PBL Netherlands Environmental
Assessment Agency

Biomass
wishes and limitations

Biomass: green with a dark rim

Biomass ① is an indispensable resource for a Dutch clean economy, as it is in many other countries. The organic material is used as a replacement for fossil resources. It thus, for example, reduces resource use and CO_2 emissions related to energy.

It is, however, all but simple. Not all biomass is equally sustainable. There are limits to the amount of biomass that can be produced without, for instance, harming biodiversity or food supply. What are the advantages and disadvantages of biomass? And where and how could it be best utilised?

PBL has made calculations for many of these aspects, listing the pros and cons and showing where the uncertainties lie. Additional information can be found in the explanations that also contain links to background documents with further details.

PBL Netherlands Environmental Assessment Agency ②

1. UP FOR DISCUSSION 2. TENSIONS 3. LIMITED SUPPLY 4. SMART APPLICATION 5. TECHNOLOGY

Biomass: up for discussion

Worldwide demand for energy and resources will increase substantially, over the coming decades. Their increased use will lead to more greenhouse gas emissions, while countries have agreed to reduce emissions in order to mitigate climate change. Europe, for example, strives for a low-carbon economy by 2050, with 80% to 95% lower greenhouse gas emission levels. Biomass, such as organic waste, wood and agricultural crops, is often seen as one of the solutions. In addition, it would cause the economy to be less dependent on countries that produce fossil fuels, such as oil and gas. However, using biomass does not only have positive consequences, and the various parties involved use the arguments **against or in favour of biomass in different ways.**③ This means biomass is often in the news. Is or isn't biomass a good alternative for fossil resources?

Many parties, with as many interests

Biofuel production causes increase in greenhouse gas emissions

NRC.nl - 05 January 2013

Port of Amsterdam goes for biomass

ANP - 31 January 2012

Experts: 'Bio-based economy is the answer to shale-gas revolution'

argo-chemie.nl - 18 April 2013

EU investigates Shell about misleading biofuel price

duurzaambedrijfsleven.nl - 15 May 2013

UN rapporteur: 'EU biofuel policy is criminal'

Website Energieraad - 4 May 2008

Europa puts the brakes on biofuel: 'too much food ending up in the fuel tank'

NRC - 11 September 2013

Professors: Stop incinerating good timber

De Volkskrant - 5 September 2013

Working together for a bio-based economy

De Volkskrant - 5 September 2013

Tension between wishes and possibilities

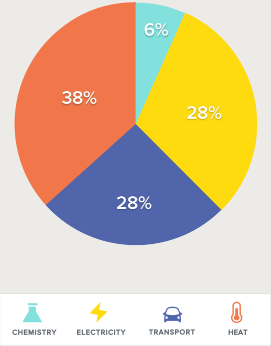
Biomass currently is the main source of renewable energy in the Netherlands. Plans show that, by 2020, the amount of biomass used to replace fossil resources will have doubled, compared to 2010 levels. For other European countries, biomass is also an important source of renewable energy. And the plans for 2050 are even more ambitious.

Wishes for biomass in 2050 for the Netherlands

TOTAL DEMAND FOR BIOMASS (2050):

1600 PJ

Based on **ambitions for 2050.** ⑤



USE IN THE NETHERLANDS

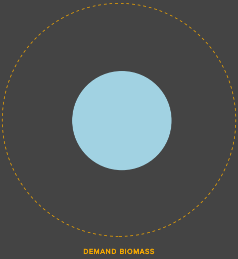
Around 2010, the share of renewable energy in the Netherlands fluctuated around 4%. Three quarters of this was in bio-energy ④ The demand for biomass will keep increasing, looking at the ambitions for 2050 (around 1600 PJ). ⑥

How much biomass could be available to the Netherlands in 2050?

TOTAL BIOMASS SUPPLY (2050):

290 PJ

Based on an average global availability ⑧ in 2050 for NL, based on the number of inhabitants, ⑨ this will be around 290 PJ.



In the Netherlands, in 2050, no more than **200 PJ** ⑦ in biomass could be collected. Imports – if available – could supplement this amount; this is also the case elsewhere in Europe. But how large this supplement will be is uncertain.

What causes the tension?

It is particularly unclear whether or not, in the future, sufficient amounts of biomass could be produced in a sustainable manner – i.e. without negative **impacts on climate, biodiversity and food supply.** ⑩
The possibilities for the Netherlands to use more biomass in the future, furthermore, not only depend on potential global production levels but also on the demand in other countries. If biomass becomes profitable and thus an attractive renewable resource for use in the Netherlands, this will also be true for other countries, causing a large demand. The Netherlands does have the advantage of its large, well-situated ports, suitable for large-scale importation.

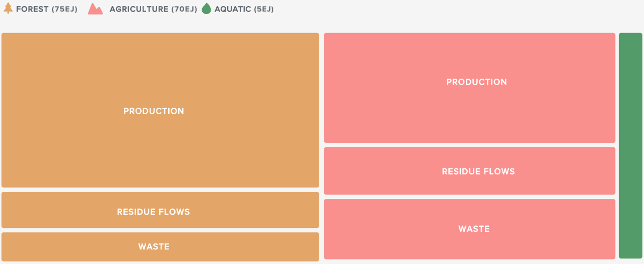
Other clean energy sources are also needed

The Netherlands and other countries have options to import sustainably produced and affordable biomass, but it is uncertain whether the amount of such biomass needed will be available to implement the plans by the various sectors, in the long term. It is therefore important to also develop other clean energy sources, as well as work on a supply of sustainably produced biomass that is as large as possible.

Tension between wishes and possibilities

The larger demand for biomass projected for 2050 will require a larger global supply. However, not all biomass is sustainable by definition. Would it be possible to step up the production of biomass without negative impacts, such as on the CO2 balance or on nature? Three biomass sources can be distinguished: agriculture, forestry and aquaculture. These, in turn, can be subdivided in primary production, related waste flows, and the waste from industrial processing and consumption.

Sources of biomass on a global scale in 2050?

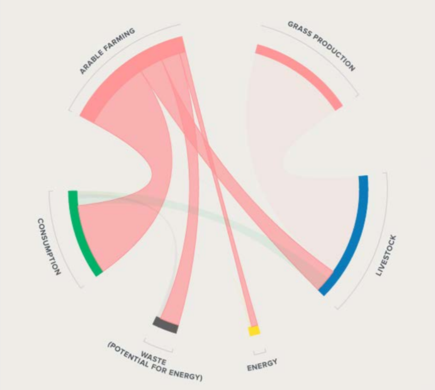


Biomass as a substitute for fossil resources comes from forests, agriculture and aquaculture. The expected amounts (in terms of energy) for the first two have been subdivided into energy crops in **agriculture and wood production (felling)**, ⑪ ⑭ ⑰ usable **residues of that production (waste flows)** ⑫ ⑯ and **waste resulting from processing and use.** ⑬ ⑮ This figure shows the average projections for the global biomass supply in 2050.

Current biomass sources

Agriculture and forestry already produce a large amount of biomass. When expressed in energy, this concerns around 400 exajoules (2010 levels). However, that biomass is mostly used for purposes other than energy. For example, **in agriculture biomass is used as food and feed,** ⑱ and large amounts of **wood are used for making paper and timber products.** ⑲ Here, this is illustrated. Could this biomass be used more effectively for energy, without taking away from the other applications?

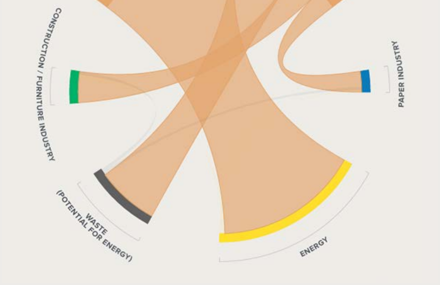
Energy from agriculture



ARABLE FARMING
The current global production in arable farming, when expressed in energy, represents around 123 exajoules per year. **Most crops are processed for human consumption, parts become animal feed and over 10 exajoules are used in biofuel production.** ⑳ Crops also contain inedible parts (estimated at 77 EJ), such as straw and leaves, which currently are not utilised. A large share remains on the land to ensure soil quality, but around 24 exajoules could also be utilised for energy. This potential will only be realised if the costs of collection and transport outweigh the benefits.

Energy from wood

FORESTRY



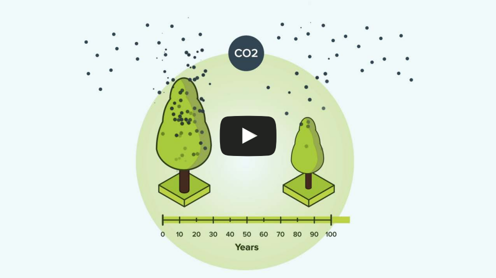
Expressed in energy, all the forests on earth, currently, yield around 66 exajoules in wood. A large share (close to 40 exajoules) is used in developing countries as firewood, often in primitive form and with a negative impact on human health. In addition, a large energy potential of around 17 exajoules is formed by currently unutilised felling residues (branches and tree stumps).

Agricultural crops as a sustainable source of energy?

Nature areas are converted to agricultural land for growing agricultural crops used for energy, both directly and indirectly (i.e. indirect land-use change (ILUC)). This results in additional greenhouse gas emissions and **biodiversity loss.** ㉑

There are indications of the negative effects of such **biofuels sometimes being greater that those related to fossil fuels.** ㉒ Therefore, the European Commission has drafted a **proposal** ㉓ according to which the use of agricultural crops for biofuel production is no longer stimulated, while providing incentive for the use of residues and waste flows.

Wood is not always sustainable



Using wood instead of coal or other fossil fuels is not always better for the environment. Along this line, the term **carbon debt** ㉔ is used. It namely costs time for the carbon cycle to close. To date, no sustainability criteria have been set for the production of wood and other solid biomass as a source of energy. This is currently looked at on a European level, but **opposing interests have turned this into a difficult process.** ㉕

Increasing the global supply in a sustainable way is challenging

Estimations about how much biomass potentially would be available on a global level, vary substantially. By far not all biomass can be produced sustainably, and by far not all biomass, on balance, leads to lower CO_2 emissions. However, agricultural crops and wood could contribute more, in this respect, than they do currently. For example, by a better utilisation of residues and waste flows. Moreover, productivity levels in agriculture and forestry could be increased, and cultivation of aquatic biomass at a successful development could also contribute more to the supply of energy. This requires biotechnological knowledge, and the greatest challenge is the practical application of such knowledge.

Smart application of biomass

A far-reaching reduction in emissions by 2050 requires a **broad package of measures, with the use of bio-energy as an indispensable element.** ㉖ If the availability of sustainably produced biomass is limited, it would be most effectively applied in the sectors that do not (also not in 2050) have any clean alternatives at their disposal. A possible preference for the use of biomass in certain sectors would require specific government policy. Policy in the Netherlands, for example, includes a limitation on the co-firing of biomass in power plants.

If bio-energy could be combined with the capture of CO_2, **'negative' emissions** ㉗ could even be realised. This could be applied for existing large plants or industrial sources, as well as for new large-scale installations that produce biofuel or green gas.

Are clean alternatives to biomass available?

ELECTRICITY

ELECTRICITY PRODUCTION: There are many clean

CHEMISTRY

CHEMICAL INDUSTRY (PRODUCTION OF PLASTICS):

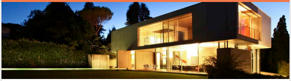
alternatives for electricity production, such as wind, solar or hydro power, possible also geothermic power and nuclear power. The last would be dependent on social acceptance, the guarantee of safety and a viable solution for safe waste storage.

Biomass is the only alternative to fossil fuel that contains energy as well as carbon. These are crucial components in the required resource.

PROCESS HEAT INDUSTRY

PROCESS HEAT INDUSTRY: Perhaps, at some point in the future, hydrogen or electricity could be used for generating more high-temperature heat, but as yet this is still uncertain. Currently, solid biomass and green gas are the only alternatives for current gas use. For industries with high CO_2 emission levels, this may be combined with CO_2 capture.

SPACE HEATING



SPACE HEATING: All alternative options have their limitations; particularly in existing buildings. In the winter there is no solar heating, geothermal energy only suits a limited number of locations, and heat pumps often require far-reaching renovations. Green gas is one of the main options.

PASSENGER VEHICLES

PASSENGER VEHICLES: Electric cars and those on hydrogen are already on the road and are a serious option for the future, although they still have to prove themselves, with respect to price–performance ratio and user-friendliness. Application of biomass, in that case, would be less or not at all necessary.

FREIGHT TRANSPORT

ROAD FREIGHT, AIR TRANSPORT AND SHIPPING: No feasible alternatives to biofuels are expected to be available yet, by 2050. For trucks, this applies particularly to long-distance transportation of goods.

Where could biomass be best implemented? Are we taking the abovementioned considerations into account? Increasing the share of biomass for certain applications would reduce the supply for others. What choices are made in society and on which sectors could the government direct its focus?

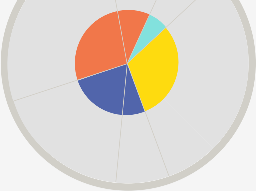
Making strategic choices

PROCESS HEAT INDUSTRY

... clean alternatives uncertain.
CO_2 can be captured.

CHEMISTRY

... no clean alternatives.



SPACE HEATING

... or using local sources
(soil heat, solar).

TRUCKS, AEROPLANES AND SHIPS

... no clean alternatives. CO_2 capture
is an option for biofuel production.

ELECTRICITY

... or solar, wind, hydro,
nuclear power. CO_2 can be
captured.

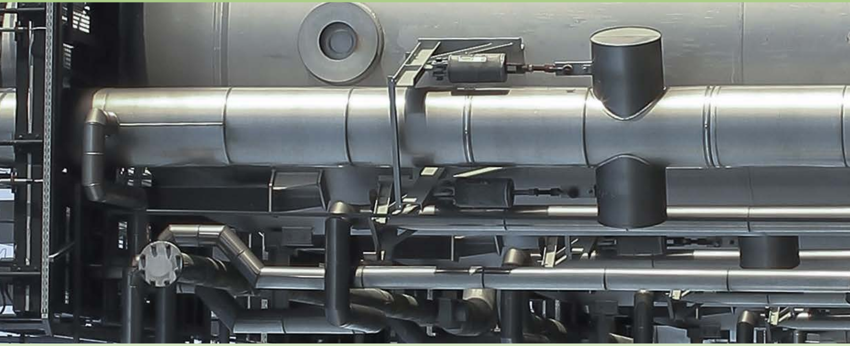
PASSENGER VEHICLES

... or electric or hydrogen vehicles.

In this example we used an estimation of **800 PJ** ㉘ of biomass to be implemented between different applications.

Strategic application of sustainable biomass

The possibly scarce, sustainably produced biomass could be used most effectively in applications for which there are no alternatives. This applies for example to heavy transport, aeroplanes or as green gas in the gas grid. In the production of those biofuels or that green gas, a large amount of the related CO_2 could also be captured and stored or reused. This combination can be an important building block for a low-carbon economy, although further innovation is required to make this combination an economically viable option.



Wanted: the right

technology

Residues from agriculture and forestry and woody energy crops, in the future, may become an important source of biomass: biomass containing high levels of lignocellulose. If these types of biomass can be converted into liquid fuels, green gas or plastics, products will be created that can easily be implemented in our current energy system. The required infrastructure is already there. Gas equipment, after all, is very commonly used and vehicles, ships and aeroplanes already use liquid fuels.

However, it is the technology required for such conversions that is still **very much under development**. ㉙ Gasification and advanced forms of fermentation are options, in this respect. Many of such current projects are large scale demonstrations. In this area, there are many innovative challenges; among which the combination of storage of renewable electricity (wind and solar) with CO_2 reuse (**power to gas**). ㉚ Perhaps this also offers opportunities for a green economy. Utilisation of these opportunities requires explorative studies, investments and new collaborations.

Biomass: wishes and limitations

A low-carbon economy by 2050 must be jointly built by the many parties involved. This also applies to the role of biomass. These are the challenges:

1. Using knowledge and expertise to increase current production in agricultural and forestry systems, to improve the use of residue and waste flows, and to further develop aquatic biomass production.
2. Ensuring internationally supported sustainability criteria, to prevent negative effects and provide investors with guarantees about the acceptation of biomass as a resource.
3. Developing technology for the conversion of dry, woody biomass into liquid fuels or green gas, making this into an alternative in the energy system or chemical industry.
4. Utilising and, where necessary, modifying the existing infrastructure.

The process is a joint effort by national, European and global policymakers and politics, oil and gas companies, nature and environment organisations, farmers and other entrepreneurs. The objective for the long term requires actions to be taken in the short term. This includes the try-out of and investment in new technologies and collaborations.

For comments and questions on 'Biomass: wishes and limitations', please contact Jan Ros (MSc) or Anne Gerdien Prins.

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EXPLANATION

1. Biomass

Biomass includes all materials originating from organisms recently grown, such as food, wood, agricultural products, algae, animal fat and biodegradable waste. There is no precise definition of the term ‘recent’, in this context, as it may include timespans of a few dozen years (e.g. for trees), but biomass does not include fossil raw materials such as petroleum, coal and gas, which were formed many millions of years ago from plant materials. At the combustion of biomass, CO_2 is released that had been taken up during the growth of the organisms involved. This therefore represents a short carbon cycle.

Biomass can be converted into all desired forms of energy (energy carriers), such as liquid fuel, gas, solid fuel (pellets), electricity, and raw materials for plastics, and thus can replace any fossil raw material. This has the advantage of not requiring any major modifications to the infrastructure or at implementation. However, growing biomass as a source of energy does require land and, therefore, may compete with food production or nature.

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2. PBL Netherlands Environmental Assessment Agency

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For more information or comments about ‘Biomass. wishes and limitations’, please contact Jan Ros or Anne Gerdien Prins.

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3. Many parties with many interests

A far-reaching change in the energy system, such as large-scale replacement of coal, petroleum and gas by biomass, affects many parties and many interests. This not only leads to opportunities and threats, but also to complicated dilemmas. In many cases, these dilemmas are related to the negative effects (e.g. an increase rather than a decrease in emissions) involved in the production of **agricultural crops** or wood. A few examples of such dilemmas are provided below.

NATIONAL GOVERNMENTS

The EU Member States have reached certain agreements about reducing greenhouse gas emissions (20% reduction by 2020, compared to 1990 levels) and increasing the share of renewable energy (20% in Europe by 2020; 14% for the Netherlands). They are searching for cost-effective solutions to meet their obligations, and in many cases bio-energy does fit the bill. Here it is very important that the emissions from biomass or biofuel combustion are not included in national emission data, because the CO_2 released during this combustion is soon after taken up by plants again; the carbon cycle thus is both short and closed, in contrast with that of fossil fuels. The emission impact from biomass production is also excluded, as long as it occurs outside national borders. The Netherlands benefits from this fact, as it imports relatively large amounts of biomass and biofuels, compared to its own production levels. This is not to say that there is no emission impact at all, but the degree of impact is uncertain. National governments are responsible for matters of environmental quality and nature management; therefore, they must ensure that biomass is being produced in a sustainable manner. EU sustainability criteria have been set for this reason. In all likelihood, however, this will cause the level of biomass production to remain limited, while, without biomass, it will be more difficult to achieve EU energy and climate targets. This is a political dilemma.

PETROLEUM INDUSTRY

For companies that earn their money with crude oil products, biofuels form a direct competition. Unsurprisingly, these oil companies were not enthusiastic about the first-generation of biofuels based on agricultural crops. After all, also small enterprises are able to produce these types of biofuels. Mixing biofuels in with petrol and diesel became compulsory, and this made oil companies worry about the quality of their fuels.

The ‘second-generation’ biofuels, based on waste flows, often require more knowledge and capital than small enterprises can muster, but oil companies do have such resources available. In addition, focusing on these fuels is seen as taking ‘social responsibility’, which is therefore also a good selling point. These companies have entered into some innovative initiatives to study the use of biomass, but ultimately they weigh the actual implementation against the risks (higher costs) of new technology development, and there must be a solid guarantee of the availability and sustainability of the required raw materials. Whether the large oil companies want to invest in biofuels also depends on the force behind policies that create a market for these sustainable biofuels. Without that, they see entering into such new developments as nothing more than competing with their own products.

ENVIRONMENT AND NATURE ORGANISATIONS

Environment and nature organisations argue that something must be done about the climate issue, that bio-energy could contribute to a solution, and that, therefore, this type of energy generally needs to be considered in a positive way. They do recognise the negative effects related to certain types of biomass, such as those on biodiversity. Thus, from an ecological perspective, bio-energy is not automatically good or bad. Often, it is a question of the degree to which these positive and negative effects manifest themselves – something that is not easy to determine.

INNOVATIVE, SMALL ENTERPRISES

The importance of biomass for achieving climate and energy objectives encourages creative entrepreneurs to develop new ideas for application possibilities, sometimes using innovative technology, but also with relatively simple, existing technology. A few years back, for example, small and larger biodiesel and bioethanol factories mushroomed. Potential initiators, however, are confronted with negative information about the unsustainability of biomass and, as small players in this field, they have only limited insight into the complex issue and can hardly exert any influence in this complex force field.

ARABLE FARMERS

At the start of the 21st century, the European agricultural sector faced high production costs, compared to its global competitors. The demand for biofuels, therefore, was a blessing, as it created new market possibilities for products such as maize and rapeseed. They did not consider critical remarks by scientists, NGOs and later also policymakers about possible **negative indirect effects** as being related to their own type of production. European arable farmers also have no influence on nature losses elsewhere in the world. Meanwhile, more stringent European sustainability criteria have been proposed for biomass production. These proposals are threatening to bring the development of agricultural crops as a basis for transport fuel to a halt; the opposition from the side of the agricultural lobby against these proposals therefore is understandable.

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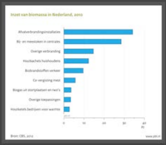
4. Bio-energy in the Netherlands in 2010

A total of 115 petajoules of biomass was used in the Netherlands, in 2010, in the supply of energy. The figure on the right shows the distribution of this use over the various applications. The main applications are in waste incineration and in co-firing of biomass in coal-fired power plants. In 2010, bio-energy was the main form of renewable energy available in the Netherlands. To date, all Dutch households together generate more renewable energy using wood burners than they do using solar panels.



Implementation biomass in the Netherlands (Dutch) 2010.

READ MORE

Compendium voor de Leefomgeving, dossier hernieuwbare energie (Dutch).

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Renewable energy in the Netherlands in 2011 [*Hernieuwbare energie in Nederland in 2011* (in Dutch), Statistics Netherlands (CBS) (2012).

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5. Preferred application of biomass in the Netherlands, in 2050

The amount of biomass that the Netherlands will need in 2050 is of course as yet uncertain. Any statement to this effect is based on a very large number of assumptions. The data presented here are not based on scenario analyses, but on documented or proposed ambitions of various social parties and sectors. The data indicate the total demand for biomass if all sectors would realise their ambitions. One of the assumptions for these data is related to the total energy demand in the Netherlands in 2050 being very similar to that of today. This means that it is assumed that energy saving will compensate for a possible increase in economic activities.

Ambitions and data show that a transition towards a low-carbon economy has begun, and that biomass is a popular renewable energy source, in this respect. A similar picture emerges from the plans as presented in 2010 (National Renewable Energy Action Plans, NREAP) by the EU Member States to achieve the targets for 2020.

READ MORE

Sustainability of biomass in a bio-based economy. A quick-scan analysis of the biomass demand of a bio-based economy in 2030, compared to the sustainable supply, Ros, J. et al. (2012).

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6. Petajoule/exajoule

1 petajoule (PJ) is $1x10^{15}$ joules (a million times a billion joules).

1 exajoule (EJ) is $1x10^{18}$ joules (a billion times a billion joules).

1 exajoule = 1.000 petajoules.

Illustrative example: in 2011, the Netherlands used over 3,000 petajoules, or over 3 exajoules, in energy. Worldwide energy use currently is around 500 exajoules. Global primary energy use in 2050 is projected to be between 700 and 1,000 exajoules (OECD, 2012).

REFERENCES

Environmental Outlook to 2050, OECD (2012).

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7. Biomass production in the Netherlands

It is estimated that the Netherlands, in the long term, may produce or collect no more that around 200 petajoules in biomass to replace fossil raw materials. Achieving this maximum quantity will be a real challenge. Most of the increase in biomass can be achieved by a better utilisation of waste flows, such as those from agriculture and forestry, the food industry and wood processing companies, household waste and waste water, and residue flows from nature, park and roadside management. Specifically grown energy crops – crops and trees grown for the production of biomass (e.g. willows) – are projected to only contribute a small portion, also due to the limited amount of existing or newly developed agricultural land available for this purpose. If sectors and businesses wish to use more than 200 petajoules in biomass, this would have to be imported.

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8. Estimation of future global sustainable production

Estimations for 2050 of possible global production of biomass for energy vary between around 50 to over 400 exajoules, or more. The level of uncertainty, therefore, is large, also because future supply depends strongly on future global developments in, for example, population growth, agricultural technology and consumption patterns, as well as on the feasibility of initiatives specifically aimed at the production or collection of biomass in the future. Therefore, here, we distinguish three different projections/scenarios:

HIGH

- Agriculture will become more efficient; thus, there will be land 'left over' to grow energy crops
- Nearly all residue and waste flows will be utilised
- Research developments will lead to successful applications

MEDIUM

- Agriculture will partly become more efficient; leaving land available to grow energy crops
- A large share (around half) of residue and waste flows will be utilised
- Research developments only lead to successful applications in niche areas

LOW

- Land use for energy crops is not considered sustainable
- Only a small share of residue and waste flows is utilised, from both a practical and a business economic perspective
- Research developments do not lead to successful applications

See the **section on sustainable supply** for specific information per source.
For comparison: current global energy use is around 500 exajoules, mostly in fossil fuels such as coal, crude oil and natural gas. The conversion of energy from biomass to usable forms of electricity, transport fuels and heat is less efficient than from fossil sources; replacing 1 petajoule of fossil fuel generally requires 1.5 to sometimes 2 petajoules of biomass.
For comparison: in 2010, the global agricultural production of biomass on arable land and pastures – particularly of food and feed – contained over 300 exajoules in energy, and over 80 exajoules in trees were felled and collected, globally. For the development of a clean energy system, realising the medium scenario , with a total biomass supply of 150 exajoules, is already considered a challenge, one for which many initiatives will be required.

READ MORE

Biomass Assessment. Assessment of global biomass potentials and their links to food, water, biodiversity, energy demand and economy, Dornburg et al. (2008).

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9. Allocation of global production

Projections of the global supply of biomass by 2050 vary roughly between 50 and 400 exajoules, with 150 exajoules being regarded as feasible with the help of fairly successful initiatives (see **limited supply**). The supply, therefore, is not unlimited. What part of this could be available to a given country in 2050? No hard data are available, of course, as supply and demand will partly depend on biomass affordability, technological developments, and the policies in various countries. For example, policies on climate and energy (e.g. in targets for renewable energy sources and emission reductions in Europe) as well as those on the environment and nature (based on sustainability criteria) all influence the 'biomass market'. To provide something of an indication of the amount of biomass that could be imported into the Netherlands, we constructed an impression of the biomass available to the Netherlands, on the basis of two possible 'distribution keys':

Divided according to the number of inhabitants: Potential biomass production is distributed over the world population (an equal amount of biomass, per capita). By 2050, the Dutch are projected to make up 0.19% of the world population; 0.19% of 150 exajoules is nearly 0.3 exajoules (for comparison: total energy use in the Netherlands in 2013 was around 3 exajoules, or 3,000 petajoules).

Divided according to income: Potential biomass production is divided on the basis of gross domestic product. OECD projections indicate that the Netherlands, according to GDP, by 2050, will make up 0.6% of the global economy; 0.6% of 150 exajoules equals around 0.9 exajoules, or 900 petajoules.

To place the global potential into a European perspective: if, for 2050, an equal distribution per capita is assumed, the potential for Europe (including trade) would be about 10 exajoules. A distribution based on income may deliver twice that potential. Another important factor is the national or regional availability of biomass, as transport costs can be high. Costs related to liquid waste flows, for example, will be too high to warrant long-distance transportation. Furthermore, experience has shown that countries with a large biomass production (such as those of Scandinavia) also use much of that biomass for themselves.

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10. The use of biomass has an effect on climate and biodiversity

Biomass implementation is seen as one of the options for reducing CO2 emissions, but this may also involve negative ecological effects. Biomass production first requires land. If nature areas are used for this purpose, this will have – direct or indirect – consequences for biodiversity. Moreover, greenhouse gases will be released during the conversion of nature areas and the intensified use of agricultural land. The magnitude of such effects is uncertain. In the second place, the felling of trees affects the carbon stock in forests, and – when fossil fuels are replaced with wood – it may take a very long time before CO_2 levels in the atmosphere really come down.

READ MORE

Identifying the indirect effects of bio-energy production, Ros, J. et al. (2010).

Evaluation of the indirect effects of biofuel production on biodiversity: assessment across spatial and temporal scales, Oorschot, M. van, et al. (2010).

Indirect effects of biofuels: intensification of agricultural production, Stehfest, E. et al. (2010).

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11. Biomass sources: wood production

Wood production, here, refers to forests and forest plantations, supplemented by fast-growing types of wood, such as willows, grown on land no longer used in agriculture (see **information on agricultural production**). Because the types of energy crops that will be chosen in the future are as yet uncertain, the distribution of agricultural land for fast-growing grass and fast-growing wood, in percentages, has been kept at 50:50. The ‘low’ scenario assumes that using additional land for growing wood will be regarded unsustainable. According to the ‘medium’ and ‘high’ scenarios, additionally grown wood will provide a respective potential of 20 and 75 exajoules in energy.

In addition to this potential of specific energy crops, there is the use of wood from different types of forests. In 2010, close to 50 exajoules in wood was taken from forests and directly used as energy (for combustion) (**current biomass sources**). Some trees were felled for this purpose, while another part was in gathered residues; but the ratio between the two is unknown, nor do we know whether this was done in a sustainable manner. Partly for this reason, the scenarios do not assume all of this practice to be continued. Furthermore, an additional 15 exajoules in wood is assumed to be needed by 2050 for more wooden products and paper, which is subtracted from the projected amount of wood available for energy.

The minimum – under the ‘low’ scenario – is assumed at 10 exajoules. A strong downward trend is expected in the use of woody biomass as a traditional energy source. For the future, it is furthermore expected that certain sustainability criteria also will be applied to woody biomass. It is, however, also expected that a limited amount of wood can always be harvested in an acceptable, sustainable way.

The maximum – under the ‘high’ scenario – is assumed at 35 exajoules, plus around 75 exajoules in fast-growing trees on vacant agricultural land. The medium scenario indicates 25 exajoules from forests also used in 2010, plus an additional harvest worth 20 exajoules.

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12. Biomass sources: wood residue flows

In 2010, tree felling resulted in an estimated 15 to 20 exajoules in wood residues, globally. This concerned branches, tree tops, less suitable trees / tree species and dead trees. These residues often are left behind in the forest or are burned on location because taking them out is not economically viable. They could be used for energy (**current biomass sources**). For the future, the demand for wood in the form of wooden products and as a material is expected to increase up to 25 exajoules (OECD, 2012), and so will the amount of felling residue. Under the ‘high’ scenario, an optimal utilisation of these residues is expected, and thus a future supply of 25 exajoules.

The ‘medium’ scenario assumes 15 exajoules in woody biomass from residue flows, assuming a policy is implemented to stimulate the use of these residues. The full potential of these residues is not assumed to be used, as this for practical reasons is expected to be unviable. The ‘low’ scenario assumes that, for the reasons above, only a small share (5 exajoules) will be used for the supply of energy.

REFERENCES

Environmental Outlook to 2050, OECD (2012).

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13. Biomass sources: wood waste

In 2010, around 5 exajoules in wood and paper waste was utilised for energy. This is less than the input of wooden products in society. The stock of wooden furniture and construction materials therefore is increasing; more wooden furniture and construction materials are created than are being discarded or recycled. Eventually, therefore, more wood waste will become available. In addition, an increase in the demand for paper, wooden products and construction materials is expected (35% up to 2030, and 58% up to 2050 (OECD, 2012)).

The ‘high’ scenario for 2050 assumes an increasing waste flow, equalling the amount of input in 2030, all of which is expected to be used in energy generation. This could yield close to 20 exajoules. The ‘medium’ scenario assumes an amount of usable waste that more or less equals the 2010 input of 15 exajoules. The ‘low’ scenario assumes the utilised waste flow to remain around 5 exajoules.

REFERENCES

Environmental Outlook to 2050, OECD (2012).

▲ GO BACK

14. Biomass sources: agricultural production

The main agricultural energy crops are those used for biofuels, such as rapeseed, oil palm, sugar cane, maize and wheat. As these are also food crops, their use in this respect is often criticised. The main sustainability aspect is that of land use. **European policy is aimed at no further stimulation of these types** of energy crops. For these crops, a basic production level of around 5 exajoules is expected to remain, nevertheless.

In addition, there are rather new developments in the form of growing grasses, such as miscanthus, or fast-growing trees, such as willows and poplars. These crops are assumed only to be regarded as sustainable if and when there is no competition with food production; thus, that such production takes place on vacant agricultural land. There is a high degree of uncertainty about the exact ratio between land crops and fast-growing tries on the available agricultural land. Our projections assume 50% wood crops and 50% agricultural production. Various studies over the last decade have estimated the potential of energy crops. All of these studies have excluded the agricultural land globally needed for food and feed production in 2050, as well as nature areas. The remaining agricultural land area is then assumed available for biomass crops. Estimations vary between 0 and 1,500 exajoules per year. More recent studies have reduced this range to between 200 and 500 exajoules per year, and those assuming practical as well as more realistic starting points have even brought this down to between 44 and 133 exajoules. The most recent projections exclude an additional number of areas, such as those with degraded soil or water scarcity, and areas with large amounts of carbon stored in the vegetation and soil.

Studies that result in high estimations have assumed production levels of agricultural crops to more than triple, in the long term. This would reduce the size of land required for food crops and leave a large amount of land available for biomass crops. In addition, they assume the yield of the biomass crops to increase substantially, in the long term. We do not consider this a realistic scenario. Our ‘high’ scenario assumes a land area of 6 million km2, which is in line with studies that assume an increase in agricultural productivity that is more or less equal to that of the past decade. The yield in energy crops per square kilometre is assumed to be 1.5 times higher than of current forest plantations. This would deliver around 150 exajoules in potential energy, distributed over agriculture and forest plantations, which leads to 80 (75 + 5) exajoules from agriculture. The ‘medium’ scenario assumes sustainability criteria to also be applied for this biomass, and that, therefore, not all land will be suitable. Thus, we assume a total available land area of 2.5 million km2. Yields, in that case, would be similar to those of 2010: 15 megajoules per square metre, providing a total of 40 exajoules in potential energy, in turn, leading to 25 (20 + 5) exajoules in agricultural crops.

According to the ‘low’ scenario, these yields will not be realised, as they appear unprofitable and/or are not supported because of stringent sustainability criteria. The potential, thus, does not exceed 5 exajoules. The method of excluding certain areas is valuable to determine the size of the area potentially available, without having an impact on, for example, food production. In practice, these crops are unlikely to be grown in specially designated locations, seeing the current liberal character of the economy; therefore, competition with food and feed production is likely, and these crops are expected to be grown wherever that would be economically viable. Transport costs, energy prices and climate policy will be important factors, in those cases.

READ MORE

Biomass Assessment. Assessment of global biomass potentials and their links to food, water, biodiversity, energy demand and economy, Dornburg, V. et al. (2008).

▲ GO BACK

15. Bronnen van biomassa: afval uit landbouw

Losses are incurred during the transportation, storage, processing and consumption of food. The amounts and rate of loss vary per region. In countries with a good infrastructure and industrial processing, losses are relatively small at the front end of the chain and much is being reused, whereas at the end of the chain large amounts of food are being wasted. In less-developed countries, however, losses occur predominately at the front end of the chain. Increasing consumption levels towards 2050 are likely to also lead to more waste. Future developments will depend on the choice between avoiding losses and reuse. Manure is projected to be used mainly for soil improvement.

Waste flows in 2010 generated around 12 exajoules in energy. The ‘high’ scenario, under the assumption of a growth in production and improved utilisation of the largest part of all waste flows, estimates a maximum potential of around 45 exajoules. The ‘medium’ scenario assumes that, in practice, only some of the waste flows will be able to be used (30 exajoules), whereas under the ‘low’ scenario the emphasis rather is on avoiding losses and utilisation as animal feed, which then will result in 20 exajoules.

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16. Biomass sources: residue flows from agriculture

Agricultural residue flows consist of materials not used for food or animal feed, such as stalks and straw. Agriculture, by 2050, is projected to produce an additional 60%, compared to 2005 levels (OECD, 2012), and yields per hectare over the coming decades are expected to increase further, in many agricultural regions. Plant breeding plays an important role here. Because the focus of breeding is on increasing food production, residue flows will be increased to the same amount (e.g. because of larger wheat grains and shorter stalks).

Furthermore, a certain amount of residues is assumed to be left on the land, to maintain soil quality. The ‘high’ scenario assumes that, under this restriction, nearly all residues will be gathered and can be utilised for energy (around 30 exajoules). The ‘medium’ scenario assumes over 50% of residues to be gathered, while the ‘low’ scenario only counts on 10% to 20%, the last mainly because it would not be interesting enough, from a business economics perspective. Leaving residues behind on the land is easily done, and also contributes to improved soil quality.

READ MORE

Integrated analysis of global biomass flows in search of the sustainable potential for bioenergy production, Born G.J. van den et al.

REFERENTIES

Environmental Outlook to 2050, OECD (2012).

▲ GO BACK

17. Biomass sources: aquatic production

Aquatic biomass includes all biomass growing in the aquatic environment (fresh water and saline), such as fish, seaweed and algae. This type of biomass can be from oceans, seas, lakes or rivers, but increasingly more often from specific aquaculture.

Fish are caught or farmed for food, and a large share of the fish residues are also used as food or fish feed. There is only a small amount that can be used as a source of energy. Only a few examples of energetic utilisation of fish waste exist, but on the total the contribution is negligible.

Farming of algae and seaweed is still in an early stage, with the size of its contribution to the supply of energy being uncertain. Production costs currently are still much too high and processing (e.g. drying) requires a relatively large amount of energy. Commercial possibilities of farming algae particularly can be found in the production of specific chemical compounds (e.g. certain fatty acids) with a good market price. Residues resulting from these processes likely can be used as a source of energy.

Estimations about the future potential are rather speculative. A possibly successful option is that of growing algae for removing pollutants from the gas that is released during combustion in power plants and other industrial chemical processes (flue gas); experiments are currently done on a limited scale. Flue gasses containing relatively large amounts of CO_2, as well as often nitrogen compounds, are led through basins with algae that feed off the CO_2, thus removing it from the air flow. This also reduces emissions; 50% reduction in this respect is considered a good result. Under the 'medium' scenario, a limited contribution of 5 exajoules has been included, mainly based on this option.

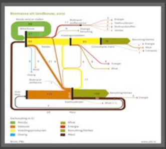
REFERENCES

The Energy Report: 100% Renewable Energy by 2050, WWF (2011).

▲ GO BACK

18. Biomass from agriculture: how much is it and what happens to it?

Global biomass production from agriculture consists of two main flows: arable farming (crops and crop residues) and grasslands (natural and culture grasslands). The diagram shows the energy content of these flows and of the main semi-finished products and end products (food and animal feed), energy and materials. The thickness of the depicted flows represents their calculated size (in this case, in terms of energy).



Biomass from Agriculture 2010

Expressed in energy, arable farming and horticulture generates around 200 exajoules. Subtracting the residues that are usually left behind, partly to maintain soil quality, leaves 123 exajoules. Grasslands generate a net 115 exajoules. Together, the arable land and grasslands generate a total of 238 exajoules. Of this total, 142 exajoules are used as animal feed, which, in turn, provide 17 exajoules in animal consumable products, such as meat, milk and fat. The energy in the feed is used by the animals mostly as nourishment. A small amount ends up in the manure.

The energy in human food is also mainly used as nourishment. In addition to the 17 exajoules in animal products, another 84 exajoules in plant-based biomass is processed into human food products. A small share ends op in waste water. In 2010, a total of around 15 exajoules was used for energy, partly from biofuel compounds from crops, and partly from waste flows.

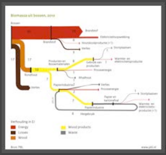
READ MORE

Integrated analysis of global biomass flows in search of the sustainable potential for bioenergy production, Born G.J. van den et al.

GO BACK

19. Biomass from forests: how much is it and what happens to it?

An inventory was made of the total amount of wood harvested from forests in 2010, and of how it was subsequently used. The flows (expressed in exajoules) are presented in the figure on the right.



Biomass from forestry 2010

In 2010, a total of around 83 exajoules in wood was felled, of which 66 was used and around 17 was either burned or left behind in the forest as felling residue. The global production of wood in wild forests and plantations can be distinguished into timber for building materials, furniture, toys, and paper (17 exajoules), and wood directly used for energy (49 exajoules). The latter has a large share, particularly in developing countries where many people use wood as their – often only – source of energy. Whether this use of wood is always sustainable is unclear. Statistics on the gathering and use of firewood in these regions is barely documented.

Most wooden products will be used for decades; think of timber used in buildings or in furniture. Because of increasing prosperity, more wooden products are made than are discarded. As the number of wooden products increases, the waste flow is likely to increase in the long term. This means more biomass waste for energy generation.

Dutch policy is aimed at using timber for as long as possible, the so-called cascaded use. When the timber is no longer suitable for certain high quality applications, such as for furniture, often there are lower quality options available, such as using it in paper production. In turn, paper can also be reused a number of times. The inventory shows that wood is already being recycled often. In part, due to the objectives formulated for the use of renewable energy in electricity generation, wood is increasingly being applied in biomass-fired power plants or co-fired in coal-fired plants. An overly strong stimulus for applying biomass in energy generation may lead to less wood being recycled.

READ MORE

Integrated analysis of global biomass flows in search of the sustainable potential for bioenergy production, Born G.J. van den et al. (in voorbereiding)

GO BACK

20. . Animal feed or energy crops?

There is no infinite amount of agricultural land available to grow food as well as biomass crops for energy. The highest priority, of course, is that of food supply, but a large share of the land is being used for growing animal feed. Consumption of animal products in the Netherlands, as in various other countries, is substantially higher than would be needed or even advisable from a health perspective. This may be a reason for re-weighing the importance of animal feed against that of bio-energy.

The possible result is illustrated for the situation in the Netherlands. How much space would be available for additional biomass production under the preconditions of not increasing the Dutch footprint (in this case, the use of agricultural land) if the Dutch consumption of meat would be less? Halving the consumption of meat and dairy would provide space for additional biomass – a production level that would be able to meet 10% of the total Dutch energy demand for consumption (in the form of direct use, plus indirect energy use for the manufacturing of all products used). That would be twice the current contribution of renewable energy. This 10% seems modest, but in the long term could make a crucial contribution to achieving climate targets.

Such analyses, incidentally, are not easy to make, as agricultural crops are used in a wide array of products. Animal feed sometimes is a by-product, in certain cases even of biofuel production, and residues from animal feed crops in turn can be used for making biofuel.

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Concurrerend gebruik van landbouwgrond: bio-energie versus dierlijke producten [Competitive use of agricultural land; bio-energy versus animal products (in Dutch)], Rood, T., D. Nijdam & J. Ros (2014).

The contribution of by-products to the sustainability of biofuels, Ros, J. et al. (2010).

GO BACK

21. . Indicator of the impact on biodiversity

Discussions about sustainability criteria mostly concern greenhouse gas emissions. However, there are other sustainability issues, such as around biodiversity. The current directive on biofuels does include criteria to counter any direct, local impacts on biodiversity, but there are no criteria on indirect, global impacts. It is difficult to arrive at a good and widely accepted indicator that includes all impacts on biodiversity. For example, how should the short-term effects of a local loss of one hectare of nature area be weighed against the global long-term impact of climate change on ecosystems? Moreover, uncertainties in the long term are also much greater.

PBL, in collaboration with other institutes (see references), has developed an indicator that provides insight into various impacts on biodiversity on a global scale, as well as the related uncertainties. Analyses show that the use of agricultural crops for energy can have a long-lasting negative impact on biodiversity (sometimes lasting for centuries).

READ MORE

Evaluation of the indirect effects of biofuel production on biodiversity: assessment across spatial and temporal scales, Oorschot, M. van et al. (2010).

▲ GO BACK

22. Uncertainties about indirect land use for biofuel

The European Commission, over the past years, has studied which policy measures could be used to limit, as much as possible, indirect land-use effects (so-called ILUC effects) of growing biofuel crops, and particularly in relation to the amount of emissions this causes. Therefore, much research has been done to determine the magnitude of an ILUC effect and whether indirect emissions can be determined per crop. In order to do so, several bottlenecks must be overcome. It is, for example, unclear where a certain effect occurs, and biofuel-policy effects must be separated from developments that would have occurred anyway. For instance, is the rapeseed yield larger because of the policy objective to mix biofuel in with traditional fuels, causing the demand for rapeseed to be greater? Or would this increase in yield have occurred even without the obligation to use biofuels in this way? Direct effects of the production process of biofuels are often measurable and, therefore, certain requirements can be set, but indirect land-use effects may occur anywhere in the world and are difficult to relate to the processes that cause them. Moreover, the biofuel manufacturer has little influence on these effects.

Any indirect effects can be calculated afterwards, using reported data (e.g. FAO production statistics). For these calculations, several assumptions are made, such as on the ratio between land expansion, yield increases and the agricultural use of the land. This cannot remove every uncertainty, but results do show that indirect land-use effects are likely and with substantial impact on greenhouse gas emissions. An example is that of analyses of the impact of biofuels applied in 2011 in the Netherlands on greenhouse gas emissions (including all direct and indirect effects, also outside the Netherlands). The uncertainty margin between a reduction of 20% and an increase of 100%, compared to fossil fuels (PBL, 2012).

The ILUC effects of certain biofuels can also be determined in advance, using economic and/or biophysical models. This also involves assumptions. Many of such assumptions are hidden in the model structure, such as substitution elasticities in economic models. These determine, for example in the case of increased agricultural production, the ratio between additional land and additional input (e.g. artificial fertiliser). This parameter is crucial in the calculations of indirect land use, as is the dynamic of the ratio between built-up and undeveloped land. The latter may lead to a tenfold difference in calculated values for the indirectly converted land area. Other assumptions are determined when creating the scenario for a future without biofuel policy: What would be the demand for food in the future? How large would the yield increase in agricultural crops be, regardless of what happens with biofuel? What will be the future ratio between biodiesel and bio-ethanol?

Similar to those in the calculations that use reported data, these assumptions also have a large impact on the results. This causes differences not only in the results from one model with various assumptions, but also between results from various models and studies. Differences are so large that biofuels that are beneficial for the climate according to one result, are not beneficial at all according to another. Some of the uncertainties are simply due to the fact that we cannot predict the future. Another part is because we can never model the system to exactly represent the world itself.

The European Commission and Parliament, seeing the uncertainties in their proposals, chose not to assume a certain amount of indirect emissions per type of biofuel. However, they do consider the effect to be large enough to reduce the contribution of agricultural crops to biofuels.

READ MORE

Assessment of the Human Environment, PBL (2012).

Identifying the indirect effects of bioenergy production, Ros, J.P.M. et al. (2010).

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23. Sustainability criteria for biofuels

A number of sustainability criteria have already been set for biofuels. These criteria are coupled to the EU Fuel Quality Directive and Renewable Energy Directive. For example, a minimum reduction in greenhouse gas emissions has been set, compared to the levels of the fossil fuels petrol and diesel. In addition, the conversion of natural areas or carbon-rich land into agricultural land used for growing biofuel crops is also considered as unsustainable.

This last point concerns direct land use, but there can also be indirect land-use effects (ILUC effects). The criteria set in 2010 announced additional criteria for such indirect effects. At the end of 2012, the European Commission made a proposal to that effect, and the European Parliament reported on this in 2013. In both cases, a limit was put on the contribution of biofuels based on the main products made from agricultural crops (starch, sugars, vegetable oils). The EC proposed a limit of 5%, the EU Parliament suggested 6% and the European Council proposed a 7% limit. The general signal is that biofuels are not considered to be sustainable.

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24. The sustainability of wood; only a matter of time

Woody biomass often is considered sustainable or carbon-neutral. After all, the CO_2 that is emitted at combustion is taken up again during new tree growth; this closes the so-called carbon cycle. However, for wood, decades may pass before a tree is as large as the one felled before. During the growth time of the new tree, there will be more CO_2 in the atmosphere than before the old tree was felled. Moreover, in many European forests, the trees are still maturing. New trees, in the beginning, grow less fast and thus take up less CO_2 than older trees. Therefore, even when young trees are planted to replace those felled, CO_2 uptake is less in the initial years.

A more positive situation can be created through different forest management. For example, trees could be planted at optimal distance from each other, thus increasing the yield. In that way, despite additional fellings, more carbon can be taken up than in the original situation. But new trees take a long time to mature and, therefore, the amount of additional carbon uptake is difficult to calculate. Furthermore, often natural forests are converted into plantations, with all the negative consequences imaginable for biodiversity.

In order to realise high productivity levels, the choice can also be made to plant fast-growing species, such as willows, which can be harvested within ten years. This, in fact, no longer involves forests but rather plantations that resemble agricultural systems. And, similar to agricultural crops, it involves a change in land use during which additional CO_2 may be released. These effects are as yet unclear.

Utilising woody residues left behind after felling does not have such a negative impact. However, when left in the forest, these types of residues have a useful function in maintaining soil quality and biodiversity. In forests that are managed in a sustainable manner, only part of this residue can be removed and used for generating energy. When left in the forest, these woody residues break down very slowly and thus the stored CO_2 within them is released very gradually. These emissions would be avoided if the wood residues are removed from the forest. However, because the transportation and pretreatment of this woody residue takes much more energy that would be needed for coal, and because the combustion output is lower, it often takes between 5 and 25 years before there really is less CO_2 in the atmosphere.

From the perspective of emission reduction, having the carbon stored in the wood for as long as possible is a positive thing. This could also be in construction materials or timber products such as furniture. The longer the wood is used and reused, the longer CO_2 remains stored. Ultimately, the wood may serve as a source of energy at the end of its life cycle, such as often happens in the Netherlands. More reuse does mean there is less woody residue available for bio-energy, in the short term.

In the Netherlands probably little or no felled wood is used for bio-energy (not all details are known about the sources of imported timber). More stringent targets for renewable energy and greenhouse gas emissions could substantially increase the demand for wood. Although sustainability criteria for solid biomass have received attention in Europe for a number of years now, no criteria have been set to counter the unsustainable felling of trees.

READ MORE

Climate effects of wood used for bioenergy, Ros, J.P.M. et al. (2013).

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25. Sustainability criteria for solid biomass

The policy process for setting sustainability criteria for solid biomass is a slow and difficult one. Opposing interests appear to lead to a stalemate. In the summer of 2013, an EC draft proposal was leaked, but to date (end of September 2014) no formal steps have been taken. There are, however, various certification systems for wood. These systems, for example, are aimed to prevent illegal felling, but they do not incorporate the carbon balance or time factor.

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26. The pathway towards a different energy mix

The Netherlands has an ambition of emitting 80% less greenhouse gas by 2050, compared to 1990 levels. Without the application of sustainably produced biomass, however, it is more or less impossible to achieve this target. In addition to biomass, there are also other building blocks crucial to achieve a low-carbon economy in the Netherlands by 2050:

- Reduction in the demand for energy. Energy saving is the basis of a clean economy. From a technology perspective, many products and processes could be more efficient. In addition, people could change their behavioural patterns.
- Carbon capture and storage, particularly at large industrial and energy companies. The total storage capacity for CO_2 and related social acceptance are currently uncertain.
- Electricity generation without direct CO_2 emissions (using wind, solar or nuclear energy), in combination with electrification at consumer level (more electric vehicles and heating systems). The use of hydrogen, produced with electricity, could also be an additional option.

Far-reaching modernisations in the energy system will take time, therefore it is important to start as soon as possible.

READ MORE

Exploration of pathways towards a clean economy by 2050: How to realise a climate-neutral Netherlands, PBL & ECN (2011).

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27. Bio-energy in combination with carbon capture and storage: negative emissions

The combination of bio-energy and carbon capture and storage (bio-CCS), within two steps leads to the removal of CO_2 from the atmosphere. In the first step, the growing biomass takes up CO_2 from the atmosphere. In the second step, the CO_2 that is released at biomass combustion is captured before it leaves the chimneys. Subsequently, it is stored in underground storage reservoirs. The CO_2 thus has been removed from the atmosphere, permanently: a negative emission!

This combination can only be applied if CO_2 capture is viable, both technically and economically, which is only possible at large industrial installations and power plants and under sufficiently forceful policy (CO_2 standard or sufficiently high CO_2 price).

In the future, CO_2 could also be captured at new large-scale installations that convert biomass into methane or liquid transport fuels. These processes only incorporate part of the carbon in the products. Another part is released as CO_2 which can then be captured.

This option depends on the availability of reliable storage capacity, and particularly also on public support for CO_2 storage.

READ MORE

Houtachtige biomassa voor bio-energie: CO2-effecten en technische ontwikkelingen [*Woody biomass for bio-energy; CO_2 effects and*

technological developments (in Dutch)], Smeets, W. & J. Ros (2014).

GO BACK

28. Strategic choices

This interactive figure presents a very simplified version of reality, and shows, using the Dutch situation, the need for making choices with respect to biomass use, seeing the limited supply of sustainable biomass. An indication is given of the effect of choosing a certain use of biomass in one sector on the possible use in another sector.

The figure is based on a number of assumptions. The most important of these are:

- The total energy demand and distribution over the various sectors by 2050 have been kept at the same level as in 2012. Economic developments and more rapid or slower energy saving could lead to a different situation. This also applies to technological developments in energy use, such as in electric vehicles or heating systems.
- The contribution of a certain amount of biomass to total energy demand in a certain sector depends on the energy yield at the conversion of biomass into another form of energy. This figure assumed a standard yield; in reality, there will be small differences in yields between applications.

- For the contribution of biomass, the fact that biomass is an energy source of a lower quality than fossil alternatives, such as gas, oil and coal, has been taken into account. This means that replacing 1 petajoule in fossil fuel requires more than 1 petajoule in biomass – in many cases this will be 1.5 to 2 petajoules.

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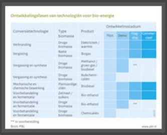
29. The technologies required are not yet market-ready

The conversion of biomass into the desired product requires specific technology. Some of these technologies are fully developed and easy to apply, such as the combustion of biomass for the supply of heat, or the fermentation of sugars to produce ethanol. Other techniques, particularly those for converting dry biomass into diesel or hydrocarbons, such as methane, are still in a developmental phase. This phase involves four stages:

- Pilot: Large research setting
- Demo: Small practical setting
- Flagship: First large-scale application
- Commercial: Proven technology



Ontwikkelingsfasen van technologiën voor bio-energie

Conversietechnologie	Type biomassa	Product	Ontwikkelinstadium			
			Pilot	Demo	Flagship	Commercieel
Verbranding	Droge biomassa	Elektriciteit / warmte	🟦	🟦	🟦	🟦
Vergisting	Natte biomassa	Biogas	🟦	🟦	🟦	🟦
Vergassing en synthese	Droge biomassa	Methanol / groen gas / biodiesel	🟦	🟦	**	
Vergassing en synthese	Droge biomassa	Bulkchemicaliën	🟦			
Mechanische en chemische bewerking	Plantaardige oliën	Biodiesel	🟦	🟦	🟦	🟦
Voorbehandeling en fermentatie	Zetmeel / suikers	Bio-ethanol	🟦	🟦	🟦	🟦
Voorbehandeling en fermentatie	Droge biomassa	Bio-ethanol	🟦	🟦	**	
Voorbehandeling en fermentatie	Droge biomassa	Chemicaliën	🟦			

** in voorbereiding
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Stages of development for bio-energy technologies (in Dutch)

On the right, the phases of development have been indicated for a number of technologies (in colour the phases that have been completed).

The Netherlands has a substantial capacity for producing biodiesel from vegetable oils (rapeseed, palm and sunflower oil, but also waste oil. Bioethanol is mostly imported. Standard crops are mostly sugar cane, sugar beet, wheat and maize). In addition, the Netherlands produces Ethyl tert-butyl ether (ETBE) based on bio-ethanol, as an additive to petrol.

Furthermore, in the Netherlands, a relatively large amount of dry biomass, including wood pellets, is co-fired in coal-fired installations. And, over the last years, there has been a substantial increase in the fermentation of manure and waste flows (biomass with a relatively high moisture content) to produce biogas.

An interesting development is that of processing dry biomass into bio-methanol, which can be applied in the transport and chemical sectors. The set up of the first large-scale gasification installation is being prepared, under European subsidy. Whether this option would play a large role in the Netherlands in the future depends partly on the future supply of sustainable biomass. For the Netherlands, a relevant question would be whether the main share of global waste flows from agriculture and forestry could be transported to Dutch ports against acceptable costs, for large-scale processing.

The schematic does not include developments in biotechnology in the chemical industry. This concerns particularly the production of specific chemical compounds and, in many cases, is about utilising more bio-knowledge (bio-technology) rather than the application of more biomass.

REFERENCES

Houtachtige biomassa voor bio-energie: CO_2-effecten en technische ontwikkelingen [*Woody biomass for bio-energy; CO_2 effects and technological developments* (in Dutch)], Smeets, W. & J. Ros (2014).

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30. Combination of biomass gasification and power to gas: one solution for five problems?

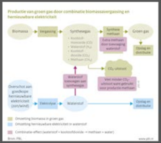
A study on the possibilities to achieve far-reaching emission reductions shows that this would lead to a number of issues:

- The supply of solar and wind energy over 24 hours is not in balance with the level of demand at various times; sometimes there is a surplus, at other times a shortage in electricity.
- Electricity is difficult to store, certainly in a country without mountains (electricity could otherwise be stored in mountain lakes: pumped storage).
- The exchange of electricity on a European scale – to achieve a better balance between demand and supply – requires expansion of the power grid; here, the geopolitical, spatial and organisational barriers are high.
- Biomass gasification is an interesting technology to convert the available biomass into green gas or transport biofuels, but efficiencies are relatively low and costs are high.
- Carbon capture and storage as an additional option also involves a large amount of uncertainty; among other things, due to public resistance.

The combination of biomass gasification and power to gas would be an option, which could contribute to at least partly solving all of the issues named above. The execution is depicted in the figure on the right, which distinguishes the following steps:

- Biomass gasification is used to produce a syngas mixture of hydrogen (H_2), carbon monoxide (CO) and methane (CH_4).
- The surplus in renewable electricity (wind and solar), during certain periods of time, is converted via electrolysis into hydrogen (and oxygen); in this way, electricity can be stored chemically.
- The hydrogen that is not used immediately can be added to the syngas.
- Syngas is the raw material for methane. Because of the added hydrogen, the CO_2 can largely be converted into methane, instead of being emitted to the atmosphere. The CO_2 no longer has to be stored and the yield achieved by the conversion of the carbon in the biomass into carbon in methane is strongly increased.

- The infrastructure for distributing the produced methane (green gas) is available, and if necessary can be stored in underground gas fields.


Productie van groen gas door combinatie biomassavergassing en hernieuwbare elektriciteit
Biomassa
Vergassing
Synthesegas
• Koolstof-monoxide (CO)
• Waterstof (H₂)
• Koolstof-dioxide (CO₂)
• Methaan (CH₄)
Synthese methaan
Groen gas
Extra methaan door toevoeging waterstof
Opslag en distributie
CO₂-uitstoot
Waterstof toevoegen aan synthesegas
Veel minder CO₂-uitstoot want gebruikt voor productie methaan
Overschot aan goedkope hernieuwbare elektriciteit (zon/wind)
Elektrolyse
Waterstof
Opslag en distributie
Omzetting biomassa in groen gas
Omzetting hernieuwbare elektriciteit in waterstof
Combinatie-effect (waterstof + koolstofdioxide → methaan + water)
Bron: PBL
www.pbl.nl

Production of green gas by combining biomass gasification and power to gas (Dutch)

Over the past years, the first experiments for this technology have been started in Germany and the United Kingdom. The viability and affordability of this combination must be researched further. Although cheap (surplus) electricity is used, its supply is irregular and its capacity will therefore not be used to the full. This causes the financial burden of the electrolysis step to increase. These and other considerations related to this option have to be studied further. A combination such as this one does show that system-level solutions also carry opportunities.

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