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What to expect form bioenergy?

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- **Bioenergy is one of the largest renewable energy sources globally and one of the main energy pillars in the future energy mix**
- **Biomass feedstock could be converted through different chemical, bio-chemical, mechanical, or thermo-chemical processes to multiple energy forms such as cooling, heating, electricity production, or the production of biofuels**
- **The carbon neutrality and the versatility of bioenergy give it an important role and put it at the center of the energy transition as a major source of renewable energy**
- **Securing supply of sustainable biomass and the tradeoff between using available resources for food versus fuel purposes are key challenges of the development of bioenergy**
- **No role of bioelectricity in the Netherlands as the Dutch biomass supply is prioritized for chemicals and materials, followed by transport biofuels**

Introduction

Bioenergy is one of the largest renewable energy sources globally and one of the main energy sources in the future energy mix. Bioenergy is unique as it provides alternative sustainable fuels that do not require major changes in existing infrastructure. The use of biomass for energy purposes has long been there even before the fossil fuel age but in traditionally inefficient uses such as the direct combustion of wood to create fire or in open-fired cook stoves. Modern sustainable bioenergy relies on the use of enhanced fuels, such as pellet, wood chips, and others in modern equipment to produce heat, electricity or biofuels.

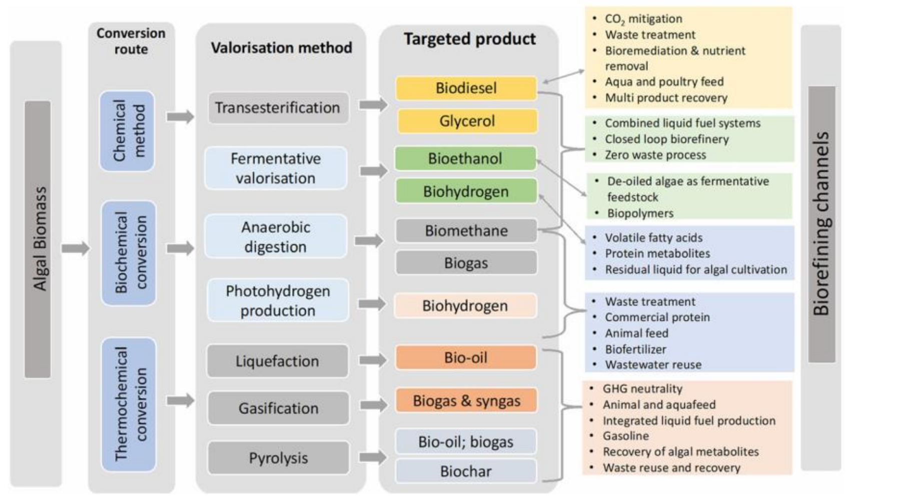
This note focuses on different sources of bioenergy, its role in the transition towards a low carbon economy, the challenges associated to its development, and its current status in Europe and we end with the landscape of bioenergy in the Netherlands.

From biomass towards bioenergy

Bioenergy is usually derived using biological material that originates from living or recently living organisms, so-called biomass. That is biomass provides the raw inputs for bioenergy. For energy purposes, the biomass used is usually plant-based. Main feedstocks include residues from forest harvesting, residues from the agriculture processes (for example, waste wood, willow corn and corn stover, small pine trees, manure, forest residues, sugarcane straws, macro-algae, used vegetable oils), energy crops and waste, especially the municipal solid renewable waste.

Biomass feedstock could be converted through different chemical (esterification, hydrogenation, steam reforming and others), bio-chemical (fermentation and anaerobic digestion), mechanical (extraction, fiber separation, pressing, upgrading and others), or thermo-chemical (combustion, gasification, pyrolysis, and hydrothermal upgrading) processes to multiple energy forms such as cooling, heating, electricity production, or the production of biofuels like biogas, bio-jet fuels and marine biofuels (see more here). The chart below summarizes the channels from bio-based feedstocks to various products.

From biomass resources to targeted products



Source: Uma et al, 2022.

Advantages of bioenergy

Bioenergy has many advantages. First of all, is the renewable and circular nature of biobased energy, where any emitted carbon had already been naturally captured during the growth of plants. That is, bioenergy is carbon neutral. Thus, bioenergy can act as a substitute for fossil fuels and avoids adding carbon emissions into the atmosphere. Furthermore, unlike fossil fuels, biomass is more evenly distributed across the world, that in turn allows for spreading bioenergy production across different geographical areas, which helps in reducing vulnerability to supply shocks. Additionally, bioenergy is a versatile source of energy which can be used to produce a fuel, heat, or electricity. Also, the use of bioenergy does not require major changes in existing infrastructure. Finally, for some sectors with little feasible clean alternatives, such as aviation and maritime sectors, biofuels are the main alternative source of energy during the transition period. In addition, the development of bioenergy could give a stimulus to rural development. All these advantages put bioenergy at the center of the energy transition as a major source of renewable energy as we will see next.

The role of bioenergy in the transition

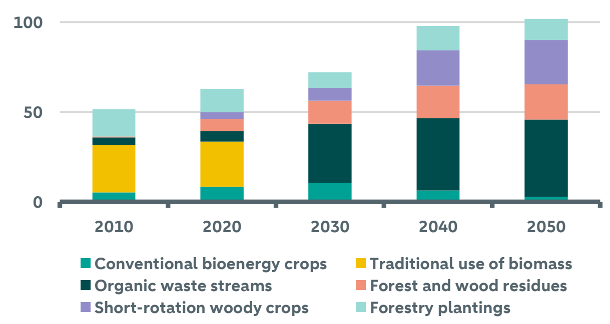
Global bioelectricity capacity has been growing rapidly with an increase of 127% between 2010 and 2022. The majority of this increase took place in Asia especially in China. In 2022, China had 34 GW of installed bio-power capacity, the largest in the world, followed by 17 GW in Brazil and 11 GW in the United States. Accordingly, bio-power generation in China hit 137 TWh in 2022 with municipal solid waste and forest and agriculture biomass as a main feedstock.

According to the International Energy Agency (IEA), under the Net Zero Emissions (NZE) scenario, traditional use of bioenergy is set to phase out around 2030, while more than 60% of supply in 2050 will come from sustainable waste stream (see chart below (left)). Furthermore, global power generation from bioenergy is set to increase more than 5-fold under the NZE scenario as illustrated in the chart below (right).

The versatility of bioenergy gives it an important role in the energy transition as it can be used by many sectors. The share of bio-based electricity in the global power mix is expected to increase to 4.5% (currently 2.3%) under the IEA's Announced Policies Scenario (APS) by 2050. For the European Union, the 2050 bio-electricity capacity is expected to increase by 25% and 175% under the STEPS and ASP scenarios, respectively, which will keep its share in the power mix close to current levels at around 6% under these scenarios in 2050. Moreover, for international mobility, especially for aviation (using Sustainable Aviation Fuel (SAF)) and maritime shipping (using bio-methanol), the use of synthetic and biofuels is indispensable for reducing emissions in these sectors (see more here). Also, biogas and bioheat is essential for the transition of the built environment and some industrial processes. To read further on the different kinds of bio and synthetic fuels, see our previous note here.

Global bioenergy supply under IEA's NZE scenario

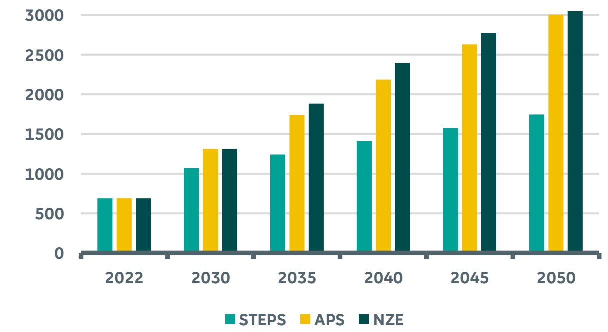
Exajoules (EJ)



Source: IEA, ABN AMRO Group Economics

Global bio-power generation (IEA's scenarios)

TWh



Source: IEA, ABN AMRO Group Economics

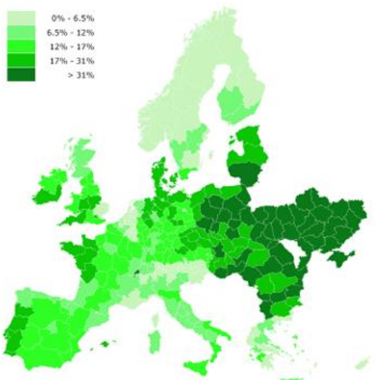
The European Union supports the use of bioenergy in electricity and heating purposes through its revised Renewable Energy Directive (RED-II). Accordingly, European total energy supply from modern bioenergy increased by around 33% in 2022 compared to 2010 levels.

Sustainability challenges for bioenergy

Like any other energy source, there are still some challenges associated with bioenergy. As a start, securing supply of sustainable biomass is the key determinant of the development of bioenergy in the future. In Europe, biomass technical potential (Arable land available for dedicated bio-energy crops divided by the total land) differs widely across countries, with highest potential in east European countries, such as Ukraine, Slovakia and Poland, while the Netherlands is one of low potential countries as shown in the chart below (left). The chart reflects the technical potential within Europe, however, what we need to consider is whether this potential is technically and sustainably possible.

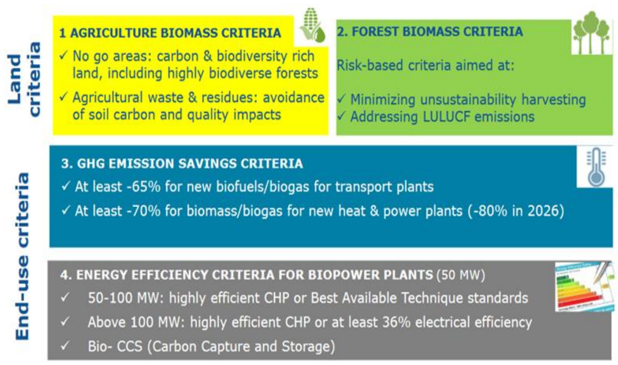
European biomass potential

Countries with darker green have higher biomass potential



Source: Wit & Faaij, 2010.

EU Bioenergy sustainability criteria post-2020



Source: European Commission

Indeed, one of the major challenges for a sustainable supply of biomass for energy uses is the tradeoff between using available resources for food versus fuel purposes given the capacity boundaries (land) that exist. More precisely, the conversion of some food commodities to the production of biofuels will induce an upward effect on food prices. Another challenge is the possibility of change of land use, which could have direct and indirect effects, such as biodiversity loss, deforestation, and converting rainforests to produce food crop-based biofuels which would result in higher carbon emissions overall. That is, emission savings from the energy sector are offset by lower natural absorptions. Moreover, there is an intertemporal concern with biopower: it takes decades for the CO2 released during wood burning to be absorbed from the air again. Noting that future regulation in the EU will focus on life cycle emissions of CO_2eq rather than only CO_2. This will also address the fact that Nitrogen and other harmful substances are also released when biomass is burned.

In order to tackle some on these challenges, the European Commission outlined its sustainability criteria in its RED-II directive distinguishing between land and end use criteria as illustrated in the figure above (right), which complement other relevant policies such as EU-ETS, LULUCF regulation, Air quality legislation, common agriculture policy, and Ecodesign regulation. Furthermore, in its most recent revised version of the RED in 2023 the commission emphasizes the need to align policies with the principle of cascading use for bioenergy, that prioritize the material use of biomass over the energy use, which in turn guarantees a fair access to biomass raw material market for new innovative solutions for a sustainable bio-economy (see more here).

Additional challenge to bio-power is the correlation between biofuel prices and feedstock cost, which induces differences in bioenergy costs across countries. The table below depicts the Levelized Cost of Energy (LCOE) for bio-based electricity across regions (left). The chart shows the lowest LCOE in regions with abundance with biomass resources such as India and China, while Europe tends to have higher average LCOE in comparison with other G20 countries. At the same time, as see in the chart right chart below, the CAPEX and OPEX costs of different bioenergy technologies in the EU are set to decrease along the transition period. However, the rate of the decrease relative to renewables sources is low especially between 2040 and 2050.

LCOE of bioelectricity

2022 $/KWh

	5th percentile	Weighted average	95th percentile
China	0.046	0.062	0.124
Europe	0.053	0.092	0.232
India	0.040	0.060	0.109
North America	0.050	0.101	0.195
Rest of the world	0.042	0.074	0.156

Source: IRENA, ABN AMRO Group Economics

Bioenergy technologies CAPEX and OPEX

	Overnight Investment Costs in a greenfield site, excluding financial costs during construction time EUR/kW				Fixed Operation and Maintenance costs, annually EUR/kW			
Technology	2020	2030	2040	2050	2020	2030	2040	2050
Steam turbine biomass solid conventional	2000	1800	1700	1700	47.5	40.1	39.2	38.4
Steam turbine biomass solid conventional w. CCS	4050	3675	3305	3205	81.5	69.1	63.0	61.4
Biogas plant with heat recovery	500	465	458	450	28.8	24.3	23.8	23.3
Small waste burning plant	1650	1615	1608	1600	52.3	44.5	41.8	39.2
Biomass gasification CC	2650	2405	2353	2300	27.1	22.9	22.4	21.9

Source: EC scenarios

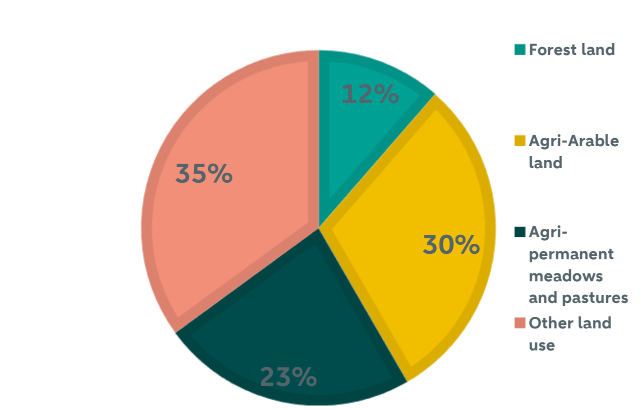
The landscape of bioenergy in the Netherlands

The Netherlands is a highly dense country with limited resources for biomass, accordingly, most biomass shares come from imports, residue, and waste. Up until 2012 bioelectricity had the lion's share among renewable power in the country, which is now dominated by solar and offshore wind. The challenge facing the scaling up of bioenergy in the country is the limited availability of feedstock which limits the potential capacity of power plants in the country. The Netherlands aims for an overall renewable share of final energy demand of 27% by 2030, which is higher than the European obligatory share of 14% stated in RED-II. Renewable energy sources have a share of 14.97% of final consumption in 2022, according to CBS. Around 40% of renewable energy supply came from biomass (109 PJ), followed by wind energy (77 PJ) and solar energy (63 PJ).

The Dutch land use across different purposes is illustrated in the chart below (left). The biggest sources of the Dutch biopower are through co-firing, followed by renewable municipal waste as illustrated in the chart below (right).

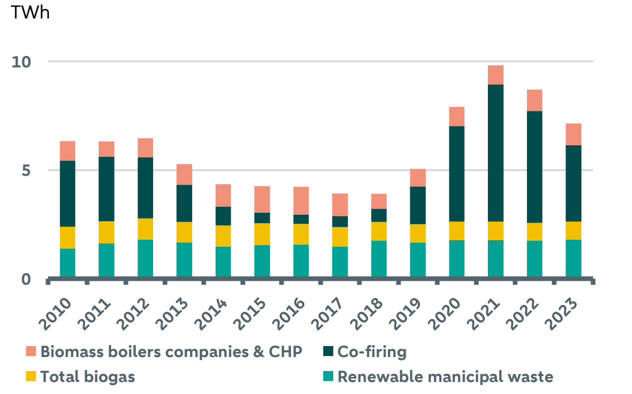
Overall, there is a negative attitude towards the burning of biomass in the Netherlands, which is reflected by the reduction in financial support for biomass power and heating. Accordingly, no further growth is expected in coming years, unless there is a change in policies. This was reflected in the climate agreement signed in 2019, which was mainly focused on strengthening and building up the solar and wind capacity, while phasing out coal power generation by 2030, which will also mean the end of the use of biomass in large scale power plants.

Dutch land use



Source: FAOstat, ABN AMRO Group Economics

Dutch bioenergy generation



Source: CBS, ABN AMRO Group Economics

From a regulatory side, The Netherlands has introduced a new biomass policy in 2020, with the cascading principle for the use of biomass resources in focus. Accordingly, Dutch biomass growth is prioritizing the use of biomass for chemicals and materials, followed by transport biofuels (heavy road, aviation, shipping), while the use of biomass for heating and power purposes is recommended to be reduced in the coming years. Furthermore, the Dutch bioenergy approach focuses on the capture of the value of bioresources in an efficient way through biorefineries.

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