EU bioeconomy in the context of the 2040 climate target

As recognised across several strategic elements of the EU policy framework[1], the utilisation of biomass can be a powerful tool in climate mitigation, offering both economic and environmental benefits. However, its climate impact is highly context-dependent, and concerns remain about the sustainable scale of its deployment. As the EU looks to aligning its policy mix with a new 2040 climate target, expectations for land resources are intensifying, with increasing demands to replace fossil inputs in energy and materials, while sustaining low-emission food production systems, supporting ecosystem recovery, and delivering carbon sequestration and resilience. In this context, **a more comprehensive and coordinated bioeconomy policy framework is essential to manage trade-offs, avoid technological lock-ins, strategically direct bioresource supply, and ensure a cost-effective transition to carbon neutrality.**

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As the EU prepares to release an updated Bioeconomy Strategy, this briefing examines the current policy framework governing biomass use and explores bioenergy pathways outlined in the Commission's Impact Assessment accompanying the 2040 climate target communication. It highlights how:

- A persistent **imbalance in policy incentives for biomaterials, bioenergy, and land carbon stock maintenance**, alongside challenges in the implementation of sustainability safeguards, have

[1] See e.g. the Communication on Sustainable Carbon Cycles, Communication on the 2040 Climate Target, or the Competitiveness Compass.

had a negative impact on resource efficiency and the EU's land-based net carbon removals.

- The bioenergy demand and supply projections indicate that, in the absence of demand-side adjustments, and considering the simultaneous policy ambition to scale up biomass use in material applications, the EU may be at risk of exceeding the limits of sustainable biomass availability.

- **The uncertain future deployment of resource-intensive abatement technologies, such as DACCS and e-fuels, introduces significant uncertainty into projected biomass demand trajectories.** If these technologies fail to scale and remain significantly costlier than more mature bio-based options like biofuels and BECCS, a shift to the latter could significantly increase pressure on land.

- **Modelled trajectories for certain types of biomass feedstocks**, which assume higher wood harvesting rates and an increase in the utilisation of secondary resources, **present uncertain climate benefits in practice and may deviate from the cascading principle.**

- Broader systemic uncertainties affect the land's capacity to support the bioeconomy under the conditions of climate change, suggesting that projections for the available bioenergy supply and land carbon sinks may not hold in practice.

- The significance of demand-side variables in the Commission's sensitivity analysis as part of the LIFE scenario, which underscores **the risk reduction that can be achieved through consumption shifts – delivering environmental, social, and economic co-benefits by easing pressure on land.**

The forthcoming **revision of the EU Bioeconomy Strategy represents a window of opportunity to improve cross-sectoral policy integration and address rising pressures on land and biomass** through better data, monitoring, and governance. Key priorities include aligning incentives across actors, shifting support from energy to higher-value material uses, and – crucially – implementing demand-side measures, which will be essential to ensuring the environmental integrity of the bioeconomy and achieving the EU's 2040 climate targets.

Sustainable bioeconomy within the EU policy framework and trends in use of land resources for bioeconomy

Strategic policy framework

The development of the bioeconomy has long been a central focus in EU legislation and policy discussions, particularly regarding its critical role in the decarbonisation of the economy – a role that has only gained prominence over time. The current EU Bioeconomy Strategy, which predates both the European Green Deal and the 2030 climate target, underscores that the European bioeconomy is "necessary to build a carbon neutral future in line with the climate objectives of the Paris Agreement" (EC, 2018a). This strategic perspective is reinforced across several key EU policy documents, including the Communication on Sustainable Carbon Cycles, the Clean Industrial Deal, and the Competitiveness Compass, among others.

At the same time, several strategies highlight the limitations and context-dependent nature of the sustainability benefits associated with biomass utilisation. The staff working document accompanying the Bioeconomy Strategy acknowledges that "significant data gaps remain, impeding a full assessment of the different impacts of the bioeconomy," particularly due to insufficient information on "how much biomass is available and can be mobilised sustainably, how much is being used and for which purposes, and how the increased pressure on natural resources can be reconciled with environmental, economic and social sustainability" (EC, 2018b). The New EU Forest Strategy for 2030 similarly identifies challenges to bioeconomy development, highlighting insufficient forest planning which "leads to a situation where, on the one hand, Member States have agreed at EU level to rely to a great extent on forests and forest-based bioeconomy" in the EU's transition climate neutrality, while, on the other hand, there is "no strategic framework, which would (…) make it possible to comprehensively and jointly with Member States demonstrate that the EU is on the right track and that the forests can actually deliver on their multiple demands and functions".

With regard to bioenergy production as part of the transition towards renewables, the Strategy states that bioenergy will continue to play a significant role, "if biomass is produced sustainably and used efficiently, in line with the cascading principle and taking into account the Union's carbon sink and biodiversity objectives as well as the overall availability of wood within sustainability boundaries in the 2030 perspective" (idem.). The emphasis on the cascading principle is also present in the 2018 Bioeconomy Strategy, aligning with the Circular Economy Action Plan and the waste hierarchy in the EU Waste Framework Directive, which aim to retain the value of products, materials, and resources in the economy for as long as possible. Although interpretations of cascading use vary across the literature, they consistently emphasize the importance of utilizing biomass multiple times prior to its energy recovery and final disposal (Avitabile et al. 2023).

EU legislation and observed biomass and land sector trends

Thus far, within the framework of binding EU legislation, the substitution of fossil-based materials with bio-based alternatives has been most prominently incentivised in the energy sector. Incentives for bioenergy development have been embedded in multiple EU legislative instruments, most notably the Renewable Energy Directive (RED). The RED sets binding targets for the contribution of renewable energy to the overall energy mix, includes bioenergy among the qualifying renewable sources, and establishes conditions under which Member States may provide direct financial support to renewable energy sources. As a result, bioenergy has benefited from substantial financial support. In 2022, direct subsidies provided by Member States for biomass as an energy source amounted to €15 billion – equivalent to the subsidies allocated for wind power (EC, 2023a)

Further policy mechanisms include the zero-rating of biomass emissions under the EU Emissions Trading System (ETS), which exempts utility operators from surrendering allowances for emissions resulting from biomass combustion. This exclusion from carbon pricing effectively constitutes an indirect subsidy for biomass (European Academies Science Advisory Council, 2022) and reflects the application of the 'carbon neutrality' principle in EU energy legislation, whereby emissions from fossil fuel combustion are attributed to commercial energy operators, whereas emissions from biomass combustion are not.

Most recently, the introduction of the Carbon Removal Certification Framework (CRCF) which aims to establish a certification system for carbon removals, including those achieved through bioenergy with carbon capture and storage (BECCS), provides an additional incentive for the deployment of bioenergy technologies.

With a long history of incentivisation, the demand for biomass for energy has been growing steadily, primarily due to the direct combustion of biofuels in the buildings, energy supply, and industry sectors (ESABCC, 2025). Since 2000, bioenergy use has increased by 150%, reaching 6.2 exajoules (EJ) in 2019 (Material Economics, 2021). During this period, biomass use for power generation alone rose by 1.3 EJ, surpassing the combined growth of solar and wind power. In the transport sector, biofuel consumption expanded significantly, from a negligible 0.03 EJ in 2000 to 0.73 EJ in 2019 (idem.). Bioenergy derived from agricultural, forestry, and organic waste feedstocks remains the primary source of renewable energy in the EU, accounting for approximately 59% of renewable energy consumption in 2021 (EC, 2023b)

In contrast, material uses of biomass have experienced more modest growth. Between 2000 and 2019, EU production of sawnwood increased by 13%, and wood-based panel production grew by 22%, while the production of paper and board declined by 1% (Material Economics, based on FAO, 2021; Ericsson and Nilsson, 2018).

Overall, EU demand for woody biomass grew by over 25% (equivalent to 193 million m^3) between 2009 and 2017, primarily driven by rising demand for energy purposes (121 million m^3) (ESABCC, 2024; Camia et al., 2021). Nearly half of this increase was met through intensified harvesting, and 22% came from unknown sources, which may also include harvesting. Only about one-third of the increased demand was met through secondary sources, such as residues and post-consumer wood (Camia et al., 2021; ESABCC, 2025).

The EU remains a net importer of woody biomass, primarily in the form of wood pellets and roundwood, with the imports of wood pellets from non-EU countries more than doubling between 2009 and 2023 (ESABCC, 2025).

Box 1: Sustainability of energy generation from primary biomass

The lifecycle emissions associated with bioenergy are complex and highly context dependent. Key influencing factors include the source of the biomass, the conversion technology used, energy inputs for processing and transportation, land use changes, the analytical boundaries chosen, and the timelines considered (ESABCC, 2025).

Biomass-to-energy conversion is a relatively inefficient process. The direct CO_2 emissions per kilowatt-hour (kWh) of electricity generated from the combustion of woody biomass in large-scale bioenergy plants are typically 1.5 times higher than coal and three times higher than natural gas. This is primarily due to wood's chemical composition, high moisture content, and lower combustion temperature – with pelletisation of wood not offering meaningful improvements in emissions efficiency (Laganière et al., 2017; Booth, 2018; EASAC, 2022).

While using residues from wood processing for energy may in some cases be the most efficient use of such waste materials, the use of primary biomass (i.e., wood harvested for direct use in energy) generally leads to increased atmospheric carbon for several decades (Mitchell et al., 2012; Bernier & Paré, 2013). Although regrowth of harvested trees can eventually reabsorb the released carbon, regrowing forests typically sequester less carbon in the early years than if they had been left unharvested. This results in a "carbon debt", gradually repaid over time. Over the longer term, faster growth rates may enhance sequestration, and reductions in fossil fuel use could eventually balance emissions. However, this only holds true for the initial stand harvested; as harvesting continues in successive stands, the carbon debt accumulates and requires additional time and regrowth to reach even carbon parity with fossil fuel use (Moomaw et al., 2019).

Critically, while forests regrow, increased atmospheric CO_2 drives ongoing warming, resulting in potentially irreversible impacts, such as accelerated glacier melt, permafrost thaw, and ocean warming and acidification (Möller et al., 2024). Placing additional carbon into the atmosphere for decades thus contributes to permanent climatic and ecological damage. Alongside delaying carbon recovery, the harvesting of trees can also reduce ecosystem resilience, increasing susceptibility to disturbances and additional carbon losses.

The net GHG impact of bioenergy by 2050 will depend on how forests are managed, how the energy is utilized, and what fossil fuels – coal, oil, or natural gas – are displaced. Nonetheless, modelling suggests that replacing fossil fuels with wood for energy could result in two to three times more carbon in the atmosphere per gigajoule (GJ) of final energy by 2050 (Searchinger et al., 2018). Given that the realistic renewable alternatives, solar and wind, are substantially lower in emissions, the substitution of fossil fuels with biomass could reverse projected emissions reductions. For instance, bioenergy policies could turn an expected 5% decrease in energy sector emissions by 2050 into a 5–10% increase or more (idem.).

The argument that sustainable harvesting through the management of tree density and species composition can maintain net forest growth, and thereby preserve carbon sinks, overlooks key aspects of forest carbon accounting. While the basic premise of sustainable harvesting is that logging should not exceed the rate of forest growth, this approach can misrepresent carbon neutrality. Specifically, attributing ongoing forest growth to offset emissions from wood combustion does not reflect an actual increase in carbon uptake, as illustrated by Booth and Mitchell (2020) in the example below:

In a 100,000-hectare forest with an average growth rate of four tonnes of green wood per hectare per year, the process of wood growth would sequester roughly 400,000 tonnes of CO_2 annually. In theory, one could sustainably harvest this amount from part of the forest while the remainder continues growing. However, once the harvested biomass is burned, the forest no longer delivers a net annual CO_2 removal of 400,000 tonnes. The CO_2 absorbed by new growth is now offset by the emissions from combustion, resulting in no net gain in atmospheric carbon sequestration. From the perspective of the atmosphere, the forest has ceased to remove CO_2, and the emissions from combustion are experienced as an increase in atmospheric carbon concentration (Booth & Mitchell, 2020).

The use of primary biomass for energy also exerts substantial pressure on land resources. In contrast, alternatives such as solar power generate significantly more usable energy per hectare: typically at least 100 times more than bioenergy, even on productive land, with even greater efficiencies achieved on marginal lands or rooftops (Searchinger, Beringer, & Strong, 2018; Kammen & Sunter, 2016). Moreover, solar and wind technologies benefit from rapidly declining costs, further enhancing their economic competitiveness relative to bioenergy.

While demand for biomass has been increasing, the size of the EU's reported LULUCF sink has declined by nearly one-third over the past decade, primarily due to a decrease in the forest sink (Korosuo et al., 2023). For most of the 21st century, net CO_2 removals from the LULUCF sector fluctuated between 300 and 350 $MtCO_2$ per year. However, beginning in the mid-2010s, a sharp decline became evident, driven by reduced CO_2 uptake in EU forests.

Despite regional differences, the overall decline in the EU's forest carbon sink is attributed to increasing demand for woody biomass, coupled with stagnating or declining forest growth. The latter is linked to factors such as forest age structure and climate change-related disturbances, including wildfires and droughts (Biber et al., 2020; ESABCC, 2024; Hyyrynen et al., 2023; ESABCC, 2025).

To consider bioenergy as a lower-emission alternative, its CO_2 impacts must be assessed comprehensively. This includes accounting for value chain emissions, biogenic CO_2, indirect land-use change (iLUC), and carbon debt dynamics. Recognising this, the European Commission noted in its proposed revision of the Renewable Energy Directive (RED III), a "growing recognition of the need for alignment of bioenergy policies with the cascading principle of biomass use", stating that "Member States' support schemes for bioenergy should therefore be directed to such feedstocks for which little market competition exists with the material sectors" (EC, 2021b).

Although RED III introduces more stringent provisions, following a complex negotiation process among co-legislators, some elements differ from the direction proposed by the Commission and may present challenges in aligning with broader sustainability objectives. The revised directive requires Member States to ensure the application of the cascading principle, aiming to achieve "resource efficiency of biomass use through prioritising biomass material use over energy use wherever possible" (EU, 2023). In addition, it requires that woody biomass should be used according to its highest economic and environmental added value in the following order of priorities: 1) wood-based products, 2) extending their service life, 3) re-use, 4) recycling, 5) bio-energy and 6) disposal. Some of the provisions in earlier versions of RED, which allowed support for certain bioenergy feedstocks potentially at odds with the cascading principle or associated with notable biodiversity impacts, have since been amended. For example, Member States are now prohibited from providing direct payments to operators for burning sawlogs, veneer logs, industrial-grade roundwood, stumps, and roots. However, primary woody biomass not falling under these categories can still be subsidised and indirect subsidies for bioenergy operators remain unregulated.

RED III also prohibits direct support for electricity-only biomass installations, with some exceptions (e.g., for facilities using BECCS). Beyond this ban, and the inclusion of a dedicated target for advanced biofuels in the transport sector, the directive does not further align bioenergy incentives with the availability of alternative mitigation options.

In parallel with RED III, the Fit-for-55 package includes sector-specific legislation aimed at promoting biofuel use in aviation and maritime transport – sectors where few decarbonisation alternatives exist. This includes the ReFuelEU Aviation and FuelEU Maritime regulations. However, discrepancies remain between the sustainability criteria applied under these sectoral laws and those in RED III. For instance, different treatment is given to intermediate crops, first-generation biofuels, and waste feedstocks, alongside varying applications of safeguards concerning the cascading use of biomass (ESABCC, 2024; ESABCC, 2025). This poses risks of reintroducing sustainability issues associated with biofuels, many of which were identified under previous iterations of the RED (Malins, 2023; ESABCC, 2024; ESABCC, 2025).

Policy implementation and monitoring

While sustainability criteria for biomass feedstocks have been strengthened under RED III, their enforcement continues to rely on compliance monitoring, which has faced challenges thus far (Mai-Moulin et al., 2021; Mather-Gratton et al., 2021; Sikkema et al., 2021). Compliance with the directive's sustainability requirements remains largely delegated to voluntary certification schemes, as in the earlier iterations of the RED. The EU has criticised such schemes in the past for their lack of transparency, weak governance, and inherent conflicts of interest, evidenced to have undermined the reliability of the system (European Court of Auditors, 2016; EC, 2020; EC, 2021c).

Used cooking oil (UCO), the most consumed RED biofuel feedstock, has been associated with a high risk of fraud, due in part to the chemical and physical similarities between waste oil and unused oil (French Court of Auditors, 2021; European Court of Auditors, 2023; Cazzola et al., 2022). Documented cases of fraud include instances where biofuels produced from unsustainable feedstocks such as palm oil were falsely reported as UCO-based (EC, 2022a; OCCRP, 2023; T&E, 2024). Significant discrepancies have also been observed between reported UCO consumption and its estimated maximum availability (European Court of Auditors, 2023; Imperial College London, 2021).

Feedstocks added to Annex IX of RED III following its adoption, such as intermediate crops and crops grown on severely degraded land, can be expected to pose similar challenges in terms of monitoring and verification. Effective oversight requires full supply chain traceability, particularly in cases where feedstocks cannot be physically distinguished (EC, 2022a). Notably, these feedstocks are not subject to caps in the aviation sector, which could incentivise a rapid increase in demand.

Although policy direction has shifted away from explicitly incentivising the most environmentally harmful biofuel feedstocks, the continued reliance on commercial, voluntary certification schemes raises ongoing concerns. This is especially notable given that such schemes were not considered to be sufficient under the EU Regulation on deforestation-free products (EUDR) for demonstrating compliance with due diligence obligations.

Under the Commission's implementing regulation for National Energy and Climate Plan (NECP) progress reports, Member States are now required to report biomass supply for energy use, disaggregated by biomass type and source, including primary and secondary biomass. This information is critical to assessing compliance with RED III sustainability requirements. For instance, data distinguishing between primary and secondary woody biomass is needed to assess alignment with the directive's cascading use provisions, while data on stumps and industrial roundwood provides the necessary foundation for implementing new restrictions on financial support for their combustion.

However, an analysis by the Partnership for Policy Integrity (PFPI, 2024), which examined 2021 forest biomass data from Eurostat's "supply of biomass" dataset, identified notable gaps in

Member State reporting. The analysis found that the dataset accounts for only 52% (158 million tonnes) of the wood biomass reported under "Fuelwood, wood residues, and byproducts" (305 million tonnes) in Eurostat's renewables dataset. Among Member States that do report data, it is also often unclear whether the absence of specific biomass categories indicates non-use or limitations in reporting practices.

The PFPI (2024) also highlights issues with the classification of industrial-grade roundwood. There is currently no objective definition distinguishing "fuelwood" from "industrial roundwood"; wood is classified retroactively based on end use – if burned, it is considered fuelwood; if used in material production, it is defined as industrial roundwood. This is particularly significant in the context of RED III safeguards, which prohibit direct subsidies for the combustion of industrial-grade wood. Without clearer definitions, Member States could potentially be incentivised to underreport the use of industrial wood for energy in order to continue providing financial support to national installations (idem.).

The PFPI (2024) notes that ongoing gaps in reporting essential data may hinder the effective implementation of RED III's sustainability and biomass sourcing provisions, raising questions about the ability to ensure genuine GHG savings and to prevent environmental harm.

As early as 2014, the European Commission acknowledged that an improved biomass policy was "necessary to maximise the resource-efficient use of biomass in order to deliver [...] greenhouse gas savings and to allow for fair competition between the various uses of biomass resources in the construction sector, paper and pulp industries and biochemical and energy production" (EC, 2014). To date, no overarching policy has been adopted, however. As the European Court of Auditors (2023) notes, the primary tools currently available to limit overexploitation of biomass for biofuels are caps on specific feedstocks and general sustainability criteria. Despite numerous studies on biomass potential and sustainability (EC, 2017; Avitabile et al., 2023), an EU-level assessment has not yet been conducted on the availability of biomass in relation to renewable energy targets (European Court of Auditors, 2023).

This task has instead been delegated to Member States under the Governance Regulation, which requires them to report on the national level on the availability of biomass for energy use, assess the impact of bioenergy demand on forest biomass, and evaluate its compatibility with national targets under the revised LULUCF Regulation, as part of their NECPs.

In its latest assessment of the final updated NECPs, the European Commission finds that "plans still lack information concerning the domestic supply of forest biomass for energy purposes, on how forest biomass will be used for energy production, and whether the Member States meet the relevant obligations under the LULUCF Regulation" (EC, 2025). The Commission's aggregate analysis concludes that the forest carbon sink is not projected to improve compared to current levels, and that the EU remains approximately 45–60 $MtCO_2e$ short of the 2030 target under current and planned measures. The report also notes that "most of the plans lack sufficient details on the actions needed to reach the targets, and a quantification of their impacts" (idem.).

2040 climate target scenarios: bioenergy demand and its implications for the development of biomaterials

2040 climate target Communication

In February 2024, the EU Commission adopted a Communication proposing a 90% net GHG emissions reduction compared to 1990 levels as the recommended target for 2040 (EC, 2024c). It stipulates that to deliver this reduction, the level of remaining EU GHG emissions in 2040 should be less than 850 MtCO_2-eq (excluding emissions from the LULUCF sector), while carbon removal from the atmosphere through land-based sequestration and industrial carbon removal solutions should together reach up to 400 MtCO_2.

While the communication does not explicitly recommend separate targets for absolute emission reductions and a removals target, this approach is implied by specifying the two ceilings, which correspond to a minimum reduction of emissions by approximately 83% and a CO_2 removal target of approximately 8%.

It is emphasised that that the recommendation for a net 90% reduction target follows the advice of the European Scientific Advisory Board on Climate Change, as well as representing a continuation of the current climate *policy* trajectory when compared to the theoretical extrapolation of existing policy instruments for the 2030 framework.

2040 climate target Impact Assessment

The Communication was accompanied by an impact assessment report (EC, 2024a; EC, 2024b) upon which the recommendations made in the Communication are based. The Commission's Impact Assessment (IA) presents three core scenarios, alongside a complimentary scenario, for a 2040 climate target that is compatible with reaching climate neutrality by 2050 and the 1.5°C long- term temperature goal:

- Scenario 1 (**S1**): a net GHG reduction target up to 80% for 2040: The first policy scenario relies on the Fit-for-55 energy trends delivering a "linear" reduction path between 2030 and 2050. No specific mitigation of non-CO_2 emissions is foreseen under this scenario up until 2040.

- Scenario 2 (**S2**): a net GHG reduction target of 85-90% for 2040: The second policy scenario builds upon the Fit-for-55 energy trends presented in scenario 1 while foreseeing a higher level of ambition in the land sector, i.e. deeper non-CO_2 emission reductions in agriculture and higher land carbon removals. These policy measures are complemented with a more widespread deployment of carbon capture and e-fuels.

- Scenario 3 (**S3**): a net GHG reduction target of 90-95% for 2040: The third policy scenario builds on the second scenario, while adding a "fully developed carbon management industry" by 2040, with carbon capture covering all industrial process emissions.

- Complementary variant: The **LIFE** scenario is designed to reach net GHG reductions of at least 90%, demonstrating how demand-side measures can complement supply-side technologies, while allowing a direct comparison with the overall level of emission reductions in the core scenario S3. In the context of the EU's food system, this scenario assumes a consumption shift towards more sustainable and healthy diets, with food production following the Farm to Fork and the Biodiversity Strategy objectives, mitigating pressure on land and resulting in additional nature-based carbon sequestration.

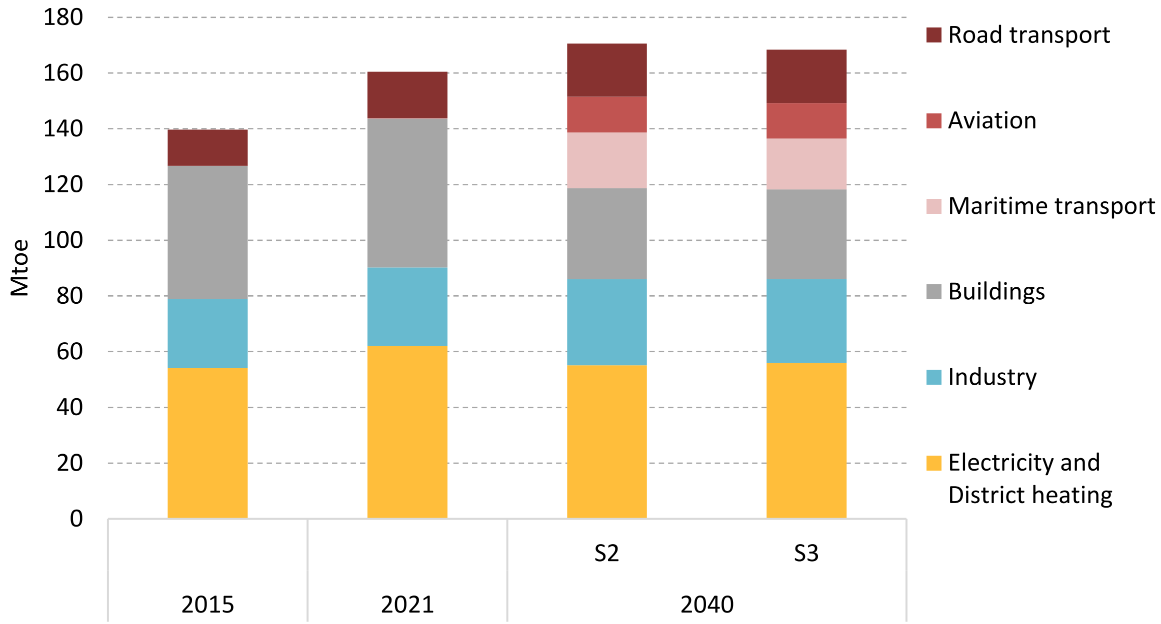
Bioenergy demand and its implications for biomass availability for biomaterials

According to the IA accompanying the 2040 target communication, the share of renewables in the EU's gross available energy is projected to rise from 17% in 2021 to between 50% and 60% by 2040 based on the modelled trajectory under scenarios S2 and S3. As part of this trajectory, the use of biomass and bio-based wastes for energy is expected to increase by approximately 30% under those scenarios, ultimately accounting for around 20% of gross available energy by 2040. Notably, this growth is projected to be driven primarily by domestic resources and waste streams, as imports of bioenergy are expected to rise only marginally, from 9 million tonnes of oil equivalent (Mtoe) in 2021 to 10–13 Mtoe by 2040.

The Commission's modelling estimates that bioenergy generation within the EU will reach approximately 170 Mtoe (7.1 EJ) in both S2 and S3 scenarios by 2040. This marks an increase from 140 Mtoe (5.9 EJ) in 2015 and 160 Mtoe (6.7 EJ) in 2021. A key factor contributing to this growth is the anticipated expansion in the use of biofuels in the aviation and maritime transport sectors. Under scenario S3, biofuel use in these sectors is projected to increase by 13 Mtoe and 18 Mtoe, respectively – up from negligible levels in the early 2020s.

However, the overall increase in bioenergy demand is expected to be partially offset by a substantial reduction in the use of biomass for residential heating, which is projected to decline by 20 Mtoe due to improvements in energy efficiency and the ongoing electrification of building heating systems.

Fig 2. Bioenergy demand by sector and scenario



Source: EC, 2024b

The IA assumes a cap of 9 EJ on the contribution of biomass to the EU's gross available energy, while acknowledging that "future analyses may assume other supply levels of biomass to stay within the sustainability boundaries, in view of the ongoing scientific debate" (EC, 2024a, Annex 6, p. 20). This cap is based on the environmental risk threshold proposed by the European Scientific Advisory Board on Climate Change (2023), which, in turn, references an analysis conducted by Material Economics (2021) as the basis for identifying this upper limit. However, no such threshold is specified in the Material Economics report.

Instead, the Material Economics study estimates the maximum safe level of biomass supply and demand, encompassing both energy and material uses, at 11 to 13 EJ. Based on 2015 data, it identifies approximately 4.1 EJ of biomass as being allocated to material production in the EU. This implies that even if biomass use for materials were to remain constant at 2015 levels, reaching 9 EJ of bioenergy consumption would exceed the report's upper bound of a likely safe biomass supply level. This raises questions about how the Commission's risk threshold aligns with the EU's objective to decarbonize material sectors through the substitution of fossil-based materials with bio-based alternatives, an ambition expected to increase demand for biomass for material use (see e.g., EC, 2021d; EC, 2024c).

Furthermore, existing evidence suggests that the current bioenergy consumption – slightly above 6 EJ – combined with biomass use in material applications, has already contributed to the degradation of the EU forest carbon sink (EC, 2017; Avitabile et al., 2023; ESABCC, 2025). This underscores the importance of a more integrated and precautionary approach to managing biomass demand across both energy and material sectors.

Box 2. Bioenergy with Carbon Capture and Storage

Scenario S3 projects an increased demand for bioenergy relative to current levels. Simultaneously, it is heavily dependent on alternative technologies such as e-fuels and direct air capture with carbon storage (DACCS). Should the deployment of these alternatives fall short of modelled assumptions, the shortfall may be offset by increased reliance on biomass-based solutions, such as biofuels and BECCS, the scaling of which could negatively impact LULUCF net removals and ecosystem recovery.

The Commission's modelling assumes that cumulative industrial CO_2 removals will reach approximately 75 Mt by 2040, evenly split between BECCS (~33 Mt CO_2/year) and DACCS (~42 Mt CO_2/year). Notably, this projection is contingent on an ambitious level of DACCS deployment, necessitated by a cap on BECCS deployment based on sustainable biomass availability thresholds introduced into the modelling. According to the IEA (2024), DACCS remains in its infancy, with only three facilities currently capturing more than 1 kt of CO_2 annually. Fifteen additional plants are under development, which – if fully operational by 2030 – will raise *global* DAC capacity to around 3 Mt CO_2/year, highlighting the scale of expansion needed for the EU to achieve 42 Mt CO_2/year within a decade.

Importantly, while the modelling imposes a biomass cap, there is no corresponding legal constraint on biomass usage within current EU bioenergy policy (ESABCC, 2025). As a result, despite facing technological obstacles, BECCS deployment remains unconstrained in practice. Reflecting this, the impact assessment presents an alternative pathway in which sustainable biomass constraints are relaxed. Under this scenario, BECCS deployment in S3 increases sharply, approaching 80 Mt CO_2/year by 2040, while DACCS deployment remains limited.

Should DACCS underperform, greater reliance on BECCS could further elevate bioenergy demand, potentially reducing LULUCF net removals. A sensitivity analysis using the GLOBIOM model under scenario S3 indicates that a 20 Mtoe increase in woody biomass demand could reduce net LULUCF removals by approximately 100 Mt CO_2e compared to the baseline S3 levels. As a result, total net removals in 2040 could range between -115 and -276 Mt CO_2e.

Scenario S3 also assumes a significant expansion in e-fuel production, inherently linked to carbon capture capacity given its reliance on CO_2 as feedstock, from zero in 2015 to 28 Mtoe by 2040. However, e-fuel production is resource-intensive, requiring abundant low-carbon electricity, captured CO_2 feedstock, and substantial water supplies (IEA, 2023). If these resources are limited, the modelled trajectory may falter, potentially prompting a shift toward greater biofuel use. Such a shift could further exacerbate land-use pressures and diminish the land carbon sink.

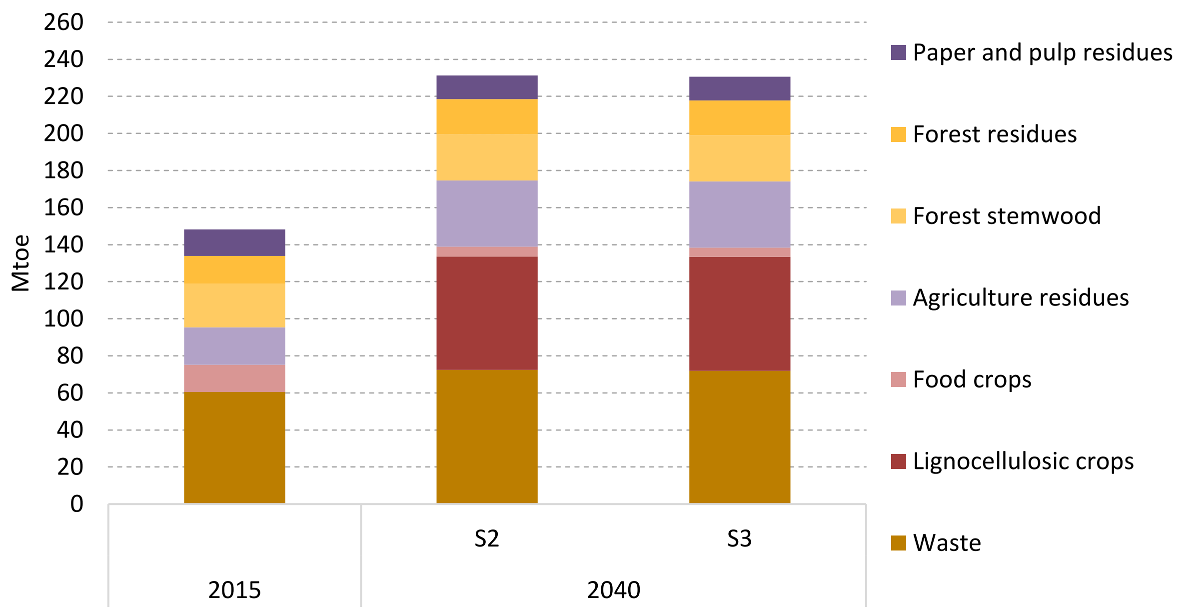
Bioenergy feedstocks

The projected increase in domestic feedstock supply for bioenergy in the Commission's modelling is underpinned by key assumptions regarding a shift in the types of feedstocks used. Central to this is a transition toward second-generation biofuels, with a particularly notable rise in the supply of both annual and perennial lignocellulosic crops (such as short-rotation coppice species and lignocellulosic grasses) projected to reach up to 61 Mtoe by 2040, while the use of food crops for energy declines significantly, from 20 Mtoe in 2021 to 5 Mtoe by 2040.

The modelling assumes that approximately 80% of the area required for lignocellulosic crop production will be developed on land currently used for cultivating first-generation biofuel crops. This assumption underpins the conclusion that the associated land-use change will be limited, with cropland area expanding by only 1.2 million hectares in scenarios S2 and S3. However, the IA notes that for lignocellulosic crops to deliver genuine environmental benefits, they must exhibit higher yields and lower water requirements than conventional feed crops. It also stresses the need for appropriate constraints on their deployment to avoid adverse impacts on land and water resources.

In terms of other feedstock categories, the modelling foresees a substantial increase in the use of agricultural residues, attributed to improved mobilisation techniques. The contribution of these residues is projected to rise from 20 Mtoe in 2021 to 36 Mtoe by 2040. Conversely, the use of waste-derived feedstocks is expected to decline slightly, falling from 80 Mtoe in 2021 to 72 Mtoe by 2040.

Fig 3. Domestic supply of feedstock for bioenergy and waste by category



Source: EC, 2024b

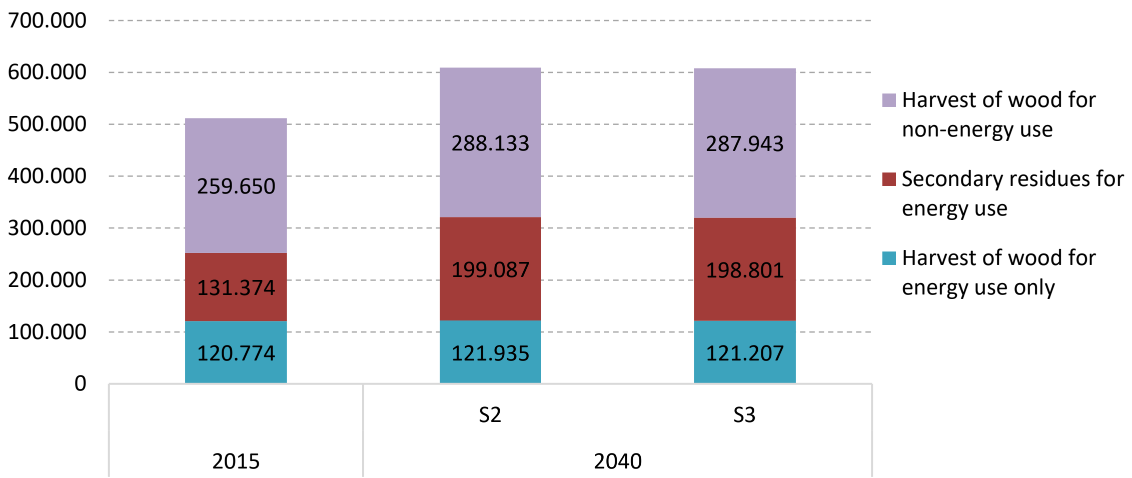
When looking at the use of forest biomass for energy, the Commission's impact assessment shows an increase by 2040 compared to 2015 levels: 25 Mtoe up from 21 Mtoe for forest stemwood, and 19 Mtoe up from 15 Mtoe for forest residues.

The authors of the IA emphasise that this trend happens in the context of increasing use of secondary residues and improved recovery of post-consumer wood. The text of the assessment highlights that "this has very important implications for the forest sink because primary woody biomass for bioenergy decreases the carbon pool and the LULUCF net removals. Therefore, an increasing use of secondary woody biomass from other uses (bark, secondary residues from material production, recovered post-consumer wood), which substitutes woody biomass coming directly from forests, has an alleviating effect on the LULUCF net removals" (EC, 2024a, Annex 8, p.120). However, no alleviating effect on the forest sink is projected relative to its current level. The IA projects that the *forest sink* under Scenario 3 will be at the level of -252 MtCO2-eq, lower than it has been at any point since 1990, the beginning of the standard GHG inventory reporting period.

The IA shows that while the recovery rate of secondary biomass for energy increases, so does the total harvest of wood in the EU. The **impact assessment shows a 19% increase in total wood harvest by 2040 compared to 2015 levels under scenario S3**, driven mainly by increased harvest for material purposes. The harvest of wood for energy use also increases, although by a small margin.

The sustainability of the modelled increase to 19 Mtoe in forest residue collection also remains uncertain, as it is in close proximity to the Commission's cap for what constitutes sustainable harvesting of forest residues, set at 20 Mtoe. Furthermore, the specific type of residues utilised plays a critical role in determining whether a genuine climate benefit is achieved when compared to fossil fuel alternatives. For example, the Commission's Joint Research Centre concludes that the use of any wood for bioenergy other than the smallest slash residues is likely to lead to a net increase in atmospheric carbon over relevant time horizons (Camia et al., 2021). This raises the question of whether improvements in the collection of these low-impact residues alone can account for the projected 4 Mtoe increase, particularly if they are also expected to substitute other types of residues with potentially higher associated emissions.

Fig 4. Harvest of wood for energy and non-energy use



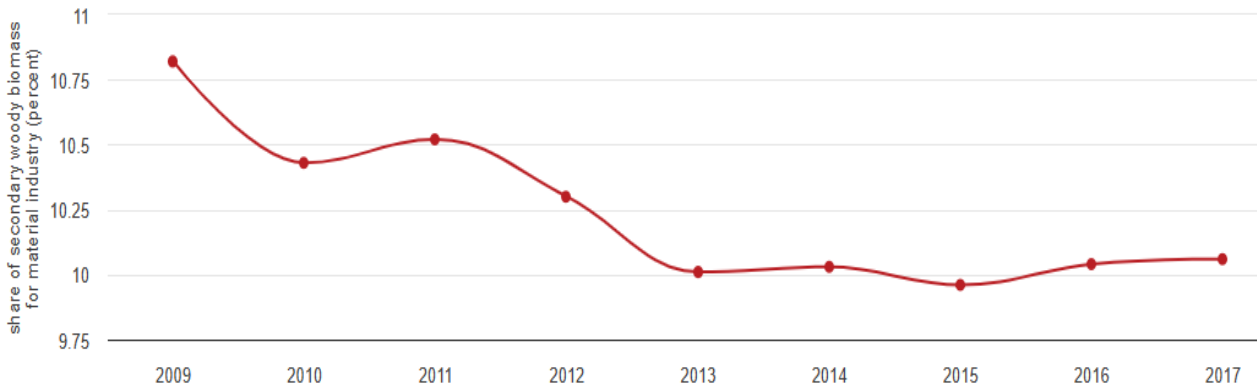
Source: EC, 2024b

As for secondary residues, in line with the assumptions quoted in the section above, the IA figures indicate that the ratio of secondary residues used for energy (i.e. residues from the processing of wood originally harvested for material use) to the total wood harvested for non-energy use increases from 34% utilisation for energy in 2015 to 41% in 2040. However, it is unclear what this increased utilisation means for the use of secondary residues for material use, and therefore for the application of the cascading principle and general resource efficiency.

The increased use of secondary residues for energy has broader implications for decarbonisation in the material sectors as energy and material uses compete for the same secondary wood and recovered woody biomass sources (see e.g., Jonsson & Rinaldi, 2017). Solid sawmilling by-products are a suitable feedstock for wood-based panel and pulp industries, as well as being used by the energy sector. Post-consumer wood without contaminants and additives can be used for both wood-based panel production and energy. In line with the cascading principle, the use of secondary residues should be maximised through material applications before being directed to energy use, and only in cases where no higher-value utilisation is feasible. This implies that increased use of secondary residues for material purposes, rather than for energy, should be prioritised.

To assess the extent to which the cascading principle has been applied in the EU to date, the EU Commission's Joint Research Centre has analysed the trends in the share of secondary wood and recovered woody biomass use for material and energy and found that the proportion of the cascade use of wood is declining within the total uses of wood. The resulting data demonstrates that between 2009-2017, the use of primary wood increased for both material and energy, but the pace of growth for materials was lower than for energy. At the same time, the share of secondary wood and post-consumer wood use for materials decreased, suggesting that the cascading principle is not being applied (Avitabile et al. 2023).

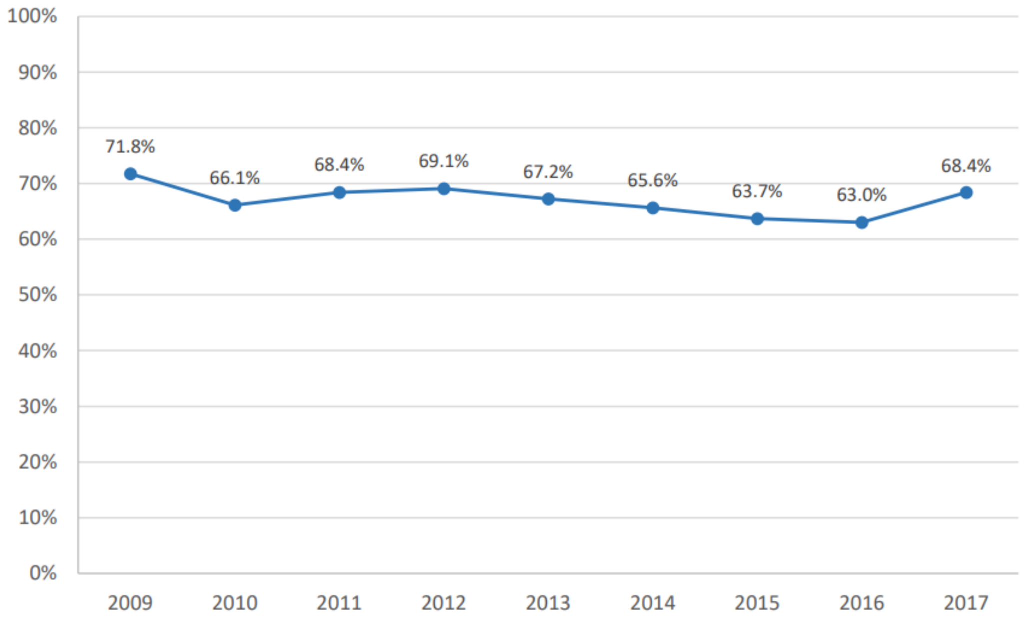
Fig 5. Share of by-products and PCW for material use, relative to the total uses of secondary woody biomass in the EU-27 (2009-2017)



Source: EU Bioeconomy Monitoring System, 2025

The JRC further examines the extent to which the cascading potential is realised within the sawmilling industry, where significant quantities of by-products – such as sawmill residues, wood chips, and wood particles – could potentially be directed towards the production of wood-based panels and wood pulp. An estimate of the cascading use rate is derived by comparing the reported use of sawmilling by-products in the wood panel and pulp industries against the total available quantity of solid by-products generated in the sawmilling, plywood, and veneer sheet industries, adjusted for net trade in by-products and unreported secondary wood. The findings suggest that, between 2009 and 2017, the material use potential of these by-products was underutilised. Furthermore, over the same period, the cascading use rate of by-products as a share of total potential slightly declined.

Fig 6. Utilised potential for the use of sawmilling by-products for material production (by-products cascade use rate) in the EU-27 (2009-2017)



Source: Avitabile et al., 2023

Overall, the JRC analysis demonstrates a continued increase in the use of recovered woody biomass and by-products for energy purposes. At the same time, figures from the Commission's IA indicate that the proportion of secondary residues used for energy (i.e., residues from the processing of wood originally harvested for material use) relative to the total volume of wood harvested for non-energy purposes is projected to increase, from 34% in 2015 to 41% by 2040. This trend appears to run counter to the stated aim of improving the cascading use of biomass.

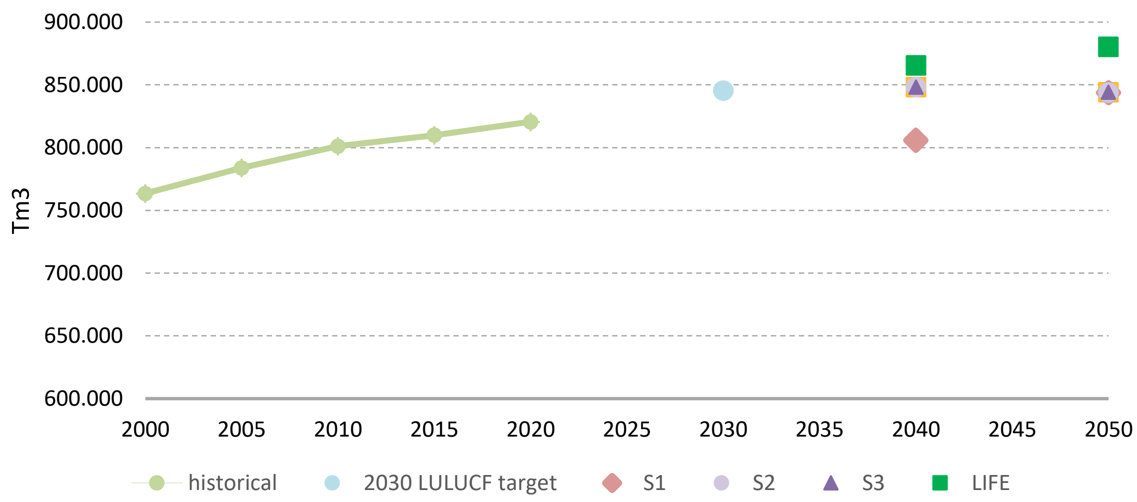
In order to achieve the EU's climate, circularity, and broader sustainability objectives, greater application of the cascading principle should be considered, promoting material use before energy use wherever feasible. This also increasingly applies to secondary feedstocks that have historically had limited alternative uses beyond energy, such as black liquor which shows potential for new applications in materials, such as bioplastics (Avitabile et al. 2023).

Primary biomass availability in a changing climate

The projections for woody biomass use presented in the IA are based on specific assumptions about sustainable harvesting limits, particularly with regard to stemwood and forest residues. Defining these sustainability thresholds for the future, and determining an appropriate forest management strategy more broadly, depends on projections of changes in forest growth and mortality, measured as the net annual increment (NAI). Between 1950 and 2005, the NAI increased steadily, but has since stabilised and is expected to decline in the coming years. This slowdown is attributed both to the ageing structure of EU forests, as older trees generally exhibit slower growth rates, as well as to increasing harvesting rates, which constrain the net carbon uptake capacity of aboveground living biomass (Avitabile et al. 2023; EC, 2024a).

The IA includes projections for total forest increment up to 2050, estimating that the increment of managed forests will peak around 2040 under scenarios S2 and S3 – approximately at the level required to meet the 2030 LULUCF target – after which it is projected to gradually decline.

Fig 7. Total forest increment of managed forests per year



Source: EC, 2024b

The projection does not account for the growing influence of natural disturbances and other climate change-related impacts, which are likely to further diminish the marginal share of forest increment available for wood supply. Europe is currently experiencing heightened climate variability and an increase in extreme weather events, contributing to elevated tree mortality rates and declining forest productivity. Droughts and heatwaves interact with other natural disturbances – such as wildfires and pest outbreaks – thereby amplifying the adverse effects on forest growth expected in the coming years (Avitabile et al. 2023). Recurrent wildfires, in particular, can lead to the loss of woody plant species, which are often replaced by herbaceous, frequently annual, or invasive species. These changes can also alter soil properties and accelerate soil erosion (idem.).

The 2040 climate target impact assessment presents the outcomes of a dedicated modelling exercise intended to reflect the possible climate change impacts on the LULUCF net sink, associated with extended growing seasons, a higher frequency of natural disturbances and changing precipitation levels, considering 16 distinct pathways. Overall, the analysis projects a possible range of removals between -70 $MtCO_2e$ and -285 $MtCO_2e$ in 2050, in the absence of additional LULUCF policies, taking into account uncertainties around carbon storage in soils. When no effect from CO_2 fertilisation is considered, all scenarios result in a significant decline in net LULUCF removals – including scenarios associated with a best estimate long-term temperature increase of 1.8°C until 2100. When assumptions on persistent CO_2 fertilisation are included, the analysis shows a range of both positive and negative outcomes, with the majority indicating stable or slightly decreased levels of net LULUCF removals when compared to the early 2020s. With regards to the potential small uptick in removals as a result of CO_2 fertilization, the IA also caveats that increased productivity depends strongly on water availability - and while precipitation levels are integrated into the modelling, "it is difficult to assess the full impact of climate change on regional water availability including groundwater levels because of high cascading uncertainties" (EC, 2024a, Annex 8, p.133).

This highlights the uncertainty surrounding the future development of the living biomass carbon sink – an uncertainty that is not fully accounted for in the core projections of biomass supply and demand. For a more detailed discussion of these uncertainties in the evolution of the land sink, see IEEP brief "EU LULUCF sink development until 2040: Trends, projections and uncertainties".

Sustainable lifestyles and demand-side measures in the LIFE scenario

The LIFE scenario in the Commission's impact assessment presents an alternative pathway to achieving the EU's climate goals through more sustainable consumption patterns and resource efficiency, offering a contrasting approach to the core scenarios (S1, S2, and S3). Unlike the core scenarios, which share common socio-economic assumptions, LIFE integrates lifestyle and consumption changes to demonstrate how climate action can be aligned with broader environmental and societal objectives.

A defining feature of the LIFE scenario is its emphasis on reducing demand across multiple sectors. This includes a marked decrease in domestic and international aviation (10% by 2040 compared to other scenarios), a modal shift to rail, and the adoption of more sustainable mobility practices such as shared transport, increased cycling, and reduced reliance on private vehicles. The underlying behavioural changes include the widespread use of video-conferencing, reduced need for business air travel, and a shift from short-distance flights to high-speed rail where available.

In the energy and industry sectors, LIFE assumes a systemic shift toward circularity and material efficiency. Actions include a significant increase in recycling, reduced scrap exports, and extended product lifespans, with greater reliance on product repair and reuse. These measures reduce the demand for energy-intensive materials and processes while maintaining service levels, lowering energy costs, and decreasing reliance on expensive decarbonisation technologies such as e-fuels and hydrogen.

The food system also undergoes a transformation. LIFE assumes a gradual adoption of healthier and more sustainable diets, accompanied by reduced food waste and a transition in agricultural practices, including a reduction of at least 20% mineral fertilisers application and 50% reduction in nutrient surplus from organic and synthetic sources. The consumption shift results in a decline in livestock numbers and a reallocation of land from intensive grazing and fodder production to extensive grasslands, forests, and rewetted peatlands. These land use changes contribute to increased carbon removals, with LIFE achieving net LULUCF removals around 40 $MtCO_2e$ higher and agricultural emissions approximately 60 $MtCO_2e$ lower than in scenario S3 by 2040. These changes also enable enhanced carbon farming-related business opportunities and other co-benefits such as a 14% increase in areas of high biodiversity value compared to S2 and S3.

Importantly, LIFE demonstrates that a demand-side strategy can reduce reliance on industrial carbon removals and e-fuels–technologies that, if deployed at scale, risk increasing pressure on land use and biodiversity. In doing so, LIFE mitigates the environmental trade-offs associated with high bioenergy demand observed in scenario S3.

Overall, LIFE illustrates the viability and co-benefits of a climate strategy that emphasises behavioural change, efficient resource use, and systemic sustainability, translating into a lower demand for bioenergy feedstocks compared to the more technology-reliant scenarios. This reduced biomass demand alleviates pressure on land resources, enabling more land to be set aside for carbon sequestration and biodiversity restoration, increasing resilience. Consequently, the pressure on the EU's land carbon sink is lessened, helping to safeguard its long-term capacity to provide climate mitigation benefits.

Implications for the EU policy mix

The forthcoming revision of the EU Bioeconomy Strategy represents a window of opportunity to enhance policy integration and realign policy incentives. Consideration could be given to placing renewed emphasis on Pillar Three of the previous Action Plan, as recommended in the 2022 Bioeconomy Strategy Progress Report. The report highlights significant challenges to guaranteeing environmental integrity, such as increased pressures on land for climate mitigation and adaptation, biodiversity conservation, and the growing demand for biomass for food, materials (e.g., bioplastics, durable wood products), and bioenergy. To address those, it emphasises the need for "additional focus [...] to resolve multiple pressures on land for mitigation, nature protection, and the supply of biomass" and underscores that "a better understanding of overall consumption of biological resources is needed to help shifting to more sustainable consumption patterns" (EC, 2022b).

Formulating concrete mechanisms to overcome policy silos and integrate objectives across energy, industrial, and environmental domains will be a critical task for the revised Bioeconomy Strategy. Coordinated policy-making can facilitate a shift toward higher value-added, long-lasting bio-based products, while helping to ensure that biomass use remains within planetary boundaries.

Data and planning

Improving data quality and addressing discrepancies between reported biomass uses and sources will be a critical prerequisite for robust analysis of the wood-based economy. As proposed in the Sustainable Carbon Cycles Communication and the Bioeconomy Strategy Progress Report, **a comprehensive bioeconomy land-use assessment would provide the analytical foundation needed to better understand existing pressures and constraints**. This would also support the development of territorially specific biomass strategies that reflect local resource availability and demand, alongside a more cohesive EU-wide policy. Robust information-oriented legislative instruments such as the proposed Forest Monitoring Law could provide the essential data inputs for this assessment.

There are clear gaps in the implementation of the EU's monitoring architecture needed to reliably track biomass flows, land-based carbon sinks, and ecosystem impacts. In the absence of a dedicated legislative instrument, it is imperative that emerging remote sensing initiatives and the improved compilation and use of existing forest inventory systems are co-ordinated to ensure data consistency across Member States. In this context, a coordinated monitoring agenda co-led by the Commission and Member States should be explored as a potential path forward, to ensure that core data needs are met while laying the groundwork for future policy pathways.

Enhanced monitoring, reporting, and verification systems must be developed not only to define sustainable limits and guide resource allocation at the macro level, but also to **ensure transparency regarding the origin of feedstocks used by individual economic operators, particularly where financial incentives are in place or where legacy subsidies persist**. The scale of potential fraud in biofuel markets poses a substantial threat to achieving sustainability objectives. Stricter definitions of sustainable feedstock types and the introduction of usage caps are necessary but insufficient on their own. A more robust system of governance is required, particularly in the short to medium term, including measures to eliminate conflicts of interest in verification processes. More broadly, the rollback of corporate sustainability-related requirements discussed as part of the proposed Omnibus Simplification Package warrants reconsideration, particularly the restriction of due diligence obligations to Tier 1 suppliers, given the central role of traceability in demonstrating compliance with sustainability criteria essential to the climate integrity of biomass feedstock for energy. These improvements are vital while economic incentives are gradually reoriented towards material uses of biomass and the preservation of land-based carbon sinks.

Policy incentives for the use of biomass in energy and material sectors

The Advisory Board has recommended that the European Union **introduce new instruments to price emissions and reward removals within the LULUCF sector** (ESABCC, 2024; ESABCC 2025). Such measures are intended to balance competing demands for land and biomass, while incentivizing enhancement of the land carbon sink and addressing the risk of reversal. **Pricing instruments hold potential** in this regard, and the Carbon Removals Certification Framework represents an important initial step. **However, carbon pricing does not account for the adaptive and ecosystem services provided by forests and other ecosystems**, the value of which may, in some cases, exceed that based solely on climate mitigation benefits. Also, the appropriate design of carbon pricing, with robust additionality criteria, does not, by definition, directly incentivise the maintenance of existing carbon stocks, which is essential to reversing the decline in the land sink. In this context, complementary instruments which potentially involve a greater role for public funding may be needed.

A foundational step must be to **address the conflicting incentives embedded within the current policy framework**. Given the uncertainty surrounding counterfactual scenarios, the importance of a full lifecycle perspective, and ongoing challenges related to transparency and compliance in biomass feedstock sourcing, adopting a more precautionary approach could help support alignment with climate mitigation objectives. In this context, reassessing existing incentives for bioenergy feedstocks through instruments such as the RED III, FuelEU Maritime, ReFuelEU Aviation, and the CRCF Regulation will be an important step toward ensuring policy coherence across sectors. **Greater incentive alignment should also be pursued across different types of actors**. The responsibility for maintaining and enhancing land sinks, which currently lies solely with Member States, should also be reflected through obligations on individual operators who are incentivised to use biomass-based feedstocks.

In shifting incentives from energy to material uses through mandates and quotas, it is important to reflect on lessons from earlier policy approaches that promoted biomass for power generation and transport fuels, approaches that have, to some extent, been overtaken by technological progress (Material Economics, 2021). This experience highlights the need for caution in applying similarly prescriptive, centrally directed mandates or subsidies for biomass use going forward.

Managing demand to ensure environmental integrity

The overall demand for biomass must be actively managed to achieve the EU's objectives in mitigation, adaptation, circular economy, and biodiversity. As the Bioeconomy Strategy Progress Report states, "consumption patterns need to become more sustainable to guarantee environmental integrity, as technological solutions alone cannot close the gap between the sustainable supply of biological resources and demand" (EC 2022b; p. 26).

The European Commission's Impact Assessment demonstrates **the substantial potential of demand-side measures to complement energy and industrial decarbonization strategies through increased circularity, sustainable mobility and behavioural changes with regards to food consumption**. **Prioritising such measures can reduce the societal cost of meeting the 2040 climate targets by lowering overall energy system requirements, decreasing reliance on resource-intensive abatement technologies, and mitigating environmental risks, while presenting new economic opportunities**. Addressing the issue of demand in the revised Bioeconomy Strategy will be essential to ensuring the long-term environmental integrity of EU decarbonisation efforts.

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