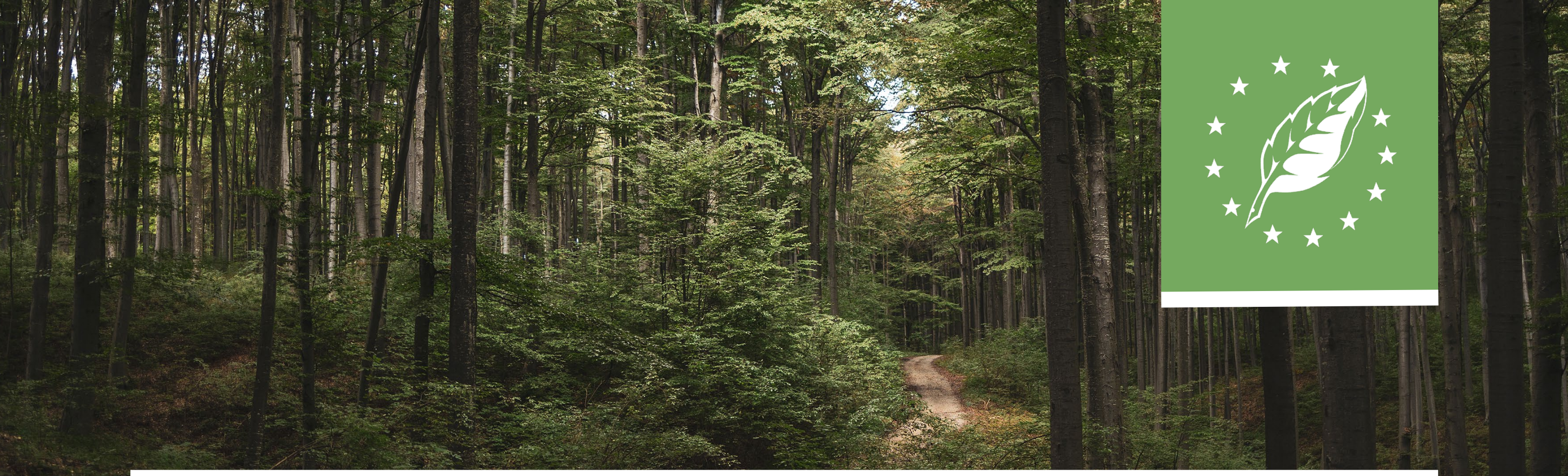

EU LULUCF sink development until 2040: Trends, projections and uncertainties

A stable and healthy land carbon sink is crucial for the EU to meet its climate mitigation obligations and ensure resilience against escalating climate impacts. However, the EU land sink has been in steady decline, with the EEA (2025) concluding that the achievement of the land use, land use change, and forestry (LULUCF) target of -310 $MtCO_2$ removals by 2030 is "very unlikely." As the EU sets its 2040 climate target, it must take a precautionary approach by accounting for the uncertainties and challenges to land carbon removals when determining their contribution, alongside that of industrial removals affecting land use, to the net GHG target.

Publication date:
March 2025

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In the context of the upcoming legislative proposal for the 2040 EU climate target, this brief discusses the decline of the EU LULUCF sink due to increased harvests, ageing forests, and climate-driven disturbances, along with current projections revealing a gap between existing and planned policies and the 2030 LULUCF target. It also explores pathways modelled in the Commission's Impact Assessment accompanying the Communication on the 2040 climate target, highlighting the role of the land sink and bioeconomy as key variables between the analysed core scenarios. Finally, it outlines the uncertainties associated with the LULUCF sink, highlighting how:

- The measurement and reporting of the land sector emissions and removals are particularly prone to high natural and statistical uncertainties.
- Significant uncertainties remain regarding the relative deployment of industrial removals: BECCS (Bioenergy with

Carbon Capture and Storage), which may put further pressure on the land sink, and its primary alternative, DACCS (Direct Air Carbon Capture and Storage), which faces challenges related to high costs and technological feasibility.

- Future estimates of land carbon sink capacity may be overly optimistic, as the Commission's own simulation of climate impacts reveals a wide range of possible outcomes, with carbon removals potentially falling well below expectations, despite the assumption of an ideal environment for the recovery of the carbon pool following extreme weather events.
- Uncertainties related to climate tipping points, which could accelerate feedback loops and lead to significant releases of GHGs into the atmosphere, warrant a precautionary approach.

The analysis supports the recommendation that the EU should ensure the environmental integrity of the 2040 net target by pursuing more ambitious emission reductions, while setting separate conservative maximum contribution limits for land-based and industrial carbon removals.

Post-2030, a dedicated, ambitious LULUCF target should be set to drive alignment between EU climate, biodiversity, and adaptation objectives. LULUCF carbon sequestration measures with co-benefits for biodiversity and other ecosystem services should be prioritised, including where these may result in lower removals than management strategies resulting predominantly in short-term carbon sink maximisation.

This document is the first part of a series of policy briefs titled "2040 EU climate target: implications for the EU land sectors".

LULUCF net GHG removals: status, trends and projections

The EU climate target and strategy framework consistently emphasizes the importance of the land sink to the achievement of climate mitigation objectives, as well as the related synergies with other strategic goals, including nature restoration and climate adaptation.

The significance of the LULUCF sector is reflected in the legislative framework establishing a dedicated Union-wide target of -310 $MtCO_2e$ of net removals in 2030, split into national targets for each EU Member State and made binding under the LULUCF Regulation. National commitments are operationalised over two distinct periods:

- *from 2021 to 2025*, adherence to the 'no-debit' rule requires Member States to ensure that emissions within their LULUCF sector do not exceed removals;

- *from 2026 to 2030*, binding national targets are determined based on the overarching EU target, average net removals in Member States' GHG inventories in the period 2016-2018, and each country's share of total EU managed area. For 2026 to 2029, the net removals in each Member State need to stay within a national budget which will be calculated based on reviewed GHG inventory submitted in 2025.

In the latest annual European Union greenhouse gas inventory, the EU-27 LULUCF sector was reported to have sequestered -236 MtCO_2e from the atmosphere in 2022[1] (EEA, 2024a). Living biomass in forests constitutes the most significant source of net removals, followed by harvested wood products which are also reported as a net carbon sink, while other land use categories, such as cropland, settlements, and grasslands, act as net sources of emissions.

Table 1: Sources of LULUCF emissions and removals (2022)

LULUCF category	Net emissions (+) and removals (-) (in MtCO_2e)
Forest land	-292,3
Harvested wood products	-39,7
Other land	+1,1
Grassland	+19,5
Cropland	+21,7
Wetlands	+23,2
Settlements	+28,7
Total	**-236,4**

Source: EEA Dataviewer, 2024

For cropland and grassland areas, the net result of the carbon stock change depends to a large extent on the presence of cultivation on organic soils, as well as on woody biomass presence, and the intensity and variation of management practices (EEA, 2024b). Each of these land use categories encompasses managed mineral soils, which generally act as a net carbon sink in the EU, and managed organic soils, which are a net emissions source.

Table 2: Area and CO_2 emissions in the EU MS reported for organic soils (2021)

LULUCF category	Area (kha)	Emissions from organic soils (in MtCO_2e)

[1] Preliminary data, which shows a possible slight increase to -257MtCO_2e in 2023, is pending validation at the time of publication.

Forest land	12.840	22,1
Cropland	1.263	31,1
Grassland	2.811	44,7

Source: EEA, 2023

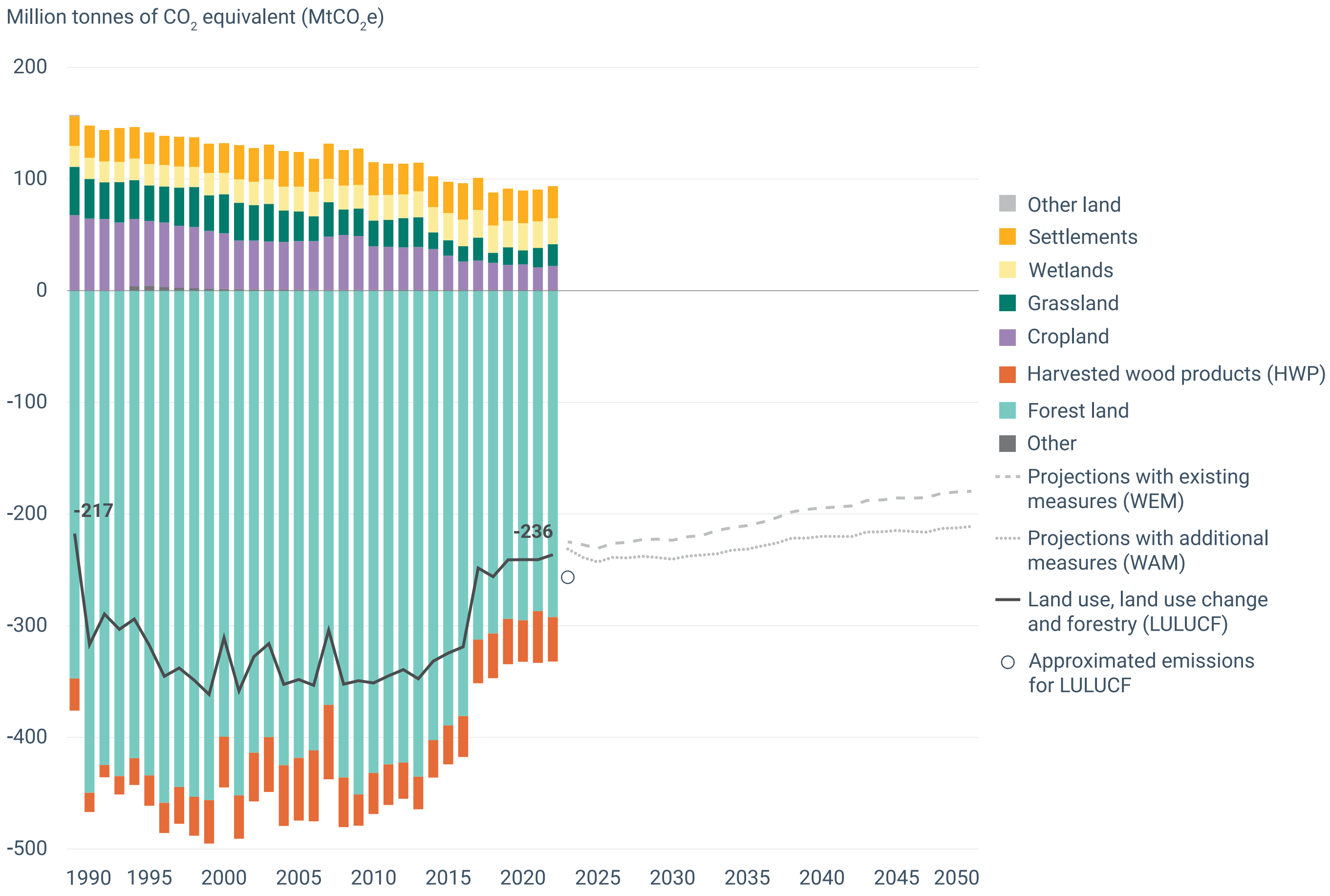
2021 EU GHG inventory data demonstrates that although most of the organic soil area is reported under 'forest land', the primary sources of emissions from organic soils are managed grasslands and croplands.

Trends and factors driving overall decline

The *net emissions* from *non-forest* land use categories within the LULUCF sector, including cropland, grassland, wetlands, settlements, and other land, have generally shown a relatively steady decline over the past two decades. This trend is primarily driven by the net emission reductions reported in the cropland category (from 43.6 to 21.7 $MtCO_2e$ between 2005-2022). Grassland emissions have also decreased, albeit at a slower rate, with a slight rebound observed in recent years. However, the changes in emissions from non-forest categories have played a relatively minor role in the overall trend of the LULUCF sector, which is predominantly driven by the development of the forest sink.

The EU's *net removals* in the *forest category* have been on a steady downward trend over the past decade (2012-2022), primarily due to factors such as a decrease in gross annual increment (i.e., forest biomass growth before accounting for natural mortality and harvesting), increased mortality (including from natural disturbances), and higher harvesting rates (Korosuo et al. 2023). The net removal decrease in recent years is largely attributed to lower net increment associated with the maturity of forests and higher harvest rates (EEA, 2024b). Driven by the forest sink decline, the EU's total reported LULUCF net removals have decreased by nearly one-third over the past decade (-30.3% between 2012 and 2022).

Figure 1: EU LULUCF sector's GHG trends and projections by main land use category

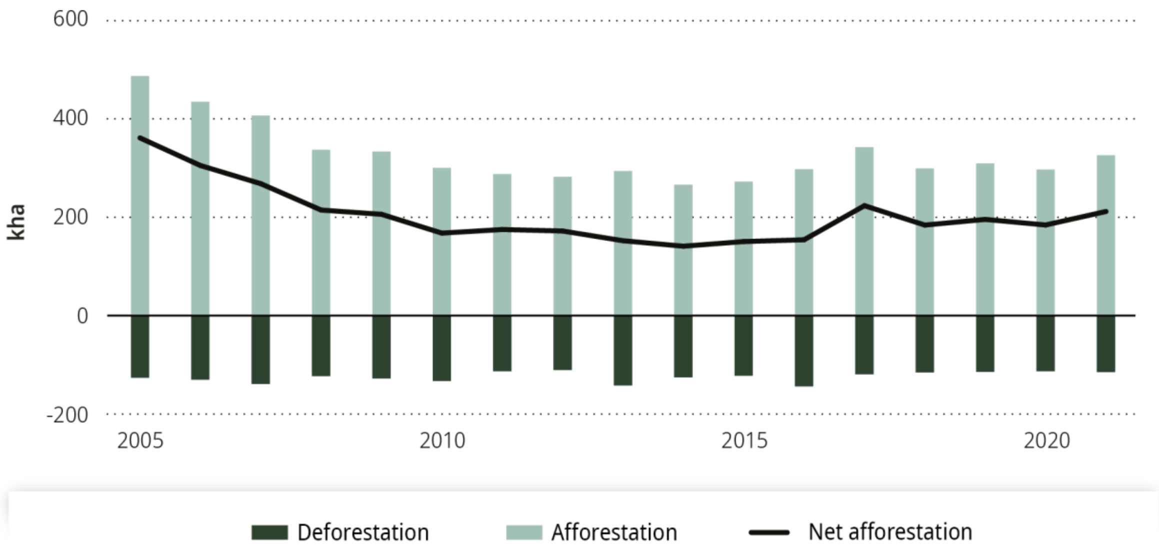


Source: EEA, 2024

Inter-annual variations in the LULUCF sector's emission trends are largely attributed to natural disturbance events. Wildfires in southern Europe, along with windstorms and insect outbreaks in parts of central Europe, have significantly contributed to GHG emissions, either through direct releases into the atmosphere or as delayed releases through carbon transfer to other pools, influencing the overall trend observed across the EU (EEA, 2023a). It should also be noted that although the LULUCF sector is a net carbon sink at the EU level, individual Member States report a range of net outcomes for their national land sectors, from a net source to a large net sink.

Notably, the general decline in forest sink capacity has coincided with an increase in the EU forest area (app. 6% as compared with 1990) (idem.). This trend is underpinned by relatively stable annual deforestation levels since 2005, which have consistently been exceeded by afforestation rates. Net afforestation slowed down between 2005 and 2010 but has remained stable since.

Figure 2: EU afforestation and deforestation rates



Source: EEA, 2023a

GHG mitigation approaches and projections based on existing and planned measures

The recovery of the EU forest sink will be a decisive factor in the achievement of the EU net carbon sink target under the LULUCF Regulation. The European Scientific Advisory Board on Climate Change (ESABCC, 2024) identifies three major mitigation levers relevant to the forest category[2]:

- Reducing deforestation and forest degradation.

  This lever is particularly relevant on short time scales. While the mitigation potential of avoided deforestation in the EU is declining (EC, 2024), deforestation is still occurring across the bloc, causing emissions of app. 30 $MtCO_2e$ on an annual basis (EEA, 2024).
- Improved forest management.

  This lever facilitates an increase in sequestration in existing managed forests, through a variety of practices such as longer rotations, lower harvest intensity,

[2] The mitigation levers identified by ESABCC largely correspond to the main mitigation pathways included in Sections 7.4.2 and 7.4.3 of Working Group III's contribution to AR6 (IPCC, 2022).

continuous-cover forestry, change of species and provenances, and increasing resilience (IPCC 2022). The costs of improved forest management are often assumed to be the lowest of all land management options, as they mainly involve compensating for lost income from e.g. longer rotations (ESABCC, 2025).

- Afforestation, reforestation and forest ecosystem restoration.

  The establishment of forests in areas where there were previously no trees (afforestation), or on land that once was forested but has been converted to another land use since (reforestation) have a relatively smaller mitigation potential. It depends on the timing of the intervention and is generally limited in the short-term as new forests take time to deliver significant removals. Considering the current prevalence of wood use for energy and short-lived products, reduced harvesting is generally a more effective climate mitigation strategy in the short to medium term (ESABCC, 2025).

Although forests constitute the most significant component of the LULUCF sector, addressing emissions from other land-use categories can contribute to the strengthening of the overall carbon sink, while yielding other environmental and social benefits. The ESABCC (2024) identifies two major mitigation levers relevant to the non-forest land use categories, as follows:

- Restoring and avoiding conversion and degradation of wetlands and other organic soils.

  This lever holds the potential to quickly reduce emissions from organic soils through rewetting, or to avoid high emissions per hectare on a short timescale. Because the elevation of water levels reduces emissions from the organic soil material, mitigation can involve taking the land out of production completely, or a productive use of wet and rewetted peatlands while preserving the peat soil (paludiculture). Peatland and wetland restoration can also increase removals on a longer timescale (IPCC, 2022a).
- Agricultural practices that increase carbon sequestration on agricultural lands, both in the soil and in above-ground biomass.
  - These include sustainable agricultural soil management practices (e.g. cover crops, reduced tillage, residue retention and improved water management on cropland and grassland) and agroforestry (the integration of woody vegetation on agricultural land used for grazing or crop production) (IPCC, 2022a; Kay et al., 2019; Sykes et al., 2020). Converting croplands back into grasslands can also yield sequestration benefits, but these occur over a longer timescale.

As indicated above, many mitigation measures in the LULUCF sector face the challenge of a time lag between their implementation and the point at which results become observable and reportable in national inventories. This issue is further compounded by the impacts of a changing climate and the increasing frequency of extreme weather events. Consequently, EU Member States have struggled to make sufficient progress toward achieving the EU LULUCF target.

Projections submitted by Member States in 2023 and 2024 indicate a decline in average annual net removals at the EU level from an average of -315 $MtCO_2e$ per year during 1990–2021 to -206 $MtCO_2e$ for the 2022–2050 period under existing measures (EEA, 2024a). This trend persists in scenarios that include planned additional measures reported by Member States, which increase average net removals for 2022–2050 by 10% compared to scenarios with only existing measures. By 2030, net removals are projected to reach -224 $MtCO_2e$ under existing measures and -240 $MtCO_2e$ with the implementation of planned additional measures[3] (idem.), demonstrating that the EU is currently not on track to meet its 2030 net removal target of -310 $MtCO_2e$. The EEA's latest assessment, released in February 2025, concludes that "it is very unlikely that the target will be met unless additional fast-response mitigation measures are implemented" (EEA, 2025, p.23).

Charting the path for the LULUCF sink in the context of a new 2040 climate target

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. It stipulates that to deliver this reduction, the level of remaining EU GHG emissions in 2040 should be less than 850 $MtCO_2e$ (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% compared to 1990 levels.

[3] At the time of publication, a handful of Member States are yet to submit their final updated National Energy and Climate Plans, which may impact the total projected net removals with additional measures.

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 (2024) which forms the basis for the recommendations outlined in the Communication. The report presents three core scenarios, alongside a complementary 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 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.

The Impact Assessment accompanying the Communication presents a range of modelling outcomes for LULUCF net removals in the four scenarios. To illustrate the uncertainties around the future evolution of LULUCF net removals, a range of estimates is included across three carbon pricing levels:

- A 'lower level', showing a lower boundary for the LULUCF net removals, implemented in the modelling by applying a carbon value of 0€/tCO_2e);
- A 'central level', based on a carbon value of 50€/tCO_2e necessary to meet the 2030 target;
- An 'upper level', showing an upper boundary of the LULUCF net removals, based on a carbon value of 200€/tCO_2e.

Table 3: LULUCF net removals by scenarios in 2040 (MtCO_2e)

	S1	S2	S3	LIFE
Lower level	-218	-213	-215	-243
Central level	-319	-316	-317	-360
Upper level	-376	-374	-376	-410

Source: EC, 2024

The central level for 2040 is close to -320 MtCO_2e in all three core scenarios by 2040, slightly above the 2030 target (-310 MtCO_2e). The Impact Assessment contends that the expected contribution of LULUCF to the 2040 climate target stays within the boundaries set out by the ESABCC, which discusses an upper bound of -400 MtCO_2e removals in 2040, representing a threshold beyond which further increases in LULUCF removals would be considered implausible[4].

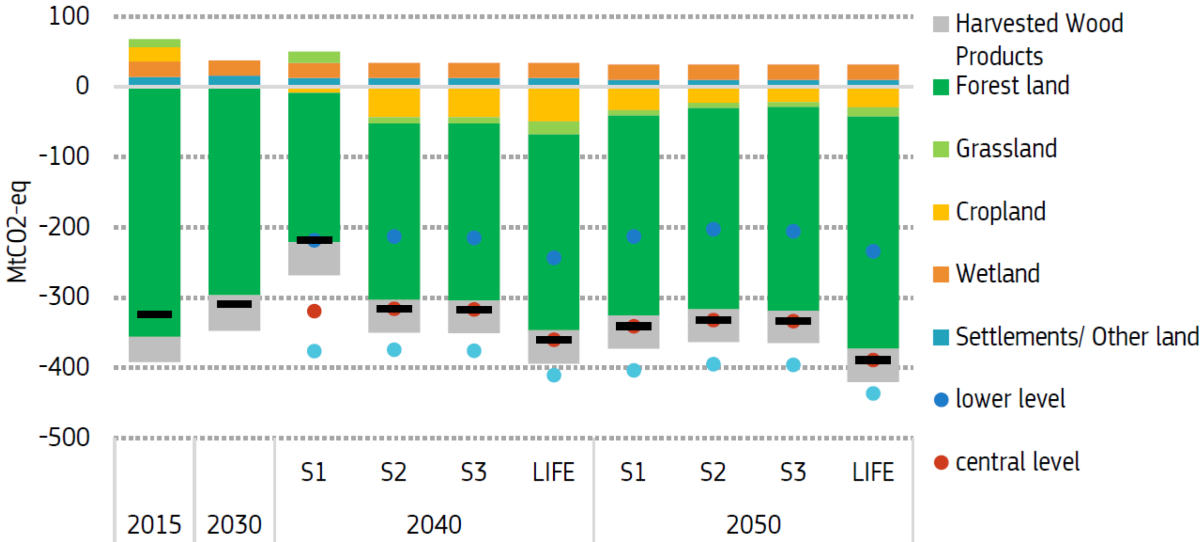
The differences between S1, S2 and S3 are largely due to variations in forest and cropland emissions and removals, driven by the different bioenergy needs of the energy systems underpinning those scenarios. As the Impact Assessment notes, the volume of the LULUCF net removals is related to biomass demand. In this context, it should be noted that the estimates of net removals are linked to specific assumptions around the deployment of second-generation biofuels from lignocellulosic crops, mobilisation of agricultural residues, availability and utilisation of bark, secondary residues from material production, and recovered post-consumer wood, among other factors. The integration of those elements alleviates demand for primary woody biomass in the scenarios, thereby reducing pressure on the LULUCF sink[5].

[4] The ESABCC risk threshold is based on research by Pilli et al. (2022) who provide as a probable range of -100 to -400 MtCO2-eq for the LULUCF sink in 2050, based on RCP 2.6 (a "stringent" mitigation scenario that aims to keep global warming likely below 2°C above pre-industrial temperatures).

[5] These assumptions will be explored further in an upcoming brief in this series, titled *EU bioeconomy and its impact on the LULUCF sector in the context of the 2040 climate target*.

The LIFE scenario is characterised by a different food system requiring fewer livestock and smaller area for growing fodder, thus freeing up land for afforestation, more high-diversity landscape features, and rewetted organic soils. The conversion of agricultural land results in a significant enhancement of the forest sink by 30 $MtCO_2e$ and a reduction in net emissions on agricultural land by 15 $MtCO_2e$.

Figure 3: LULUCF emission and removal estimates under the assessed scenarios



Source: EC 2024

Uncertainties in the quantification and development of the LULUCF sink

Uncertainties in past and ongoing measurement and reporting

National GHG inventories (NGHGIs) serve as the primary tool for tracking human-induced greenhouse gas emissions at the country, sector, and source category levels. However, individual country NGHGIs of LULUCF emissions vary widely in quality and precision, and carbon removals are a particularly large source of uncertainty in estimating anthropogenic GHG emissions (McGlynn et al., 2022; Friedlingstein et al., 2020).

LULUCF estimation uncertainty results from a combination of structural and conceptual challenges, including (1) large heterogeneity in fluxes across time and space, driven by complex biological, geochemical, and physical processes combined with variable anthropogenic and natural disturbances; (2) the inability to continuously observe fluxes over time and over large areas; and (3) differences in definitions and accounting methods across countries and studies (see Grassi et al., 2018).

The IPCC defines three methodological tiers that represent varying levels of complexity for estimating GHG emissions and removals (EEA, 2024c):

- Tier 1 (default methods) rely on readily available statistical data and standard emission factors provided in the IPCC Guidelines, which assume typical land processes for specific regions. This approach often lacks accuracy, particularly in the context of LULUCF emissions.
- Tier 2 (intermediate methods) replace the default emission factors with country-specific values, derived using more detailed knowledge of national processes and conditions relevant to the inventory.
- Tier 3 (advanced methods) are the most detailed and complex. They involve country-specific approaches based on high-resolution measurement data, often gathered through repeated surveys, such as National Forest Inventories or Soil Inventories. Tier 3 can also include advanced modelling approaches (e.g., soil models, biomass models, or harvested wood product models) that are calibrated and validated against national measurements.

Due to the relative complexity of the physical processes involved in land-based emissions and removals, EU Member States' GHG inventories rely more heavily on Tier 1 methods for the LULUCF reporting category compared to other sectors, with considerable variation in methodology use among EU countries. The use of Tier 3 methods accounts for app. 23% of all reported emissions and removals and is attributed to only a handful of Member States (EEA, 2024c). A substantial portion of land and carbon pools is still assessed using Tier 1 methodologies.

Several challenges are identified across all tiers. For example, changes in organic carbon stored in mineral soils are mostly reported with the use of Tier 1 methods, assuming that the carbon pools are in equilibrium (with no net carbon stock changes occurring in the long term), which is not in line with the 2006 IPCC Guidelines (EEA, 2024c). The order of magnitude of emissions and removals unreported as a result has been estimated to be around 45% of the current net LULUCF balance (Bellassen et al., 2022).

Under the revised LULUCF Regulation, all Member States will be required to adopt at least Tier 2 methods for all managed land categories and emission sources. From the 2030 submission onward, the Regulation mandates the use of Tier 3 methods for most forest land, grassland, and wetlands, which is expected to enhance the accuracy of the EU GHG inventory.

With the updated legislative requirements, countries are likely to prioritize improving LULUCF reporting accuracy by increasing the adoption of Tier 3 methods and refining Tier 1 and Tier 2 approaches. However, as more complex methods are implemented, greater efforts in uncertainty estimation will also be necessary (McGlynn et al., 2022).

Given the influence of various natural parameters, land sector emissions and removals are particularly prone to high natural and statistical uncertainties. Estimating uncertainty in NGHGIs is itself fraught with challenges, as some countries do not report uncertainties at all, fail to report for certain categories, or provide insufficient information on how they calculate uncertainty. The EU's latest GHG inventory submission (EEA, 2024b) for year 2022 estimates of LULUCF emission/removal data uncertainty at 52.7 % for the uncertainty of the level and 29.4 % for the uncertainty of the trend. The reporting sub-categories associated with some of the highest-level uncertainty estimates alongside considerable emission volumes include CO_2 emissions from croplands (uncertainty of 206,5%) and grassland (130,9%).

Despite ongoing efforts to improve LULUCF accounting, significant uncertainties persist, raising concerns that the actual state of the LULUCF sink could differ considerably from the existing estimates. The European Commission's 2040 Climate Target Impact Assessment acknowledges these risks, stating that "high uncertainties in current and future levels of nature-based carbon removals mean that it may not be precisely known if the LULUCF net removal is on track to match the required size in the (impact assessment) scenarios" (EC, 2024, Part 3, p. 132).

Implications of the uncertainties around the development of industrial removals for the EU land sink

As the Commission's Communication proposes, the achievement of the net 90% emission reduction target will require a contribution from both land-based and industrial removals, with the deployment of the latter projected to play an increasing role. The Communication states that this will entail the use of a large portfolio of options, notably including DACCS – i.e. Direct Air Capture with Carbon Storage – and BioCCS – the capture and storage of biogenic CO_2 emissions from the burning of biomass for energy (BECCS) or from the processing of biomass in industrial applications.

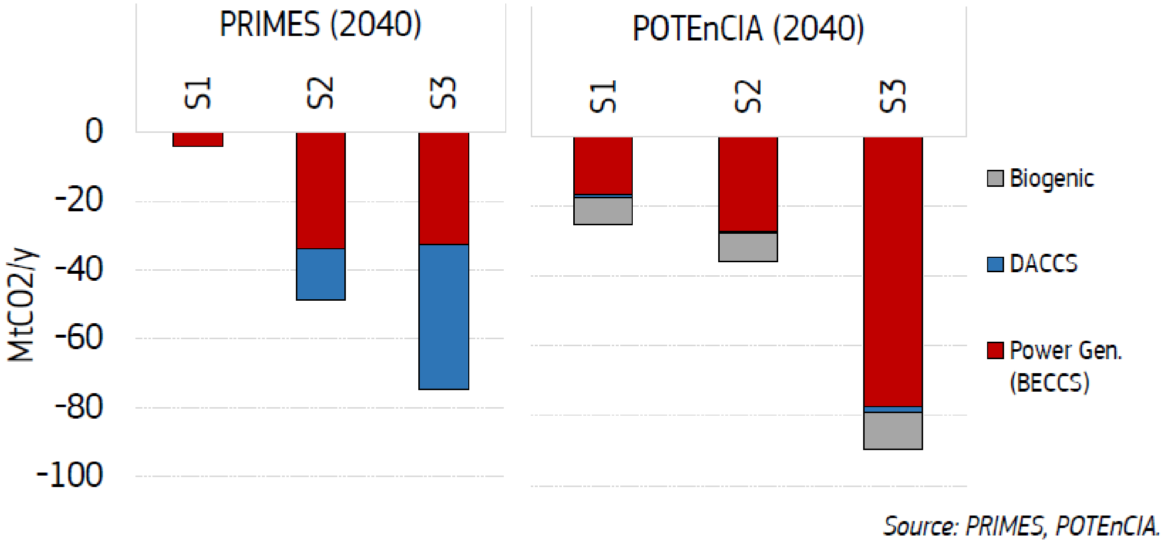
BECCS features in most integrated assessment climate modelling scenarios and is considered to be a key industrial removals technology given its relative maturity. However, the estimates of its potential rely heavily on assumptions about feedstock and land availability. Deployment of BECCS on a large scale can exacerbate the growing gap between biomass demand and supply, increasing pressure on biodiversity and ecosystems, and undermining multiple ecosystem services, including food provision (EEA, 2023b, IPCC, 2022b). The quantification of carbon removal benefits of BECCS is dependent on lifecycle emissions, including factors such as the source of biomass, land use changes, conversion pathways, energy used for processing and transport of biomass, carbon capture efficiency, the assumed analysis boundary, and the time scale considered (ESABCC, 2025). DACCS is a method with a similar level of technology readiness, but even more limited deployment to date, given the much lower concentrations of CO_2 at the point of capture compared with BECCS, and the resulting high cost and energy needs. Both CCS-based methods require substantial amounts of water and therefore risk putting pressure on dwindling water resources in the context of a changing climate. Their deployment is also conditional on the availability of CO_2 transport and storage infrastructure, which is only emerging in the EU (ibid.).

The Impact Assessment accompanying the 2040 Climate Target Communication discusses the modelled variations in the deployment of industrial removals, with the total amount of carbon removed until 2040 by industrial means reaching up to 75 $MtCO_2$ in S3, the core scenario closest aligned with a 90% net GHG emissions reduction target. Within this number, the main modelling exercise using the PRIMES model shows similar level of BECCS and DACCS by volume of removals by 2040 and 2050.

However, as noted in the Impact Assessment, the relative deployment of BECCS and DACCS is not a given. For the development trajectory of DACCS, the main factors include high cost and technological uncertainty. The International Energy Agency (IEA, 2024) indicates that more efforts are needed to scale up DACCS, with only three facilities currently capturing >1 kt of CO_2 annually worldwide. As of 2024, there were 15 more facilities in advanced development or under construction, which, if successful at achieving steady CO_2 capture at full capacity without delays, would increase the global DAC capacity to around 3 $MtCO_2$ by 2030 globally (ibid.). The PRIMES modelling in the Commission's impact assessment assumes the deployment of DACCS of approximately -42 Mt CO_2 by 2040 in the EU only, suggesting the need for a notably significant increase in deployment (EC, 2024).

The trajectory of DACCS is highly relevant for the EU land sink, because its primary alternative – BECCS – directly competes with land-based carbon removals (ESABCC, 2023). The Impact Assessment offers an alternative pathway for the composition of the industrial removal component, as projected by the POTEnCIA model. This pathway assumes a more relaxed cap on sustainable biomass supply for bioenergy and greater deployment of BECCS, reaching nearly 80 $MtCO_2$ by 2040 under scenario S3.

Figure 4: Industrial carbon removals in 2040 (PRIMES and POTEnCIA models)



Source: EC, 2024

The impact assessment indicates that a greater reliance on BECCS leads to increased bioenergy demand, which could negatively impact net LULUCF removals. To evaluate the risks to LULUCF net removals associated with higher biomass consumption, a sensitivity analysis is conducted using the GLOBIOM model based on scenario S3, simulating a 20 Mtoe increase in woody biomass demand. The results of this analysis suggest that this increase would result in a reduction of approximately 100 $MtCO_2e$ compared to the core scenario, putting total net LULUCF removals in 2040 in the range between -115 Mt CO_2 (lower level in S3) and -276 Mt CO_2 (higher level in S3).

Notably, this modelled reduction assumes that only sustainable harvesting occurs, meaning annual harvest levels do not exceed the annual increment from growth. This approach effectively assumes that higher bioenergy demand leads to higher biomass prices, reducing the use of woody biomass in materials.[6]

Uncertainties in the future development of the land sink

Finally, the potential impacts of climate change on the land sink and its future robustness present a major source of uncertainty. The EEA's Climate Risk Assessment (2024) concludes that climate-related forest disturbances are projected to increase, fuelling positive climate feedback

[6] The assumptions surrounding the sustainable use of biomass for energy and materials, and their implications for policy and target setting will be explored further in an upcoming brief in this series, titled *EU bioeconomy and its impact on the LULUCF sector in the context of the 2040 climate target*.

cycles, and making progress against the EU's LULUCF target more challenging. According to the EEA report:

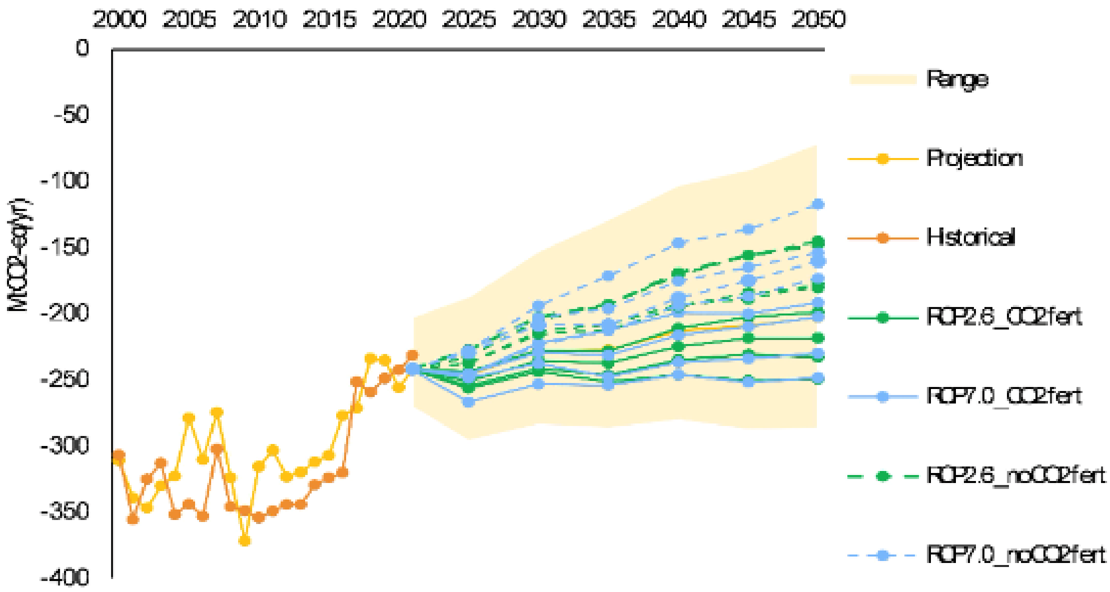
> "*Since feedbacks between more frequent/intense extreme events, forest disturbances and carbon stocks are only partially represented in future projections, current estimates of future land carbon sinks and of nature-based solutions for climate change mitigation may be overly optimistic... More droughts have reduced forest growth (Yuan et al. 2019) and increased tree mortality, even in high-productive forests (Hammond et al. 2022; Socha et al. 2023). Forests have also been affected indirectly over the past decades by increased incidence of climate-induced droughts, which have augmented the frequency and extent of natural disturbances (Patacca et al 2023; van der Woude et al. 2023; Vacek et al. 2023). Wildfires now appear in various places across Europe and at intensities not common in the past (Patacca et al. 2023), and unprecedented incidences of insect outbreaks have been observed in central Europe (Hlásny et al., 2021). As a result, many forests in Europe are experiencing declining resilience (Forzieri et al. 2016), indirectly declining vitality of one third of the European forests, and a decreasing carbon uptake (van der Woude et al. 2023; Maes et al. 2023)... Forests in many places across Europe are projected to suffer from increases in forest fires (JRC 2021), and the vitality of various forests is projected to decrease, leading to reduced biomass growth and carbon uptake (>50% reduction of annual growth under high-end scenarios) and eventually increasing tree mortality (Buras and Menzel 2019; del Castillo et al. 2022; Mauri et al. 2022).*"

To account for these risks, the 2040 climate target impact assessment presents the outcomes of a modelling exercise intended to estimate possible climate change impacts associated with extended growing seasons, a higher frequency of natural disturbances and changing precipitation levels. It considers 16 impact pathways, using two representative concentration pathways for GHG concentrations: RCP 2.6, associated with a best estimate long-term temperature increase of 1.8°C, and RCP 7.0, linked to 3.6°C best estimate long-term temperature increases until 2100. Each of the used models considers uncertainty on carbon storage in soils and is assessed both with and without persistent CO_2 fertilisation[7], given the ongoing scientific debate on the possible scale of the fertilisation effect.

The analysis shows a very wide range of possible LULUCF removal outcomes, with a deviation from the standard projection in 2040 by 68 $MtCO_2e$ to the maximum net removals level, and 111 $MtCO_2e$ to the minimum net removals level. 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.

[7] CO2 fertilisation refers to an increase in plant photosynthesis under higher atmospheric CO_2 levels.

Figure 5: Estimated climate change impacts on LULUCF net removal in EU



Source: [*EC, 2024*]

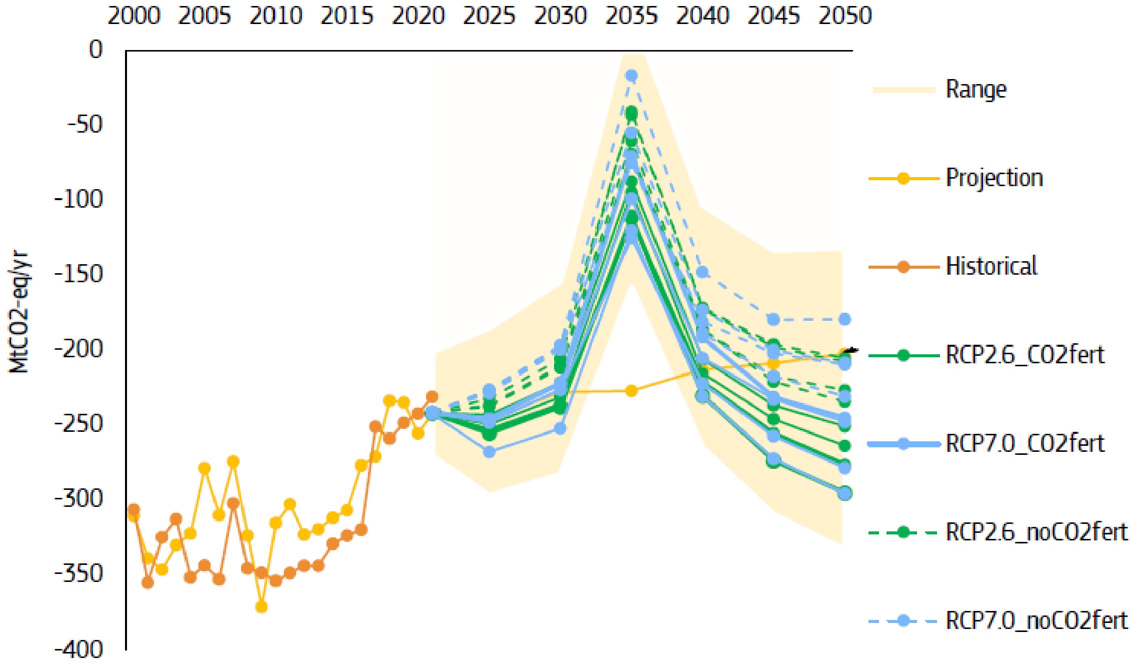
When no effect from CO_2 fertilisation is considered, all scenarios result in a significant decline in net LULUCF removals. When assumptions on persistent CO_2 fertilisation are included, the analysis shows a range of both positive and negative outcomes, with the majority indicating stable or slightly increased levels of net LULUCF removals when compared to the early 2020s.

The impact assessment notes that the potential increase in net removals in the scenarios including CO_2 fertilization are due to increased atmospheric CO_2 resulting in, on average, an increase in forest productivity in future climate scenarios. However, the assessment also stresses that the impact of climate change on EU forest 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, 2024, Part 3, p.133).

Separately, the impact assessment notes that extreme weather events have an uneven and short-term impact on net removals from the LULUCF sector and therefore add an extra layer of uncertainty to the analysis of the evolution of forest stocks. To illustrate the potential impacts of extreme weather for the LULUCF net removal, the assessment presents the results of a modelling exercise which simulates exceptional weather events resulting in a combination of fire, wind and biotic damages across the EU in the year 2035. As part of the assumptions, it uses the worst wind, fire, and biotic events over the period 1990-2020 for each disturbance agent for the most vulnerable forest stands across the EU, resulting in a total of more than 300 million m^3 of forest damage.

The simulation shows a resulting drop in net removal level of the LULUCF sector between -160 and +30 $MtCO_2e$ at the time of the disturbance.

Figure 6: Estimated climate change impacts and extreme events on LULUCF net removal



Source: EC, 2024

The projected development of the LULUCF sink following the disturbance shows a relatively quick recovery over the next five years and a slightly higher range for the LULUCF net removals in 2050 (-130 to -330 $MtCO_2e$) than the scenario without extreme events described above due to "enhanced forest regrowth of younger trees and under the assumption of immediate reforestation" (EC, 2024 Part 3, p.137).

This positive trend is due to the simulation assuming an ideal environment for the recovery of the carbon pool. It accounts for salvage logging and replanting of the damaged trees occurring the same year as the disturbance and affecting predominantly more vulnerable older and larger trees, which are then salvage logged to largest extent possible. This is assumed to result in reduced harvesting rates, which partially compensate for the disturbance-induced forest loss.

It is important to acknowledge the optimistic nature of this scenario on several fronts. For instance, a lack of capacity could lead to delays of several years just for preparing replanting and afforestation efforts. The assessment itself recognizes that the key assumptions around the severity of events, the share of wood that can be harvested after the event and replace otherwise planned harvests, the speed of forest recovery (i.e., cleaning and replanting), significantly impact the outcome. If these assumptions do not hold true in a real event, the recovery of LULUCF net removals could be significantly impeded, with cascading impacts through to wood supply disruptions and potential market shocks (EC, 2024).

These modelling results suggest potentially lower total land sink capacity under a changing climate than the anticipated contribution of land-based removals to a 90% net GHG reduction target required to ensure the achievement of the overarching climate mitigation objective. The S3 scenario in the impact assessment, which corresponds to the target proposed in the Communication, relies on a trajectory assuming contribution of -317 $MtCO_2$ (central level) from LULUCF removals, and additional removals of -75 $MtCO_2$ through industrial CCS in 2040. However, in the context of an accelerating climate change, the incentivisation of BECCS runs the risk of undermining the growth in both land and industrial removals, as increased demand for biomass extraction from land puts pressure on forest systems, undermining their resilience and thereby compromising both the land sink and stable primary biomass provisioning for BECCS and other bioeconomy purposes.

Finally, the projections underpinning the net target formulation do not account for the biggest climate uncertainty associated with the triggering of climate tipping points, i.e. the critical thresholds beyond which the global or regional climate abruptly shifts from one stable state to another, potentially causing substantial and irreversible damage to human and natural systems.

The timing of tipping points remains highly uncertain, with some potentially occurring sooner than previously anticipated. While the IPCC's Sixth Assessment Report (AR6) concluded that an abrupt collapse before 2100 is unlikely, recent research suggests it could occur much sooner, with a central estimate of 2050. Regionally, crossing tipping points could bring extreme temperatures, droughts, wildfires, and unprecedented weather patterns, while globally they could trigger a significant release of greenhouse gases, accelerating climate feedback loops and leading to a global climate less hospitable to human life.

The modelling of interactions between tipping elements (e.g. polar ice sheets, permafrost regions) and potential tipping cascades in the climate system is a complex challenge, primarily due to the difficulty in accurately representing feedback mechanisms across different climate components (see e.g. Wunderling et al, 2024). The Commission's impact assessment acknowledges that climate models face inherent challenges and limitations due to the uncertainties of climate change itself, as well as the constraints of modelling and data availability, which may not be possible to overcome.

Implications for the target-setting approach

Net 2040 climate target and LULUCF contribution

The EU should safeguard the environmental integrity of the overarching net 2040 target by aiming for the highest level of ambition in the required emission reductions, while setting separate targets for emission reductions, land-based and industrial carbon removals.

While the Commission's recommendation for a net emission reduction target of 90% compared to 1990 levels reflects the minimum recommended ambition by the ESABCC, its integrity may be undermined by the integration of a high share of carbon removals. A lack of separation between targets for technical and nature-based carbon removals presents risks in terms of potentially conflicting policy incentives that may emerge from the target once it's adopted.

Considering the many uncertainties surrounding the development of the land sink, it is clear that to ensure a net 90% reduction, a **precautionary policy approach should aim for emission reductions to exceed the implied app. 83% gross reduction by 2040**. The net target, as proposed in the Communication, may require removals of up to -400 $MtCO_2$ in 2040, the availability of which will depend on a broad range of factors impacting the land sink in the conditions of climate change, including regional water availability, the dynamics of CO_2 fertilisation, the development of industrial removals, BECCS waste-based feedstock availability, frequency and severity of extreme weather events, and the pace of land sink recovery in the aftermath of those. While -400 $MtCO_2$ represents the maximum contribution of removals, such target formulation poses risks if emission reduction incentives are calibrated to meet the minimum emissions reductions required in a case in which the removals' contribution is fully utilised.

Ideally, the EU should consider **a target within the upper range of the recommended 90-95% net reduction**, while establishing **separate maximum contribution limits for land-based and industrial carbon removals,** each **considerably beneath the environmental and technological risk thresholds** identified by the ESABCC (2023). The **maximum thresholds for industrial and land-based removals should be determined based on a conservative analysis of the interconnected dynamics of BECCS and the land sink**. This should be based on realistic assumptions informed by trends observed to date, including the ongoing decline of the land sink and ecosystem degradation driven, in part, by the growing demand for woody biomass for bioenergy, despite the sustainability criteria and reporting requirements embedded in the existing EU legislation (EEA, 2023b; ESABCC, 2025).

This approach will be critical for establishing an adequate starting point for the post-2030 policy mix, which avoids mitigation deterrence and ensures a viable pathway to climate neutrality by 2050, while minimising the overshoot of 1.5 °C and the risk of crossing global tipping points to the greatest extent possible.

Dedicated LULUCF target and its relevance to mature restoration and climate resilience objectives

It is recommended **that the importance of preserving and growing the EU natural carbon sink should be reflected through complementary targets**, which can serve to strengthen ambition and enhance effectiveness without compromising the key objective of achieving deep and rapid emission reductions. The existing framework anchored in the EU Climate Law which limits the land sink's contribution to the 2030 EU-wide net reduction target to -225 MtCO_2e "in order to ensure that sufficient mitigation efforts are deployed up to 2030", while simultaneously mandating a more ambitious target of -310 Mt CO_2e in the LULUCF Regulation, can inform the design of a similar approach for 2040 targets.

This approach should **ensure that the recommended restriction of the contribution of the LULUCF removals to the overall net GHG target does not undermine Member States' ambition in the recovery and maintenance of the land sink, as these efforts are central to other environmental and social goals** pursued at EU level.

An ambitious LULUCF target set in dedicated legislation is an important mechanism for driving alignment between EU climate, biodiversity, and adaptation objectives. Enhancing carbon sinks through sustainable land management practices can bolster ecosystem resilience against climate-induced stresses, contribute to biodiversity conservation, and provide essential ecosystem services, including flood regulation and soil stabilization. Restoring natural landscapes and implementing sustainable practices plays a major role in disaster risk reduction, protecting communities and infrastructure against the increasingly extreme impacts of climate change (EEA, 2017). Against the background of intensifying challenges to agricultural productivity and water availability, land management practices that promote soil carbon sequestration are likely to improve soil quality and health, enhance water retention, and limit soil erosion, supporting EU food security (EEA, 2024d).

Trade-offs between different objectives associated with some land management practices must, of course, also be considered. A holistic approach, avoiding a sole focus on short-term increases in the carbon sink, is crucial. LULUCF carbon sequestration measures with co-benefits for biodiversity and other ecosystem services should be prioritised, including where these may result in lower removals than management strategies targeting predominantly short-term carbon sink maximisation (Luyssaert et al., 2018). Alongside ambitious LULUCF net carbon removal targets, ensuring coherence of policy making processes will be essential to maximize synergies between climate, biodiversity, and adaptation objectives.

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This work has been produced with the financial support of the LIFE Programme of the European Union. The paper reflects only the views of its authors and not the donors.