The Symbiotic Relationship between **Bioenergy** and **Forest Management** in Europe

Contents

Introduction

As the world seeks sustainable and renewable energy solutions, the forest-based industry and the bioenergy sector have become an example of how to protect the environment and boost the economy through their symbiotic relationship. This synergy not only contributes to the mitigation of climate change but also fosters the development of a robust and sustainable energy system as well as a healthy European economy.

The forest-based industry, which includes woodworking, furniture, pulp and paper and many other related businesses, has a crucial role in the sustainable management of our forests. These industries take care of harvesting, processing, and using wood resources, making sure the forest is resilient and that a wise balance between economic growth and environmental conservation is maintained. However, the story continues beyond the production of timber and wood products; it also connects to the field of bioenergy.

One of the most promising aspects of this collaboration lies in the utilization of solid biomass for energy production (both for electricity and heat). Biomass, derived from forestry residues coming from sustainable forest management practices and sawmilling by-products, represents a renewable, reliable, and dispatchable source of energy. The conversion of wood waste to bioenergy, such as pellets, chips, and briquettes, not only reduces the environmental impact of forestry operations but also diversifies our energy matrix while making it more independent and resilient towards external disturbances.

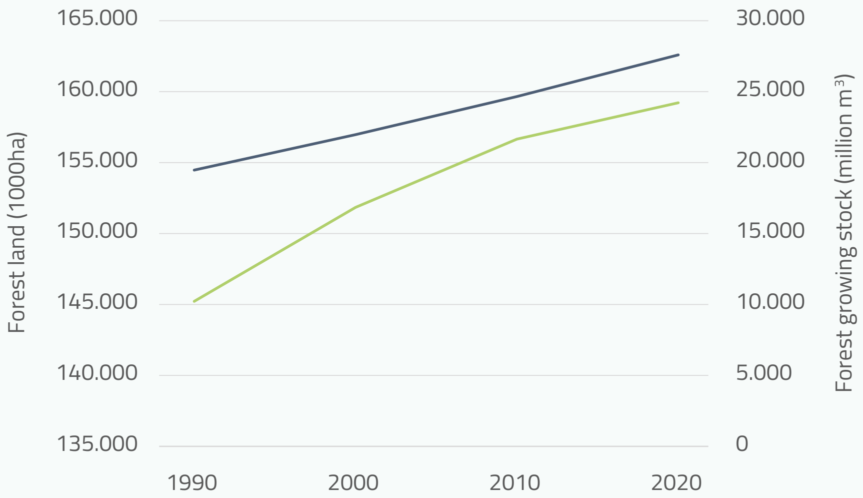
Furthermore, the use of solid biomass in energy generation aligns seamlessly with the principles of circular economy and sustainable development. Rather than allowing forest residues to decompose and release greenhouse gases into the atmosphere, harnessing this material for bioenergy enhances the overall carbon efficiency of forestry operations. In essence, the integration of the forest-based industry with the bioenergy sector closes the loop on waste and maximizes the utility of every harvested tree.

Policy measures that promote the collaboration between these sectors are of paramount importance. Support for research and development, incentives for sustainable forestry practices, and the creation of an enabling regulatory environment can propel the growth of this symbiotic relationship. Additionally, fostering partnerships between stakeholders, including government bodies, industry players, and environmental organizations, is essential for creating a thriving bioenergy ecosystem.

The Symbiotic Relationship Between Bioenergy and Forest Management in Europe

The current state of forests in Europe reflects the complex interaction between natural drivers and human activities. According to the FAO and their global forest resource assessment of 2020 (Figure 1), forest area in Europe has increased by around 10% between 1990 and 2020, representing 14 million hectares or more than twice the area of the Czech Republic. Simultaneously the EU forests' growing stock (the volume of trees contained in the forest), increased by 42%. During that same period, bioenergy use in the EU has more than doubled.

Figure 1: Evolution of forest area (1000ha) and growing stock (million m³) in the EU



Source: FAO

Forests are not only rich in biodiversity and valuable for recreation, but they also play a crucial role in water regulation, soil protection, and climate change mitigation. However, these ecosystems are exposed to a range of environmental, economic, and social pressures that challenge their perennity (Bastrup-Birk, 2016). Climate change presents significant potential risks to forests and poses additional challenges for forest managers (Keenan, 2015).

Adapting forest management to climate change requires an understanding of the effects of climate on forests, industries, and communities, and predicting how these effects might change over time. This knowledge must then be incorporated into management decisions (Keenan, 2015). For instance, site conditions may buffer or boost impacts of heat, drought, and storm events. Under conditions of limited resource supply and changed disturbance regime, we may expect a reduction of forest productivity and vitality (Spathelf et al., 2014).

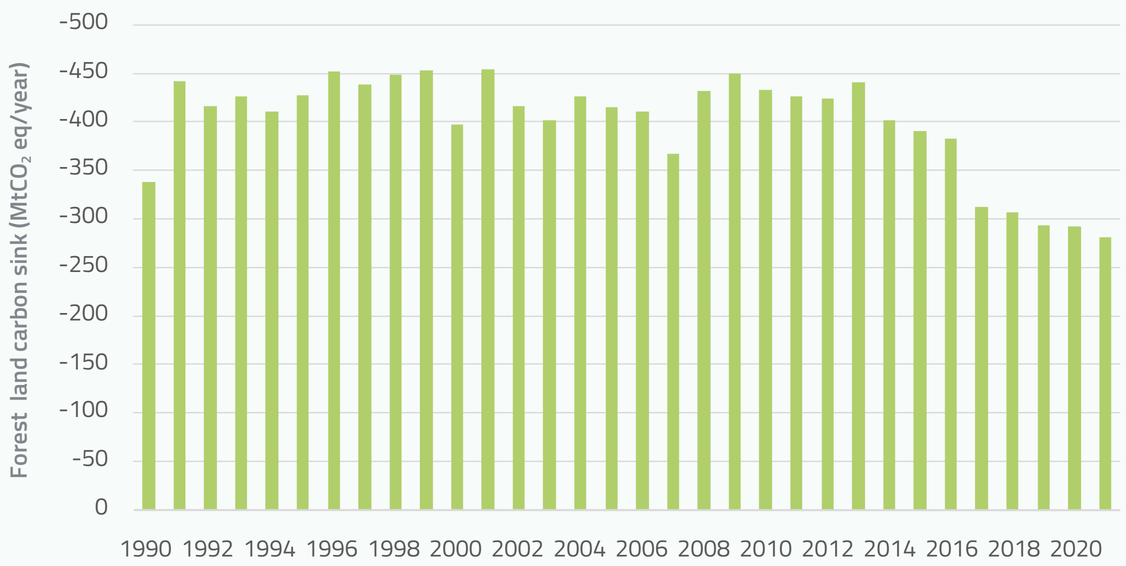
Forest management, therefore, emerges as a key ally in the survival of European forests to climate-induced disturbances and changes in ecosystem conditions. It is through smart and adaptive forest management that both carbon storage and bioenergy can be boosted (Kauppi et al., 2022). The use of woody biomass for energy production is growing at EU level (Camia et al., 2021). This not only contributes to the bioeconomy but also aids in forest biodiversity protection by stimulating management.

The symbiotic relationship between bioenergy and forest management is therefore pivotal in maintaining the health and productivity of European forests. By understanding and adapting to the impacts of climate change, forest management can ensure the survival and sustainability of these vital ecosystems for the benefit of present and future generations (Keenan, 2015), while also assisting the transition of the European energy system towards cleaner solutions.

Clarifying the Impact of Bioenergy on the Forest Carbon Sink

In recent years, the EU's Forest carbon sink—representing the capacity of forests to absorb and store carbon dioxide—has faced significant challenges. This decrease is especially highlighted in the period between 2010 and 2020, where this vital carbon sink declined by nearly a third, dropping from approximately 430 to 290 million tonnes of CO_2 equivalent per year (Figure 2). Despite this decrease, it is important to note that the forest carbon sink remains a hugely positive contributor to climate change mitigation. Even with the decline, forests continue to absorb and store large amounts of carbon dioxide, playing a crucial role in the fight against climate change.

Figure 2: Forest land carbon sink in the EU, $MtCO_2eq$.



Source: European Environmental Agency (EEA)

Factors contributing to this decline include various climate induced stressors affecting forests (fires, drought, storms, insect outbreaks, etc.), the natural ageing of these ecosystems reducing the yearly carbon uptake, and increased timber harvests associated with more demand for wood products. The aging of the forest is an element that can appear as counter-intuitive when talking about the carbon sink, as older trees sequester a larger quantity of carbon and thus contribute to a larger extent to the carbon stock. However, the stock and sink are different, and the carbon sink is quantified in terms of yearly absorption, and studies have shown that younger trees have a greater carbon absorption rate than older ones (Zhou et al., 2015).

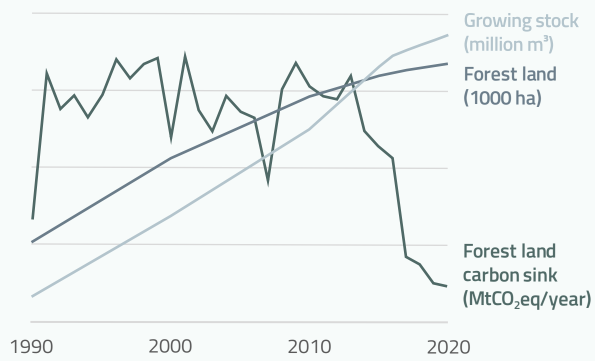
Recognizing the urgency, the EU aims to enhance the quality and quantity of this natural carbon sink through strategies like forest conservation and reducing deforestation. However, it's essential to recognize that forests alone cannot indefinitely compensate for emissions from other sectors.

Some people mistakenly believe that bioenergy is the major driver of the shrinkage of the European Union's carbon sink (Searchinger et al., 2022). However, this is not supported by scientific evidence, and it's of paramount importance to understand the difference between correlation and causation before jumping to conclusions.

It is crucial to understand that the impact of bioenergy on the forest carbon sink is not solely determined by the amount of biomass harvested for energy production, and that the carbon sink and the carbon stock are two different things.

Indeed, the relationship between sink and stock cannot be simplified to the point of "harvesting trees is reducing the carbon sink", as illustrated by the chart below. Indeed, for the last 3 decades, the forest area as well as the growing stock have been continuously improving, while the forest carbon sink experienced a much less stable trend. These fluctuations are determined by several factors, such as the age of the forest or the disturbances it experienced throughout the years.

Figure 3: Evolution of the forest area, growing stock and carbon sink in the EU27 from 1990 to 2021



Source: FAO, European Environmental Agency

Forest management practices play a significant role in maintaining and even enhancing the carbon sink capacity of forests. Removing trees for forest management purposes leads to an immediate drop in carbon stocks, as biomass removals are counted as emissions under LULUCF. Some adaptation strategies, such as thinning a stand to make it more resilient to drought for example, may appear to clash with mitigation goals since they have short-term negative impacts on the carbon stocks of the stand. These measures, while reducing the carbon stock (i.e. the quantity of biomass), don't necessarily contribute to a reduction of the yearly carbon uptake capacity of the ecosystem (i.e. the carbon sink) as the absorption is compensated by increased growth in remaining trees as well as additional growth from new individuals. Ideally, the potential trade-offs should be assessed based on the expected long-term changes in carbon flows. While some harvested forest stands may require many decades to reach their preharvest carbon levels, others may gain from reduced competition. Indeed, removing certain trees provides others with more resource and boosts the annual growth of the remaining trees reducing the time required for the stand-level carbon stocks to recover. Furthermore, recent research shows that, over time, the net growth in forest stands (meaning the share of the total growth of trees that is actually being added to the standing volume of the plot) strongly decreases, even though the total growth can remain high. Indeed, during the development of unmanaged stands, many trees die because of competition (natural process), no matter the quality of the site they're located in or the species they belong to. Forest stands that were aged between 100 and 150 years could lose up to 40% of their total volume because of competition induced mortality (Pretzsch et al., 2023).

In order to optimize productivity and mitigation potential, managers can use forest inventory data to establish baseline carbon estimates and understand how carbon stocks change over time, both in unmanaged areas and under different silvicultural practices (Ontl et al., 2020). Additionally, it has been identified that efficient investments in forest management practices associated with bioenergy policies lead to a net increase in carbon sequestration from forests (Favero et al., 2020). Moreover, the use of bioenergy can contribute to climate change mitigation by replacing fossil fuels, thereby reducing greenhouse gas emissions. This substitution effect would offset any temporary reductions in the forest carbon sink due to harvesting. While bioenergy can have an impact on the forest carbon sink through the use of woody biomass, it does not necessarily lead to its reduction as the majority of the material used is by-products or waste of other forest-based industries. The relationship between bioenergy and the forest carbon sink is complex and influenced by various factors, the most important of which being forest management practices.

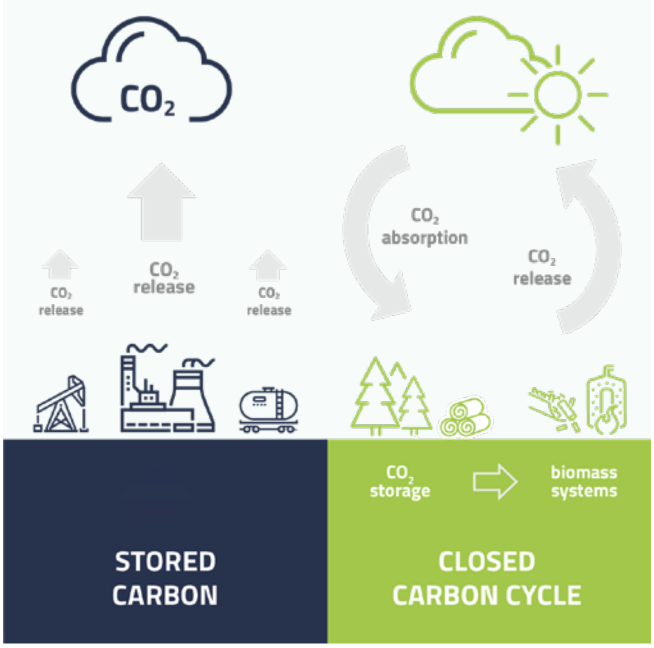
The Substitution Potential of Bioenergy

By contributing to over 50% of the current EU renewable energy mix, bioenergy plays a crucial role in the European energy landscape. As previously stated, it is versatile, capable of providing electricity, heating, and transport fuels by substituting our fossil fuel use.

Energy substitution refers to the replacement of fossil fuels with renewable energy sources, such as bioenergy, to meet our energy needs. When using bioenergy instead of fossil fuels, we don't contribute to additional CO_2 being added into the atmosphere, because the carbon dioxide released during the combustion process of biomass is part of the biogenic carbon cycle (Figure 4), meaning that it is balanced by the CO_2 absorbed during the growth of the biomass. This cycle results in a net-zero increase in atmospheric carbon dioxide levels, unlike the use of fossil fuels, which releases carbon that was previously locked into the earth for millions of years, and therefore increasing the total concentration of CO_2 in our atmosphere. This substitution effect is a critical component of bioenergy's climate mitigation potential.

Figure 4: Biogenic vs fossil carbon

Source: Bioenergy Essentials



The energy substitution potential of bioenergy is a significant benefit contributing to our fight against climate change. By using bioenergy, we not only reduce our reliance on fossil fuels but also save the emissions that would have been produced from burning those fossil fuels.

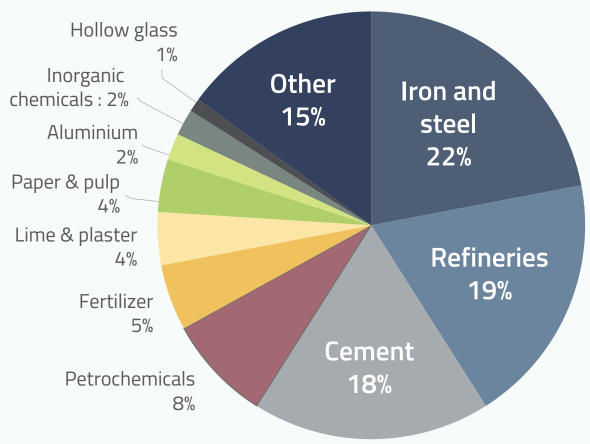
The energy substitution potential of bioenergy is therefore a critical factor that should be considered when assessing its climate impact. By replacing fossil fuels with bioenergy, we can significantly reduce greenhouse gas emissions and make substantial progress towards our climate change mitigation goals. However, when talking about substitution, the use of biomass for energy purposes also implies another type, whose mitigation potential is often overlooked, the material substitution.

Material Substitution and the Role of Bioenergy

The transition towards greener materials and a circular economy, as advocated by the European Commission in recent years, is increasingly reliant on the sustainable management of forests. This shift is not only beneficial for the environment but also paves the way for the efficient use of by-products in bioenergy production.

Forests, when managed sustainably, provide a renewable source of wood, a material that has significant potential for substitution in various sectors. Wood can replace non-renewable materials, thereby reducing our dependence on fossil resources and mitigating the environmental impacts associated with their extraction and use (Myllyviita et al., 2021). Indeed, two of the three largest emitting sectors among the energy intensive industries are related to construction, with iron and steel taking the lead and representing around 22% of industrial emissions, and cement taking the third places with around 18% (Figure 5).

Figure 5: GHG emissions in energy intensive industries in the EU27 in 2018



Source: European commission, EU ETS 2018

Replacing (partially) these energy and climate intensive materials with bio-based ones such as wood is therefore a highly effective way of combating climate change, and the use of bioenergy fits in perfectly with this approach, as it stimulates the forest management that is vital to the survival of Europe's forest ecosystems. Indeed, the production of wood for industry generates a phenomenal quantity of residues (whether linked to management directly in the forest or to the processing of materials in sawmills) which in turn can be used to replace fossil fuels to meet energy needs. Furthermore, the sale of these residues is a considerable and necessary source of secondary income for forest managers, for whom the effects of climate change are having a huge impact on the survival of their activity. This is the reason why the forestry and bioenergy sectors are inextricably linked, and why they need to be considered as a whole when developing policies.

Biodiversity and Forest Management

One of the key objectives of the European Green Deal is to protect and restore biodiversity, which is essential for the functioning of ecosystems and the provision of ecosystem services. Forests are among the most biodiverse ecosystems in Europe, hosting about 80% of terrestrial species[1]. However, forest biodiversity is under threat from various factors, such as climate change, invasive species, pests and diseases, fires, and other climate induced disturbances. Therefore, it is crucial to adopt effective measures to conserve and enhance forest biodiversity, as well as to monitor its status and trends.

Forest management is one of the main tools to influence forest biodiversity, as it affects the structure, composition, and dynamics of forest ecosystems. Different forest management practices can have different impacts on biodiversity, depending on the type, intensity, and frequency of interventions, as well as on the local environmental and socio-economic conditions. In general, forest management can be seen as a trade-off between the production of timber and other forest products, and the conservation of biodiversity and other ecosystem services.

To maximise the biodiversity potential of European forests, it is necessary to apply sustainable forest management that balances the multiple demands and benefits of forests, while maintaining their ecological integrity and resilience. One of the aspects of sustainable forest management that can enhance forest biodiversity is the promotion of structural and functional diversity, which means creating and maintaining a variety of forest types, age classes, stand structures, species compositions, and habitats within and across forest landscapes. Structural and functional diversity can increase the heterogeneity and complexity of forest ecosystems, thus providing more niches and resources for different species, as well as more options and flexibility for coping with disturbances and changes. Structural and functional diversity can be achieved through various forest management practices, such as:

- Selective harvesting, which removes individual trees or small groups of trees, instead of clear-cutting large areas, thus creating gaps and edges that favour the regeneration of shade-intolerant species and the establishment of mixed and uneven-aged stands.
- Retention forestry, which leaves some trees or patches of trees standing after harvesting, either permanently or temporarily, thus creating deadwood and preserving old-growth elements that are valuable for many species, especially saproxylic[2] ones.
- Continuous cover forestry, which maintains a permanent forest cover and avoids clear-cutting, thus reducing soil erosion and nutrient loss, enhancing microclimate stability, and supporting species that depend on continuous canopy cover.

These forest management practices have been shown to have positive effects on forest biodiversity, compared to more intensive and uniform ones, such as clear-cutting, even-aged monocultures. However, they also pose some challenges and limitations, such as higher costs, lower yields, and lower compatibility with mechanisation and automation. Therefore, they need to be carefully planned and implemented, taking into account the specific objectives, conditions, and trade-offs of each forest situation. Moreover, they need to be supported by adequate policies, incentives, and information systems, as well as by the involvement and cooperation of various stakeholders, such as forest owners, managers, workers, consumers, and civil society. It would seem that over the last few years, many initiatives based on very strict forest protection have emerged from various sides of the society. The main idea behind this movement is that, in order to restore the state of the forests, it is necessary to stop all human intervention and "place the forest under a protective bubble". However, one extremely important point needs to be emphasised here: we live in a world in which the climate and the living conditions of species are changing at a very rapid pace, far beyond the capacity of forest ecosystems to adapt. As a result, it is becoming increasingly difficult and risky to leave forest ecosystems at the

[1] Forests | Department of Economic and Social Affairs (un.org)

[2] Species that rely on deadwood for one or multiple stages of their development.

mercy of changing conditions for which humans are responsible, and to expect to benefit from the ecosystem services that the forest can provide without assisting it in its transition. Therefore, it's important to understand that replacing trees is not necessarily detrimental to the general health of the forest, as long as it is done in a sustainable way that respects the natural dynamics and diversity of the forest ecosystem. Forestry operations can actually enhance biodiversity by creating a variety of habitats, opening up the canopy and allowing light to enter the forest, what is stimulating regeneration and succession of different species. Foresters have the health of the forest in mind when managing it, and they have a long-term vision because of the long-time span of forest management operations. Foresters will never unwisely harvest the forest plots that they spent their lifetime maintaining and improving and this requires a high level of knowledge, skill, and commitment from the forestry sector, which is currently facing many challenges, such as labour shortages, low profitability, and market uncertainties.

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