through crop developments and choice of crops.

Oat has particular potential, as the seeds from this crop contain a lot of oil. Some wild oat seeds contain 28% oil. This offers the potential for cultivation of oat species which could replace rapeseed in the production of plant oil. In addition, oats remain a good source of starch, therefore the total yield could be greater than that from rapeseed in terms of energy. Rapeseed is another challenge for plant breeders, as seed production is low in comparison with other cultivated crops. Doubling of the yield might offer one opportunity, which would make the cultivation of rapeseed for biodiesel more economically attractive in moderate climates.

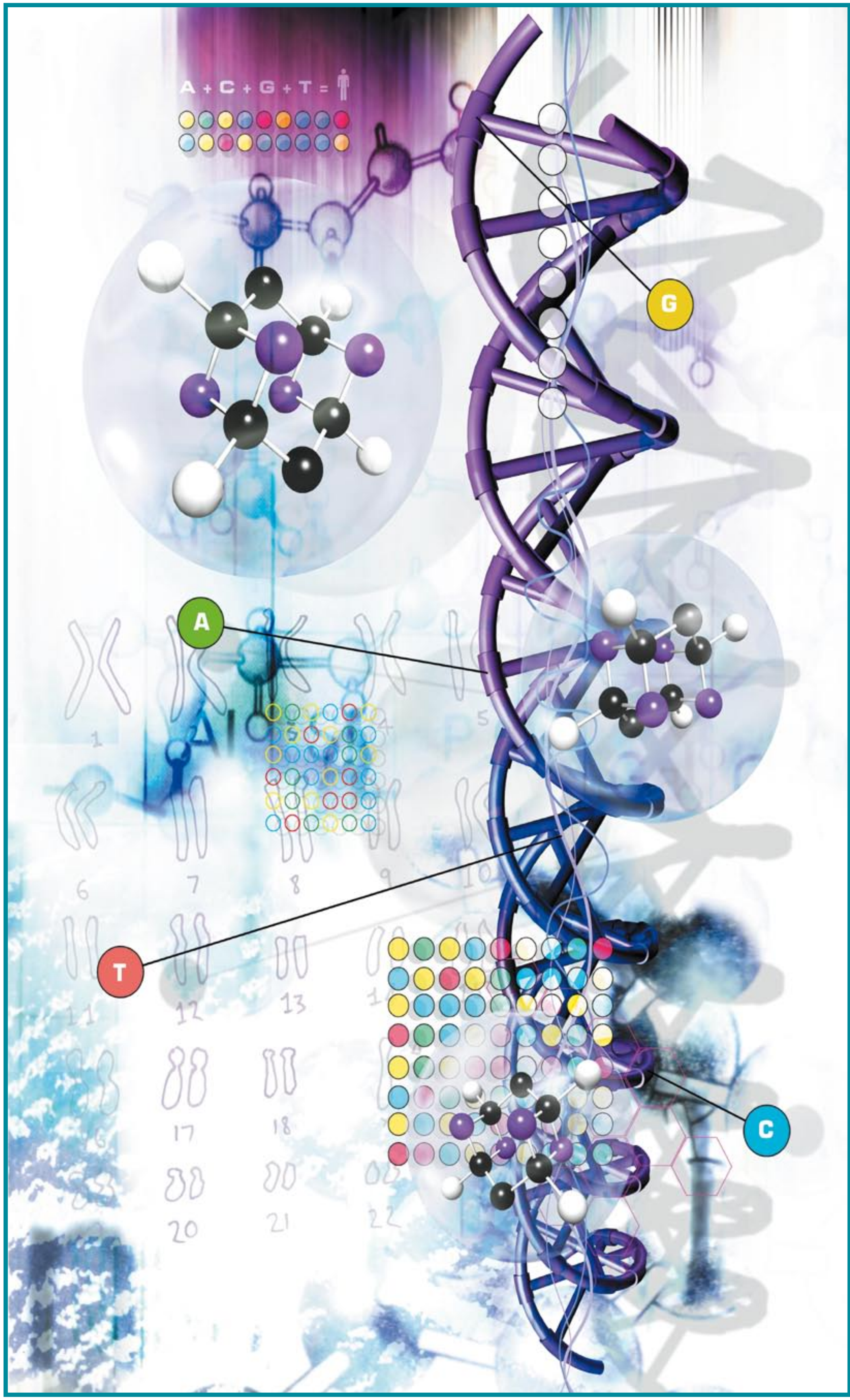
Plant breeding will also play an important role in improvements of agricultural productivity, which is one of the conditions imposed by the Biobased Raw Materials Platform for responsible use of biobased raw materials. Plant breeding may use traditional technologies or recombinant DNA technology to create genetically modified organisms (GMOs). The latter technology is particularly controversial in Europe.

"The enormous profits enjoyed by agriculture in our part of the world has not been experienced across the majority of the globe; this in itself will create enormous opportunities of using existing agricultural land with much higher yields, and thereby release greater sections of acreage for, for instance, energy crops and/or other applications. It is of the utmost importance that those profits are realized in the near future, to prevent woodland being burnt down in favour of food production – as is often happening now in third world countries (this production could easily be realised on existing farmland with improved yields).

This improvement in efficiency will have to be achieved in the first instance with traditional breeding technologies and the application of fertilisers and crop protection (both natural and artificial), but I would not want to reject GMOs if they can be specifically applied for energy crops."

Paul Hamm
Chair Biobased Raw Materials Platform



Genetic modification

A genetically modified organism (GMO) is an organism where the genetic material has been changed through recombinant DNA technology. This technology consists of introducing "foreign" DNA into an organism's genes, and so altering the hereditary properties. "Genetic modification" is the scientific term for this process; this is a neutral term, indicating that genes have been "modified" (altered). "Genetic manipulation" is an alternative term; this term places an emphasis on the "manipulation" applied.

The discussions regarding GMO in association with biobased raw materials will in particularly be concerned with the use of recombinant DNA technology. The types of plants developed in this way are referred to as transgenic plants. Modification of plant DNA is also the basis of natural evolution and traditional plant breeding, through for instance, cross-fertilisation. The term transgenic plants is exclusively used for plants where foreign DNA material has intentionally been introduced in a laboratory using recombinant DNA technologies to change the plants' properties. The properties introduced may originate from related, as well as entirely different species of organisms.

The application of recombinant DNA technology is controversial. Many environmental organisations *oppose it. At an international level the European Union, in particular, opposes this technology. The most important argument against transgenic plants is that the properties introduced may be released and spread through naturally occurring species. This could happen when mutated plants are crossed with naturally occurring related species, particularly when the mutated properties are dominant. This could lead to new species, which could act as a weed and disrupt the harvest, or in more serious instances lead to displacement of natural biodiversity. This threat of displacement of natural vegetation is seen as a particular argument against this technology. Furthermore, there is also the fear that the inbuilt resistance introduced by the recombinant DNA technology, for instance against a pesticide, could also protect the plant and its progeny produced from cross-fertilisation against a particular beetle species, for instance. This could of course affect the natural equilibrium, for instance the animals feeding on these beetles.*

Transgenic plants are not essential for the application of biobased raw materials. Proponents of the technology emphasise the point that recombinant DNA technologies allow new properties to be applied rapidly and efficiently to plants, whilst this would take many years using traditional techniques.

In other words, if increases in the oil contents of oat seeds are required, this could be created more rapidly and efficiently by producing transgenic oats. However, this is not essential for the future of biobased raw materials.
The same effect could probably be achieved with traditional techniques with more difficulty and considerably more time.

Proponents of GMO use also point out the need for crops which are resistant to plagues and droughts in the third world. They claim that transgenic plants are an urgent necessity for increasing food production and preventing failed harvests. They are of the opinion that the rejection of recombinant DNA technology is an affordable luxury in countries not frequently confronted by failed harvests and no famines. Opponents believe that GMOs are only acceptable when the risk of these organisms escaping has been reduced to virtually nothing, as is the case in aquatic conditions.

The Biobased Raw Materials Platform is not taking any position in this political – scientific debate, but is of the opinion that discussions around GMOs should be continued. Up to now the debate has mainly centred around the use of recombinant DNA technology for food crops. It is possible that balance of pros and cons may change when this technology is applied in protected (for instance, aquatic) environments and/or to "energy crops".

Creative Energy

Energy Transition

Import

Import

The potential import volume is very large, as we have noticed. In practice, the biomass import is promising, but difficult as well, especially if we want to limit effects for the environment, improve social conditions in exporting countries and limit competition with food supply.

The limitations

However, in the short term considerable import streams of biobased raw materials will be available, particularly as a result of the European guidelines on biofuels. Wood pellets for electricity production already form one of the larger streams. In addition, it is anticipated that large-scale imports of oil-containing seeds will take place (particularly rapeseed) or rapeseed oil extracted for biodiesel, and wheat for bio-ethanol to add to petrol. Large export streams have already been generated: for ethanol between Brazil and Japan, oil-palm stones (by-product of palm oil) between Malaysia and the Netherlands and wood pellets from Canada and Eastern Europe to Western Europe.

The fact there are not as yet stable markets is illustrated by price fluctuations. In the winter of 2005-2006 the demand for wood pellets was higher than expected: many households in Europe switched over from expensive fossil fuels to wood, the combustion of wood in power stations for electricity increased and supplies experienced problems due to frost. This led to prices rising considerably. Events like these made it difficult for long-term contracts to be concluded, as these were considered to be too risky. There is still a long way to go along the road to the stable markets required for the necessary volumes.

There are other conditions which will need to be satisfied before the markets become reasonably stable. Biomass will have to be properly pre-treated in export countries. Inadequately prepared biomass may lead to the threat of the import of moulds and foreign insects.

Another frequent objection against untreated biomass is that the energy density is too low, whereby there are proportional increases in transport and storage costs. Suitable technologies for more compact production are pyrolysis and torrefaction (see Chapter 6), but users are still wary about pyrolysis oil and torrefaction is still in the developmental stages.

In export countries the infrastructure will need to be developed in the form of storage and transhipment facilities and transport capacity to harbours. The price of biomass landing in Europe is still too high, partly as a result of insufficient volume and continuity in export. It is only once continuity and volume are ensured, that there will be a basis for investments, which will reduce costs.

As happens with every new commercial stream there are limiting and poorly tailored regulations in place for biomass. For instance, in the EU biomass containing starch residues are designated as animal feed and are consequently taxed on import.

Furthermore, the import of methylated ethanol receives a considerable tax of 4.9 €/GJ in the EU.

Care for the environment could be a reason for reticence about import: large-scale energy plantations could be bad for the environment. The dangers here are, for instance, loss of biodiversity, erosion, water extraction, rinsing away and pollution of food produce through pesticides. However, various studies have shown that energy crops are often less harmful to the environment than large-scale agriculture. Fast growing timber crops (such as willow and poplars) have clear benefits: they require fewer pesticides and are often better for animal life than agriculture. In erosion sensitive areas they may contribute to the necessary soil solidity in areas that are no longer suitable for agriculture. Only branches and the trunks are removed during harvesting (once every five years), while the roots remain intact.

Many slopes around the globe suffer from poor water retention as a result of erosion, in other words: rain washes away too rapidly, causing large variations in river flows. The planting of quick growing timber crops for energy production on eroded slopes offers a number of simultaneous advantages. Therefore, a conflict between proper environmental care and the cultivation of energy crops is not a fact of life.

Social conditions in the biomass producing countries may also be problematical. What is the effect of cultivating energy crops on the quality of work and child labour, education and healthcare? This a point of concern for all large-scale export projects in developing countries.

Burkina Faso

Mali

Ethiopia

It is apparent from research that conditions on energy plantations are, in general, no different than the average conditions encountered in the country concerned. Social security and child labour continue to cause concerns in, for instance, Brazil, an important producer of energy crops. However, significant progress has been observed in these areas over the period 1992-2004.

What about competition with food production? At first sight the answer seems clear: energy crops require land – land that is urgently required for agriculture to solve the world's food problem. As the markets for biobased raw materials start to develop, the chances of farmers switching over to these markets will increase proportionally, even in poor countries with serious food supply problems.

However, often the problem does not lie with food production capacity, but rather it is the lack of spending power that causes hunger. Furthermore, a closer inspection reveals that there is no absolute competition between the cultivation of crops for food or energy production – with a good selection of crops, wheat, sugar cane and sugar beet may be concurrently cultivated for both purposes, particularly if the principle of biocascading is applied and, for instance, "crop residuals" are used for energy. Sugar cane is an example where significant residual products can be processed for energy export. There is a real chance that in some countries the cultivation of energy crops will compete with cultivation of animal feed, which could lead to higher prices for animal feed. In a country such as Sweden the paper industry fears to suffer from a shortage of wood pellets (following increases in prices) when increasingly larger proportions of this are being used for energy production.

The environmental movement in the Netherlands had already identified the import of biomass for energy production as a problem at an early stage. As a result of this debate a commission was established under the chairmanship of Prof. Jacqueline Cramer, which produced a report in July 2006 for the Tweede Kamer (Second Chamber). The commission discussed the points presented here and created criteria which sustainable import would need to satisfy in its opinion: a list of minimum criteria to be presented in 2007, and supplementary and stricter criteria for 2011. The commission has attempted to comply with existing conventions and quality marks, as far as possible.

"With biobased raw materials there is always the competition between food/feed and energy and material production. The world food problem continues to be a cause for concern. The UN target to halve poverty by 2020 will not be achieved. There are alarming reports about fresh water provision. The statement that biobased raw materials do not have to conflict with food supply is too simplistic. At a macro level this works, but large tensions may arise at a micro and meso level, with the human factor in the middle. There might be large agricultural producers, even in famine areas, who would not concern themselves with people and who would cultivate energy crops if they produced more profit.

On the other hand, there are also a lot of reasons for optimism. When we were younger we saved aluminium paper and coins for the world's poor. Since those times 2 billion new people have been able to function properly. It is amazing that so many people have achieved a reasonable standard of living in such a short period of time".

Alle Bruggink

Member of the Biobased Raw Materials Platform

The commission refers to, for instance, guidelines of the International Labour Organisation (ILO) for working conditions.

In terms of competition with food supply the commission wants to make the reporting of the local situation compulsory, including the description of food, energy supplies, building materials and medicines. A system of controls, such as these reports, will be necessary for a responsible import of biomass.

The University of Utrecht has conducted a study into ethanol production in the Brazilian state Sao Paulo, where 85% of Brazilian production is concentrated. According to this study current production largely fulfils the criteria for 2007; however, the question is whether the stricter criteria for 2011 will also be satisfied. It is perhaps possible that only biologically cultivated sugar cane will still satisfy these criteria.

The competition between use of biobased raw materials for food and for energy and chemicals (transport fuels, in particular) should not be under-estimated.

For the current small volumes the use of biobased raw materials for energy does not appear to be a problem, however, this could rapidly change if volumes increase and transport fuels were still being largely produced from food produce. Therefore, this situation needs to be continuously monitored. A structural solution for this food/energy competition lies, as has already been described, in the development of second generation technologies. The application of pyrolysis oil may also contribute to limiting this problem.

The large-scale import of biomass would perhaps also produce problems domestically. The Netherlands has battled for years with a manure problem due to the large numbers of livestock and levels of imported feed. This will need to be prevented in respect of the import of biobased raw materials. Therefore, prior attention would need to be focused on the flipside to this import: what remains after processing and could this be utilised in the Dutch environment?

Source: European Bulk Services (E.B.S.)

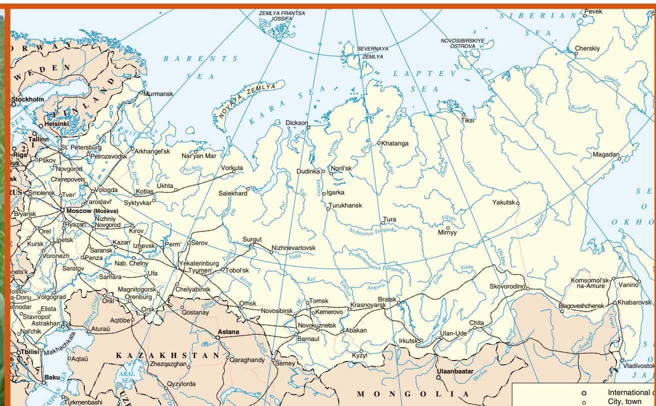
The opportunities

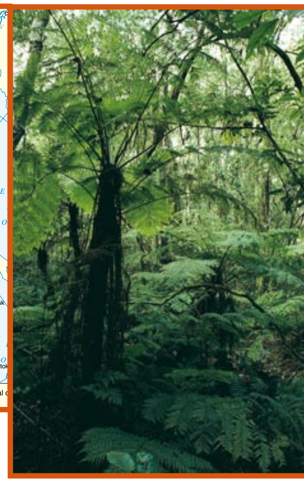
International commerce in biomass could be advantageous to both the exporting, as well as the importing party. Cultivation and transport of biomass, including the conversion of residual materials from food production to raw materials for energy, are new economic activities, which may contribute to the economic development of the exporting country.

In some cases the conversion of primary and secondary residual streams from food production in the export country could even be a solution to local environmental problems. For instance, the processing of stalks and straw is a problem when cultivating rice and wheat. These are partly ploughed back into the soil and partly usefully employed, but a significant proportion remains on the land and is burned, causing damage to the local environment.

Residual streams and surpluses from food production are potentially a very significant source of energy. The four largest Latin American biomass producing countries (Brazil, Cuba, Mexico and Colombia) alone already produce an annual 134 million tonnes of biomass from the primary residual products from the sugar cane harvest (leaves and tops). Another 113 million tonnes is produced in India, Pakistan and Thailand. At least 62 million tonnes is released annually as straw in large wheat producing nations such as the Russian Federation, Kazakhstan, Ukraine and Turkey.

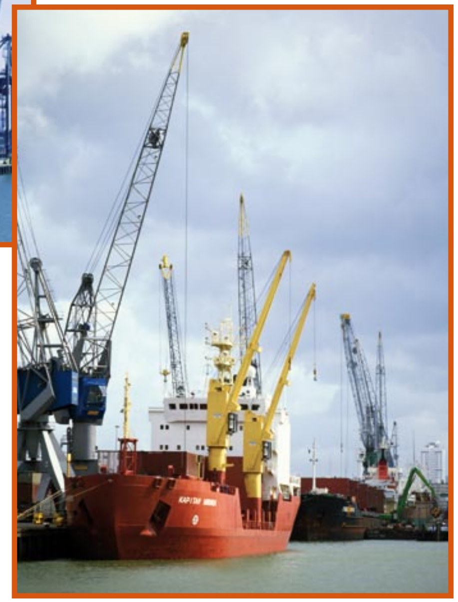
Further potential raw materials for energy arise from secondary residual streams. For instance, 25% of the biomass yield from sugar beet is left as bagasse, consisting of approx. 50% water and often used for nothing more than ineffective combustion.
The total production of bagasse in the countries above amounts to 221 million tonnes. If this material was properly pre-processed, it could be easily transported by sea.
All the streams described here are expressed in terms of dry material. An average energy content of biomass can be assumed to be 17 GJ/tonne, so the quantities mentioned above, which collectively amount to 530 million tonnes, represent an energy stream of approx. 9,000 PJ per year, three times the energy consumption of the Netherlands.




In addition to the use of residual streams and agricultural surpluses, specific energy crops will also be cultivated on a large scale. There is the global potential for the cultivation of large quantities of biomass at cost prices of 1-2 €/GJ, particularly in regions such as southern Africa, Latin America and Eastern Europe. If pre-processing and international transport are included, these would deliver cost prices of 3-4 €/GJ in West Europe. New conversion technologies for the second generation of biofuels (see Chapter 6) would deliver production costs of 6-9 €/GJ fuel (biodiesel or ethanol for addition to petrol). Biofuels at these prices would be competing with petrol and diesel starting at approx. 40-50 $/barrel.

However, we do not have to look far for the import of biomass. The potential for biomass production is considerable in Western Europe. Increasingly more agricultural land is becoming marginal – commercially attractive exploitation of land is not possible anymore at current world prices and with the reduction of European agricultural subsidies. The French wine industry, for instance, barely provides sufficient income – with the exception of the Grands Crus, which often feature at official functions – through competition from South Africa, Chile and other new wine nations. Sunflowers are only being cultivated as an alternative for the European subsidy. Replacement energy crops need to be sought intensively in order to prevent land falling fallow.



The Netherlands would not be the Netherlands if the commercial advantages of an active approach to biomass import had not already been considered. Imported raw materials have been passing through Rotterdam harbour on a large scale for years. Rotterdam could also become the point of entry for biomass to a large hinterland. Furthermore, biomass would not have to pass through unmodified; on landing it could be forwarded for industrial processing, as happens in the petrochemical industry. We will explore the full potential of this in Chapter 7.

The import of biomass has another important advantage: the dependence on foreign energy suppliers becomes distributed and thereby reduced. Biomass grows across the globe and control of these raw materials will be more equally distributed than control of fossil and mineral sources.

Overview table

The Biobased Raw Materials Platform's vision for the import and cultivation of biobased raw materials for 2030 is summarised in Table 2. The Table has been divided into priorities in accordance with the Platform's vision. The replacement of natural oil has priority over CO_2 reduction. The use of biobased raw materials takes priority where this provides the greatest value, therefore preferably in the chemical industry. The Table demonstrates, according to the Platform, that its goals can be achieved: 852 PJ is required to realise the ambitions, while the potential amounts to 1136 PJ. There is the possibility of achieving more than the targets set in all sectors: chemical industry, motor fuels, electricity, heat and SNG.

The Platform has consciously striven to designate a larger availability than immediately required for its objectives, since a number of developments have a significant potential, although there are also a large number of uncertainties at a technical and economic level. There will have to be a considerable investment to achieve these potentials. If that does not succeed, then the contribution of biobased raw materials will be lower. An example here is the production and processing of seaweeds.

The proportion of imports will be higher if we do not succeed in developing wet cultivation adequately. This type of shift will only be evident in the course of time: wet cultivation will only be become available in the future. If the Netherlands does not make sufficient efforts to optimise its own potential (crop development cultivation in the Netherlands and improving yields from use of residual streams), then the Netherlands will also become more dependent on the import of biomass.

Fossil PJ avoided		E / H / S *	Ethanol	Biodiesel	Chemicals	Total	Import [%]	Additional land efficiency [kha/PJ]	Additional land use [kha]
a	Residual streams	261	70	10	70	411	50	0	0
b	Dry cultivation	69	78	57	36	240	75	9	2300
c	Wet cultivation	114	24	37	81	256	0	(2)	(300)
d	Import of residual, semi and end products	73	44	112	0	229	100	5	1250
Total		**517**	**216**	**216**	**187**	**1136**	**55**	**3**	3550
Platform ambitions		**388**	**324**		**140**	**852**			

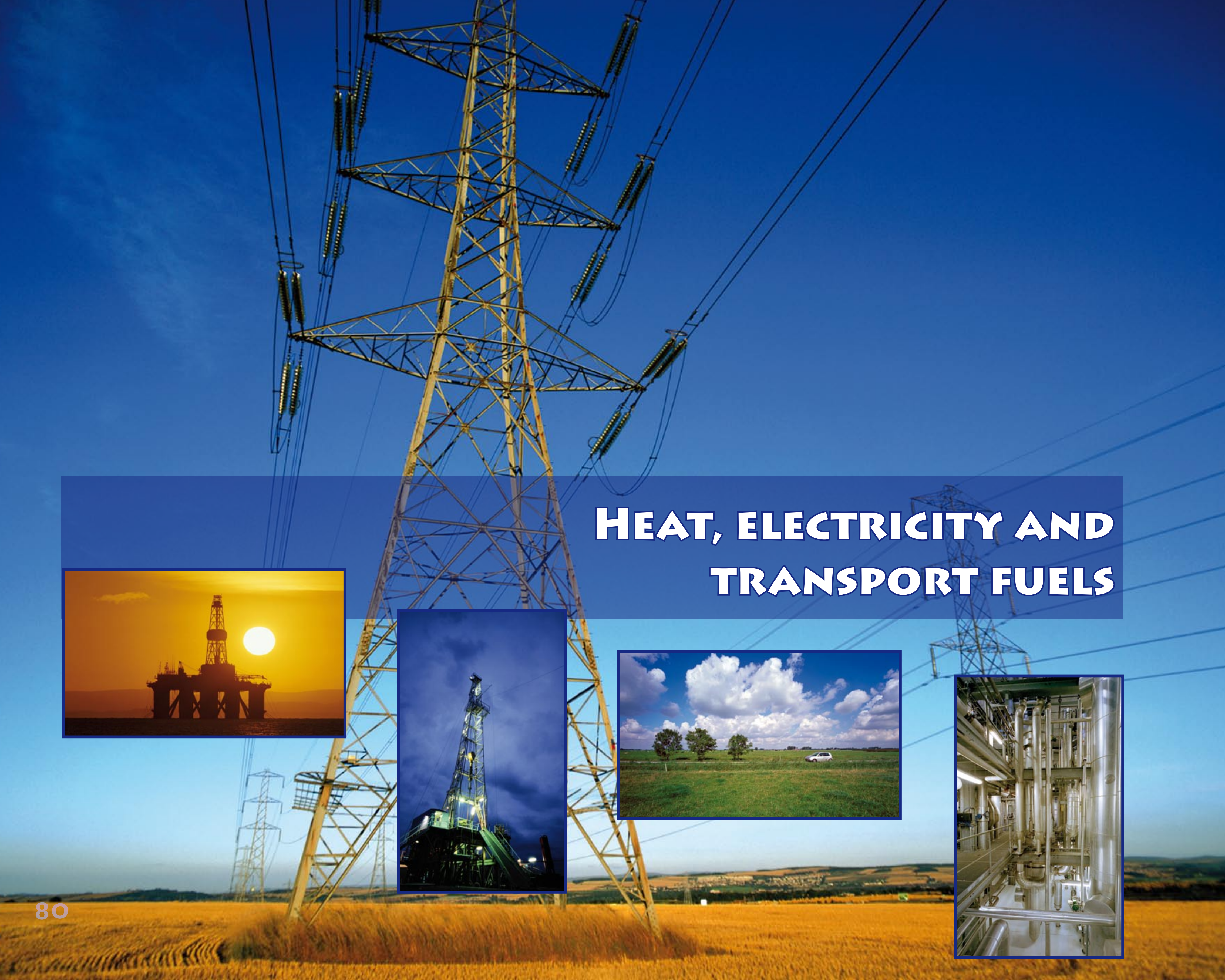
** E = electricity, H = heat, S = SNG*

Table 2. Potential contribution of biomass by sector, 2030 (source: Sustainable production and development of biomass, both in the Netherlands as well as abroad; final report study group transition path 1 of the Biobased Raw Materials Platform, 2006)

Creative Energy

Energy Transition

Heat, electricity and transport fuels



Heat, electricity and transport fuels

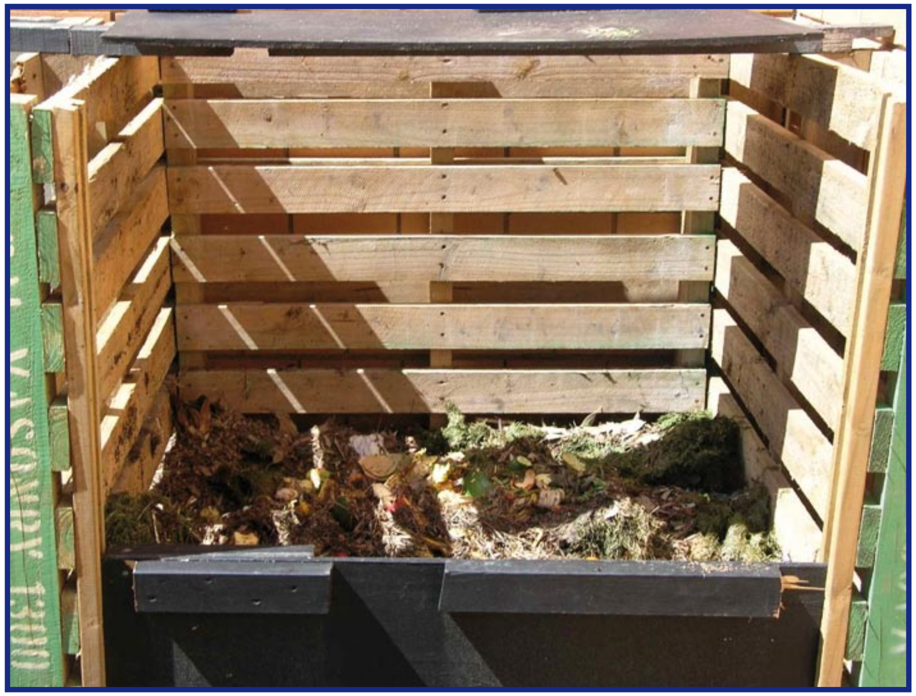
In Chapters 6 and 7 we will explore the applications of biobased raw materials. The efficient use of biomass is partially dependent of the development of new technologies. Some new technologies are targeted at converting raw materials into usable fuels to be used for heat and electricity production and transport. These will be considered in Chapter 6. Others are targeted at releasing valuable chemicals and materials, which will be considered in Chapter 7. The most important existing technologies and those in development will be considered in the review.

Electricity and heat

A large number of technologies are available for converting biomass into electricity and heat; some of these still need to be further developed.

Combustion. This is the simplest technology, which is not always applicable as a lot of biomass contains moisture. Dry biomass, such as wood pellets, is easily combusted, but the yield is low. Flue gas filtration is the principal problem when combusting biomass on a large scale, particularly due to the production of dust. For this reason the co-firing of biomass is limited to a maximum in coal power stations. Furthermore, there are types of biomass, such as silt from sewage plants that contain undesirable elements (for instance, fluoride and mercury), which existing purification plants are not set-up to process. Combustion has the lowest priority – the aim is to process the raw material to produce a higher yield.

Composting. The biomass is converted under the influence of bacteria in the presence of oxygen (aerobic) to material that is rich in cellulose and minerals, which can be used as a fertiliser or for soil improvement. Yields are low, as the heat generated by this process escapes unused.

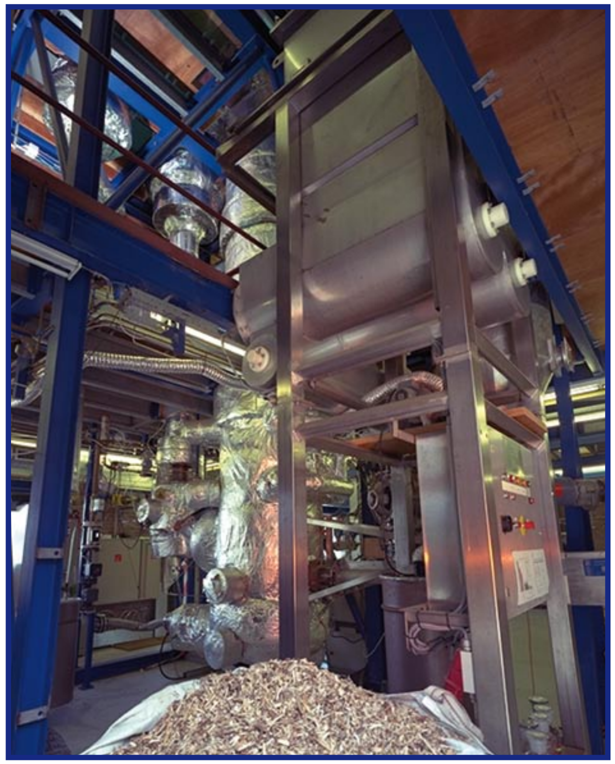


Fermentation. This technology is used for the conversion of wet or fluid biomass by anaerobic (no oxygen) bacteria into biogas, primarily consisting of a mixture of methane and carbon dioxide. The environmental benefit does not just consist of the reduction in CO_2 emissions due to the replacement of fossil fuels, but also in the reduction of CH_4 production in the breakdown of manure in the ground. Methane is 21 times more powerful than greenhouse gases, such as carbon dioxide. Fermentation is a fully developed technology, readily available on the market. However, the financial yield is too low at current market prices, which has meant that fermentation installations have only been built with subsidies.

The biogas product can be utilised for electricity and heat production in a installation co-generation plant directly linked to the fermentation plant. The fermentation process requires heat, so a proportion of the heat production can be used from the co-generation plant. Generally speaking though, the electricity produced is delivered in full to the electricity network, as that is currently being provided with subsidies. Biogas installations are often small-scale, in order to use the heat produced effectively (heat is difficult to transport). Further growth in the fermentation process will become possible when biogas can be converted to natural gas quality, which would mean it could be supplied to regional natural gas networks. The earliest that this can be achieved is expected to be 2008.

Gasification. In gasification biomass is heated with low levels of oxygen. Synthesis gas arises at temperatures above 900 °C, also referred to as syngas, consisting primarily of CO and H_2.
Syngas is the basis for the production of many compounds, including diesel oil. Gasification of fossil fuels is a commercial technology; there are hundreds of gasification systems across the globe. Gasification of biomass presents new challenges for scientists: biobased raw materials are much more complex than fossil fuels and contain a lot more bound nitrogen. Gasification of biomass is still primarily at a developmental and demonstration stage.

A new kind of power station could be created based on gasification, where coal and biomass are gasified and the syngas is used flexibly for the production of both fuels and chemicals, as well as electricity and heat.



ECN Gasification installation

Although power stations like this score highly in terms of sustainability, the general expectation is that this technology will not be used for the next generation of coal/biomass power stations on the Maasvlakte.

Pyrolysis. In pyrolysis the biomass is anaerobically heated to 500 °C, creating an oil. As pyrolysis oil biomass is easy to transport, for instance by ship. It is evident that pyrolysis factories will be built in countries exporting biomass. Pyrolysis oil has a reputation for polymerising rapidly, however, there are claims that this problem has been overcome. It is not easy to predict when this technology will break through, but if childhood diseases are overcome than pyrolysis will have a great potential.

Pyrolysis test installation, University of Twente (photograph and copyright: Webletters, Anne Groot)

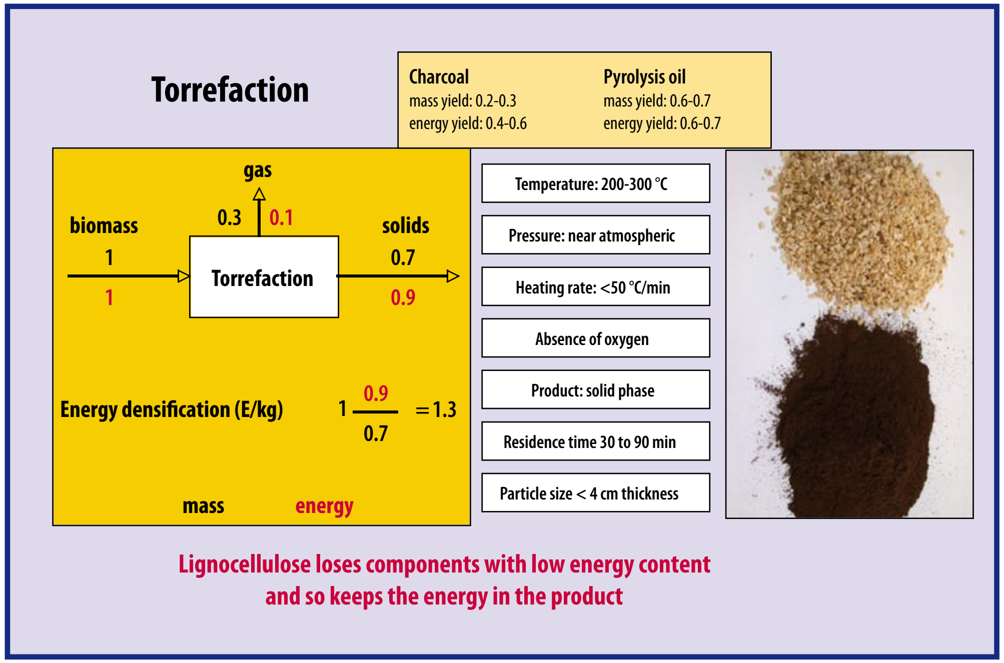


Figure 8. Torrefaction (source: presentation Gasification and torrefaction, H.J. Veringa, ECN, 2006)

Torrefaction. In torrefaction biomass is heated anaerobically at much lower temperatures (250-300 °C). This prevents volatile components being created; the cellulose fraction remains unaltered, but loses the majority of its structure, creating a product which can be easily ground, is water resistant, and therefore easily transportable. The considerable input of energy in the grinding of the wood (up to 20% of the energy content) largely remains behind with torrefaction. However, torrefaction too still under development.

SNG production. SNG (synthetic natural gas) is created through the processing of synthesis gas. CH_4, CO_2 and water can be generated from CO and H_2 in the so-called synthesis step. There is a large factory in the USA which produces SNG from coal, which is intended to reduce dependence on natural oil. However, the production of SNG from biomass is still in development, for instance at ECN.

Once water and the largest proportion of CO_2 have been removed, SNG is suitable for feeding into the natural gas network. Sooner or later the existing gas infrastructure in the Netherlands will be used to distribute gas from biobased raw materials (green gas) to users. Green gas will not have exactly the same composition as natural gas derived from fossil sources, although the combustion quality (the Wobbe Index) will have to fall within the narrow predetermined range. Pollutants are possible in the form of hydrogen, H_2S, ammonia, chlorides and siloxanes. The effect of many of these components on pipes and combustion plants, as well as the maximum limits for concentrations, is not known. To gain experience the use of green gas will, in the first instance, be experimental in nature. The earliest addition of SNG is expected to be 2015.

Transport fuels

In the short term a lot of attention is being focused on biofuels. These are relatively easy to produce and easily adaptable within the existing infrastructure, as additions to petrol and diesel oil is permissible up to certain levels for existing cars. Global production of ethanol has more than doubled between 2000 and 2005, whilst production of biodiesel has quadrupled.

Biodiesel from plant oils. Biodiesel can be produced by different methods. Technically it is possible to run diesel engines with pure plant oil (PPO); the diesel engine was originally designed for this.

Addition of PPO to diesel oil has been tested using various oils, for instance good results have been reported using Jatropha oil. There are often complaints of frying odours emerging from the exhaust gases when percentages are too high.

In general, other options are selected. The normal route to biodiesel currently consists of hydrolysis of plant oils, creating fatty acids and glycerol. The fatty acids are re-esterified with methanol or ethanol to biodiesel, which differs chemically from diesel oil derived from fossil sources, but is suitable as a supplement up to a given percentage. Europe has been very active in the production of biodiesel. Germany produced almost 2 billion litres in 2005 and France 0.5 billion, leaving the USA with almost 300 million litres far behind.

Process installation Nedalco

Biodiesel from biobased synthesis gas. Using syngas as a base, diesel can also be produced with the Fischer-Tropsch process. This technology is being developed in particular in Germany and South Africa. The diesel oil produced by this method primarily consists of hydrocarbons and therefore looks, in chemical terms, more like normal diesel. Where the base product is syngas originating from biological sources, then the diesel oil produced is also characterised as biodiesel. The production of biodiesel from biobased raw materials using the Fischer-Tropsch process is one of the so-called second generation technologies, which will be of great significance for the long-term application of biomass.

Ethanol from sugars and starch. Fermentation, which has been used for generations to produce alcoholic drinks, can be used to obtain ethanol from sugars and starch. The first country to apply this on a large scale for the production of transport fuel was Brazil, which is rich in sugar, but poor in natural oil. Bio-ethanol is now considerably cheaper in Brazil than petrol due to scaling-up. In the USA, which is attempting to overcome its oil addiction through bio-ethanol, domestic ethanol from corn is now able to compete with petrol. European efforts have been limited in comparison with these two countries. Whilst Brazil and the USA produced more than 16 billion litres of ethanol together in 2005, the production in the EU was stuck at 950 million litres.

Ethanol from lignocellulose. An important component of biomass is lignocellulose; this partially consists of cellulose and hemicellulose (complexes with C6 and C5 sugars) and partially of lignine (primarily polyaromates). Lignocellulose is difficult to break down; it is, for instance, highly resistant to moulds, which is incidentally a characteristic of plant and tree survival. Until recently, lignocellulose could only be converted using two intensive methods: conversion at high temperatures through combustion or gasification. However, the rapid development of fermentation technologies has led to the possibility of conversion into ethanol and other valuable chemicals at low temperatures and in fluids. A lot of exploratory work is being undertaken into this route, which is included as a second generation technology.

Biomethanol. Residual products such as glycerol (from the production of biodiesel or from the residues from the oil and fat processing industries) can be converted into synthesis gas under high temperatures and pressure using a new technology; methanol is then produced using existing technologies. This means that methanol will become available from biobased raw materials. Methanol is suitable for addition to petrol or may even be used (after engine modifications) in its pure form as engine fuel. Additionally, methanol can be converted into MTBE, which is already added to petrol as an anti-knocking agent, which has meant that a green MTBE has been available since recently.

Process installation Nedalco

Case: biomethanol

There were two options available when Methanor, a methanol manufacturer in Delfzijl which belonged to Akzo Nobel, DSM and Dynea, had to close its gates in 2006: either sell-up to the Russians or to a consortium of venture capitalists formed by Econcern, NOM and Oakinvest, who wanted to start producing biomethanol. The latter option was chosen and Methanor has already made a new start under the name of Bio Methanol Chemie Nederland. BMCN, largely with its old complement of staff, intended to use a new process to produce bio-methanol from glycerol, a by-product of biodiesel production; large quantities of glycerol were released on the market in a short period of time. The initiators expect that the Dutch demand for bio-methanol (as a lead-replacement in petrol or as a direct supplement) is already enough to sell half of the production (500,000 tonnes) by 2007. The rest remains to be exported. The most surprising aspect of all this is that it has occurred without a penny of government subsidies having to be spent.

Hydrogen from biomass

The automotive sector is currently fully engaged in applying fuels cells for vehicles of the future. The fuel cells used require hydrogen (H_2) for their charge, which can also be created from biomass. However, hydrogen currently available on the market is not green, as it is produced from naphtha.

One route for green hydrogen is gasification of biomass at high temperatures (1100-1300 °C). At these temperatures the synthesis gas consists virtually exclusively of CO_2, CO, H_2 and water. Hydrogen produced in this way needs to be filtered thoroughly, as the type of fuel cells used in cars is highly sensitive to CO. This makes the cost of hydrogen relatively expensive.

Hydrogen can also be obtained through fermentation of biomass with suitable organisms. One proven route involves micro-algae. Firstly, solar energy is captured in the form of carbohydrates, formed in algae through photosynthesis. The algae are harvested and subjected to dark fermentation; this produces hydrogen and organic acids. In the next step in the process, photofermentation, these acids are also converted into hydrogen (and carbon dioxide). There are great expectations about this process, particularly for applications in desert areas. However, the various steps have only been carried out on a laboratory scale. Alternative forms of biomass may be used for the dark fermentation process instead of algae. The biomass material needs to be pre-treated to enable the fermentable products (soluble sugars, amino acids, fatty acids) to become available in the fermentation step.

Biophotolysis is another alternative: the direct conversion of water into hydrogen and oxygen through micro-organisms in the presence of sunlight. This process results in very pure hydrogen, without the addition of carbon monoxide or methane. However, yields have been too low up to now.

Yields up to 10% have been obtained in laboratory settings, yet in practical trials outdoors, yields amount to no more than 0.2% - and only when the sun is shining. In addition, investment costs are high, and the problem of separating hydrogen and oxygen has still not been solved properly.

The Biobased Raw Materials Platform is also of the opinion that from a biobased raw materials perspective it is more logical to develop other transport fuels as alternatives for petrol, such as methane or methanol.

Creative Energy

Energy Transition

Chemicals and materials

Chemicals and materials

Although the fine chemicals industry has already demonstrated the potential for bio-processes in the last 25 years, the promise of biobased raw materials for the future also lies in the development of technologies where bulk chemicals and materials can be extracted from biomass. The potential here lies with the significant amount of added value. Potentially a large proportion of plastics could be produced in the Dutch economy from biomass using two emerging technologies: white biotechnology and biorefinery. In the near future these will have a significant impact on the chemical and agricultural sectors, respectively.

White biotechnology: the future of chemistry

White biotechnology is the controlled use of micro-organisms for the production of products from sustainable raw materials. Fermentation is the basis of white biotechnology, a collective noun used to describe biochemical processes utilising bacteria and moulds. Fermentation has been used down the ages as the foundation of foods, such as beer, wine, soya sauce, etc. The fermentation technology has made striking advances in the last twenty years. This technology started its rise in the production of high-value medicines and is now at the point of making breakthroughs in the production of bulk goods from biobased raw materials.

The changes which will be introduced with fermentation technology can be properly illustrated with a history of the industrial production of penicillin. In the 1970s a kilogram of penicillin cost hundreds of dollars. It was therefore only, in effect, a medicine for wealthy countries. These days penicillin costs a couple of tenners per kilogram and is used around the whole globe. Most factories are located in India and China. The cost price has decreased by a factor of ten and this has resulted in public availability increasing a hundredfold. Currently, in India between 600 to 700 million people have access to antibiotics, twice the population of the United States. In China these figures are between 800 and 1000 million people – twice the population of the European Union.

These successes have been made possible by successive replacements of chemical conversions at high temperatures by biocatalytic and fermentative conversions in fluid solvents, a process that has come to be known as the "greenification of the chemical industry". Two Dutch companies, DSM and Gist-brocades (one company these days) have been market leaders in this process since the 1970s. The economic basis for these developments has been that antibiotic products have a high market price and long shelf-life: the products produced in the 1970s are still being sold. Continuous specific adaptations in production technology have meant that the reductions in market prices have been maintained through the reduction in production costs.

The ultimate winner is the environment. Many of the new processes have therefore been able to be introduced with subsidies for environmental friendly technology. In the 1960s 1 kg of antibiotic produced 50-60 kg of waste. In the 1980s that amounted to 25-30 kg. Since biocatalysis has been introduced, this has been reduced to 3-5 kg. The waste product consists virtually entirely of ammonium sulphate, which can be converted into fertiliser. Halogenated solvents have disappeared, as biocatalysis takes place in fluids. Quality has also increased; the product is pure white and crystalline and does not have the characteristic bitter taste anymore, if you are unfortunate enough to chew into the capsule. The application of fermentation technology in this sector can therefore be used as a perfect example of the reality and success of "factor 10 thinking": the challenge of developing products and services which ensure the same or – even better still – an increased level in living standards, which are concurrently less of an environmental burden by a factor of 10 (or 90%).

Products from fermentation processes

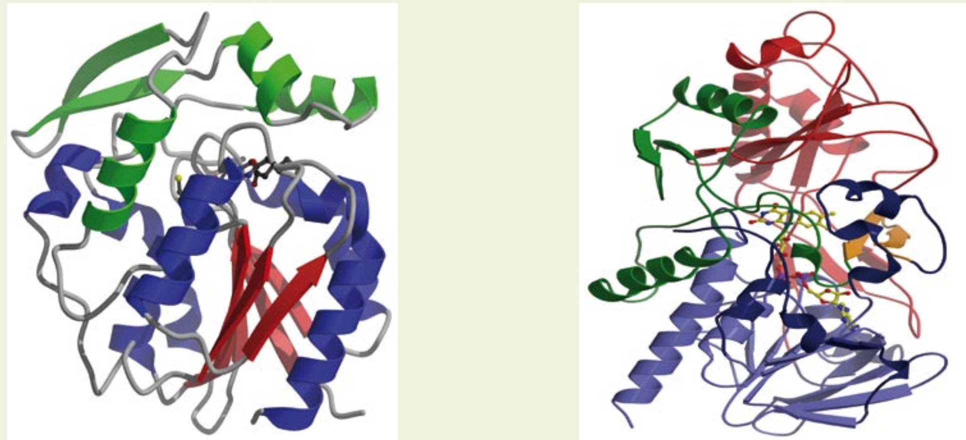
Greenification of the chemical industry relies on two processes:

- **Biocatalysis**
  The use of enzymes for chemical conversions.

- **Biosynthesis**
  The use of modified or unmodified micro-organisms to produce complete chemical products. Fermentation is a part of biosynthesis.

Use of micro-organisms for biosynthesis is uncontroversial and this usage is not part of the discussion surrounding genetic modification. Micro-organisms continue to mutate by themselves and useful exploitation of these has never been open to debate. The modified organisms remain in the factories or the active components have even been used in computer chips.

Each biochemical company has one or more micro-organisms for which the genome is known(the house organism), which can be applied according to requirements, for instance, the penicillin mould or E. coli bacteria. The house organism does, however, have to be tamed. In nature, micro-organisms use 90% of their energy for reproduction. This is not required for biosynthesis and is even an undesirable property. Biosynthesis is used to produce very pure products. Changes are introduced to the organism's metabolism to effect this, whereby certain routes are cut-off and others are stimulated. It is sometimes possible through knowledge of the genome to produce multiple products from a single organism,



Lyases, examples of the enzyme structure as used in fine chemistry

Figure 9. Lyases

according to requirements. For instance, a single organism could be used for the production of ethanol or lactic acid. This could be quite responsive to price variations.

Biocatalysis is also undergoing significant advances. Biocatalysis was originally primarily used in the purification of waste streams (a well-known example being the addition of enzymes to washing agents). Waste often consists of a very wide variety of products, but with biocatalysis highly specific conversions can be implemented, even under extreme conditions (for instance severe waste). Leading companies in this sector have a motto: "for every problem there is a bacteria which can solve it", which leads to a lot of excavation of micro-organisms in extreme environments, such as volcanic lakes and waste dumps.

The green epoch has already started

"Given the leading role adopted by the chemical industry in the transition to a biobased economy, it is no wonder that many existing research programmes and plans waiting in the pipeline fit closely with the scenarios sketched out in this chapter. The industry co-finances these programmes which strengthens the rapid evolution towards commercial applications. Important programmes include, for instance: B-Basic, IBOS (biocatalysis and biosynthesis), ASPECT (chemocatalysis in competition with biocatalysis), PoaC (miniaturisation of processes), research by the top technological institute, the DPI (green materials) and the national Genomics programme (fundamental insights into biotechnological processes).

Currently a total of approximately € 100 million per year is being invested in developments of the green chemical and materials sector. The recent decision by the Dutch Innovation Platform to designate chemistry as one of the five key areas for a national knowledge economy has led to an increase in the development of new plans which fit excellently with the desired green transition. An increase in investments in research and development to approximately € 200 million per year is now expected. This does not include efforts being made for potential demonstration projects within industry or finance. More specifically in respect of materials, the activities and plans by DSM and Philips in the field of bio(medical) materials and equipment deserve a mention."

Alle Bruggink
Member of the Biobased Raw Materials Platform

After the greenification of medicine production the next step now is the greenification of bulk production, which is mostly based on sugars. In the 1970s DSM intended to produce lysine (an amino acid which plays an essential role in human and animal food) from caprolactam originating from the petrochemical industry. Now the opposite process is being considered: a plan to create caprolactam (building block of nylon) from biological products. Lysine is already being produced through the fermentation of sugars for less than $1 per kilogram. There are as yet no concrete plans for the production of caprolactam from biomass, but this should be achievable within ten years.

The developments in this field are progressing at a rapid rate. Biocatalysis, used originally in breakdown processes, is being increasingly used for the opposite process: synthesis. Complex conversions can be achieved using a series of linked enzymatic syntheses, utilising processes within living organisms. In contrast, some biosynthesis processes can now be created from dead rather than living organisms, so that the two fields are fusing.

An important breakthrough is anticipated in the second generation technologies, which have already been referred to, which are directed at the biotechnological conversion of lignocellulose into usable compounds. It is the intention to find fermentation processes which will release C5 sugars in particular. These can then be converted through fermentation into valuable chemicals, such as xylose, methanol and ethanol. Second generation technologies are still in the development stages, but their appearance in the market is anticipated in the next ten to fifteen years. The industrial application of these technologies means that in the future not only food products, such as sugars and starch, could be used for the production of transport fuels and heavy chemicals, but the entire plant as well.

Figure 10 provides an outline of the road to greenification of the chemical industry. The arrows on the left represent the accumulation of knowledge. Our chemical knowledge, which started with processes in food preparation and energy production, was increasingly refined until we developed insights into the smallest building blocks of life. In the first instance our knowledge was applied to produce medicines, but appears to be useful to the production of fine chemicals. The production of bulk chemicals and petrochemicals is the next step in the expansion of our knowledge. This will allow us to base the backbone of our industrial system on biobased raw materials.

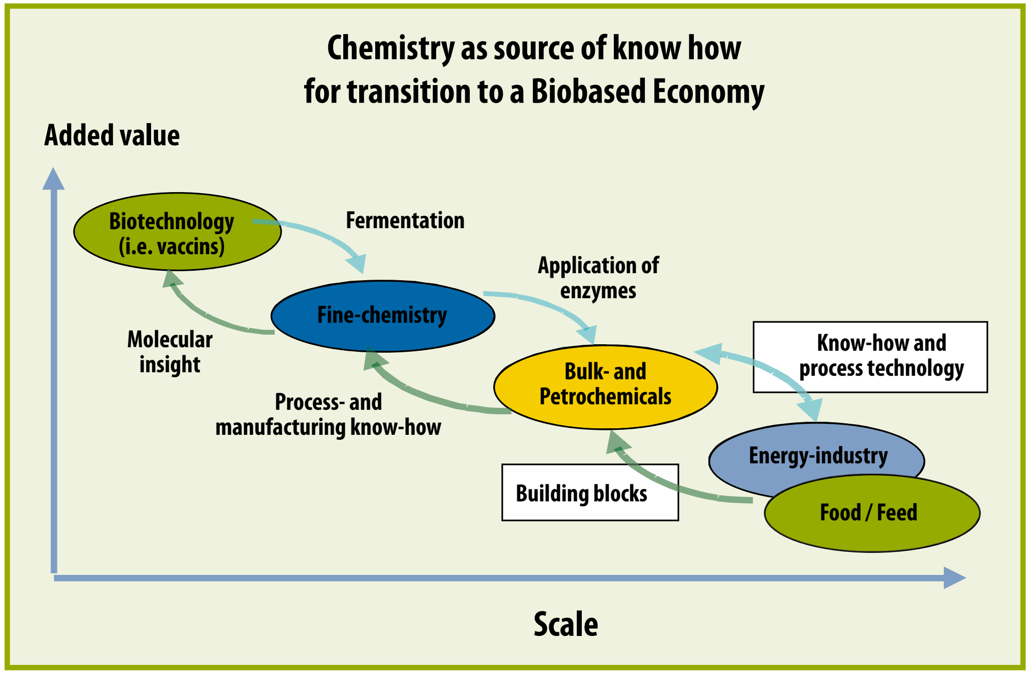


Figure 10. Chemistry as source of know how for transition to a biobased economy (source: New sources for chemistry, final report transition path 5 of the Biobased Raw Materials Platform, A. Bruggink, 2006)

Biorefinery: the future of agriculture

Plants consist primarily of lignocellulose and proteins, in addition to varying quantities of compounds, such as oils (particularly in seeds), minerals, saccharides and polysaccharides, and organic acids. Biorefinery is a concept targeted at both the separation and optimising the economic value of all parts of the plant.

A lot of biomass is harvested with an emphasis on a plant component with high food value: seeds for their starch (grains) or oil (sunflowers, coleseed and rapeseed, peanut, etc.); the stems for sugar (sugarcane); the roots for starch (potato, mangold) or sugar (sugar beet). The focus within biorefinery is exactly on those residual streams which remain after harvesting food (stems, leaves and roots), or even the entire plant when this does not contain any edible components, such as grass. The first step in optimising the economic value of biomass will often consist of separating the lignocellulose fraction out from the rest. This can sometimes be achieved mechanically, for instance in the processing of sugar cane the lignocellulose-rich bark is separated from the core.

In most cases, a pre-treatment phase will be required, which will consist of simply treating the ground biomass in an acidic environment, in order to encourage this separation. Most biomass components, with the exception of lignocellulose, are soluble in mild acidic solutions. Avébé developed, along with others (in the Progras consortium), a procedure for biorefinery of grass in the 1990s.

Although in its raw form grass does not provide yields greater than € 50-70 per tonne, the value of this grass increases in value by more than ten-fold to € 700-800 per tonne – see Figure 11 – when separated into its components. However, this technology has not been applied up until now.

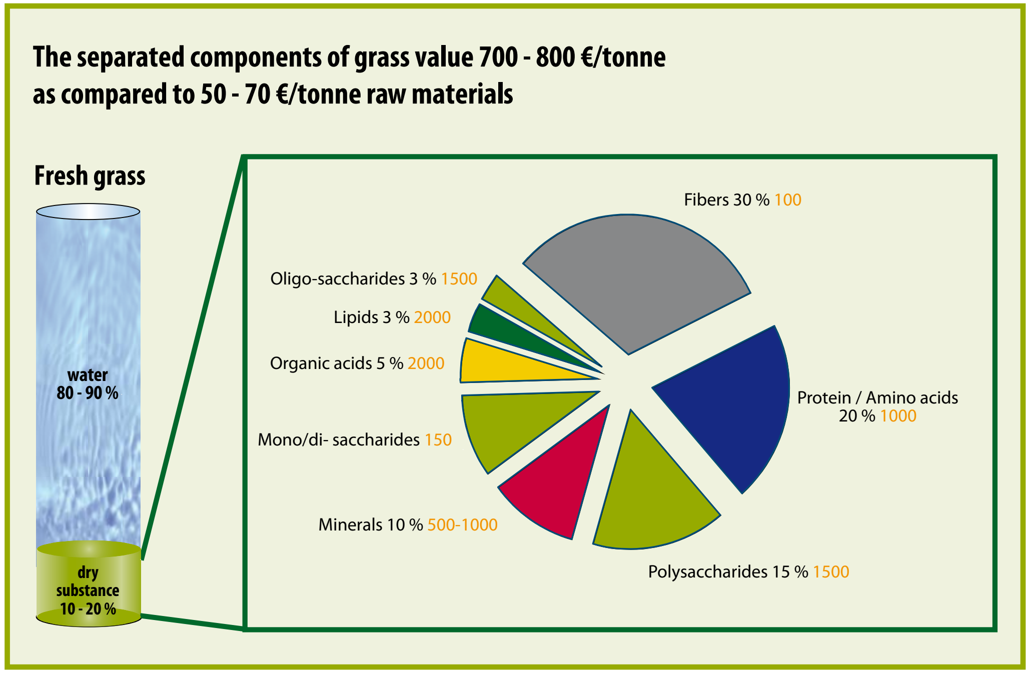


Figure 11. Optimisation of the economic value of grass components through biorefinery (source: lecture Johan Sanders, WUR: Biorefinery, the Bridge between Agriculture and Chemistry, York 6-8 September 2006)

An important part of the added value is derived from proteins. Proteins are biological structures, constructed from amino acids which are linked together in a specific order and spatial structure in each protein. Proteins have relatively little value, as they cannot be industrially processed in this state.

They are however valuable when applied to animal feed – as this means that pig's gastro-intestinal tracts are not taxed anymore by the useless lignocellulose and their digestive efficiency increases significantly.

The next step is the separation of the extracted proteins into amino acids, which is the subject of a lot of research. The main problem is the isolation of each amino acid at an acceptable cost. There are at least twenty amino acids from which proteins are constructed, yet bulk separation is a technology which has still not been perfected. Many applications of biomass in the high-value sectors depend on effective and affordable amino acid separation.

Once amino acids have been separated, further division of residual streams is possible. The most valuable amino acids are the essential amino acids, so-called as they are essential to animal life, but cannot be produced in animals' bodies. For instance, humans are unable to produce eight amino acids. The simplest and most important in the group of essential amino acids is lysine. Humans have to derive this from food, and the same applies to pigs, chickens and cattle, who all receive lysine as a food supplement.

When proteins have been split into amino acids the essential amino acids can then be processed further into animal feed (further reducing the manure problem), while the non-essential amino acids can be used as raw materials for chemical production.

In addition to proteins many other valuable products can be isolated from plant material, such as saccharides and polysaccharides, which can be fermented using centuries-old technologies to ethanol or used for fermentative conversion. Organic acids are also valuable products.

The extraction of proteins and organic acids from biomass is still in its infancy, as plants have not been selected and bred for the production of these materials up to now. It is anticipated that a good cultivation programme will increase the yields significantly.

An alternative to petrochemistry

Nearly all organic products which are used by humans can be produced from natural oil. This is associated with conversions which are high in energy demand, energy which is supplied by many exothermic (heat producing) reactions in the petrochemical industry (see Figure 12).

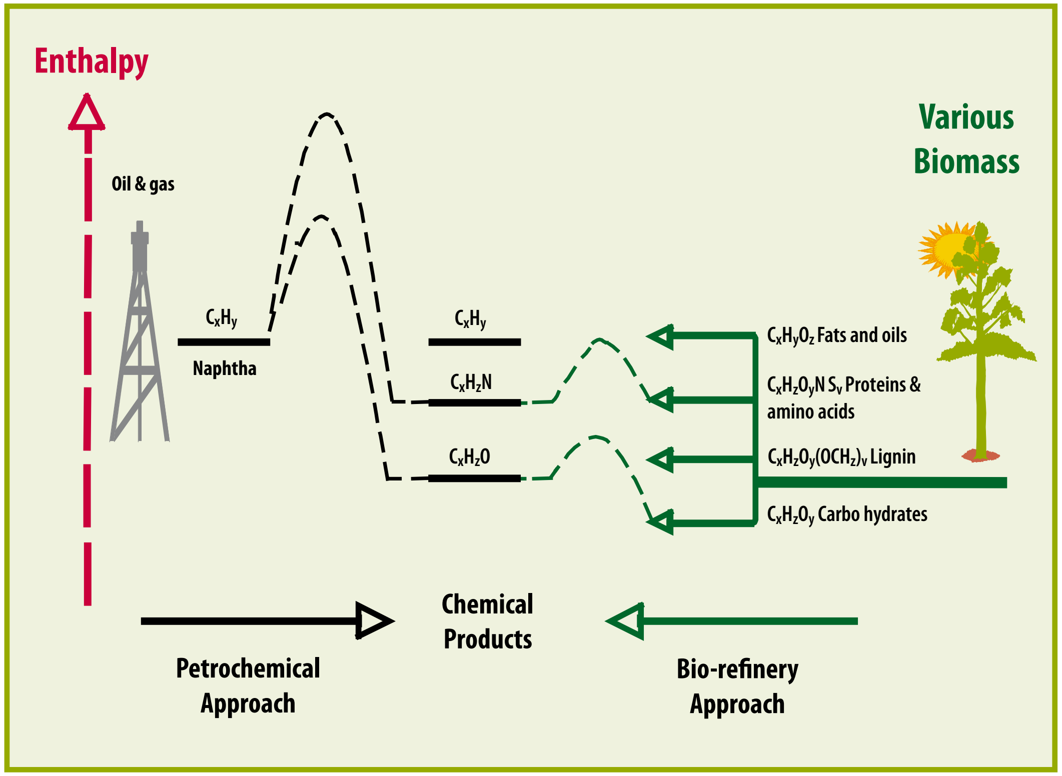


Figure 12. Energy saving alternatives for the production of oxygen and nitrogen containing chemicals from bio-based raw materials (source: lecture Johan Sanders, WUR: Biorefinery, the Bridge between Agriculture and chemistry, York 6-8 September 2006)

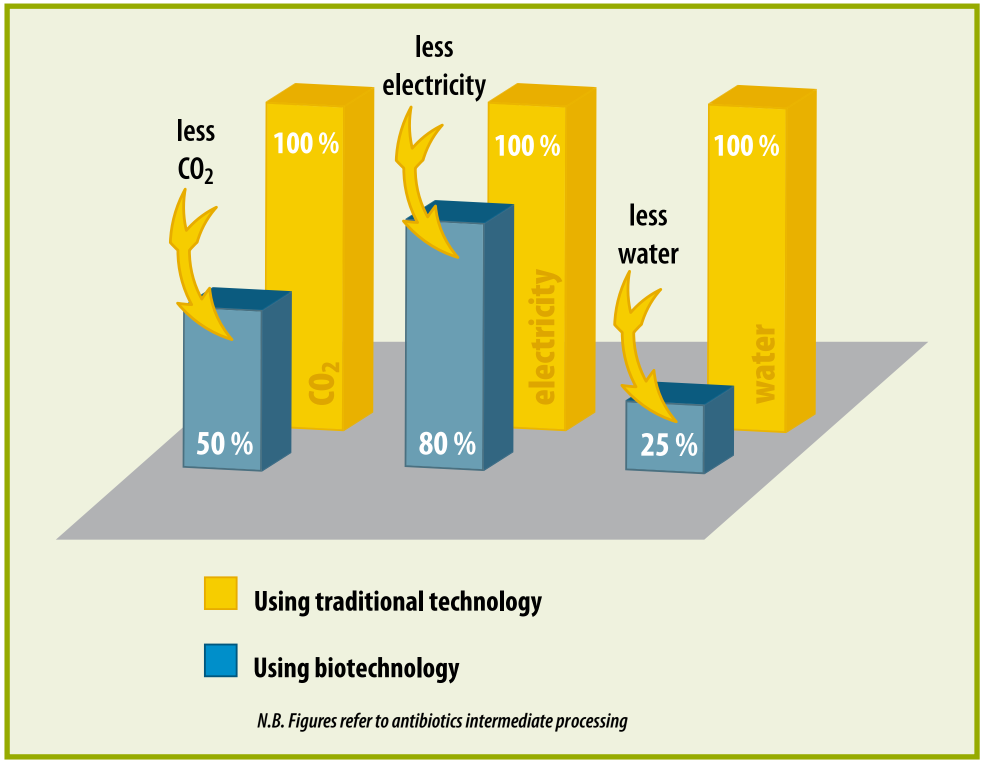


Figure 13. Comparison between biological and traditional production processes (source: www.europabio.org)

An example: 1,2-ethanediamine is an important raw material for rubber, chemicals, medicines, lubricants and detergents. It is industrially produced from ethane, which is created when natural oil is processed. The first step is chlorination, followed by nitrification: the chlorine atoms are replaced by amino groups. Chlorine is required for the chlorination step, which is produced from the electrolysis of table salt; ammonia is needed for the nitrification, which is produced through the synthesis of oxygen and nitrogen. The production of 1,2-ethanediamine therefore requires three energy intensive processes: breakdown of natural oil, and chlorine and ammonia production. The total waste stream for these processes is considerable. 1,2-ethandiamine can be produced from serine or ethanolamine, compounds which occur naturally in plants, using much less energy.

However, why should one want to produce 1,2-ethanediamine from biobased raw materials? After all, this compound is just another intermediary step in the synthesis of more complex compounds. These complex compounds could perhaps even be obtained through biorefinery or the fermentation of biobased raw materials.

A general rule is that most valuable chemicals are characterised by the presence of oxygen and/or nitrogen groups. These can only be produced from natural oil using energy-intensive processes. Chemicals with oxygen and nitrogen groups form a quarter of the volume in the petrochemical industry, yet their production requires half of all the energy consumption in this sector. The most difficult step in the petrochemical process is catalytic oxidation, which is the first step required to arrive at the desired end-product from hydrocarbons. It is exactly this step that can be avoided when we transfer over to biobased raw materials.

It is expected that in the future there will be an increasing number of products on the market derived from biological sources. An example of this is bioglycerol, a by-product of the hydrolysis of plant oils in the production of biodiesel. Glycerol by itself does not have many applications, however, it can be converted using chemical processes into heavy chemicals, such as glycol, isopropanol and acetone, compounds which are often building blocks for further syntheses.

These developments have already led to new paths, even in the petrochemical industry. Dupont in the US has recently started producing the semi-finished product 1,3-propandiol through fermentation of corn using a process developed by the biotechnological company Genencor. At the same time Shell is continuing to produce this compound from naphtha in Rijnmond. This will lead to interesting competition between both routes with continuing improvements to both processes being the potential outcome. Competition between petrochemicals and production from biobased raw materials may arise in many other semi-finished products.

Biobased raw materials may also lead to the development of new materials. An interesting new plastic, polylactate, has been produced from lactic acid, a raw material derived from plants. Polylactate can be used as a substitute for polyethylene in many applications, and in comparison it has one major advantage: it is bio-degradable. Examples include plastic beakers and even t-shirts. Furthermore, it is also being applied to medicine, for instance as an anti-wrinkle agent. The future for polylactate looks bright.

There are bio-alternatives to virtually all hydrocarbons from the oil industry for hydrogen compounds containing oxygen, as represented in Table 3.

	From oil	**From biobased raw materials**
C_1	Synthesis gas (CO/H_2), methane	Methanol, synthesis gas, methane
C_2	Ethylene	Ethanol
C_3	Propylene	Glycerol, lactic acid, propanols
C_4	Butene, butadiene	n-butanol
C_5	Various hydrocarbons	G_5 sugars
C_6	Benzene	G_6 sugars, lysine
C_7 and higher	Aromates	G_7 sugars

Table 3. New biobased resources for the chemical industry (source: New sources for chemistry, final report transition path 5 of the Biobased Raw Materials Platform, A. Bruggink, 2006)

The opportunities for producing nitrogen-containing end-products from biomass containing nitrogen are even more interesting. Nitrogen is a very difficult element in the current agro-industrial cycle. Plants need nitrogen to grow. This is currently added using very energy-intensive processes (artificial fertiliser production). When plants are harvested and the residual products are broken down biologically, for instance in the soil, then nitrogen is released; a large proportion of this is elemental nitrogen N_2 (cannot be used, as the release means that it has to be added to the fertiliser again), part of it is released as N_2O (damaging greenhouse gas) and part is released as nitrate (damaging when flushed into waterways and ground water).

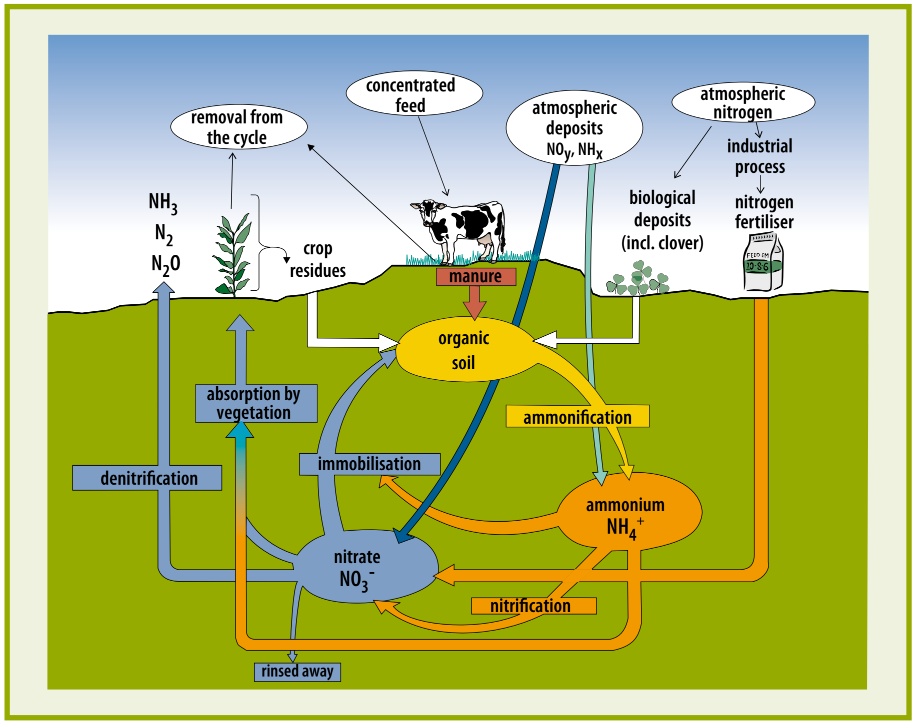


Figure 14. Nitrogen cycle between the soil and the atmosphere (source: The fleeting spirit: ammonia from of agriculture and the consequences for nature, J.W. Erisman, Betatext, 2000)

Bioplastics from Rodenburg Biopolymers

The challenge is to shorten the nitrogen cycle by developing fertilisers from biomass by preserving the carbon-nitrogen compounds, in other words in the form of amines. The separation of a fraction consisting primarily of amines (or amino acids) from biomass would not have a significant impact on energy production, as the energy in biomass is mainly based in the carbon and nitrogen. On the contrary, there are clear advantages to this process: when biomass is combusted, the bound nitrogen is a problem due to the formation of the acidic nitrogen oxides, NO and NO_2. Separation of amines and amino acids from biomass for further processing therefore offers advantages from all sides.

These can be isolated and processed separately to form fertilisers and as raw materials for the chemical industry. There is also an interesting opportunity here for competition between biobased raw materials and natural oil products, as the catalysis process has been rapidly developing in recent years; this means that hydrocarbons can react directly with airborne nitrogen to produce nitrogen compounds.

The ambition of the Biobased Raw Materials Platform is to replace 25% of fossil fuels used in the chemical industry by biobased raw materials by 2030, although developments have the potential to go even further. Around 2030 half of the chemical industry could be based on biobased raw materials. This will not only be achieved through the replacement of natural oil products by biomass, but also through savings in raw materials.

"It will not take very long for significant amounts of oxygen-containing heavy chemicals to be provided from biomass: glycol, 1,3-propanediol, isopropanol, acetone, methylbutyl-ketone and replacement of MTBE by ETBE. These compounds comprise 10-15% of heavy chemical products in the Rijnmond. Glycerol is one of the raw materials being considered for these heavy chemicals. In the long-term (from 2015) it is anticipated that nitrogen-containing heavy chemicals, such as 1,2-ethanediamine, acrylonitril, acrylamide and caprolactam produced from biological sources will come onto the market."

Johan Sanders
Member of the Biobased Raw Materials Platform

An important role will be set aside for products which are able to produce the same results with less material (dematerialisation). Areas where this will be applied include packaging, glues, composites and medicines. Further savings are possible through better organisation of the recycling of plastics, other polymers and bulk chemicals. Further developments around artificial fertilisers for the energy consumption in industry (currently highly energy intensive) are of great interest.

It is evident that the production of artificial fertiliser will take entirely different routes, which cannot as yet be predicted, when biobased raw materials start becoming a significant part of our industrial system. In general the non-energy use of fossil fuels could reduce significantly through the arrival of biomass as feedstock.

Biobased raw materials could replace natural oil products. This will occur gradually, as this involves large volumes of products. In addition, there will be a reluctance by industry to become dependent of harvests, given the possibility of crop failure. However, when viewed at a global level, the use in the chemical industry is just a fraction of the product streams in agriculture and energy supply. The latter two involve billions of tonnes per year, where the chemical industry "only" involves tens of millions of tonnes. At a macro-level it is therefore easily imaginable that the chemical industry will become based to a significant extent on biobased raw materials, even though the petrochemical industry will continue to play an important role for decades to come.

Creative Energy

Energy Transition

Balance


Gäller ej lastbilar
Bensin 95 9,53
Bensin 96 9,69
Bensin 98 9,83
Diesel 7,97
Etanol E5 9,43
Etanol E85 7,41

Balance

In the previous chapters we have seen that different kinds of biomass can be converted into fuels and chemicals using various technologies. Priorities in these technologies will now need to be explored for determining a strategy for the future.

The Biobased Raw Materials Platform's working group, WISEBIOMAS, has carried out extensive model calculations to explore how the use of biobased raw materials score on economic and sustainability criteria, depending on the priority of those criteria and the technologies employed.
WISEBIOMAS stand for: Working Group for Innovative and Sustainable BIObased energy and MAterialS). The working group distinguishes between five potential objectives:

1. Minimum land use for biomass
2. Maximum margins for the Dutch industry
3. Minimum investment costs for the conversion processes
4. A restricted land use with minimal input of fossil energy
5. A restricted land use with minimal CO_2 emissions

Each objective leads to other priorities for the way in which biomass is used, and therefore to other priorities for alternative technologies and other end products.

There are important questions regarding the interaction between the criteria: would economic yields be reduced significantly if agriculture was minimalised and vice versa? What are the mutual scores for the sustainability criteria? The central question is whether the economic and sustainability criteria are significantly in conflict with each other, in other words, whether a conflict between the economy and the environment could arise around the use of biobased raw materials.

WISEBIOMAS has used three kinds of biomass as the basis for its calculations: lignocellulose, oil-containing biomass and protein-containing biomass. These can be converted using different technologies: biorefinery, fermentation and thermochemical conversion (gasification and combustion). The potential products from these conversions are bulk and fine chemicals, transport fuels, electricity and heat. The costs and yields from these products to the environment and economy when 30% of biomass is used have been compared with those from existing processes used to produce these products from natural oil, natural gas or coal.

The working group firstly produced a simplified model of energy housekeeping in the Netherlands. This is a so-called Sankey diagram.

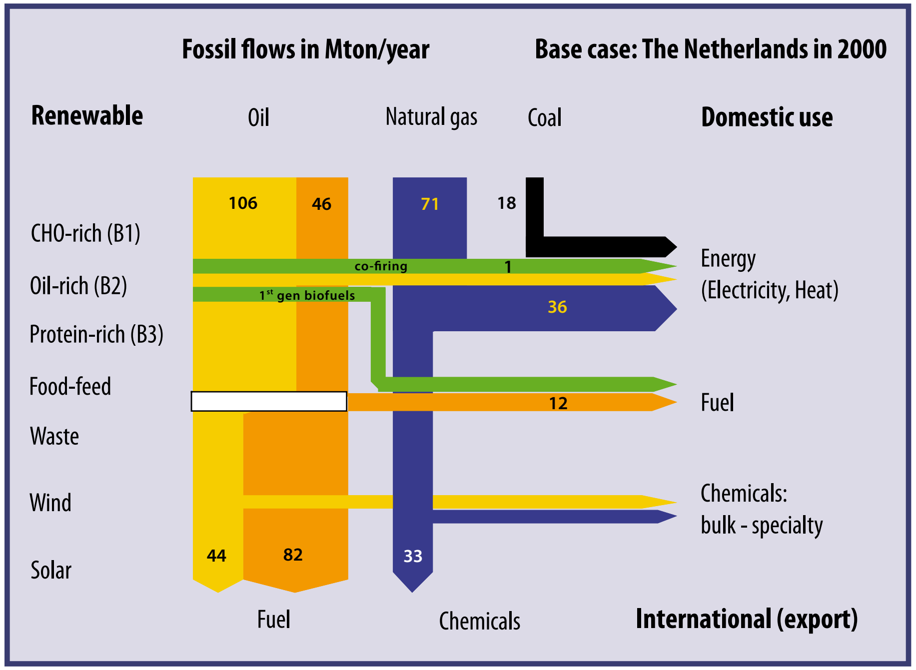


Figure 15. Base case: energy flows for import, domestic use and export in the Netherlands in 2000 (biomass flows not to scale) (source: Potential of coproduction of energy, fuels and chemicals from biobased renewable resources, WISEBIOMAS, 2006)

This figure should be read as follows:

- the thickness of the arrows represents the extent of the stream, unless reported otherwise
- fossil fuels are represented at the top
- biomass is represented on the left
- domestic use flows out from the right
- export flows out from the bottom
- **yellow** = petroleum **orange** = petroleum products
  blue = natural gas **black** = coal
  green = biomass

- for biomass there is a distinction between lignocellulose-rich biomass (B1), oil-rich biomass (B2) and protein-rich biomass (B3).

WISEBIOMAS produced the following scheme in investigating the way in which biomass could best replace fossil fuels by 2030, making use of both proven technologies, as well as those still in development.

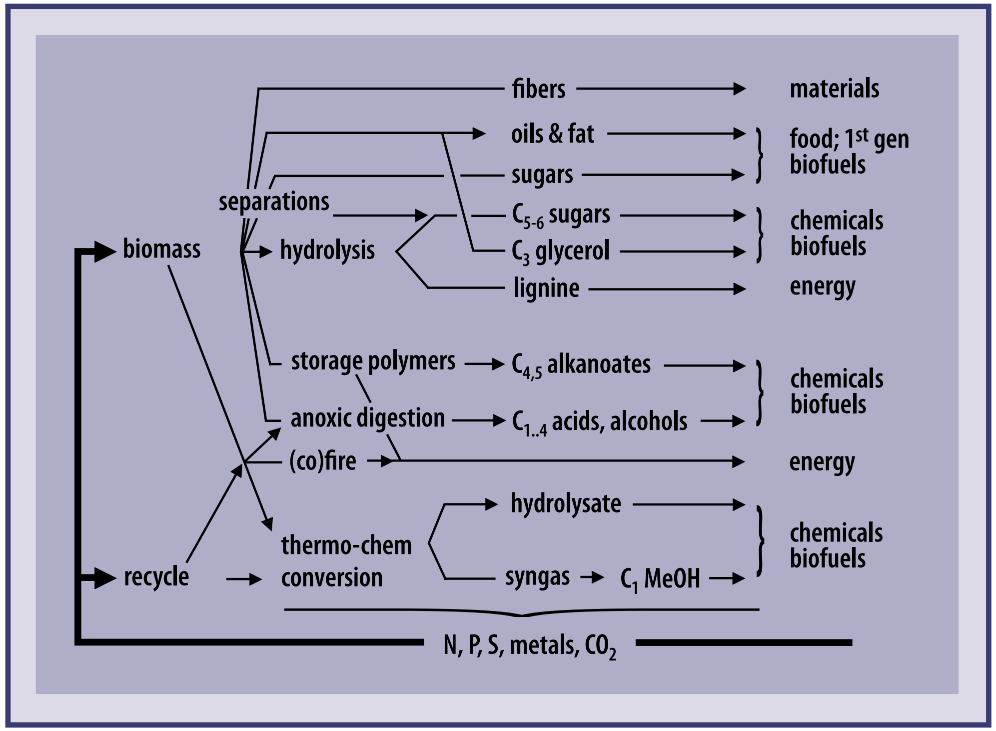


Figure 16. Simplified overview of fractionation and conversion of biomass into desired industrial and consumer products (source: Potential of coproduction of energy, fuels and chemicals from biobased renewable resources, WISEBIOMAS, 2006)

Detailed schemes were produced for all conversions, as for instance, represented below.

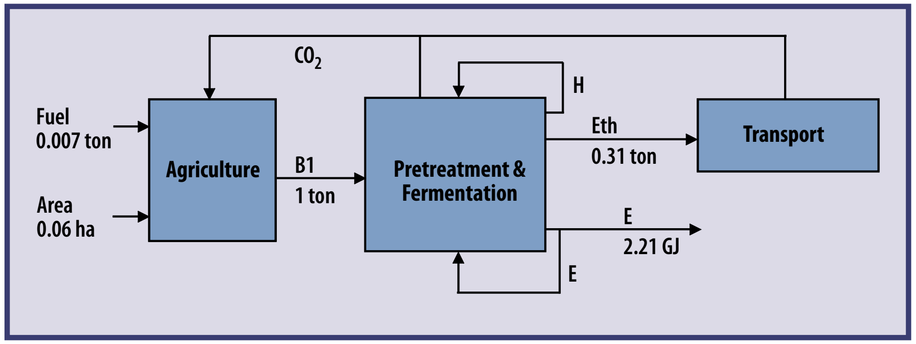


Figure 17. Conversion of lignocellulose rich biomass (B1) into transport fuel (ethanol) and electricity (second generation technology), using fossil fuels and agricultural land as input (source: Potential of coproduction of energy, fuels and chemicals from biobased renewable resources, WISEBIOMAS, 2006)

For the calculations by the working group oil prices are assumed to be \$50/barrel by 2030, varying up to \$70/barrel. The working group used the price of €100/tonne for biomass. This price is considerably higher than current prices, varying between €25 to €50 per tonne. The working group has attempted to prevent painting too rosy an image of the potential of biobased raw materials with these assumptions. Another assumption is that electricity production from natural gas will not be permitted by 2030. Capture and storage of CO_2 has not been taken into consideration in this overview.

The five scenarios developed differ strongly from each other along important lines. The second generation fermentation technology, which converts durable lignocellulose into high-value bio-fuels, scores highly when economic criteria are prioritised.

When the replacement of scarce natural oil is the most important goal, then the Fischer-Tropsch synthesis takes the lead, given that this involves a larger proportion of biomass being converted into transport fuels. Yet when reductions in CO_2 emissions are the primary aim, as much biomass as possible needs to be combusted as a replacement to coal, which is the fossil fuel with the highest CO_2 emission.

An example is presented of the scheme for energy housekeeping in the Netherlands in 2030 with the aim of "maximum yield", where biorefinery plays an important role alongside fermentation technology.

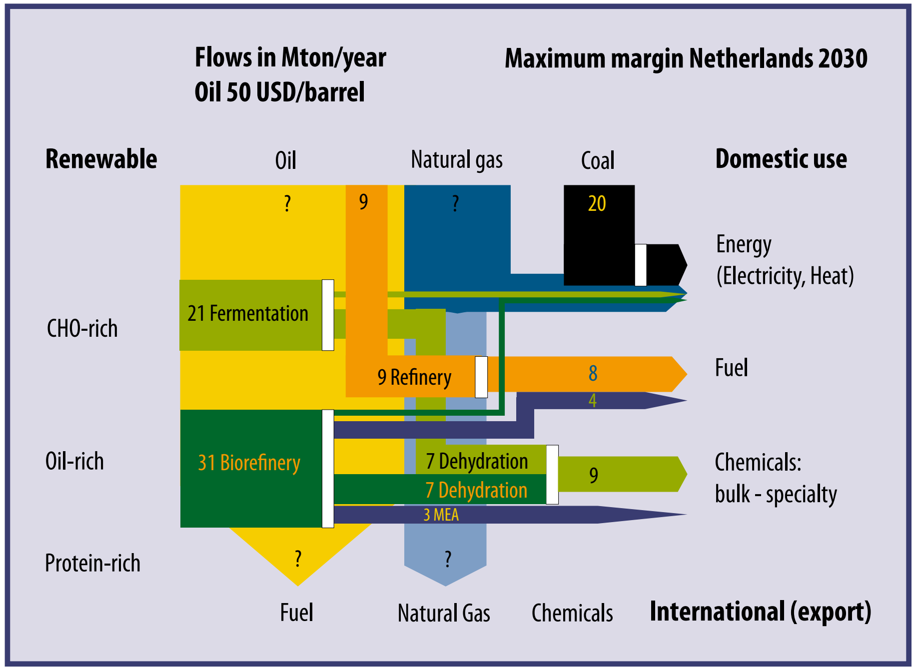


Figure 18. Energy flows for import, domestic use and export in the Netherlands in 2030 (objective 'maximum yield') (source: Potential of coproduction of energy, fuels and chemicals from biobased renewable resources, WISEBIOMAS, 2006)

The environmental effects of the various routes differ surprisingly little, irrespective of the level of difference in outcomes for the technologies chosen. Even route 5 does not score much higher than the others. This is illustrated in the following figures.

For instance, it is remarkable that CO_2 emissions do not differ strongly between the various routes and that the route providing the "maximum yield" even leads to fewer CO_2 emissions, than the route with a minimal CO_2 output (with restricted land use). In contrast, land use for maximising yield is relatively large.

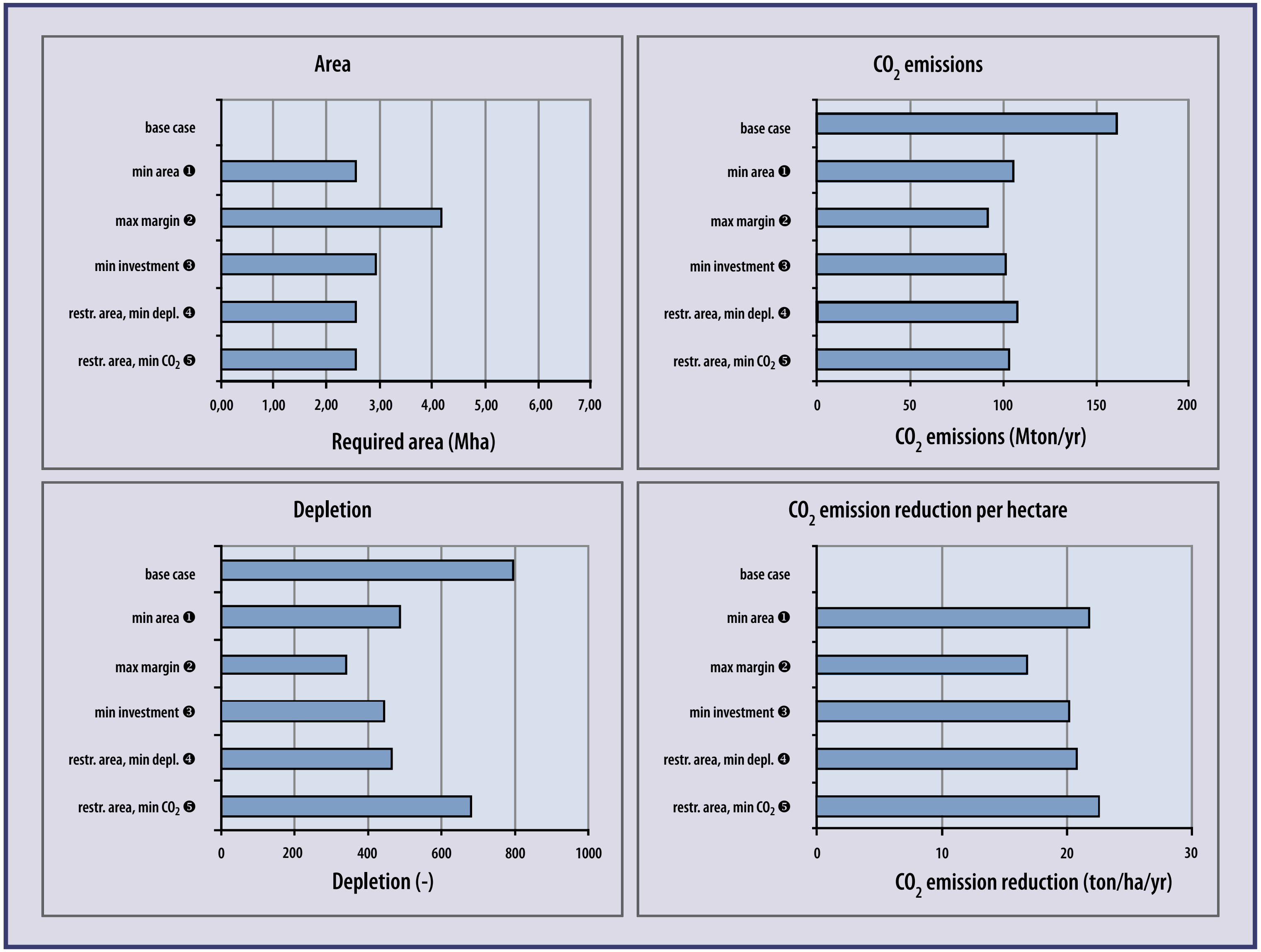


Figure 19. Scores from various targets on environmental impact (source: Potential of coproduction of energy, fuels and chemicals from biobased renewable resources, WISEBIOMAS, 2006)

In comparison with the environmental results, there is a great diversity in the economic results.

The most important detail of the economic effects is the negative result for route 5.

This arises because the available biomass is used to a maximum here to replace the cheapest fossil fuel, coal.

The results demonstrate that route 2 (allocate space for economic opportunities) is the most interesting.

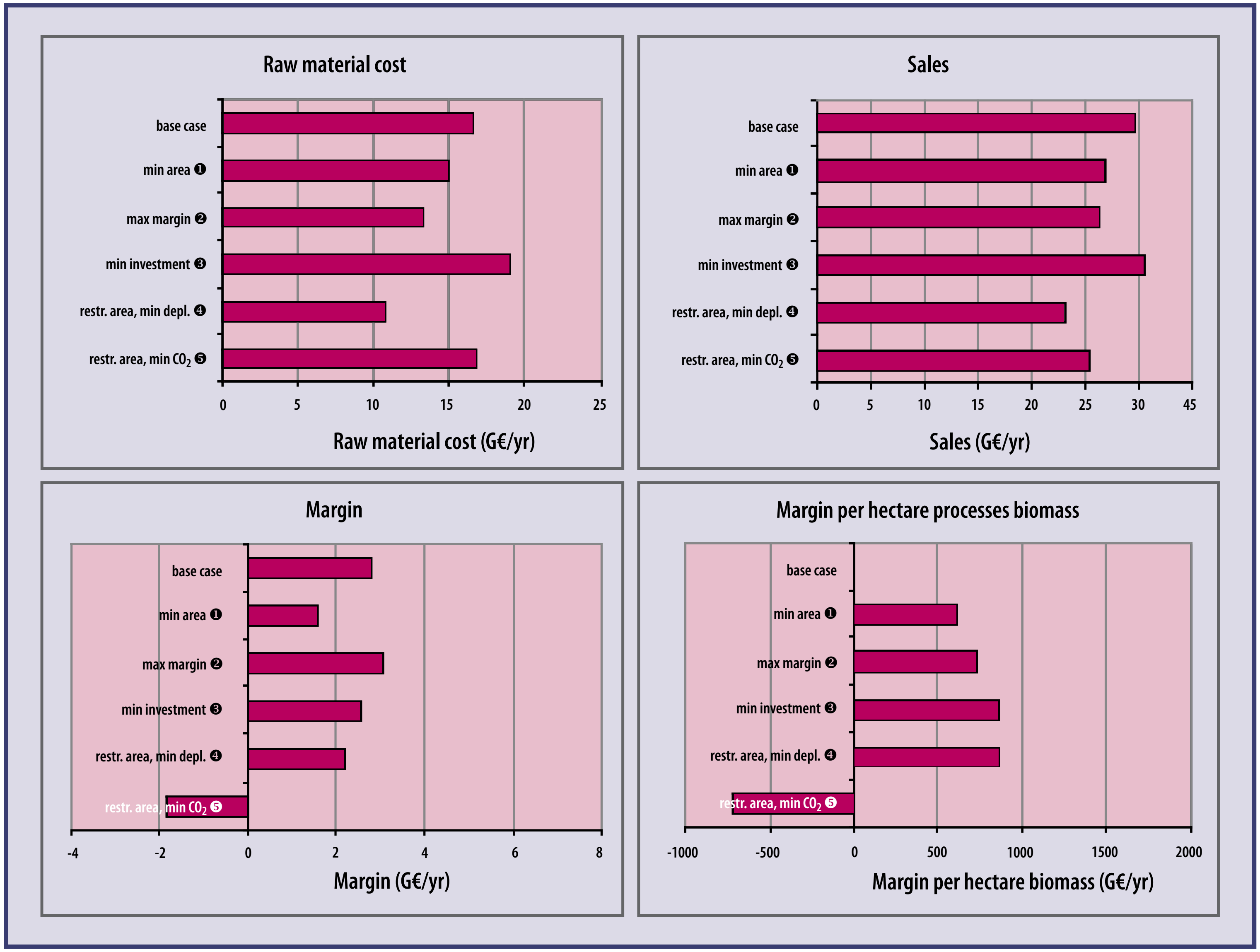


Figure 20. Scores from various targets on economic impact (source: Potential of coproduction of energy, fuels and chemicals from biobased renewable resources, WISEBIOMAS, 2006)

This leads to the largest margins for companies and thereby to increases in the Gross National Product. Replacing oil with biomass in 2030 appears to be more attractive than replacing coal.

WISEBIOMAS arrives at the conclusion that intelligent use of biomass in the future will be good for the economy, but that there currently is no clear winner between the technologies that would need to be employed for this. It is, however, important that the second generation technologies are developed as quickly as possible.

The working group believes there are four "paths" for biomass use. These paths will require collaboration between agriculture, and the energy and chemical sectors.

1. **The first path is the production of the second generation of transport fuels and other products from lignocellulose and agrarian residuals through fermentation and gasification.**

2. **The second path is "co-production" of fuels and chemicals alongside electricity and heat in large-scale co-gasification installations for coal and biomass.**

3. **The third path consists of improvements in use of existing residual streams from the agro-food industry through biorefinery and further conversion.**

4. **The fourth path is small-scale biomass (pre-)conversion near the source (land).**

Industry, government and researchers should now be encouraging the development of these four technology pathways, which are full of potential. In this way the Netherlands would be able to maintain and strengthen its position as a distributor and significant player in the chemical and agrarian sectors.

Researchers in Nijmegen and Delft have investigated mould from elephant droppings, as elephants are capable of extracting nutritive substances from hemicellulose. Researchers have identified the gene that makes this possible. By building this gene into a yeast, lignocellulose biomass can be converted into ethanol (second generation technology).

Creative Energy
Energy Transition

Strategy

Strategy

The use of biobased raw materials is unbelievably challenging and complex, as this requires diverse sectors in the economy and various new technologies to be become linked. It is exceptional that the Netherlands has a leading role in many of these technologies and that biobased raw materials, in addition, link-up well with the strengths of the Dutch economy. Three significant factors are the harbours, agro-industry (agriculture, horticulture, cattle breeding, food) and the chemical industry. The biobased raw materials theme links these, enabling them to profit from each other and develop further into what we would refer to in Dutch as a biobased economy.

Harbours play a role in the first instance within this scenario as a landing place for foreign biomass. Part of this will be transported on, and it is evident that that will partly take place following processing, as is currently the case for natural oil. A new, large-scale processing industry will be established around the harbours. Yet harbours will also play a role in the export of biobased raw materials and the products to be created from this. This is the advantage of having agriculture and horticulture close to the sea. It is not necessary for the development of these opportunities that all activities are concentrated in Rotterdam; Rotterdam, together with Delfzijl, Amsterdam and the Sloe area could become a single bioport.

The innovative character of Dutch agriculture and horticulture will be partly targeted on the development of biobased raw materials in a biobased economy. Therefore, the unique knowledge infrastructure of the Dutch agrosector, with research and application closely interwoven, offers all kinds of opportunities.

This conversion has in fact already been initiated. Wageningen University Research (WUR) is busy developing biobased raw materials for the production of energy and chemicals, which is being closely followed by both the agriculture and horticultural sectors.

The greenification of the chemical industry has provided the use of biobased raw materials with new impetus. The strong knowledge base in catalysis and biosynthesis in companies such as DSM and universities such as TU Delft can be usefully employed here. The transfer to biobased raw materials has already been in process for around 10 years in the chemical industry, and has led to the Netherlands taking a leading role.

Harbours, agriculture and the chemical industry are all looking for a new impetus. Biobased raw materials is the concept they could collaborate on and strengthen their position.

Market leadership

In various sectors in trade and commerce there are global market leaders. The New York stock exchange is a market leader in share trading; the diamond exchange in Antwerp has a similar position in its field, as have the flower auctions in Aalsmeer. The market leader is the key figure in business: the leader to whom other players look for direction. Many companies are concentrated around the market leader who profit, and at the same time contribute to his influence. The market leader is the nucleus of commercial activities, influencing places where the most important investments are made.

Market leadership is also referred to as stage direction, and in some sectors referred to as a hub or a main port. Market leadership is something that simply develops and chance alone will not predict whether and where a new market leader will emerge in any given field. Three elements appear to be essential: infrastructure and sales market, knowledge, and making the right choices based on an enterprising spirit.

The Netherlands has the potential to become a market leader in biobased raw materials based on its current position.

Infrastructure and sales market

This is without doubt an existing strength. The Netherlands has the Rotterdam harbour, a good network of rail and roads and a hinterland of 50 million consumers. This puts the Netherlands in a strong position for import, transfer and transport of bulk and fine goods. The Netherlands also has a leading global position in the fields of agrobusiness and logistics (flowers, vegetables, bulbs, seed potatoes) and food processing (coffee, cocoa).

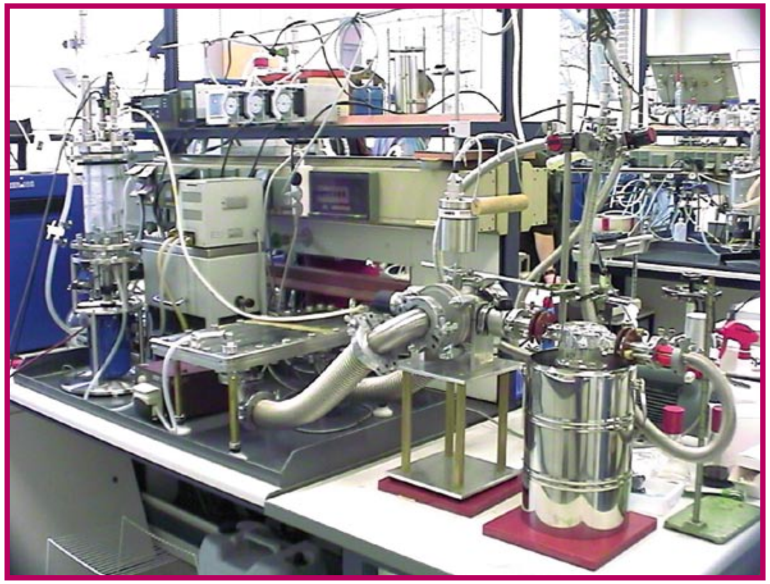
One aspect of logistics includes the organisation of optimal distribution. Energy production from locally produced and imported biomass can be maximised through control of production and storage and through the distribution of available raw material streams across local and international energy power stations. It is of course possible to leave this entirely to the market, but collective and co-ordinated management will more than likely lead to lower energy and economic losses. The challenge is to properly develop the management and distribution of domestic and imported biomass.

Knowledge. The Netherlands has an excellent position in extremely diverse supplementary fields.

Crops and cultivation. Traditionally the Netherlands has a lot of knowledge of cultivating tropical crops. The tropics are important suppliers of biomass through the large amounts of sunlight available. There is also a lot of knowledge concerning crop systems in the moderate climate in the Netherlands, which is applicable to large parts of Western Europe. The population levels will start to decrease, whilst food production continues to rise; it is anticipated that this will release land for the production of raw materials for energy and chemicals.
Models calculating the effects of the use of land, water, energy and food on various crop systems can also be used to contribute to the Dutch market leadership in this field.

Rights to seeds. A powerful way of controlling the chains is to have ownership, through variety rights, on basic plant material having a high production per hectare or other particular characteristics, such as trueness of variety or drought resistance. The Netherlands has an excellent tradition in this field. Patents can be applied to seeds and genes, which provide an attractive source of income for the owner.

Energy technology. The Netherlands has one of the leading knowledge institutes in the world in the field of energy in ECN. Gasification (with an emphasis on tar removal), torrefaction and pyrolysis are being developed in particular for biomass.



Biocatalysis in Germany

Fermentation technology. In general, the most value is added at the end of the chain, and this is where biotechnology is of great importance. As already described, fermentation technology has developed through the production of medicines; now the step towards the production of heavy chemicals can be made. A good knowledge position in this field will lead to new commercial developments and to more investments in processing of biomass in the Netherlands.

Right choices on the spirit of enterprise. Market leadership also involves making the right choices. Choices for investments are often made on advantages based on subsidisation. However, people perhaps base decisions on short-term benefits, which will disappear once the subsidy is cancelled (which is almost certain to happen at some point in time). Therefore, it would not be good if investments in bio-ethanol, biodiesel and biogas were only made with a view to existing advantages, such as the MEP scheme or reductions in excise duty.

These advantages are constantly debated – for instance, currently the real question is whether the MEP scheme should be differentiated by environmental impact, whereas existing regulations are only concerned with energy yields. Regulations are always the result of a range of interests, such as preventing CO_2 and NO_x emissions, water and food shortages, social effects and conflicting claims on land use.

The correct choices are made from thorough analyses. At each point in time there should be an analysis of whether the market or politics is the driving force behind developments, ensuring a quick response to events of strategic importance. How large should volumes of chemicals from biorefineries and fermentation technologies have to be at a minimum in order to influence the market?

Bio Methanol Chemie Nederland



"The development of a biobased economy is strengthened considerably by large cash streams derived from large-scale applications (energy, food production) after developments in fermentation technology. This dynamic could be employed in a national strategy. The world energy crisis will not be solved from the Netherlands, but we could make good use of strengths exploited elsewhere. Countries where the continuation of global energy supplies is particularly important are the US, India, China and Japan – and not the EU in the first instance! How's the pressure going to work from these countries, which direction will developments take? Even though the route from corn to ethanol is not economically feasible, this route will be explored, for instance, in the US, both because a lot of land lies fallow, and because of the strategy of replacing oil products. The Netherlands would be able to react to this with second generation technology.

Another development where the Netherlands has little influence is the arrival of palm oil. There is a considerable focus on this in Indonesia. Singapore is building a factory producing hundreds of kilotonnes. What is Brazil going to do? What is South Africa going to do? We would have to think through many scenarios to work out what the plans in these countries would mean for our scenarios for sustainable energy supplies. The provisional lesson is this: loose ends will have to remain unsolved for a while and the opportunities for a Dutch knowledge economy have never been this great!"

Alle Bruggink
Member of the Biobased Raw Materials Platform

Trial installation for pyrolysis at the Biomass Technology Group B.V. te Enschede

What influence does the introduction of a new product have on (for instance) the product chain in the petrochemical industry? How strong are the driving forces behind the (political) will to introduce biofuels on the market? The right estimates for these types of questions are important for the exploitation of biobased raw materials and eventually for the duration of the sphere of influence exerted by players in this new arena.

Large and small scale

There are potential surprises to be found in a biobased raw material economy. Industrial logistics, which are currently heavily dominated by the petrochemical industry, will have been re-developed. One of the surprising developments, which has been noticed by a number of members of the Biobased Raw Materials Platform, concerns the tendency towards small-scale industry.

"I am becoming more convinced that there's something to be had in decentralisation. Professional fermentation is extremely feasible on a small scale, as everybody who makes their own beer knows. Small-scale in combination with white biotechnology provides the opportunity to adapt specific processes to specific local conditions. Decentralisation allows adaptations to local conditions. Even small-scale gasification is a possibility, but small-scale syngas production is difficult, which is a reason for preferring methanol as an end-product on a local level. An example of industrial small-scale applications is the smokeless oven for gasification/combustion of biomass with high yields, which Philips has developed for application in third world countries".

Luuk van der Wielen
Member of the Biobased Raw Materials Platform

In a world of fossil fuels there is an inherent tendency towards large-scale. From a technological processing perspective, this is caused by the significant heat production generated by petrochemical processes. Conducting heat to other processes or into the environment costs a lot of effort (money), and processes with significant heat demands are therefore inherently large-scale. Biological processes demand much less heat and therefore can easily be adopted on a small scale.

This principle can be applied advantageously in the biobased economy. Sugar beets can once again be used as an example. Sugar beets are transported directly from the harvest to the sugar factory, as otherwise they would rot. Here they are processed into products of which 10% (mainly minerals) are returned back to the land.

In a biobased economy new technologies will have been developed whereby sugar beets could be processed at small-scale installations immediately after harvesting (washing, grinding, re-washing and condensing). This creates long-lasting pulp, which could be offered to a factory at an appropriate time, as well as a significant stream of residual products (70%), which can be fermented and of which the residue can be returned to the land. This offers various advantages. Firstly, the sugar factory would no longer be a seasonal concern; the factory would become continuously operational and therefore more efficient. The farmer would make savings on artificial fertiliser, as the digestate from the fermentation could be used on the land - resulting in a shorter and therefore more efficient nitrogen – carbon dioxide cycle. And, a non-negligible point: the farmer receives higher profits, as part of his products are fermented and thereby usefully exploited.

Biorefinery of grass can be approached in the same way. No application could be found for the procedure developed by the Progress consortium and Avébé when the latter persisted in focusing more on starch. Current insights would mean that large-scale utilisation would not be required. Central processing of grass means transporting 80% water, which is unnecessary when the same processes are adapted on a small scale. The building of a trial installation for grass biorefinery is being explored in Friesland in the framework of Courage, an association encouraging and supporting innovation in dairy farms in the Netherlands.

The biobased economy does not offer any advantages anymore for the expansion of most processes. This offers particular opportunities to countries currently not using naphtha and industrial infrastructure based around this. However, it is also important for the Netherlands, which does have a large naphtha capacity, to focus on the biobased economy. The production of heavy chemicals based on petrochemistry will possibly disappear gradually from the Netherlands, not because workers' pay is too high, but because natural gas is being combusted off as a by-product in some parts of the world and therefore could be used free of charge for the petrochemical industry.

"The focus on a biobased economy is still in its infancy. Previously, all biomass was used for food and feed; energy supplies were provided by fossil fuels. It is only recently that the cross-connections between these two fields have been charted. Price rises in fossil fuels and the use of agro-products for energy have suddenly ensured that other questions are starting to be posed. The fermentation industry is wondering where their raw materials will come from in the future. The sugar industry expected that the price of sugar would drop once agricultural subsidies were abolished, however, instead of this prices have risen, as ethanol is now also being produced from sugar and sugar prices are therefore directly linked to oil prices. The compound feed industry has pointed out that there is also demand for their raw materials from a different perspective".

Johan Sanders
Member of the Biobased Raw Materials Platform

Stimulation

The Biobased Raw Materials Platform has arrived at the conclusion from the calculations in Chapter 8 that the utilisation of biobased raw materials will be profitable, even without subsidies and other financial support by government. Significant support will however be required in the start-up phase, primarily due to the important differences to the current industrial structure. Large-scale investments within and beyond Europe confirm this.

Developments in biomass chains transcend sectors (involving agriculture/food, energy and chemistry) and therefore developments are progressing slowly. The danger is that the strong knowledge position is not being exploited sufficiently. The number of potential projects is enormous, both at a large scale (around the harbours), as well as a small scale (processing of agricultural residual streams).

Bio Methanol Chemie Nederland

The Biobased Raw Materials Platform believes it is of great importance that a level playing field is created for the applications of biomass: production of electricity, heat, transport fuels and chemicals. The government should encourage all initiatives, where the level of support depends on the contribution to CO_2 reduction and the economic perspective. Market parties and the government could put the Netherlands on the map. For instance, the government should support the production of biofuels by ecologically and commercially responsible processes, such as bio-ethanol from lignocellulose, bio-methanol and biodiesel, or the production of synthesis gas from biomass, or biorefinery of residual streams from the ethanol, biodiesel and soya processing industries. Developments and implementation of biomass production, biomass gasification and various forms of large- and small-scale biorefineries should be supported by the government, preferably in programmes closely associated with commercial life at a national and international level.

A bottleneck in the development of many new technologies, particularly in the Netherlands, is the availability of (venture) capital. Here lies the potential key to success. Therefore the Platform is proposing to create a public-private venture capital fund to which the government and financial institutions would contribute. This fund would be directed at investments in projects which fit in with the selected transition pathways and will be established for a period of ten years with an annual budget of 500 million Euro. The fund would be like a VC fund in nature, which means that it is not possible to determine in advance which projects would ultimately receive investments.

However, the commercial and sustainability criteria which projects would have to satisfy would be known in advance.

The intention of the fund is not to replace subsidies, but to be used for other investments.
It is intended to finance growth of activities which have been assessed in advance as being commercially successful.
This different investment perspective is also important for employers, who will not only receive incentives, but would also have the opportunity to be involved with critical participants who will see a return on their investment over the course of time. This demands a different attitude by government: not to aim at certain losses in infrastructure projects that are always too expensive, but aim towards uncertain profits with sustainable value.

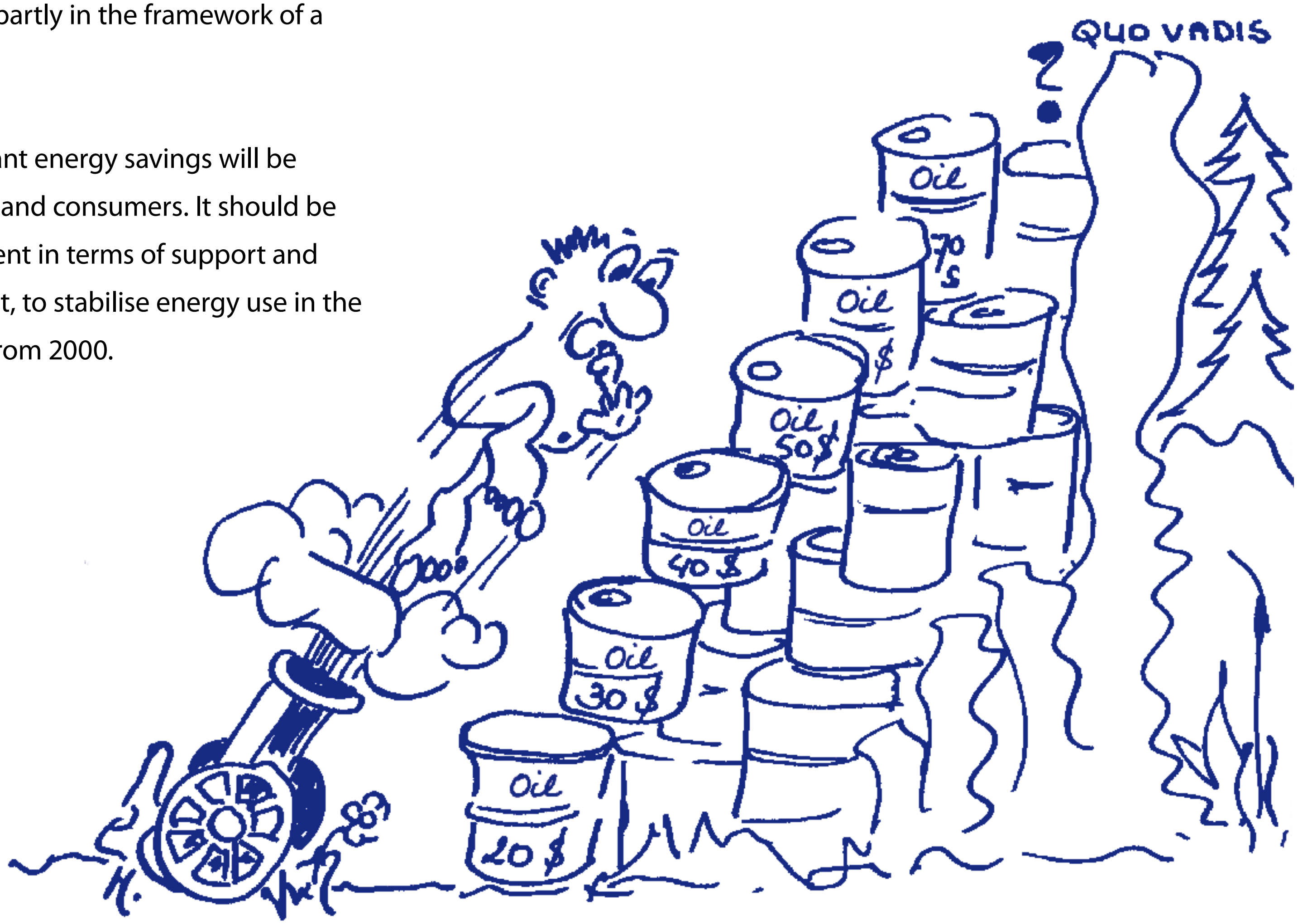
The fund will have a revolving character, as it is anticipated that it will deliver more money than is invested in it.

After a number of years the annual budget will be largely provided through the resale of earlier participations. The management of the fund will be independent and will have to rely significantly on funds from the optimisation of its economic value. It will have to be decided whether private equity partners and the government will have the right to veto new investments. This approach has proven to be valuable abroad. Given the relatively new nature of biobased raw materials, a supportive fund such as this is essential in order to realise the target of a minimum replacement of 30% of fossil resources by biomass in 2030.
Soundings from (large) banks and venture capitalists enforce the conclusion that such a fund would receive substantial support, in all cases.

From this perspective, the import of biomass will be led along responsible pathways through the introduction of a certification system by the government and market parties, which will tie-in to the already developed framework conditions for sustainability. Efforts will be made to introduce this system across the whole of Europe. Sustainable crops and processing of biomass for our imports are best developed collectively by the government and market in a number of selected countries, partly in the framework of a developmental collaborative.

The Platform assumes that significant energy savings will be made by the government, markets and consumers. It should be possible, with significant involvement in terms of support and encouragement by the government, to stabilise energy use in the Netherlands by 2030 to the levels from 2000.

The Platform is a proponent of the introduction of a broadly constituted group which will monitor activities in energy transition, supported by up-to-date scenarios, from, for instance, the CPB *(Netherlands Bureau for Economic Policy Analysis)*. This group will support the transition activities where required. The Platform wants to use this measure to provide the impulse currently required for the development of biobased raw materials in the Dutch economy.



For some people, things are changing a little too fast!

Towards a biobased economy

The biobased economy is an opportunity which should not be wasted. Green chemistry puts humans in a position to replace previously polluting and energy intensive processes by virtually clean production methods with low energy consumption. Biobased raw materials will provide the agricultural sector with a new impulse. Over a long transfer period, biofuels will help combat climate changes.

The biobased economy is only just in its infancy and there are still many loose ends. By being alert to changes on the world scene, the Netherlands could potentially start to play an important role in this new field, with positive consequences for domestic energy supplies, national commerce, and eventually for the environment as well.

Creative Energy
Energy Transition

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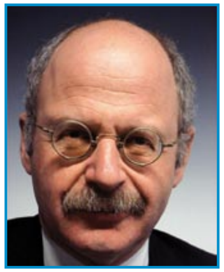

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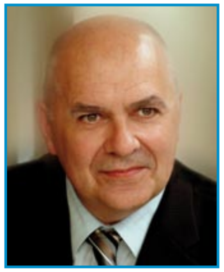

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Colophon

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Obverse of photograph: Mark Reinders' field of sugar beets in Emmen

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Industry, governments, knowledge institutes and civil society organisations all work together to ensure that energy supplies in 2050 are sustainable. Energy will then be clean, affordable for everyone, and in continuous supply.

Energy Transition demands and supplies creative energy.

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