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Biomass for energy–managing the risks recognising the benefits

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1 Introduction

Biomass refers to all organic matter of vegetable and animal origin such as forestry and agricultural residues, organic matter from sewage, organic solid waste and other organic wastes from industrial processes. It is a versatile form of renewable energy and the most widely used form today. It is used to generate electricity, to supply heat for industrial processes and buildings, and to provide liquid or gaseous fuel for transport. Unlike variable renewable resources such as wind and solar, biomass can provide controllable and flexible power. When converted to biofuels for transport, biomass can be stored and shipped over long distances, replacing petroleum in global energy markets. Biomass can also be converted to biomethane and substitute natural gas. Via biorefineries biomass can be converted into a portfolio of biobased products (i.e. food and feed ingredients, chemicals and materials) and bioenergy (fuels, power, heat) (Bos et al, 2017).

There is, however, a great deal of confusion surrounding its designation as a renewable energy source. There is a lot of polarised information regarding the sufficient availability of sustainable biomass to meet the policy driven renewable energy demand and also produce materials for chemical industry. Biomass has been at the centre of a decade long debate among scientists and received quite some media attention over its sustainability, renewability and carbon neutrality.

This document aims to contribute to the ongoing discussions with well substantiated information. First, it introduces the current use of biomass for energy purposes in the EU28 and the Netherlands. It recaps the results of the most relevant sustainable biomass supply potential assessment studies and compares these with the policy driven demand for 2030 and 2050. The next section introduces the debate surrounding sustainability, renewability and carbon neutrality of biomass use for energy purposes. In this section different viewpoints of biomass use for energy purposes are presented. Finally, the last section touches upon the optimal use of limited resources and their contribution to achieving the Paris Agreement Goals, more specifically limiting global warming to well below 2°C.

No recommendations are included to this document as the aim was to present the current state of discussions rather than define recommendations or future priority research areas.

2 Biomass use for energy purposes in Europe and in the Netherlands

In 2016, biomass contributed to around 65% of gross inland consumption of renewable energy in the EU28 (Eurostat, 2018). More than two thirds of biomass consumed in the European Union consisted of solid biomass. These were mostly forestry residues and to a limited extent agricultural by-products. Biogas and biofuels represented 12% and 11% of gross inland biomass based energy consumption. The renewable fraction of municipal waste, used for energy purposes, represented the fourth main type of biomass for energy reaching 7% in 2016 (Eurostat, 2018).

Solid biomass refers to wood, timber industry byproducts (wood chips, sawdust, etc.), wood pellets, black liquor from the paper industry, straw, bagasse, animal waste and other solid plant residues.
Biogas refers to gaseous fuels produced through biological degradation of biomass – primarily agricultural substrate such as liquid or stable manure or energy crops (maize, rye, sugar beet, etc.), from organic waste such as cut grass, waste food and by-products of the food industry.
Biofuels refers to liquid or gaseous fuel for transport produced from biomass.

In the Netherlands, the share of renewable energy in final energy consumption was 7.4% in 2018 and biomass comprised around 60% of the total renewable energy (see Figure 2)(CBS, 2019). Solid biomass (44%) and the renewable fraction of municipal waste (37%) were the largest sources among the biomass consumption for energy. Biogas -represented 12% of the gross inland energy consumption of biomass, followed by liquid biofuels (8%) (Eurostat, 2018). According to Statistics Netherlands (Meurink et al., 2017), primary consumption of biomass for the generation of renewable energy in 2016 amounted to 117 PJ. About 30% of this consisted of woody material (wood pellets, waste wood, wood chips, residual wood and logs).

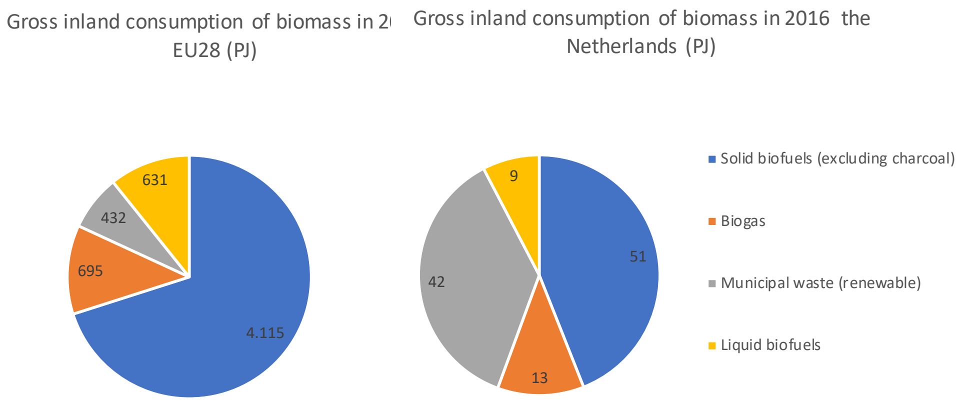

Figure 1 Gross inland consumption of biomass in 2016 in EU 28 an the Netherlands (Eurostat, 2018)

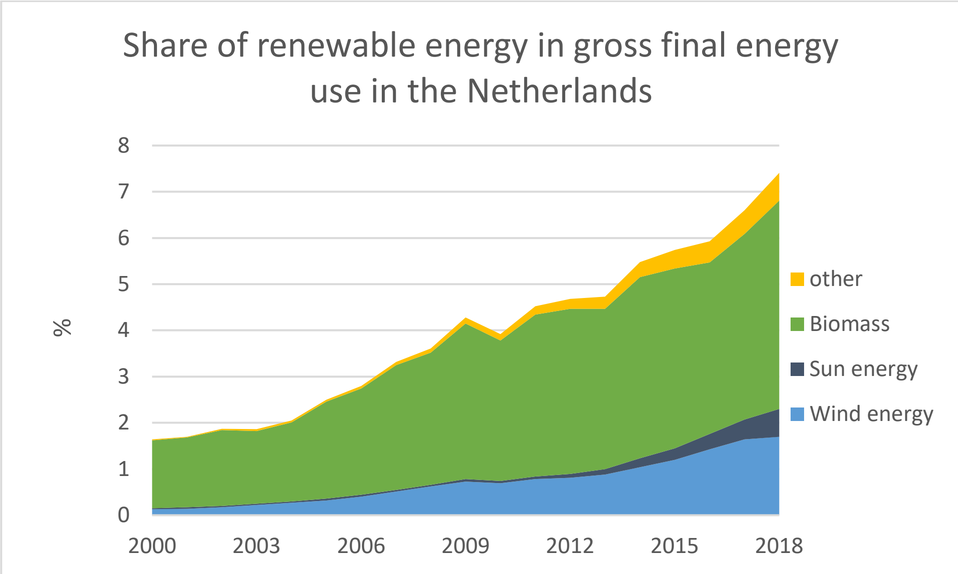

Figure 2 Share of renewable energy in gross final energy use in the Netherlands (CBS, 2019)

2.1 Extra-EU import of biomass

In 2016, around 95% of EU28 bioenergy consumption was derived from local/European sources. Approximately 4.6% of the total solid biomass (188 PJ) consumed for energy was imported from outside of the EU – from the USA, Canada, and Ukraine (EurObserver, 2018). The UK has become the largest net importer of wood pellets, followed by Belgium and Italy. The main reason behind this latter trend relates to the conversion of coal plants to 100% biomass plants.

In the Netherlands, the import of solid biomass was the highest in 2013 due to wood pellet imports used for co-firing in coal plants. Between 2013 and 2017, the import has been reduced by 76%. The wood pellet import was registered as zero in 2015 and 2016 (CBS, 2018). It was, however, stipulated in the Energy Agreement that co-firing of biomass would be stimulated for a maximum amount of 25 PJ. This means that around 3 Million tonne (~60 PJ) pellets can be imported for co-firing.

There are various biomass-to-energy conversion routes. The most common ones are briefly introduced below.

Co-firing or co-combustion of biomass with coal and other fossil fuels are a common practice in countries like Poland, Finland, Denmark, the Czech Republic and Hungary. In recent years, coal plants have been converted to fully burn biomass in the UK, Belgium and Sweden due to changes in the subsidy regimes. There are quite many criticisms and objections to these practices. The main criticisms can be summed up as follows.

- Coal plants are at large scales. This makes sourcing biomass locally and sustainably challenging.
- Subsidies provided to co-firing are heavily criticised due to their indirect support for coal units on the same site, prolonging their lifetime.
- Converted old coal plants are likely to have lower efficiencies than dedicated biomass units.

There may as well be some prospects for full conversion of modern, highly efficient coal plants to 100% biomass, where they supply not only electricity but also heat. For instance, they can be preconditioned to use low grade biomass as feedstock, which can help to establish logistics for such feedstocks. Such modern plants can ramp-up and down quickly and help balancing the intermittency of solar and wind power.

Biomass CHP is the simultaneous generation of electricity and heat and is called cogeneration or combined heat and power (CHP). CHP uses the heat which is emitted during electricity generation, and therefore increases the efficiency of the process up to over 80 %. There are various processes for the production of power and heat from biomass, such as biomass gasification (fixed-bed or fluidized-bed gasification), biomass combustion, and utilization of biogas from anaerobic digestion.

Biomass boilers and wood stoves produce heat. A stove is a space heater with a completely enclosed combustion chamber, whereas a boiler is the heat generating part of a central heating system. The main criticism regarding these applications relates to the NO_x and particulate matter, both of which are causing local air pollution.

Anaerobic digestion is the process where organic waste and residues are converted to biogas in a biological process in the absence of oxygen. Biogas, in general, consists of 50-75% methane and 25-50% carbon dioxide. Biogas can be burnt in a biogas boiler to produce heat, in a CHP unit to produce heat & electricity or upgraded to natural gas quality, upon which it can be directly fed into a natural gas grid.

Bioethanol production process uses biomass containing a sufficient amount of sugar or substances that can be converted to sugar via fermentation. Conventional production uses sugar from sugar cane, sugar beet, starch from corn, wheat or potato. Second generation ethanol, also called cellulosic ethanol, uses cellulosic feedstock (e.g. from agricultural residues) which require further pre-treatment. Ethanol can either be used as high blend (E85) in dedicated flex-fuel vehicles, or as low blend in most current vehicles without modifications. The blending rate is usually up to 10%.

Hydrotreatment to HVO-Hydroprocessing can use a wide range of waste fats and oils as feedstocks. The synonym HEFA Hydroprocessed Esters and Fatty Acids is increasingly applied. The product is sulphur-, oxygen-, nitrogen- and aromatics-free diesel which can be used without modification in diesel engines. These diesel-type hydrocarbons, also referred to as hydrotreated vegetable oil (HVO) or renewable diesel. Vegetable oils from rapeseed, sunflower, soy bean as well as palm oil and others, alternative non-food oils such as jatropha and algae oil, waste fats such as animal fats or used cooking oil (UCO) are the most common feedstocks.

Biodiesel production contains transesterification of vegetable oils, animal fats or waste cooking oils. They can be blended with fossil diesel and used for transportation.

Biomass gasification refers to thermochemical treatment of biomass at temperatures around 700-1300 °C. The biomass feedstock is gasified in the first stage of the process. The gas produced is then treated further to clean it, remove tars, particulates and gaseous contaminants, and to adjust the ratio of the required gases (hydrogen and carbon monoxide) depending on the preferred end product. The result is a balanced syngas that can be further processed to produce biomethane or other biofuels such as gasoline, dimethyl ether (DME), alcohols or Fischer-Tropsch (FT) products.

Biorefining is the sustainable processing of biomass into a spectrum of bio-based products (food, feed, chemicals, and materials) and bioenergy (biofuels, power and/or heat (IEA, Task 42). In biorefinery systems, several technological processes can be applied to convert biomass feedstock into marketable products. The main processes consist of mechanical/physical, biochemical, chemical and thermochemical processes (Cherubini et al., 2009).

3 Biomass potential for energy purposes and the future demand

3.1 EU28 domestic potential compared to demand

The main reason behind the criticisms regarding biomass use for energy purposes boils down to the limited availability of sustainable biomass resources and a possible mismatch between supply and the policy driven demand.

A number of studies has looked at the sustainable terrestrial biomass potential in the European Union that can be supplied for energy generation. Sustainable biomass potentials in these studies refer to the technical potential, where biomass use for food, feed and fibre are met and the remainder is considered for energy utilization. They also comply with the sustainability restrictions. Figure 3 illustrates the different estimates of the selected studies and within studies for various supply scenarios (Hoefnagels & Germer 2018). The estimated results present a wide range of sustainable biomass supply potential for energy purposes; 8.6-24.9 EJ in 2030 and 8.2-21.1 EJ in 2050. The differences in results relate, mainly, to the different assumptions applied (i.e. implementation of sustainability criteria, assumptions regarding productivity, the role of dedicated energy crops, forest removal and mobilization assumptions).

In December 2018, the EU agreed to a binding renewable energy target and the new revised Renewables Energy Directive (2018/2001) entered into force. According to this directive the share of energy from renewable sources should be at least 32% of the Union's gross final consumption in 2030. While the role of bioenergy in achieving this target will depend, among others, on the developments in other renewable energy technologies the modelling work of the European Commission indicates the role of biomass for energy to be in the range of 7.5-8.5 EJ in 2030, representing 12-13% of total energy demand in 2030. (EC, 2016). More recently, the Commission has updated its analysis to set a long term strategy. In this updated scenario analysis the total biomass demand in 2050 is calculated to be in the range of 9-13 EJ (contributing to around 15-20% of energy demand in 2050). Only 4 to 6% of the solid biomass is assumed to be imported from outside the EU by 2050 in this study.

Figure 1 illustrates the EU28 domestic biomass potential range derived from literature in comparison to the biomass demand scenario analysis conducted for the Commission. The higher end of the biomass demand range appears to be slightly higher than the most conservative projections of European biomass supply potential. The biomass demand range for energy generation also appears to be lower than most of the projections both in 2030 and 2050. Therefore, a first order conclusion can be that domestic/European biomass potential, when mobilized, appears sufficient to meet the demand for energy purposes However, it is important to highlight that such a direct comparison based on the quantities can be misleading. It can be socio-economically quite challenging to mobilize the demanded sustainable biomass potential. At the same time not all biomass is fully suitable to all conversion technologies. In many cases the feedstocks may need to undergo pre-treatment to match the minimum biomass quality requirements for a broad portfolio of thermochemical and biochemical conversion technologies.

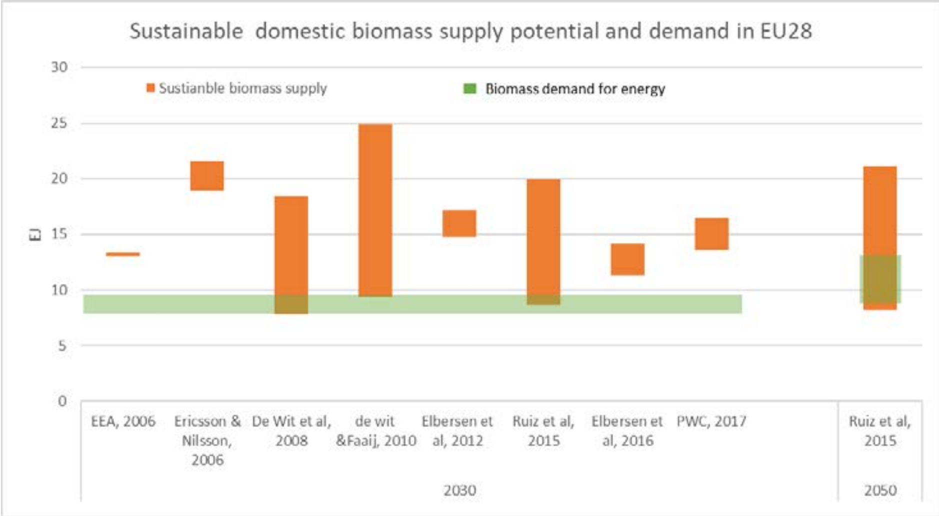

Figure 3 Sustainable primary biomass potential and policy driven demand in 2030 and 2050 (supply data derived from Hoefnagels & Germer, 2018)

There are many criticisms to these potential assessment studies, mainly regarding biodiversity concerns that the studies may not have taken into account sufficiently. There are views that larger shares of woodlands need to be left alone or at least be managed more on their nature qualities and less on their productivity, and the same applied to agricultural lands.

3.2 Import potential from other world regions

Renewable energy and climate mitigation targets of industrialized countries (Europe, US, Korea) combined with the availability of abundant and cheap biomass resources in many other world regions have been the main drivers of global biomass trade for energy purposes. Biomass trade for energy purposes has been increasing, including wood pellets and processed biodiesel and bioethanol. The export potential of six potential export regions, including Kenya, Indonesia, Colombia, Brazil, the US and Ukraine has been analysed in different studies. The export potential refers to the surplus potential where the domestic market demand and demand from other world regions areas are met and the remainder is considered as the export potential to Europe.

Figure 4 illustrates the extra-EU import scenario results of a number of literature study. The results show a large variation, which can partially be explained by the uncertainties regarding the demand from other countries. It also shows that the most conservative assumptions result in total export that can satisfy only 3.5% of the total EU demand in 2030. This is a 1.5 times increase when compared to the 2016 net import of EU wood pellets. The most optimistic scenario assessment indicates around 20% of the EU demand can potentially be met by resources outside of the EU in 2030.

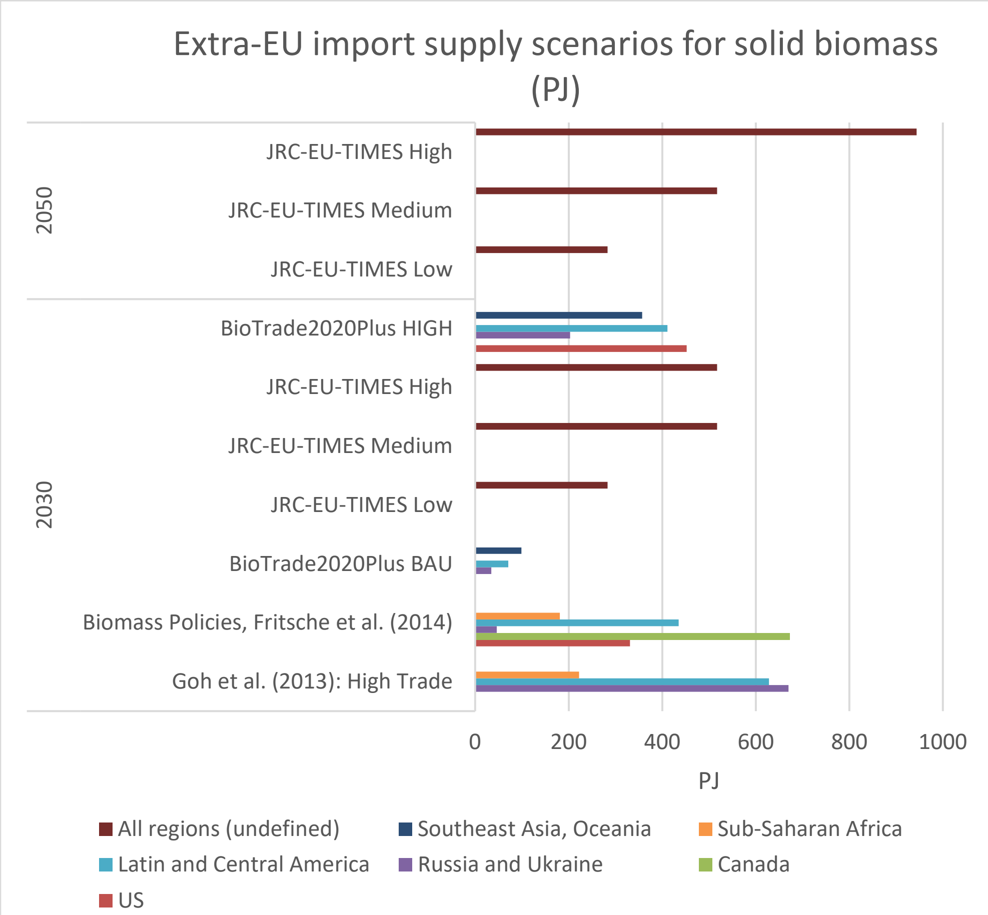

Figure 4 Extra-EU import supply scenarios for solid biomass (derived from Hoefnagels & Germer, 2018)

3.3 Domestic biomass, import potential and the demand in the Netherlands

Similar to the EU, biomass currently is the main source of renewable energy in the Netherlands. The supply potential of terrestrial domestic biomass resources is indicated to be around 150 PJ in 2030[1] (see Figure 5), of which only about 1/3 consists of woody resources.

Biomass import potential to the Netherlands is very difficult to define. Import to the Netherlands will consist of import from other EU countries and import from non-EU countries. Natuur en Milieu has recently published a report (2018) in which import potential is calculated with an allocation rule based on the number of inhabitants. This study defines the biomass potential for the Netherlands to be in the order of 50-100 PJ per year. PBL introduces import potential either based on the number of inhabitants (100-760 PJ) or based on the Gross Domestic Product (GDP) (300-2400 PJ) in 2050. Another approach can be to estimate the import potential from outside the EU and import from other EU countries based on the studies illustrated in the previous sections.

- Import/surplus potential from outside the EU to the EU is defined as 200-1600 PJ (see Figure 4) in 2030. When the relative share of the Dutch gross inland energy

[1] ProBos study focuses only on woody biomass. It does not include other feedstocks suitable for instance for anaerobic digestion to produce biogas.

consumption (compared to EU28) is applied, the import potential from non-EU countries to the Netherlands will be around 10-80 PJ in 2030.

- EU28 potential is estimated at 9-25 EJ. Applying the same assumption as above, import potential from the EU can be estimated at around 450-1250 PJ in 2030. In 2050, the range can be estimated at 400-1000 PJ. It is, however, again necessary to highlight that not all biomass potential can easily be mobilised or match the quality requirements of the conversion technologies.

As can be seen, the assumptions regarding the sustainable biomass import potential to the Netherlands include large uncertainties, where the range is 480 -1300 PJ in 2030 and 420-1100 PJ in 2050.

The draft Climate Agreement of 21 December 2018 mentions biomass use in different sectors. Biomass is proposed to produce biofuels for transport, green gas for the built environment, reinforcement of biobased chemistry and balancing of renewable electricity . Environmental planning Bureau (PBL) has made an initial estimate of biomass demand based on the earlier version of the climate agreement. They estimated the total demand for biomass demand at 340-570 PJ in 2030.

Figure 5 illustrates the comparison of the future demand to the sustainable biomass supply potential. The demand assumptions from the PBL study are indicative. Previous publications estimated lower future demand– in the range of 130-345 PJ– in 2030. In any case, the results clearly show that the biomass import will need to be significant in the future to meet the expected demand. Again, Figure 4 illustrates only the order of the magnitude and needs to be treated carefully as both supply and the demand data includes many uncertainties.

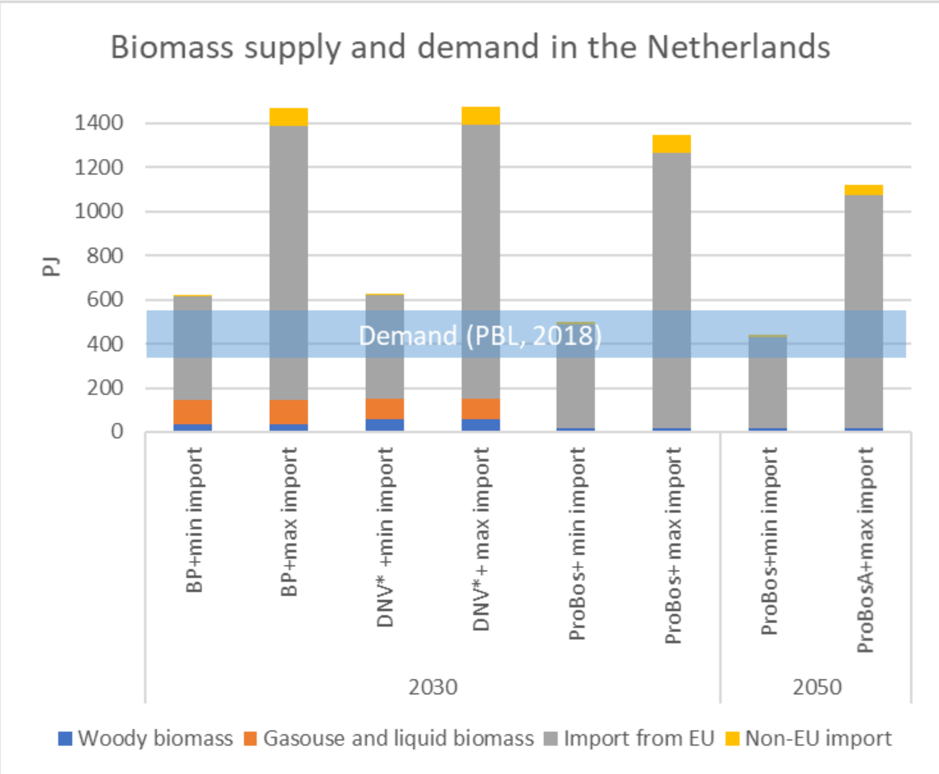

Figure 5 Comparison of domestic biomass supply and possible import potential to the likely demand (supply potential is derived from Hoefnagel and Germen, 2018)

BP refers to Biomass Policies project (Elbersen et al., 2016)
Data from the DNV GL study are for 2035.
The ProBos study focuses solely on woody biomass supply potential. It does not include gaseous biomass potential

Aquatic biomass potential
This paper limits the biomass supply potential to terrestrial biomass resources.

Aquatic biomass, particularly algae*, has the potential to produce considerably large amounts of biomass and lipids per hectare (~55 tonnes per ha per year, up to twice that of terrestrial plants (IEA, 2017). Their high oil and biomass yields, widespread availability, absent (or very reduced) competition with agricultural land, high quality and versatility of the by-products, their efficient use as a mean to capture CO_2 and suitability for wastewater treatments and other industrial plants are mentioned to make algae and aquatic biomass a promising and attractive renewable sources. (Source: European Algae Biomass Association - EABA).

In the Netherlands there are multiple ongoing research projects experimenting with marine offshore seaweed production and the prospects for seaweed production within offshore wind farms have been discussed. There are ambitions to seaweed farming that can be co-located with off-shore wind farms. In the integral knowledge and innovation agenda (integrale kennis- en innovatieagenda–IKEA) it is stated that there will be co-location of off-shore wind and seaweed farming in 14 000 km2 in 2050 (Taakgroe Innovatie, 2019), to be used for protein and chemicals production, and for energy products (e.g. biofuels).

** There are major distinctions of cultivation methods between micro- and macroalgae. Macroalgae (seaweed) are mainly cultivated off-shore in open systems, whereas microalgae can be cultivated on-shore in either open or closed systems.*

4 Biomass for energy use – the dispute surrounding the renewability, sustainability and carbon neutrality

Biomass use for energy has created a lot of confusion regarding how renewable, sustainable and/or carbon neutral it is or can be in the future. The role of biofuels in global food price dynamics has been heavily debated since 2007 and received a lot of media attention. This is accompanied by the discussions surrounding the direct and indirect land use change effects of biomass feedstock and how to factor in such possible negative effects[2]. Numerous modelling activities have focused on quantifying the possible indirect land use change (ILUC) effects of biofuel use. While the results have acknowledged the possible ILUC risk, there has been no agreement on how to quantify related GHG emissions. As a result, the biofuels produced from food based feedstocks are capped in the revised Renewable Energy Directive (2015). More recently, the debate has shifted to woody biomass, its sustainability, renewability and the carbon neutrality.

A good understanding of the terminology is necessary to shed some light to the ongoing debate. The relevant terminology is defined below.

- Renewable resource – a natural resource that either increases in quantity or otherwise renews itself over a short (i.e. economically relevant) period of time (WTO, 2010). Hence, if the rate of extraction takes account of limitations in the reproductive capacity of the resource, renewables can provide yields over an infinite time horizon.
- Sustainability – the most commonly accepted definition is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987).
- Carbon Neutrality – a transparent process of calculating emissions, reducing those emissions and offsetting residual emissions such that net carbon emissions equal zero (DECC, 2009).

4.1 Renewability and sustainability

Biomass resources are natural resources that can increase and renew themselves when the necessary conditions are present. Historically, unsustainable harvesting operations such as clear cuttings were the main concerns. The argument around biomass use for energy purposes relates to creating policy driven markets for forest-based products or for processing residues from forestry industry resulting in destruction of whole forests and drastic land use change. In addition to this, with biofuels gaining market share and international trading of biomass, raw materials and biofuels expanding, the concerns regarding the socio-economic sustainability along with the whole biomass-to-energy supply chain has increased. A number of sustainability risks is linked to increased use of biomass for energy generation and the public opinion about benefits and risks of bioenergy is mixed. Some of the possible negative and positive environmental impacts are listed below.

[2] When biofuels are produced on existing agricultural land, the demand for food and feed crops remains, and may lead to someone producing more food and feed somewhere else. This can imply land use change (by changing e.g. forest into agricultural land), which implies that a substantial amount of CO_2 emissions are released into the atmosphere.

Negative environmental impacts:

- The production of agricultural biomass can result in negative impacts on soils (e.g. loss of nutrients and soil organic matter, erosion, peatland drainage), water availability (in particular in water scarce areas (JRC, 2016) and biodiversity (EC, 2016). These concerns mainly relate to agricultural products (such as cereals, starches and oils) used for biofuel production.
- The use of agricultural residues (such as straw) can cause negative impacts on soils (fertility and structure) and on biodiversity if extracted in excessive amounts.
- An increased production and use of forest biomass for energy can also cause negative environmental impacts (EC, 2016). Intensification of the use of forest land may lead to loss of areas of high biodiversity, such as pristine forests or grazing lands that are home to many threatened species.
- An excessive removal of harvest residues, or the removal of stumps, can harm soil productivity, biodiversity, and water flows.

Positive impacts when done sustainably:

- Removal of early thinnings can be beneficial to biodiversity, improvement of forest structure, prevention of fires, pests and diseases, afforestation on eroded land (EC, 2016).
- The use of waste (for example manure) to produce biogas can significantly reduce methane and other emissions.
- Carbon-rich residues from thermochemical biomass processing can be used for soil remediation.
- Bioenergy can reduce GHG emissions, strengthen rural regions, and diversify cultivation systems by enhancing soil, water, and biodiversity

In the EU, the rules of cross-compliance under the Common Agricultural Policy ensure the implementation of existing environmental requirements and the requirement of maintaining land in good agricultural and environmental condition.

Sustainable forest management (SFM) is also actively promoted in the context of the EU Forest Strategy (COM(2013)659) in the EU and in the Forest Europe process. Most Member States have legislation and other measures in place to promote sustainable forest management practices (State of Europe’s Forests, 2015). There are, however, no EU-wide binding standards ensuring an equal and high level of sustainable forest management practices, and such standards don’t necessarily exist in non-EU countries that supply biomass to the European market.

4.1.1 *Sustainability criteria*

The EU has defined a set of sustainability criteria to ensure that the use of biofuels (used in transport) and bioliquids (used for electricity and heating) results in real and significant carbon savings and protects biodiversity. In 2009, the Renewable Energy Directive (RED) has introduced sustainability criteria. According to these criteria, only biofuels and bioliquids that comply with the criteria can receive government support or count towards national renewable energy targets. The European Commission has issued non-binding recommendations on sustainability criteria for biomass. These recommendations are meant to apply to energy installations of at least 1MW thermal heat or electrical power. On 4 December 2018, the Council adopted the recast of the Renewable Energy Directive (REDII), which sets the framework for renewable energy in the European Union for the period after 2020. Article 29 of REDII introduces reinforced EU sustainability criteria that cover not only biofuels but also, for the first time, solid biomass and biogas for heating/cooling and electricity generation (see BOX I). The main elements of the sustainability criteria are as follows.

- To be considered as sustainable, biofuels and solid biomass must achieve minimum GHG emission savings
- They cannot be grown in areas converted from land with previously high carbon stock such as wetlands or forests
- Biofuels cannot be produced from raw materials obtained from land with high biodiversity such as primary forests or highly biodiverse grasslands.

This is the first time that an EU-wide sustainability criteria will cover biomass use across the all energy domains (electricity, heating and for transportation) .

However, there have been some concerns regarding the implementation of these criteria. One of them relates to certification of low ILUC biofuels. According to the REDII Commission will adopt a delegated act by February 2019 to supplement the directive. This Act will set out the criteria for certification of low ILUC-risk biofuels, bioliquids and biomass fuels and determine the high ILUC-risk feedstock (for which a significant expansion of the production area into land with high-carbon stock is observed). The stakeholders were concerned that there can be some loopholes in the directive, opening a back door to 'high ILUC' risk biofuel imports being certified as 'low ILUC'[3]. On March 2019 the Commission adopted the delegated act that sets out the criteria for determining high ILUC-risk feedstock and the criteria for certifying low ILUC–risk biofuels, bioliquids and biomass fuels (see BOX II for details).

Another concern is about the new sustainability criteria for forest biomass that aims at minimising the risk of using biomass from unsustainable production. Rules for sustainable forest management are added to REDII and it covers the legality of harvest, forest regeneration after harvest, maintaining or improving long-term production capacity, maintaining soil quality and biodiversity (i.e., minimising negative impacts of harvest), and respecting existing protected areas. These is a concern[4] that these biodiversity criteria can be ineffective as there are no reference data as a benchmark for the biodiversity status of an area.

There is a threshold set for the application of sustainability criteria for heat and power generation. The criteria will apply to installations larger and equal to 20 MW and there is a concern that this may result in unsustainable biomass being used in smaller plants.

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[4] See https://blog.oeko.de/erosion-of-european-sustainability-requirements-for-bioenergy/

BOX I REDII sustainability criteria

Main elements of the Sustainability criteria in the revised Renewable Energy Directive (REDII) as of 21 Dec 2018

- ***Also covers solid biomass and biogas for heat & power (beyond biofuels/bioliquids)***
- Sustainability and GHG criteria apply to
  - all biofuels/bioliquid installations,
  - solid biomass installations with fuel capacity equal or above 20 MW
  - biogas installations with a fuel capacity equal or above 0.5 MW
- Bioenergy from waste and processing residues (e.g. saw dust, manure, black liquor) only needs to meet the GHG saving criteria
- ***Streamlines the sustainability criteria for agricultural biomass***
  - Remove criterion on cross compliance (dealt with under the CAP)
  - Set a minimum size for highly biodiverse grassland
  - Clarify that highly biodiverse grassland is to be identified by competent authorities
  - Ensure a stricter peatland protection (easier to verify)
- ***Minimise risk of unsustainable forest harvesting***
  - The following minimum requirements apply to forest biomass (domestic or imported):

    i) Legality of harvesting; ii) Forest regeneration; iii) Protection of high conservation value areas, including wetlands and peatlands; iv) Minimization of harvesting impacts on soil & biodiversity; v.) Harvesting does not exceed the long-term production capacity
- ***Minimise risk of negative impacts on forest carbon stock***
  - The following minimum requirements apply to forest biomass (domestic or imported) as part of the LU/LUCF accounting:
    - Option A) the country of origin of the biomass is a party of/has ratified the Paris Agreement, or has submitted an NDC, including LU/LUCF accounting, or has a national system for LU/LUCF reporting
    - Option B) management systems are in place at the forest holding level to ensure that the forest carbon stock and sink level are maintained
- ***Promote carbon efficiency throughout the supply chain, delivering optimal GHG savings***
  - Biofuels/bioliquids at least 50% GHG emission saving (plants in operation before October 2015), 60% (plants in operation after October 2015), 70% (plants in operation after January 2021)
  - Biogas/biomethane for transport (plants equal or above 0.5 M) 70%
  - Biomass in heat and power (plants equal or above 20 MW) at least 80% (plants in operation after 1 January 2021), 85% for those plants starting operation after 1 January 2026
- ***Limit pressure on limited forest biomass resources and promote resource efficiency***
  - Electricity from biomass in large scale plants (equal or above 20 MW) must be produced through high-efficient cogeneration technology (EED) and meet the EU sustainability and GHG criteria

BOX II Delegated Act on high/low ILUC-risk feedstocks

High ILUC-risk fuels are fuels that are produced from food and feed crops that have a significant global expansion into land with high carbon stock such as forests, wetlands and peatlands. There is no limitation on the importation or on the use of these fuels. Member States will still be able to import and use fuels included in the category of high ILUC risk biofuels, however, they cannot count these towards the renewable energy targets.

Determining high ILUC-risk feedstocks

The Delegated Act identifies the following, cumulative, conditions:

a) the global production area of the feedstock has increased annually by more than 1% and 100,000 hectares after 2008.

This criterion verifies whether the feedstock is actually expanding into new areas. Feedstock for which no, or only very limited, expansion of the production area is observed (mainly because production increases are generated by improving yields rather than expanding the production area) do not cause significant deforestation and, therefore, do not give rise to a very high level of GHG emissions from ILUC.

b) more than 10% of such expansion has taken place on land with high carbon stock.

This criterion determines whether, or to which degree, biofuels, bioliquids and biomass fuels can be expected to achieve GHG emission savings. In order to calculate if a feedstock is above or below the 10% threshold, a formula is applied. This formula takes into account factors that have an effect on the amount of GHG emissions that can be released or saved because of the use of biofuels, bioliquids and biomass fuels.

Determining low ILUC-risk biofuels

They are fuels produced in a way that mitigate ILUC emissions, either because they are the result of productivity increases or because they come from crops grown on abandoned or severely degraded land.

The certification can be granted if fuels meet the following cumulative criteria:

- compliance with the sustainability criteria set in the recast Renewable Energy Directive, which entails that feedstock can only be grown on unused land that is not rich in carbon stock;
- Use of additional feedstock resulting from measures increasing productivity on the already used land, or from cultivating crops on areas which were previously not used for cultivation of crops (unused lands), provided that a financial barrier has been overcome, or the land was abandoned or severally degraded, or the crop has been cultivated by a small farmer; and
- Robust evidence proving that the two previous criteria are met.

4.2 Carbon neutrality and the CO_2 accounting

Carbon neutrality of biomass, mainly the woody resources, is naturally entangled with the discussion on CO_2 accounting. For biomass resources to be carbon neutral they must be renewed on a sustainable basis such that the uptake and release of carbon during growth and energy conversion are in balance. Recently, the carbon neutrality of biomass, the carbon accounting and the possible flaws in the accounting system have come under criticisms from several angles.

The underlying principle regarding biomass carbon neutrality is that since trees absorb carbon as they grow, forest growth will balance the carbon emitted by burning wood for energy. Under international GHG accounting rules set down in the Kyoto Protocol, CO_2 emissions from biomass combustion are not reported in the energy sector (‘**zero rating’**). This zero rating has been misinterpreted as meaning that biomass combustion emissions are always compensated by regrowth while this is done to avoid “**double counting**” emissions. The Intergovernmental Panel on Climate Change (IPCC) guidelines for the national GHG inventories estimate CO_2 emission/removals from forestry based on changes in the carbon pool (live biomass, litter, soil, wood products). These are reported in the LULUCF sector (land Use, land-use change and forestry), independently from the end-use of such biomass. The carbon contained in biomass used for energy is reported as an emission in the year and at the point of harvest (when biomass is removed from the land) (JRC, 2014). This means, the sequestered carbon in forest and the carbon flux during harvesting are accounted for the country where the feedstock comes from (e.g., USA, Canada). The bioenergy generating county (e.g., NL) considers only supply chain GHG emissions that are released on the territory. They exclude the biogenic carbon release during the energy conversion process.

There are a number of research assessing the carbon debt of forest based bioenergy, indicating long payback periods (how long it takes for forests to grow back and re-absorb biomass emissions that is in the same amount of CO_2 emissions released during combustion) when whole trees or large shares of forest biomass are used for bioenergy (Langiere et al, 2015; McKechine, 2010;Mitchell et al, 2012; Lamers &Junginger, 2013). However, forests are grown and managed for a wide range of products such as lumber, panel and pulp. Forest residues (primary residues like branches and tops, or secondary residues like wood chips, shavings and sawdust form wood processing) are used for bioenergy, neither large shares of forest biomass nor mature whole trees are used solely for bioenergy generation. Defining the carbon debt is a very complex issue and the climate change mitigation potential of bioenergy needs to be evaluated across a range of different type of forests, locations, rotations and management regimes, where carbon stocks, fluxes and emissions of the complete forest system (including forest, products and bioenergy feedstocks) at forest landscape level are included. An important aspect, here, also relates to what would have happened if the forest biomass was not harvested for energy purposes: vegetation may have continued to grow, been used for other purposes, or been burned in-situ, each of which has a different effect on GHG emissions.

Currently, the forest biomass that is used for energy purposes in the EU consists mostly of industrial residues (more than half) as well as harvest residues (branches, tree tops) and traditional fuel wood. Studies show that these feedstocks generally have short carbon payback times and deliver a beneficial GHG performance when compared to fossil fuels (EC, 2016). In addition, the European Forest Institute (EFI, 2018) highlights the synergies between forest management, bioenergy and climate mitigation. According to EFI, the EU forest carbon sink and forest harvesting have increased simultaneously since the 1960s. This is to a large extent the result of improved and more extensive forest management. The increased demand for forest products – including bioenergy products – stimulates and provides income for active forest management that promotes regeneration, enhances growth and helps protect forests against disturbances, such as fires.

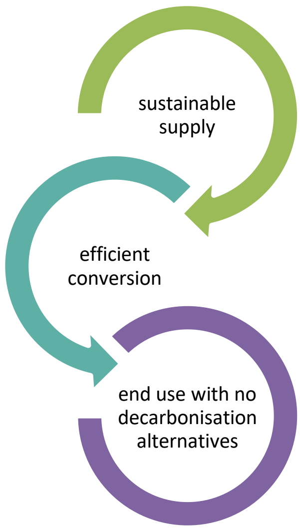
Derived from EFI web page
A group of scientists (from universities or research institutes related to forestry, forest ecology, forest economy; environmental and rural sciences) has published a letter exploring the use of forest biomass to produce energy, ahead of the European Parliament vote on the EU Renewable Energy Directive on 17 January 2018.

In most European countries, sawlogs and pulpwood are the main income-generating wood assortments from managed forests. Processing these to produce forest products generates side-streams of residues that are used for bioenergy. Small trees from thinnings, logging residues, and low-quality wood that is not suitable to produce sawnwood and paper products are also used for bioenergy. This situation is reflected in the fact that despite forest bioenergy having increased significantly in the EU in this century, the roundwood production is at the same level today as it was in the beginning of the century. The increased forest bioenergy production is neither the result of EU having increased energy wood imports. Currently, about 96% of the forest bioenergy use in the EU is based on domestic raw materials. Also, EU wood fuel imports - 4% of EU forest bioenergy use - are roughly equal to its wood fuel exports (Data: FAOSTAT).

The scale of use of forest biomass is the main reason behind the risk stated above and will depend on how other, non-forest feedstocks are used for bioenergy (e.g. agricultural residues, short rotation coppice, etc.) and how well sustainable forest management practices are applied as well as on the overall bioenergy demand. In addition, there are uncertainties on how the market may respond to increased demand for wood for energy. This relates to the behaviour of forest owners: will an increase in the demand for forest biomass for energy and the wood price increase cause higher harvesting intensity leading to decreased carbon stocks in the forest, or will it result in better management of forests, preservation of carbon stocks through deforestation on increased investments in the forest to secure the revenue (EFI,2018; EC, 2016).

5 Sustainable use of biomass for energy and the need for negative emission technologies (NET)

The best use of limited resources requires a sustainable supply of biomass feedstocks. Studies show that there can be a significant potential for increasing the supply of sustainable domestic biomass (domestic biomass refers to biomass produced and supplied within the EU). The environmental impacts of biomass supply are typically lower or even positive when waste and residues are used. It is also possible to grow biomass for energy purposes on land which is underused or not used for other purposes. Growing perennial ('multi-year') plants, applying multiple cropping systems and agroforestry can even have positive impacts on the environment when done on marginal lands. Sustainably supplied biomass resources will need to be used efficiently. There is a broad choice of technologies for converting biomass into usable energy and biochemicals/-materials. Energy conversion facilities with low efficiency, such as old power plants with biomass co-firing, should not be a preferred option in the long-term. Improving the efficiency of conversion will certainly lead to greater replacement of fossil fuels and, in many cases, more avoided GHG emissions. In addition to conversion efficiency, the resources need to be used strategically. Their use in sectors for which there are no or very limited alternative options to decarbonise needs to be prioritised. Transport is the only major EU sector in which GHG emissions are increasing and it is very challenging to reduce them. Aviation, shipping and heavy duty vehicles in road transport, particularly, have very limited or no other renewable alternative other than biofuels in the short to medium term.



Moreover, Europe moves from a linear to a circular economy, in which biomass use for high value products, such as chemicals and materials, get the highest priority. Reducing, re-using, recycling and expanding the life time of materials are the important building blocks to improve efficiency and produce as little waste as possible. According to the cascading use concept raw materials that have already been used for higher value purposes shall be reused and recycled first. When they have no other use they can be used to produce energy. This concept in principle encourages the energetic use of side streams of processed raw materials and wastes. Biorefineries will have a crucial role in the circular economy. With multiple products and processes, biorefineries can maximise the value of biomass and minimise the amount of unused waste.

Another important aspect of bioenergy systems is the possibility of combining these with carbon capture and storage technology. This enables removing CO_2 from the atmosphere, thus achieving so called "negative emissions". Global integrated assessment models indicate the importance of technologies that can achieve negative emissions in scenarios that limit warming to below 2˚C above pre-industrial levels. These temperature limits are defined in the Paris Agreement in order to reduce the risks and impacts of climate change.

One of the most promising options for achieving negative emissions is the use of sustainable biomass energy coupled with carbon capture and storage (BECCS). This option avoids fossil fuel use and at the same time results in capturing the CO_2 from the atmosphere.

Biomass binds carbon from the atmosphere as it grows; but with the burning of the biomass, this carbon is again released as CO_2. If, instead, the CO_2 is captured, transported to a storage site and permanently stored deep underground, this would result in a net removal of CO_2 from the atmosphere.

6 Conclusions

Currently, the majority of the solid biomass used for energy purposes in the EU is considered to deliver substantial greenhouse gas (GHG) benefits even when biogenic emissions are taken into account. This is because the forest biomass that is used consists mostly of industrial residues (more than half) as well as harvest residues (branches, tree tops) and traditional fuel wood. This is followed by wastes and residues to produce biogas. The wood pellet import contributes to less than 5% of the total use. In the Netherlands, solid biomass and the renewable municipal waste are the largest sources among the biomass consumed for energy.

There is an ongoing debate regarding the sufficient availability of sustainable biomass to meet the policy driven EU demand in 2030 and beyond. The results of the literature analysis present a wide range of sustainable biomass potential in Europe and almost all of them indicate that sufficiently large amounts of sustainable biomass can be produced in Europe to meet the policy driven demand for 2030 and 2050. Thus, the availability appears not to be the main issue but existing barriers to mobilisation of these in large quantities with required feedstock qualities does. This results in concerns that less sustainable but more economically viable practices (i.e. imports from regions where sustainability requirements may not be respected) may take place in the future.

The domestic biomass potential in the Netherlands is limited–studies suggest the domestic potential to be around 150 PJ. The future demand is projected to be more than two times the domestic potential, indicating a significant amount of biomass will need to be imported.

The sustainability requirements have been so far addressed through sustainability criteria for biofuels used for transport sector in the Renewable Energy Directive. More recently, the minimum sustainability criteria has been expanded to also cover electricity and heat production in the revised renewable energy directive (REDII) for the time frame 2020-2030. The implementation of these criteria is one of the building blocks of a framework to eliminate the sustainability risks of biomass use. Furthermore, the role of biomass within a circular economy has been shifting from “extract and consume” to “cascading use and biorefinery approaches” where full chain resource efficiency can be optimised. The Netherlands is one of the front runners in Europe in moving towards a circular economy and advancing in the areas of biorefining and biogas extraction.

While the sustainability risks of biomass should be eliminated, the many benefits of using sustainable biomass resources to produce energy and biobased products should not be overlooked. All renewable resources will be needed to decarbonise the energy system and combat climate change. There is increasing concern that the Paris Agreement target – to limit global warming to well below 2°C – will not be achieved unless large amounts of CO_2 are withdrawn from the atmosphere. Among the negative emission technologies, biomass energy combined with carbon capture and storage is one of the most mature options, of course provided that the biomass supply chain is sustainable.

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