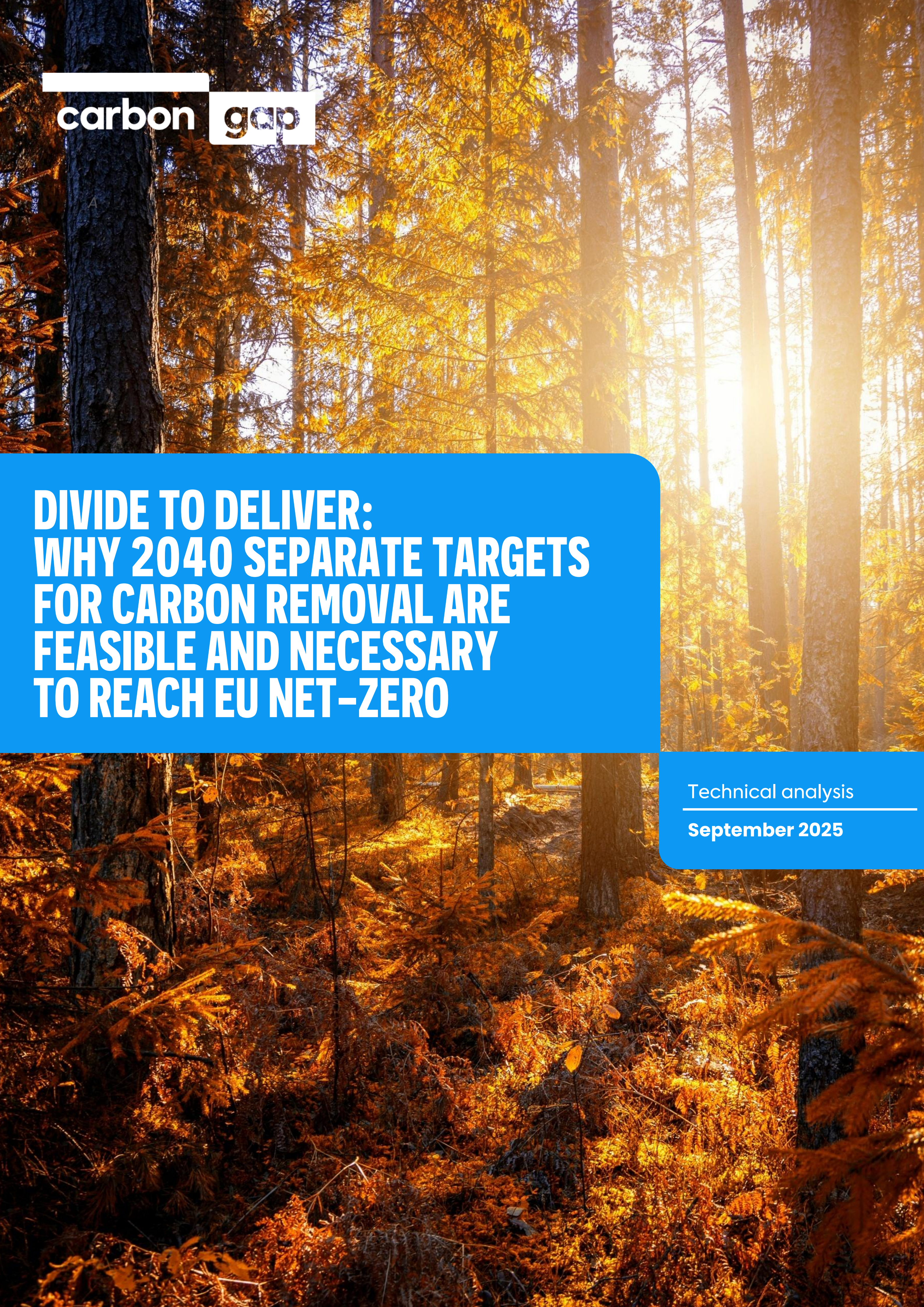

carbon gap

DIVIDE TO DELIVER: WHY 2040 SEPARATE TARGETS FOR CARBON REMOVAL ARE FEASIBLE AND NECESSARY TO REACH EU NET-ZERO

Technical analysis

September 2025

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This technical analysis gives further insights from scenario modelling related to CDR deployment in the long-term (beyond 2040), the impact of weakening LULUCF capacity, and the effect of modelling choices surrounding competition for biomass feedstocks. These findings result in key policy recommendations. For a short summary of the highlights and policy relevance of this study, please also see our previous publication.

1. EXECUTIVE SUMMARY

With only two years of the global carbon budget left for a 66% chance of limiting warming to within 1.5 °C, the climate crisis has entered a critical phase. Aggressive emissions cuts and a rapid scale-up of **carbon dioxide removal (CDR)** globally are both essential to stay within this temperature threshold and must accelerate immediately. At such a decisive moment, the EU is negotiating a 2040 climate target of at least 90% net emissions reduction, which must place the bloc firmly on the path to climate neutrality by 2050 and net-negative emissions thereafter.

However, the credibility and feasibility of the 2040 net target depends on clarifying the respective underpinning contributions of **gross emissions reductions**, **temporary CDR** (e.g., land-based sinks) and **permanent CDR**. Without clear and separate targets, climate implementation becomes fragmented and unreliable — undermining investor confidence, delaying essential infrastructure, and eroding trust in the EU's climate trajectory.

The European Commission's February 2024 Communication indicated that up to 400 Mt CO_2/year of carbon removals will be needed by 2040.[1] Although the accompanying Impact Assessment (IA) estimates up to 75 Mt of permanent removals may be needed,[2] the Commission failed to define separate contributions for permanent and temporary CDR — a major missed opportunity for accountability and delivery planning. This omission carried over into the proposal,[3] which recommends a single net 90% emissions reduction target. Beyond announcing the upcoming integration of permanent removals into the EU Emissions Trading System, it fell short of defining the shares for gross emissions reduction, permanent removals, and temporary removals. **This lack of disaggregation undermines transparency, climate integrity, and effective policy design.**

In response to the continued dismissal of separate targets and to challenge some of the assumptions embedded in the Commission's IA, Carbon Gap and VTT have modelled alternative decarbonisation scenarios using a portfolio of CDR methods. These scenarios explore the use of the like-for-like principle, ensuring fossil emissions are balanced with permanent removals, test assumptions on biomass constraints, and consider uncertainties surrounding the capacity of the Land Use, Land-Use Change, and Forestry (LULUCF) sector. The results show that:

- **Separate targets are feasible and advantageous for reaching climate goals.** Scenario modelling shows that clearly defined 2040 targets for gross emissions reductions, temporary removals, and permanent CDR are achievable and help uphold climate integrity, policy clarity, and investment certainty.

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[1] European Commission. *Communication on a 2040 Climate Target.* CELEX: 52024SC0063 (2024). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2024%3A63%3AFIN

[2] European Commission. *Impact Assessment on a 2040 Climate Target.* CELEX: 52024SC0063 (2024). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52024SC0063

[3] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Regulation (EU) 2021/1119 establishing the framework for achieving climate neutrality*. European Union (2025). Available at: https://climate.ec.europa.eu/document/download/e1b5a957-c6b9-4cb2-a247-bd28bf675db6_en

- **Temporary removals are deployed at full capacity.** According to our scenarios, temporary removals can deliver up to around 350 Mt CO_2/year by 2040, with successful LULUCF measures. The EU must plan for the remaining gap to reach the net emissions target with a credible, permanent CDR strategy.
- **Permanent CDR needs are large and vary according to the emissions reduction strategy.** Depending on how emissions evolve, our results show that the EU will need between around 100–280 Mt CO_2/year of permanent removals by 2040 — far more than the 75 Mt estimated in the Commission's IA.
- **No single method can deliver at the scale required.** A diverse portfolio of CDR methods is required to manage cost, timing of deployment, variation in capacity, and risk across scenarios.
- **If the land sink weakens, more permanent CDR will be needed to compensate.** Given the current declining trends and uncertainty of the land sink under future climate conditions, a plausible worst-case scenario involves a weaker LULUCF removal capacity. A weaker land sink increases reliance on more expensive permanent CDR technologies.
- **A robust biomass allocation strategy will be critical to the success of EU climate efforts.** In the EU, biomass is a finite resource subject to competing demands, including ecosystem health, food security, green energy, and carbon removal methods such as BECCS, and biochar. How to best allocate this resource for the maximum climate benefit is a complex and unresolved topic.

These findings reinforce growing scientific and expert consensus, including recommendations by the European Scientific Advisory Board on Climate Change (ESABCC),[4] that separate targets for different CDR types are essential for ensuring transparency, ambition, and policy alignment.

These findings point to four essential policy priorities for the EU to embed in its 2040 climate target framework:

1. **Set separate 2040 targets** for gross emissions reductions, temporary carbon removals, and permanent carbon removals to ensure climate integrity, accountability, and investor confidence.
2. **Support the scale-up of permanent CDR** through a dedicated EU policy package, including funding, infrastructure, and demand-side instruments such as compliance market integration.
3. **Sustain and grow land-based removals** by embedding temporary CDR in the Common Agricultural Policy (CAP), forest policy, and adaptation planning, and by maintaining a robust LULUCF target.

[4] European Scientific Advisory Board on Climate Change. *Scaling up carbon dioxide removals Recommendations for navigating opportunities and risks in the EU.* (2025) DOI:10.2800/3253650

4. **Support a diverse portfolio of CDR methods and efficient use of finite biomass resources** to manage risk, reduce cost, and ensure sustainable and resilient delivery under multiple future scenarios.

2. INTRODUCTION

2. 1. The critical role of CDR in reaching Europe's climate goals

Europe has pledged to reach climate neutrality by 2050. This legally binding commitment, enshrined in the European Climate Law (ECL), means that over the next 25 years (from 2025), every sector of the European economy must transform until emissions shrink to minimal levels and are no longer the engine for economic growth.[5] Yet even with deep cuts, some emissions will remain, and only carbon dioxide removal (CDR) – the capturing of CO_2 already in the atmosphere and durably storing it for decades, centuries, or millennia – can counterbalance and bring net emissions down to zero. Developing a portfolio of both permanent and temporary solutions – combining novel technologies with revitalised land sinks – is the most effective and resilient path forward.[6]

But CDR is not just a climate imperative. With net-zero no longer a discussion of *if* but *how*, the real winners of the transition will be those who put climate solutions at the service of their economies. Scientists estimate that the world will need 7-10 Gt of removals annually by 2050.[7] Countries leading the development of these technologies will gain far-reaching advantages, namely the ability to shape the emerging global markets and influence policy frameworks. By mid-century, the global CDR market is projected to reach $1.2 trillion, which could translate into a €220 billion annual market in Europe alongside up to 670,000 new jobs by 2050 – offering a lifeline to workers in today's oil and gas sectors.[8] Realising these benefits, however, will require smart, clear, and forward-looking policies enacted within this mandate.

In February 2024, the European Commission recommended a 2040 target of at least a 90% net reduction in greenhouse gas (GHG) emissions compared to 1990 levels.[2] The Commission indicated that reaching this level of ambition would require up to 400 Mt CO_2/year of CDR. Of this, the Commission's Impact Assessment (IA) estimated up to 75 Mt CO_2/year could be delivered by permanent removal methods, with the rest expected to come from the Land Use, Land-Use Change, and Forestry (LULUCF) sector.[2] Yet the Commission stopped short of recommending separate sub-targets for the two CDR categories. Since then, discussions around the amount of removals needed – and what kind – have stalled amid political uncertainty.

2. 2. Limitations of the European Commission's 2040 Impact Assessment

The Commission's IA for the 2040 climate target presents several emissions reduction scenarios, including the S3 scenario, which reaches a 92% net reduction in GHG emissions by 2040. This

[5] European Scientific Advisory Board on Climate Change. *Scaling up carbon dioxide removals Recommendations for navigating opportunities and risks in the EU.* (2025) DOI:10.2800/3253650
[6] European Parliament and Council, *Regulation (EU) 2021/1119 European Climate Law.* CELEX:32021R1119 (2021)
[7] Geden, O. et al. *The State of Carbon Dioxide Removal: A global independent scientific assessment of carbon dioxide removal*. The State of Carbon Dioxide Removal (SCDR) consortium (2024). DOI 10.17605/OSF.IO/F85QJ
[8] German Association for Negative Emissions & Boston Consulting Group. *Carbon Dioxide Removal Europe and Germany's Role in Catalysing a Trillion-Euro Industry.* (2024). https://negative-emissions.bcg.com/home/

scenario is therefore in line with the scientific consensus[9] that at least a 90% net emissions reduction is needed by 2040 to keep the EU on track for achieving net-zero by 2050. However, we find several key limitations with the modelling exercise presented in the IA.

First, the scenario modelling includes a limited scope of only two permanent carbon removal methods: bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS). This narrow focus omits other viable and scalable CDR methods, such as applying biochar to soil and enhanced weathering (ERW), which could play a complementary role in the EU's climate strategy.

A further limitation of the IA is that it does not follow the "like-for-like" principle,[10] which requires residual fossil-fuel emissions to be balanced exclusively by permanent removals and biogenic emissions by land-based or temporary removals. Without this distinction, there is a risk that short-lived removals could be used to compensate for fossil emissions, undermining the permanence of net-zero claims.

A further potential limitation of the IA is related to assumptions surrounding LUCLUF capacity. Europe's LULUCF sector plays an important role in removing CO_2 from the atmosphere and storing it in living biomass and soils, essential for reaching Europe's climate targets. Currently, the LULUCF sector is estimated to be removing close to 200 Mt CO_2/year (as of 2023).[11] In the IA's S3 scenario, the LULUCF removal capacity reaches –317 Mt CO_2/year by 2040, therefore simulating a positive LULUCF development. This number was presented as a fairly conservative estimate, for example, excluding the adoption of sustainable lifestyle choices in the EU.

Emerging evidence shows that the land-sink in recent decades has been weakening, and future contributions from LULUCF are far from guaranteed.[12] Rising harvest rates, lower carbon sequestration in ageing forests, and climate change impacts such as droughts and pest outbreaks are likely to blame for the current trend.[10] [11] Several recent projections[13] found that continued business-as-usual forest management would likely reduce the sink further in the coming decade,[11] yet others[14] have shown increased capacity could be possible, highlighting the large uncertainty

[9] European Scientific Advisory Board on Climate Change. *Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050*. https://climate-advisory-board.europa.eu/reports-and-publications/scientific-advice-for-the-determination-of-an-eu-wide-2040

[10] Myles R. Allen et al., *Net Zero: Science, Origins, and Implications*, https://www.annualreviews.org/content/journals/10.1146/annurev-environ-112320-105050;jsessionid=PCTsAE2w6I5g3xvb_55lI1C0zI9SMj9zz45I8JuL.annurevlive-10-241-10-102

[11] European Environment Agency. Europe's land carbon sink declines, but its potential stays high. *European Environment Agency*. (2025). https://www.eea.europa.eu/en/newsroom/news/europes-land-carbon-sink-declines-but-its-potential-stays-high

[12] European Environment Agency. *Greenhouse gas emissions from land use, land use change and forestry in Europe* (2024). https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-land?activeAccordion=ecdb3bcf-bbe9-4978-b5cf-0b136399d9f8

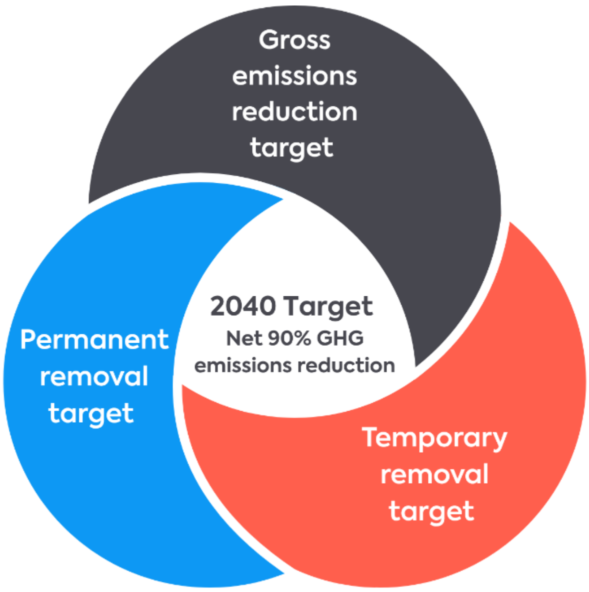
[13] Korosuo, A., Pilli, R., Abad Viñas, R. et al. *The role of forests in the EU climate policy: are we on the right track?*. Carbon Balance Manage 18, 15 (2023). https://doi.org/10.1186/s13021-023-00234-0

[14] Pilli, R., Alkama, R., Cescatti, A., Kurz, W. A. & Grassi, G. The European forest carbon budget under future climate conditions and current management practices. *Biogeosciences* 19, 3263–3284 (2022) https://bg.copernicus.org/articles/19/3263/2022

surrounding this carbon sink.[15] The European Environment Agency[10] [11] warns that even with additional measures to increase capacity, projected removals are likely to fall short of policy goals, projecting LULUCF capacity at around 230 $MtCO_2$/year by 2040 (or 200 $MtCO_2$/year without additional measures).

Therefore, reaching 317 Mt CO_2/year of LULUCF removals in 2040, as estimated by the IA, presents a challenge which deserves further consideration.

Fig. 1: Proposed 2040 target architecture



2. 3. Our approach: scenario modelling to explore meaningful 2040 targets

In light of the limitations of the Commission's IA and the importance of having robust 2040 targets, Carbon Gap and VTT Technical Research Centre of Finland embarked on a project that aims to model science-based decarbonisation scenarios for 2040, which:

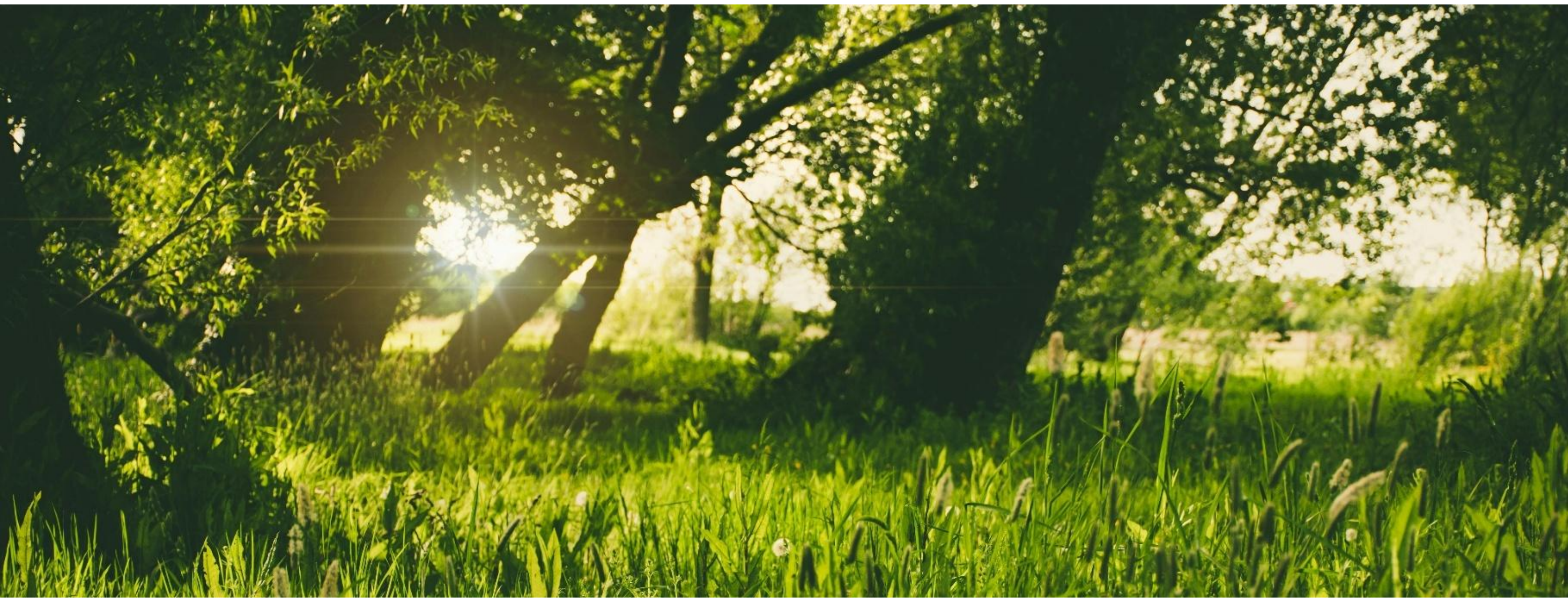
- Reflect EU policy needs and the uncertainty surrounding the capacity of the LULUCF sector;
- Assess the deployment of a portfolio of CDR methods, including BECCS, DACCS, biochar, ERW, soil carbon sequestration (SCS), and afforestation/reforestation (AR);
- Disaggregate removals by type (temporary and permanent) and test the feasibility of reaching net-zero targets while adhering to the like-for-like principle.

This modelling work builds on the scientific foundation laid by the **NEGEM project (2020–2024)**,[16] a major EU Horizon 2020 initiative assessing sustainable negative emissions pathways for Europe.

[15] Institute for European Environmental Policy. EU LULUCF sink development until 2040: Trends, projections and uncertainties. (2025). https://ieep.eu/wp-content/uploads/2025/03/EU-LULUCF-sink-development-until-2040-Trends-projections-and-uncertainties-IEEP-2025.pdf
[16] Visions and Pathways for Carbon Dioxide Removal in the EU – Summary of key results and recommendations from NEGEM project. (2024) Available at: https://www.negemproject.eu/wp-content/uploads/2024/07/NEGEM-Final-Booklet.pdf

By adopting the same modelling framework (PET-VTT) and incorporating updated data, this project further refines and expands NEGEM's findings by testing alternative scenarios, in line with evolving EU climate needs.

Crucially, this project focuses exclusively on **domestic carbon removal within the EU**. The project does not account for or assume the use of international carbon credits. This approach is deliberate; it provides a clear picture of how Europe can meet its 2040 and 2050 climate targets by implementing solutions within its own borders. While the role of international credits remains a subject of political negotiation, these credits should not be used to mask domestic inaction or delay investment in the infrastructure and innovation needed to scale up EU-based CDR.



3. METHODOLOGY

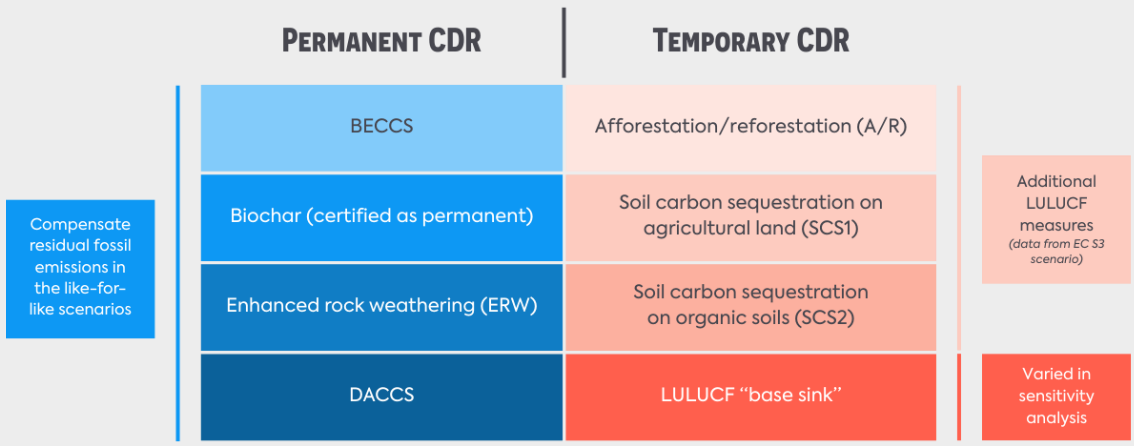
CATEGORISATION OF CDR METHODS

To ensure consistency, credibility, and policy alignment when modelling separate 2040 targets for CDR, we adopted a hybrid categorisation framework centred on the durability of carbon storage (Fig. 2). This approach distinguishes between:

- **Permanent removals**, where carbon is stored for centuries to millennia (e.g., BECCS, DACCS, ERW, and biochar with high-quality MRV);
- **Temporary removals**, which carry a higher reversibility risk and are typically stored in biomass or soils for years to decades (e.g., afforestation/reforestation, soil carbon sequestration).

This categorisation reflects the EU Carbon Removal Certification Framework (CRCF)[16] and the distinctions used in the Commission's IA (LULUCF vs. industrial removals). It is also consistent with scientific literature (e.g., IPCC AR6,[17] Oxford Net Zero[2]). However, the fungibility of biochar-based removals with more permanent forms of CDR, such as those involving geological storage, remains debated[18] due to the differences in durability, MRV, and liability mechanisms.

Fig. 2: Categorisation of permanent and temporary CDR methods modelled in our project, and also the LULUCF base sink, which is supplied as a fixed input



3. 1. Modelling approach

The modelling used the PET-VTT model, which covers all energy system sectors and integrates a portfolio of carbon removal methods. For additional details on the methods and assumptions, please see the methodological annexe.

[17] European *Parliament and Council, Regulation (EU) 2024/3012 Carbon Removal Certification Framework (CRCF). CELEX: 32024R3012 (2024)*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202403012

[18] IPCCC, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC AR 6 WG3 (2022). https://www.ipcc.ch/report/ar6/wg3/

[19] Carbon Direct. What is biochar? A carbon removal solution gaining ground. (2023). Available at: https://www.carbon-direct.com/insights/what-is-biochar-a-carbon-removal-solution-gaining-ground (accessed June 2025)

The modelling is based on several key features:

- **Pathways follow a least-cost optimisation** consistent with EU decarbonisation policy.
- CDR deployment is driven by **technology availability and cost** over time (Table 1).

Table 1: Summary of the upper limit of removal capacity and costs. Assumptions are based on literature or computed by the model. The costs for BECCS and DACCS include average transport and storage costs associated with geological CO2 storage.[19] For biochar, BECCS and DACCS, costs were computed by the model and ranges indicate the min-max values across all scenarios and sensitivity analyses. For the remaining methods, these inputs were sourced from literature. The increasing cost of BECCS and DACCS over time is related to the predicted increasing cost of energy in the future. For further details, see the methodological annexe.

	Upper capacity limit (Mt CO_2/year)			Costs (EUR/tCO_2)		
	2030	2040	2050	2030	2040	2050
BECCS	Driven by availability of bioenergy feedstock[20], sidestreams from pulp and paper industry, and geological storage potentials[16]			80-89	93-112	117-216
Biochar	Driven by availability of bioenergy feedstock[20]			48	48	49-83
ERW[21]	20	36	69	138-158	158	158
DACCS	Driven by availability of renewable electricity (computed by model) and geological CO_2 storage[19]			-	393-475	408-494
A/R[20]	48	55	82	28	26	22-27
SCS1[20]	27	37	37	56	57	42-47
SCS2[20]	38	45	48	56	57	42-47

- Net emission targets of -55% in 2030, -90% in 2040, -100% in 2050 are reached, shifting to net negative by 2060.
- Emissions from **non-modelled sectors (agriculture, waste, other)** are based on volumes from the IA S3 scenario for comparability.[2]

[20] Joint Research Centre (JRC) 2024. Tumara, D., Uihlein, A. and Hidalgo Gonzalez, I., Shaping the future CO2 transport network for Europe, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/582433, JRC136709
[21] European Commission (EC) 2024b. Commission Staff Working Document. Impact Assessment Report. Parts 1-5. Available at: https://eurlex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52024SC0063
[22] Beerling D J et al. Potential for large-scale CO2 removal via enhanced rock weathering with croplands Nature (2020) 583 242–8

- Availability of **geological storage**, a driving factor in CCS deployment, is assumed to be high already by 2040 (around 770 Mt CO_2/year).[19]

3. 2. Three core scenarios and their assumptions

We modelled three core scenarios (Table 2) to explore the volumes and portfolio of CDR methodologies the EU would need to reach its net emissions targets. These scenarios follow the same net emissions objectives and assumptions surrounding the costs and capacities of the modelled CDR solutions. They differ, however, in how they apply the like-for-like principle and in the level of ambition for reducing gross emissions. The results from these scenarios help us to assess the feasibility of separate targets for gross reductions, temporary removals, and permanent removals.

Scenario 1 — Classic least-cost (Classic LC)

For the **classic least-cost** scenario, the model seeks the least expensive way to reach the net emission targets, allowing any type of removal to offset any type of residual emission. This means fossil emissions can be balanced with temporary CDR — a practice that risks undermining the permanence of net-zero claims. This strategy mirrors the modelling approach of the Commission's IA.

Scenario 2 — Like-for-like high (LfL-high)

In the **like-for-like high** scenario, on top of seeking the least-expensive solution, the model is additionally required to follow the like-for-like principle. This means that, over time, fossil emissions are balanced only by permanent removals (BECCS, DACCS, ERW, and biochar) and not temporary methods, with the model striving to reach durable net-zero by 2060. In the LfL-high scenario, the model is given a permanent removal target above the 'optimised' outcome from the classic least-cost scenario to test if and how it is feasible to reach the net emissions targets within these constraints. For example, by 2040, the model is permitted to use permanent CDR within the range of 285–335 Mt CO_2/year. These values simulate failed or delayed ambition to reduce gross emissions in the coming decades, which would result in a high permanent CDR need. This scenario is a stress test for the system's ability to meet climate integrity requirements under challenging conditions.

Scenario 3 — Like-for-Like Low (LfL-low)

In the **like-for-like low** scenario, the model must also follow the like-for-like approach but using a permanent CDR target below the 'optimised' outcome from the classic least-cost scenario. For example, by 2040, the model is allowed to use permanent CDR within the range of 38-85 Mt CO_2/year. This scenario represents an optimistic case, with faster decarbonisation and more ambitious emissions reductions, where permanent CDR requirements are minimised.

3. 3. Sensitivity scenarios

In addition to the three core scenarios, we developed a set of sensitivity scenarios to test the impact of alternative assumptions about the performance of the LULUCF sink and biomass use.

a. Weak and extremely weak LULUCF

Europe's land sink is under pressure from ageing forests, climate change impacts, and management trends. In light of these issues, the IA's LULUCF projections (317 Mt CO_2/year by 2040) look increasingly unrealistic. To reflect real-world risk and explore the impact of limiting the capacity of the land sink, we modelled two variations (Table 2) to the three core scenarios:

- **Weak LULUCF** — Similarly to the core scenarios, the LULUCF base-sink is maintained, following the current trajectory to reach 206 Mt CO_2/year by 2050. However, no temporary removals are possible beyond the LULUCF base-sink. This scenario is comparable to the European Environment Agency's projection for LULUCF capacity without additional measures and simulates a situation where LULUCF policy has failed to expand temporary removals.
- **Extremely weak LULUCF** — The LULUCF base sink is further reduced, reaching 150 Mt CO_2/year by 2050. This reduced capacity represents a worst-case scenario where LULUCF policy fails to ensure climate-focused management and future climate change has extremely negative impacts on the land sink.

These scenarios help quantify the insurance role permanent removals would need to play if nature-based removals underperform.

b. Biochar cap

Biomass availability is a hard physical limit that constrains both bioenergy and CDR. It remains uncertain how different CDR methods will compete for limited biomass resources, and how best to represent this competition in modelling frameworks. In our core scenarios, all energy feedstocks are available for use by biochar and BECCS, with an additional biomass stream from pulp and paper possible for BECCS. To reflect tighter sustainability constraints and competing land use priorities, we tested a **biochar cap** (Table 2) limiting the available biomass source for biochar per region to 8% of the total bioenergy feedstock for the EU and the UK.

Table 2: Summary of the main modelled scenarios (classic LC, LfL-high, and LfL-low) and further scenario variations (weak LULUCF, extremely weak LULUCF, and biochar cap)

SCENARIO NAME	MOTIVATING QUESTION	CHARACTERICS
1 **Classic least-cost** (Classic LC)	How can the EU reach its climate goals considering the cost and capacity of mitigation measures such as reducing emissions and deploying CDR? What level and portfolio of removals are needed?	CDR deployment and CO_2 mitigation are used to reach the climate targets without matching removal and emissions type. Temporary removals are possible to expand the land-sink capacity beyond the LULUCF base sink.
Like-for-like (LfL)*	If/how can we reach geological net zero in the coming decades by using the LfL principle when balancing fossil emissions?	Builds on the classic LC scenario by experimenting with fixed target for permanent CDR, which in turn controls the trajectory of fossil-emissions. Aims to reach geological net-zero by 2060.
2 **High permanent need** (LfL high)	When applying like-for-like, what happens if decarbonisation efforts are unsuccessful and therefore, higher permanent CDR targets are needed?	The fixed target range for permanent CDR is set high (285-335 Mt CO_2/yr for 2040), meaning fossils emissions decrease less dramatically.
3 **Low permanent need** (LfL low)	What happens if we move quickly to eliminate fossil emissions and therefore need lower permanent targets are needed?	The fixed target range for permanent CDR is set low (35-85 Mt CO_2/yr for 2040), meaning fossils emissions decrease more rapidly.
SENSITIVITY SCENARIOS		
+ **Weak LULUCF**	Over the last few decades the LULUCF sink has been declining and with changing climate, its future capacity is uncertain. What happens if these trends continue and/or LULUCF policies are unsuccessful?	Additional temporary removals measures are excluded; only the LULUCF base sink is allowed.
+ **Extremely weak LULUCF**	What if future climate change has extreme negative impacts on the LULUCF capacity and policies are unsuccessful?	The LULUCF base sink is further reduced, reaching 150 Mt CO_2e/year in 2050. Additional temporary removals measures are excluded; only the LULUCF base sink is allowed.
+ **Biochar cap**	Biomass is a finite resource and has several competing uses, for example, for BECCS or biochar, making modelling these interactions complex. What occurs when the feedstocks are controlled?	For each region, the biomass available for biochar is limited to 8% of the total bioenergy feedstock for the EU27 and the UK.

**The like-for-like principle means that the type of CDR used should match the type of emissions being offset. For example, if emissions are long-lasting (like CO_2 from fossil fuels), they should be balanced with permanent CDR methods—not short-term solutions like tree planting that may only store carbon temporarily.*

4. MAIN FINDINGS

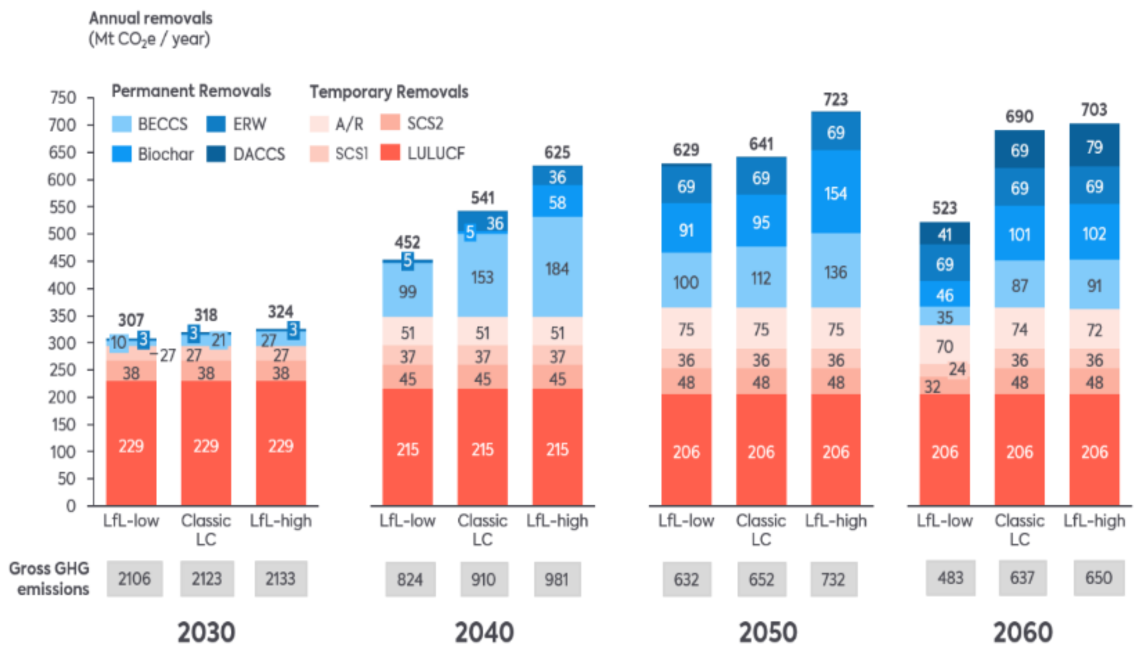
4. 1. Interpreting the results

The outcomes of the modelling exercise reflect cost-optimised pathways for reaching the EU's net emissions goals, following the underlying assumptions and limitations of the model. It is important to recognise that the model has 'perfect foresight', meaning it can simulate instantaneous shifts in investment between technologies. However, in real-world applications, the implementation of climate mitigation strategies may not purely prioritise cost, and further challenges exist for executing such actions that are not fully captured by the model. For this reason, these results should not be interpreted as a realistic future development scenario or an investment plan. Nonetheless, the outcomes of this modelling exercise offer a basis for understanding both the urgency and magnitude of necessary responses, and for comparing the effects of alternative policy structures and scenarios.

4. 2. Summary of the core scenario results

The results from the three main scenarios (i.e., **classic LC, LfL-high, LfL-low**) highlight the different CDR deployment pathways under varying levels of ambition and constraints.

Figure 3: Modelled permanent and temporary CDR volumes can help inform long-term climate planning



In the short term until **2030** (Fig. 3), all scenarios predominantly utilise cost-efficient temporary removals methods, namely, soil carbon sequestration on agricultural lands (SC1) and soil carbon sequestration on organic soils such as peatlands (SC2), with limited deployment of permanent solutions from ERW and BECCS.

By **2040**, all scenarios predict that rapid emissions reductions are required to reach the -90 net GHG target (Fig. 3). At the same time, the use of temporary removal methods is expanded to nearly reach their full capacity, now including afforestation/reforestation methods. This consistency clearly illustrates the importance of temporary removals as a cost-effective solution for helping reach climate goals.

Yet, temporary removals cannot reach the goals alone, and by 2040, permanent removals begin to expand dramatically in all three scenarios, with BECCS supplying the largest proportion of permanent removals. At this point, more permanent CDR from ERW is also needed, with deployment at full capacity in classic LC and LfL-high scenarios. To meet the higher demand for permanent CDR by 2040 in the LfL-high scenario, a sizeable amount of biochar removals is also deployed. Interestingly, in the like-for-like scenarios, the volume of the total permanent removals generally matches the lower end of the possible range provided to the model. This occurrence suggests that by 2040, reducing emissions as much as possible to minimise the use of permanent removals is still the most cost-effective option according to our modelling.

By **2050**, the rate of emissions reductions decreases, and more CDR is needed to reach net-zero across all core scenarios (Fig. 3). Temporary removal solutions are fully deployed and generally remain so for the rest of the modelled period. To meet the higher removal demand in 2050, ERW is expanded to reach full deployment in all three scenarios. In particular, there is a large increase in biochar application; meanwhile, a sizeable quantity of BECCS removals is still used.

In the LfL-low scenario where emissions are cut the most dramatically, a very small amount of DACCS is deployed by 2050, and the total amount of permanent CDR exceeds the minimum threshold required of the model. This observation is somewhat surprising since the permanent CDR target given to the model for the LfL-low scenario was intentionally lower than the other scenarios. Yet, the model chooses to deploy more permanent CDR than required, also using the costly DACCS technology. This event signals that it has become more expensive to reduce these 'hard-to-abate' emissions than to deploy permanent removal technologies. Therefore, our modelling predicts that reducing emissions below the LfL-low scenario may not be cost-optimal, and the estimated permanent removal volumes from the LfL-low scenario can be seen as lower thresholds for permanent CDR need.

By **2060**, all three scenarios move into the net negative phase (Fig 3.). Residual emissions in the classic LC and LfL-high scenarios remain relatively high (>600 Mt CO_2/year), hence requiring the deployment of DACCS, the costliest CDR method. Even when residual emissions are lower in the LfL-low scenario, the full suite of permanent and temporary removals methods is required, including sizeable volumes from DACCS. In the like-for-like scenarios, geological net-zero is reached by 2060.

Overall, we see that all three scenarios utilised the **full portfolio of temporary and permanent CDR methods** over the modelled timeframe. This underscores that no individual CDR method, or category of methods, can be relied upon to achieve our climate goals on its own — a portfolio approach is the wisest choice.

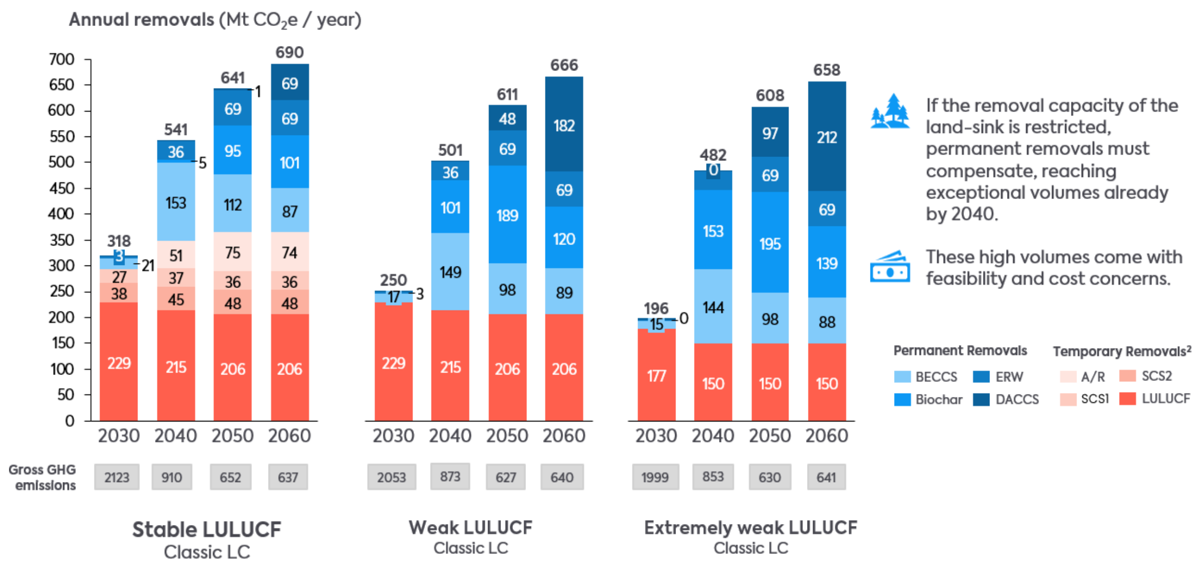
4. 3. Sensitivity analysis

a. Impact of restricted LULUCF capacity

We tested the impact of limiting temporary removals by applying a **weak** (206 Mt CO_2 year by 2050) or **extremely weak** (150 Mt CO_2 year by 2050) **LULUCF** sink to our three core scenarios. Figure 4 shows the effect of these restrictions on the temporary land-sink and permanent CDR volumes for the classic LC scenario as an illustration. This analysis confirms that if the removal capacity of the land-sink is restricted, permanent removals must compensate, reaching exceptional volumes already by 2040, with accelerated deployment of biochar and DACCS. For example, when applied to the three main scenarios, having a weak or extremely weak LULUCF meant permanent removals would need to be scaled to ~141-294 Mt CO_2/year or ~171-340 Mt CO_2/year by 2040, respectively (when applied to the classic LC scenario, permanent CDR supplies 286 or 332 Mt CO_2/year, respectively; Fig. 4). These volumes are considerably higher than the permanent CDR deployed when land-sink capacity is assumed to be strong (producing a range of 104-278 Mt CO_2/year). These high volumes come with clear feasibility and cost concerns, as expensive technologies such as DACCS need to be used in higher volumes, leading to overall higher costs for these scenarios (see pg. 32 in the methodological annexe).

Maintaining and strengthening Europe's land sink is therefore crucial. If the LULUCF sink weakens, the cost and difficulty of achieving net-zero will rise sharply. Investing in land-based removals now through forest restoration, sustainable management, and better soil practices can reduce future pressure on budgets, technologies, and public support.

Fig. 4: A limited LULUCF removal capacity jeopardises net-zero goals.

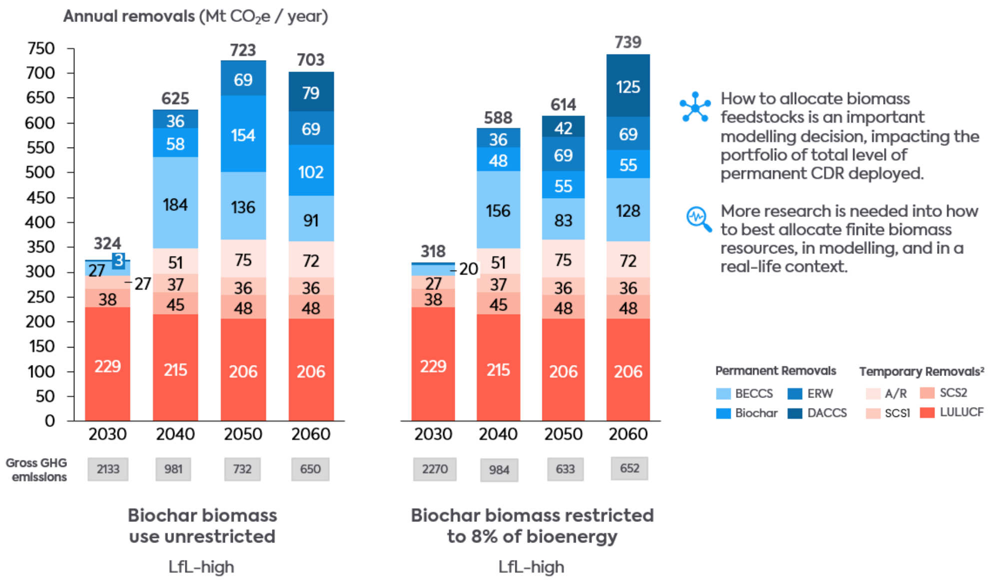


b. Impact of restricting biomass use for biochar

In our three core modelling scenarios where BECCS and biochar were allowed to access all bioenergy feedstocks, biochar consumes 9-14% of this total biomass. We tested the impact on our core scenarios of capping the energy feedstock available to biochar per region at 8% of the total feedstock for the EU and UK (**biochar cap**). Figure 5 shows the result of applying the biochar cap to the LfL-high scenario. This change greatly impacts the portfolio and total level of permanent removals required to meet the net-emissions goals. In 2040 and 2050, the lack of cheaper permanent removals from biochar means that more dramatic emissions cuts are needed. As a result of less biochar available, considerable quantities of DACCS are deployed already in 2050. Overall, this sensitivity test indicates that the allocation of biomass sources has a crucial impact on the resulting portfolio of CDR technologies available for reaching net-zero in our modelling exercise and likely in similar studies.

Biomass availability and competition for these finite resources in Europe represent a critical limiting factor for the deployment of biomass-based CDR methods. Modelling exercises should account for the most probable biomass sources associated with specific regions and technologies to better reflect real-world constraints. Our analysis underscores the need for further investigation into how biomass can and should be allocated across competing mitigation and CDR pathways, considering technological, sustainability, and safety constraints. A robust climate strategy therefore, necessarily includes a clear framework for allocating biomass across its competing uses to have the greatest climate impact.

Fig. 5: How the model allocates biomass for BECCS and biochar impacts the permanent CDR portfolio and gross emissions

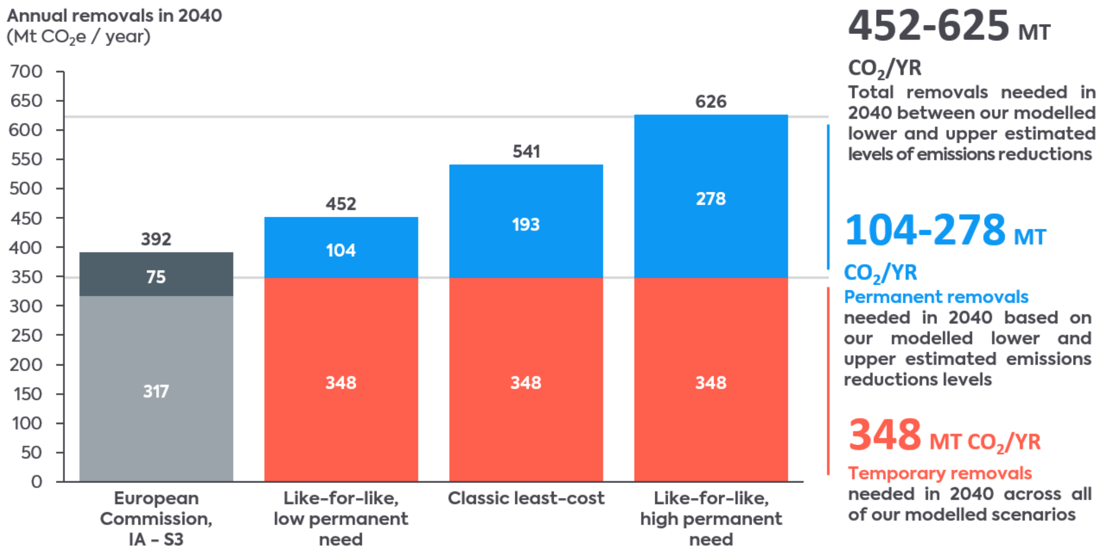


4. 4. The 2040 targets

Figures 6 and 7 zoom in on the results for 2040 from our three core scenarios. They show that a **total of 452-625 Mt CO_2/year** of CDR is needed to reach the -90% emissions goal, therefore exceeding the Commission's proposed removal target of 400 by 52–225 Mt CO_2/year.

Temporary removals are consistently deployed to their full capacity, resulting in an estimated volume of **348 Mt CO_2/year**, slightly exceeding the 317 Mt CO_2/year target from S3 of the IA. Our results clearly show that temporary removals form a crucial source of cost-effective removals in

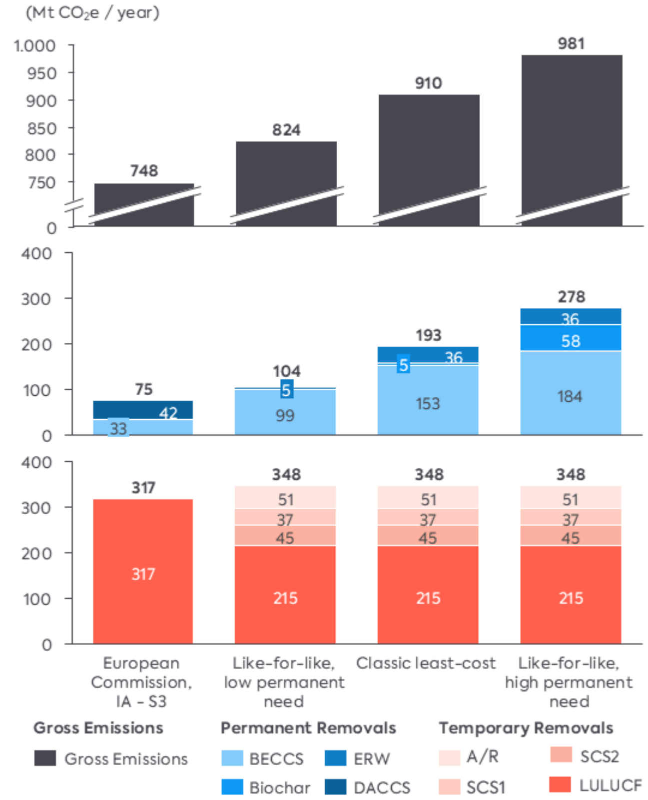
Figure 6: Scenario modelling for the EU to reach the -90% net GHG emissions target reveals a gap in projected CDR needs for 2040.



2040 and beyond (Fig. 6).

The amount of permanent removals needed in 2040 in the three core scenarios is large and varies depending on the model's assumptions (Fig. 6), ranging between **104-278 MtCO_2/year** or 23-43% of the total estimated removals. If the model follows the classic least-cost approach with no requirements for matching permanent removals and remaining fossil emissions (i.e., mirroring the approach of the IA), **193 MtCO_2e/year** of permanent removals would be needed to reach the net emission target. Reaching the -90% net emission target by 2040 is also feasible when requiring the model to gradually apply the like-for-like principle, with geological net-zero being reached in 2060 (see methodological annexe). In a scenario where we fail to reduce our emissions (LfL-high), the permanent CDR amount needed by 2040 is exceptionally high, at **278 Mt CO_2/year**. If our efforts to minimise emissions are successful (LfL-low), the permanent removal need is much lower at **104 Mt CO_2/year**. The permanent removals from our scenario modelling therefore, exceed the estimated 75 MtCO_2/year from the Commission's IA by exceptional amounts (29-203 Mt CO_2/year). Additionally, our sensitivity analysis showed that in the pessimistic situation where the

Figure 7: A portfolio of CDR methods is required to reach the 90% net target



LULUCF sink is weakened, we could potentially need much higher volumes from permanent removals (Fig. 4).

Both temporary and permanent removals are vital for cost-effectively reaching the climate goals — limiting one or the other makes reaching our targets more challenging or costly. Our scenario modelling clearly shows that a large gap could exist between the perceived CDR needs for the EU by 2040 — for example, in the case where we would follow the predictions from the Commission's IA — and other plausible future scenarios such as we have presented here.

4. 5. Modelling limitations

Although integrated assessment models such as the PET-VTT model are commonly used for assessing future decarbonisation pathways, they have certain limitations. As previously noted, the model can make rapid 'overnight' decisions — adding in and phasing out technologies swiftly — which overlooks some of the real-world challenges and constraints associated with such transitions. For example, large-scale DACCS deployment is delayed to 2060 in our three main modelled scenarios, when 41-79 $MtCO_2$/year is then required (Fig 3). However, achieving these volumes will be difficult without significant progress and upfront investment in the preceding decades. This recognition demonstrates that a deployment strategy following a purely cost-optimised approach is not likely to be suitable for DACCS implementation, and that real-world applications will depend on complementary mechanisms to the market, such as sub-mandates, or public procurement to ensure that a minimum level of DACC is being developed for these technologies to be readily available at the necessary scale in the decades to come.

Besides this limitation of underrepresenting the need for strategic deployment plans, other important considerations are also outside of the scope of this modelling exercise. For example, our approach does not capture debates around climate justice, such as the fair distribution of responsibilities, capabilities, and impacts across countries and communities. European climate targets are currently set to reach net-zero in isolation, without direct consideration for the remaining carbon budget and the coordination required between countries globally. Relatedly, in focusing on the EU's journey to net-zero, the need for CDR to tackle historical emissions is overlooked.

This scenario modelling included seven distinct temporary and permanent removal methods, yet a much larger range of CDR technologies is developing. Future modelling should also incorporate these additional promising approaches, for example, in the realm of marine CDR.

4. 6. What did we learn?

In summary, we can draw several insights from the results from our scenario modelling:

- A **diverse portfolio of CDR methods,** constituting both temporary lank-sink and permanent CDR methods, is crucial for reaching our climate goals.
- **Temporary removal methods** are an essential source of cheaper removals, but they cannot supply all the removals we will need.
- **Weakened land sinks** would make it unlikely and/or costly to reach net emission targets, potentially prohibiting us from reaching the 2040 target.
- **A single net target risks locking in over-reliance on cheap temporary removals in the short term**; meanwhile, permanent removals must supply a large part of removals already by 2040.
- **Delaying investment into permanent CDR technologies**, such as DACCS, which will likely form a crucial part of mitigation strategy in later decades, would hurt the EU's chances of reaching climate targets.
- **It is important to understand how the finite biomass source** in Europe should be efficiently allocated to satisfy several competing needs, including BECCS and biochar use, meanwhile ensuring the greatest climate benefit.

The implication from our results is clear: **separate targets for gross reductions, temporary CDR, and permanent CDR are not just desirable for transparency — they are essential for safeguarding our climate goals.**

5. POLICY RECOMMENDATIONS

What should the EU do now?

1. **Set separate 2040 targets for gross emissions reductions, temporary, and permanent CDR.** A single net target obscures the distinct roles, risks, and policy needs of reducing emissions versus removing carbon. Setting separate targets for gross reductions, temporary CDR, and permanent CDR ensures climate integrity, transparency and effective delivery. It also reflects scientific consensus and growing support across civil society, industry, and expert bodies.[23][24] To implement this principle, the EU should:
    - Amend the European Climate Law to enshrine disaggregated contributions for gross emissions reductions, temporary and permanent CDR;
    - Maintain a binding LULUCF target to reflect the temporary removal contribution and ensure land sinks are sustained;
    - Define the role of permanent CDR in compliance frameworks, including eligibility and quantification under the CRCF and ETS;
    - Track progress separately for reductions, temporary removals, and permanent removals to enable timely course corrections;
    - Apply the like-for-like principle, ensuring fossil emissions are balanced by permanent removals, while biogenic emissions are balanced by land-based sinks;
    - Mitigate market bias by ensuring that cheaper temporary removals do not crowd out early investment in permanent solutions;
    - Provide an accessible framework for civil society and the public to understand and scrutinise progress toward net-zero.
2. **Develop a tailored EU policy package to deliver a portfolio of permanent CDR at scale.** Even under the most ambitious decarbonisation scenarios, the EU will require at least 100 Mt CO_2/year of permanent removals by 2040 — and much more if reductions or temporary CDR fall short. Yet today, the EU lacks the full breadth of policy tools to support this scale-up. Once 2040 contributions are defined, a dedicated policy package is needed to enable early deployment, cost reduction and long-term scaling. To succeed, this package must send clear and predictable demand signals to unlock private investment, avoid overreliance on future technological breakthroughs, and be underpinned by robust MRV, carbon accounting, and liability frameworks that guarantee environmental integrity. This package should:

[23] European Commission. *Factual summary report on the public consultation on the EU Climate target for 2040. Ref. Ares (2023)5698212* (2023)

[24] Carbon Market Watch. *Open letter calling for a firewall between carbon emissions, land sequestration and permanent removals in the EU* (2024) https://carbonmarketwatch.org/publications/open-letter-on-separate-targets-in-2040-climate-framework

- Establish a dedicated roadmap and funding stream for permanent CDR, as part of the EU's broader decarbonisation and innovation agenda.
- Provide early-stage support for first-of-a-kind projects and shared CO_2 transport and storage infrastructure.
- Deploy demand-side instruments, such as contracts for difference (CfDs), advance market commitments, and public procurement for certified removals.
- Integrate permanent removals into compliance markets, following a sequenced approach that builds demand predictably and responsibly.
- Support a portfolio of permanent CDR methods to ensure technological diversity, improve resilience, and reduce delivery risk.
- Ensure robust MRV, accounting, and liability rules in line with the CRCF and IPCC guidance.

3. **Enhance EU and national support to sustain and grow temporary removals.** Temporary removals are essential for balancing biogenic emissions and supporting ecosystem resilience. However, despite the support for afforestation, soil carbon, and sustainable land use in the LULUCF Regulation, Europe's land sink is in decline or at best, stable. To reverse this trend, Member States must stay the course on targets rather than seeking flexibility, and work towards phasing out poor land management practices that undermine climate goals. A stronger and more stable policy framework is needed to sustain and grow these contributions. To secure stability, the EU should:

   - Strengthen land-based CDR policies through the CAP, EU Forest Strategy, and national climate adaptation plans;
   - Maintain and enhance the LULUCF Regulation's ambition, avoiding any weakening of targets or shift to non-binding goals;
   - Ensure harmonised MRV and carbon accounting rules to prevent overestimation, double-counting, and misuse of temporary removals;
   - Embed the like-for-like principle by reserving temporary removals for biogenic emissions only;
   - Invest in nature-based removals now to reduce future cost pressures on engineered CDR and enable a just, ecosystem-aligned transition.

4. **Build a resilient portfolio of carbon removal methods to manage risk and ensure delivery.** No single carbon removal method can deliver the EU's 2040 or 2050 targets alone. Each method faces different constraints and deployment timelines — from biomass availability and land use to cost, MRV challenges, and public acceptance. A diverse portfolio approach reduces systemic risk and enables responsive policy across different national contexts. To ensure resilience and feasibility, the EU should:

- Support a balanced mix of permanent and temporary CDR methods, tailored to their respective roles and limitations;
- Avoid over-reliance on any one solution, particularly high-cost or late-deploying technologies;
- Design policy tools to support portfolio diversity, including technology-specific support where needed, and differentiated MRV systems;
- Encourage Member States to develop national portfolios based on local conditions, resource endowments, and economic capabilities;
- Model and monitor biomass allocation impacts to ensure that land and feedstock use deliver the greatest overall climate benefit across mitigation and removal pathways.

6. CONCLUSION: CREDIBILITY REQUIRES CLARITY

Achieving a credible and actionable 2040 climate target requires differentiated contributions from gross emissions reductions, temporary and permanent CDR. The modelling presented in this paper shows that **separate targets are advantageous for a robust EU climate framework**. By setting clear, science-based targets and backing them with the right policy tools, the EU can lead globally in responsible carbon removal while safeguarding environmental integrity and public trust.

The EU must enshrine distinct CDR contributions in the Climate Law revision and relevant sectoral legislation. These targets must be backed by concrete delivery policies now — not in 2035 — if Europe is to reach climate neutrality by 2050.

7. ANNEXE

For further details on the modelling setup and assumptions, please see the accompanying methodological annexe: Methods_Divide_to_Deliver_VTT_July2025.

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Carbon Gap is an independent, Brussels and UK-based non-profit organisation supporting Europe's unique opportunity to lead the responsible deployment of carbon dioxide removal (CDR) to fight climate change through independent and science-led advice.

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