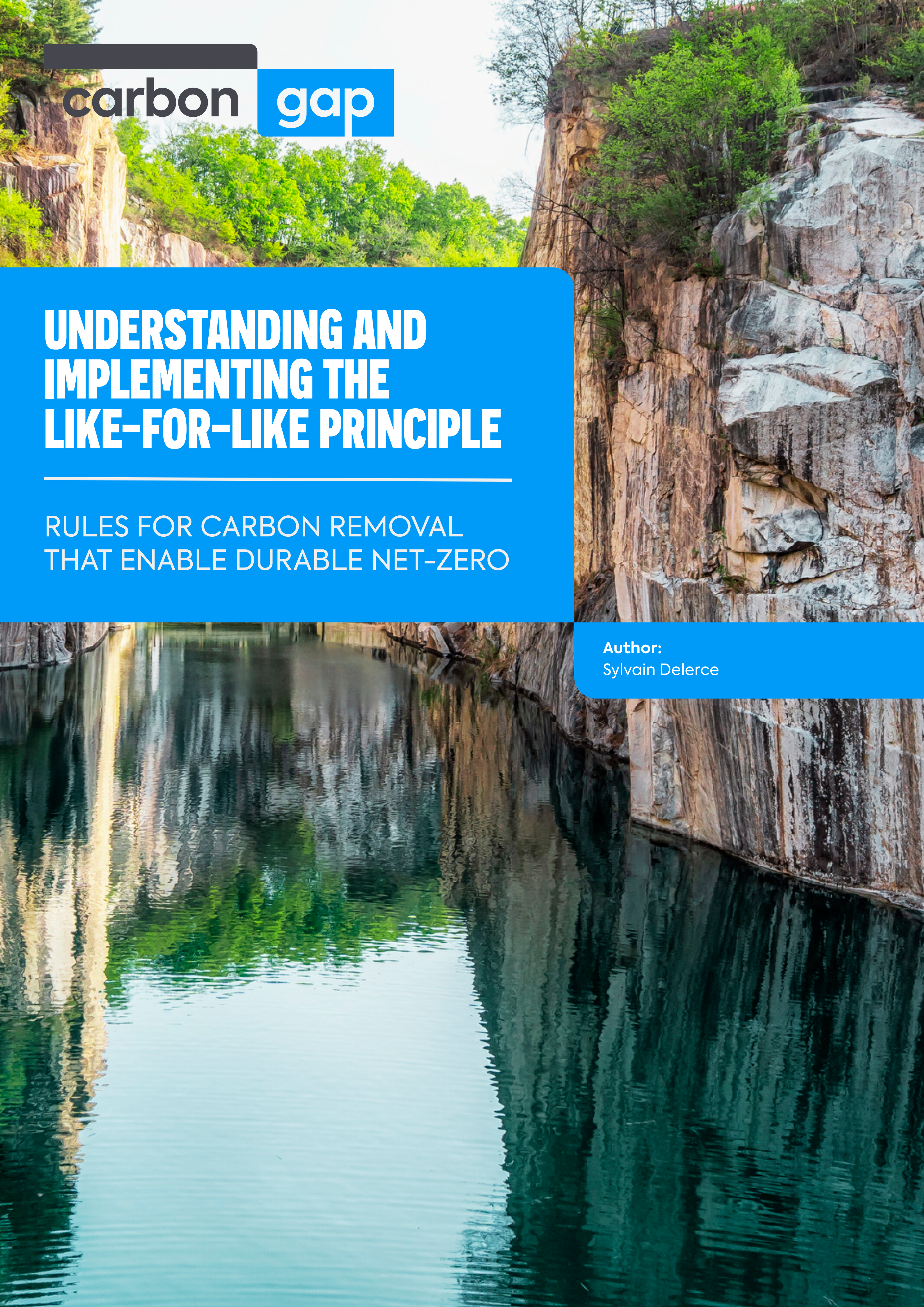

carbon gap

UNDERSTANDING AND IMPLEMENTING THE LIKE-FOR-LIKE PRINCIPLE

RULES FOR CARBON REMOVAL THAT ENABLE DURABLE NET-ZERO

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KEY TAKEAWAYS

- To effectively halt global warming, **net-zero CO_2** must be sustained in the long run. This requires a state of "**durable net-zero**", where carbon fluxes are rebalanced with the appropriate removals, and carbon pools are stabilised.
- The Like-for-Like (LfL) principle establishes **minimum requirements** for employing carbon dioxide removal (CDR) to durably neutralise residual emissions:
    - Any remaining fossil CO_2 emissions can only be neutralised using permanent CDR.
    - Biogenic removals can be used to neutralise residual biogenic emissions, such as those from agriculture, land use change, or the temporary warming effect of methane matching their duration.
- By creating robust rules for neutralisation, the LfL principle strengthens the incentive to cut emissions, clarifies the use cases of temporary removals and creates the demand for permanent CDR to scale up to the relevant volumes.
- The implementation of the LfL principle faces a series of challenges in the short term, among them limited supply and the high costs of permanent removals.
- Carbon Gap recommends enshrining the LfL principle in legislation now and creating mechanisms for a gradual implementation.

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GLOSSARY

CDR: carbon dioxide removal

Contribution: contribution refers to purchasing or generating removals without pursuing compensation (offsetting) goals, hence without using removals to compensate for continued emissions.

Durable net-zero: a state where remaining anthropogenic GHG emissions are balanced with anthropogenic removals such that carbon fluxes are balanced and carbon pools stabilised, creating a long-lasting equilibrium that effectively halts global warming.

ESABCC: European Scientific Advisory Body on Climate Change.

GHG: greenhouse gases, the four main ones being carbon dioxide, methane, nitrous oxide and chloro-fluorinated gases.

$GTCO_2$ / $MTCO_2$ – gigatonnes/megatonnes of CO_2 (one billion/ one million metric tonnes of carbon dioxide).

Global warming potential (GWP): a measure of how much heat is trapped by a greenhouse gas in the atmosphere relative to carbon dioxide (CO_2) over a specific time period. It is expressed as a multiple of the warming caused by the same mass of (CO_2), so by definition CO_2 has a GWP of 1.

IPCC: Intergovernmental Panel on Climate Change.

Legacy emissions: refers to GHG emitted in the past.

LfL: Like-for-Like

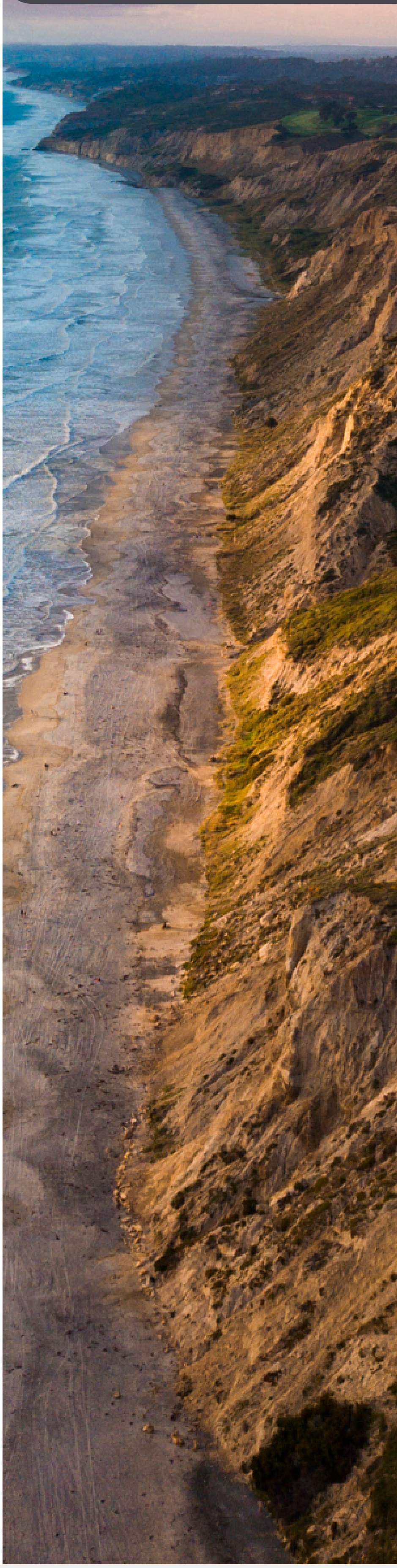
LULUCF: Land use, Land use change and forestry

Novel CDR: CDR methods that generally have a lower level of readiness for deployment and are therefore currently deployed at smaller scales. The captured carbon is stored in geological formations, the ocean or products. Such methods include Bioenergy with Carbon Capture and Storage (BECCS), Direct Air Carbon Capture and Storage (DACCS), enhanced rock weathering, biochar, mineral products and ocean alkalinity enhancement.

Permanence (permanent): in this paper we use "permanent" removals to refer to the physical permanence of the storage allowed by the methods, depending on how and where they store the carbon.

Photolysis: chemical degradation of reactants due to light.

Residual emissions: in this paper, we use the term "residual emissions" to refer to those emissions that are hard or impossible to abate at a given point in time for technical and/or socio-economic reasons. The pool of such emissions is therefore expected to shrink as societies transition and more technological alternatives become available.



1. INTRODUCTION

The beginning of the decade has seen carbon dioxide removals (CDR) grow and materialise in a diverse set of methods[1] generating equally diverse climate benefits. The evolving roles of carbon removal in reaching our climate goals have also been clarified, notably in the 6th assessment report of the IPCC.[2]

In the nascent policy landscape fostered by this growth, the Like-for-Like (LfL) principle has emerged as one of the main discussion points for industry players, researchers, and policymakers alike. It has even begun to shape regulation, for example in the EU Parliament's position on the Green Claims Directive requiring companies to use only permanent removals for claims based on the neutralisation of fossil emissions.[3]

The LfL principle proposes guidelines for using carbon removals to neutralise residual emissions in order to reach durable net-zero, a sustainable state that would effectively halt global warming and can be maintained over the long term. In simple terms, the LfL principles maintains that fossil emissions should be compensated for with permanent removals and biogenic emissions with biogenic removals so the carbon cycles restabilise. In practical terms, the execution of the LfL principle is more nuanced, specifically around carbon fluxes (the amount of carbon that moves around the carbon cycle) and the varying lifetimes of different greenhouse gases (GHGs). This two-pronged definition has led to multiple interpretations of the LfL principle, preventing the emergence of a consensus and hindering its adoption.

In this brief, we review the **origin** of the LfL principle and its role in defining net-zero strategies towards durable net-zero. We analyse the two parts of its **definition** – on carbon fluxes and GHG lifetimes – to show that they are complementary and explain that they apply differently to the different GHGs in a meaningful approach to matching removals with residual emissions.

Following the initial examination of the LfL principle, we review the challenges posed by its **implementation** and provide a series of recommendations to enshrine it in legislation while progressively creating the conditions required for its full implementation.

1 *See Carbon Gap*

2 *IPCC, AR6 WGIII report (2022), chapter 12.3; SPM C 11.4*

3 *European Parliament (2024), Report on the proposal for a directive of the European Parliament and of the Council on substantiation and communication of explicit environmental claims (Green Claims Directive)*

2. THE ORIGIN OF THE LIKE-FOR-LIKE PRINCIPLE AND THE SCIENCE BEHIND IT

The Paris Agreement of 2015 describes the necessity to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of the century".[4] While the document strengthens the concept of net-zero as a key milestone in the fight against climate change, it lacks precision on how sinks should be deployed and used. Since then, consensus has grown on the need for net-zero and an increasing number of actors have committed to net-zero targets.[5]

The exploration of the many possible scenarios to meet the net-zero goals has illustrated how the Paris Agreement framework allows for a lot of leeway in the quantity of ongoing emissions and associated removals at net-zero; some low emissions scenarios require minimal amounts of removals while other scenarios with high remaining emissions require large-scale removals. This ambiguity has sparked intense debates on the levels of residual emissions,[6,7,8] and on how net-zero targets can be used to perpetuate emissions.[9]

> ***Reaching and sustaining net-zero global anthropogenic CO_2 emissions and declining net non-CO_2 radiative forcing would halt anthropogenic global warming on multi-decadal timescales***
>
> *A.2.2. IPCC Special Report on Global Warming of 1.5 °C (2018)*

Yet within these varying scenarios, one principle is clear: **to effectively halt climate change over multi-decadal timescales, net-zero must be sustained.**[10]

To understand what makes a net-zero state sustainable, in the following sections, we explore how the natural carbon cycle works, and how GHGs behave once they are released into the atmosphere.

2.1 Natural carbon cycle(s)

Carbon is naturally cycled through four main pools on a continuous basis: the biosphere (terrestrial and marine ecosystems), the atmosphere, the oceans, and the lithosphere (Earth's crust). The different timescales and magnitudes of the carbon flows between these pools have led to the definition of two sub-cycles:[11]

- **The fast carbon cycle** involves surficial pools (atmosphere, biosphere and oceans). It moves several hundreds of $GtCO_2$ every year which creates the seasonal oscillation of the atmospheric CO_2 concentrations first demonstrated on the Keeling curve.[12] The average turnover time (the average time it takes for one molecule to run through the full cycle) in the fast carbon cycle is equivalent to one human lifetime.
- **The slow carbon cycle** involves exchanges between the surficial pools and the lithosphere, mostly through volcanism and the weathering of silicate rocks. It only moves approximately 1 $GtCO_2$ per year. The average turnover time is in millions of years.

4 *UNFCCC (2015) Paris Agreement, article 4.1.*
5 *Net Zero Tracker (2025)*
6 *Buck et al. (2023) Why Residual Emissions Matter Right Now*
7 *Lund et al. (2023) Net Zero and the Unexplored Politics of Residual Emissions.*
8 *Smith et al. (2024) Residual Emissions in Long-Term National Climate Strategies Show Limited Climate Ambition*
9 *Van Coppenolle et al (2023) Reframing the climate debate: The origins and diffusion of net zero pledges*
10 *IPCC (2018) Special Report on Global Warming of 1.5 °C, A 2.2.*
11 *Berner, R.A. (1999) A New Look at the Long-term Carbon Cycle*
12 *NOAA (2025) Global Monitoring Laboratory*

Figure 1 displays the structure of the fast and slow carbon cycles, the flows that connect them and their respective magnitudes.

In nature, carbon is sustainably transferred across two carbon cycles with different timescales & flow quantities

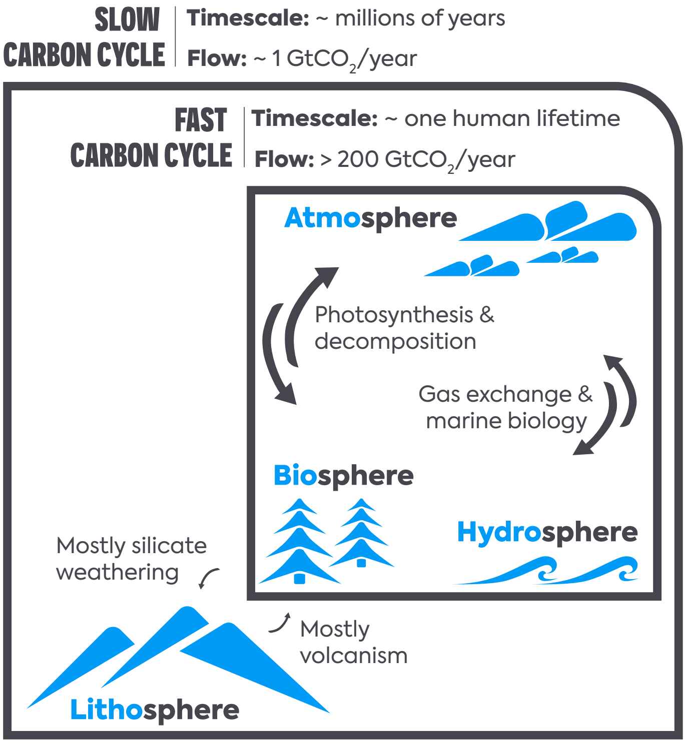


Figure 1: A simplified representation of the natural carbon cycle composed of the fast and slow carbon cycles.[13]

13 See also IPCC (2021), AR6, WG1, Chapter 5,6 box 5.3

In the fast carbon cycle, carbon is stored in biomass through photosynthesis and then released through decomposition; gas exchange in the ocean also stores and releases carbon. This fast uptake to and release of emissions from the oceans and lands[14] allows for a relatively **rapid equilibrium** between surficial pools (atmosphere, biosphere and oceans). The current uptake of CO_2 from the ocean and the biosphere is a response to the fast increase in atmospheric CO_2 concentrations. As soon as additions to the atmosphere cease (net-zero), this natural uptake will slow down and progressively cease (over multiple decades)[13,15].

The lithosphere is the primary carbon storage pool of the slow carbon cycle, with carbon stored in rocks, minerals, and sediments. Although its fluxes appear small compared to those of the fast carbon cycle, a feedback mechanism between the emissions (volcanism) and uptake (weathering) in the slow carbon cycle - coined "the earth's thermostat"[16] - has **held atmospheric temperature and CO_2 concentrations relatively stable over hundreds of thousands of years.**[17]

2.2 Current net-zero strategies

The main perturbations to the natural carbon cycle result from human interventions.[18] The combustion of fossil fuels increases the transfer of stable carbon from the slow carbon cycle to surficial systems (fast carbon cycle), and deforestation reduces the storage capacity of the biosphere in the fast carbon cycle. The magnitude and speed of the perturbations created exceed by far the capacity of the natural feedback mechanism over human timescales. As a result, CO_2 accumulates in the atmosphere, biosphere and oceans, and the earth's climate warms up.

14 Shields, G.A. Carbon Cycle in Encyclopedia of Geology, (2005) p. 335-345

15 Jones et al. (2016). Simulating the Earth System Response to Negative Emissions

16 Walker et al. (1981) A Negative Feedback Mechanism for the Long-term Stabilization of Earth's Surface Temperature

17 Falkowski et al. (2000) The Global Carbon Cycle: A Test of Our Knowledge of Earth as a System

18 Berner, R.A., (1999) A New Look at the Long-term Carbon Cycle

Currently, carbon is unsustainably transferred to the atmosphere and surface pools, causing climate change

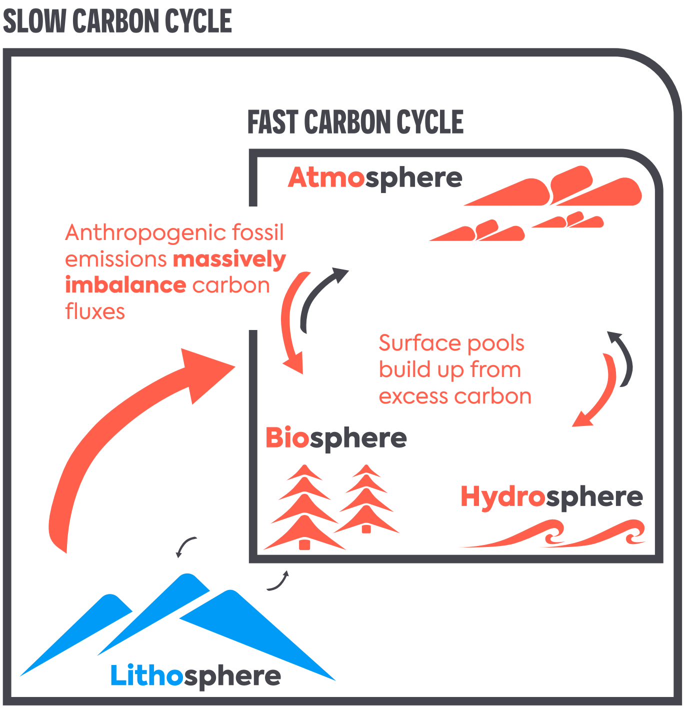


Figure 2: Anthropogenic perturbations to the natural carbon cycles.[19]

[19] See also IPCC (2021). AR6, WG1, Chapter 5.6 box 5.3

Existing plans to re-equilibrate these perturbations and reach net-zero rely largely on cutting emissions and compensating for residual emissions with some CDR methods, but fall short of the volumes needed to limit warming to 1.5°C (the CDR gap).[20] Efforts primarily focus on preserving natural land sinks (also called passive uptake[21]) and building up biogenic removals[22] despite concerning trends in the natural capacity of forests and ecosystems to keep acting as sinks.[23] Such plans perpetuate the transfer of stable carbon from the lithosphere to the biosphere by neutralising fossil emissions with biogenic removals. As the biosphere carbon pool builds up, it increases the risk in case of reversal or saturation.[24] Figure 3 depicts the current architecture of net-zero strategies.

Existing net-zero plans lead to the unsustainable transfer of fossil carbon into the biosphere

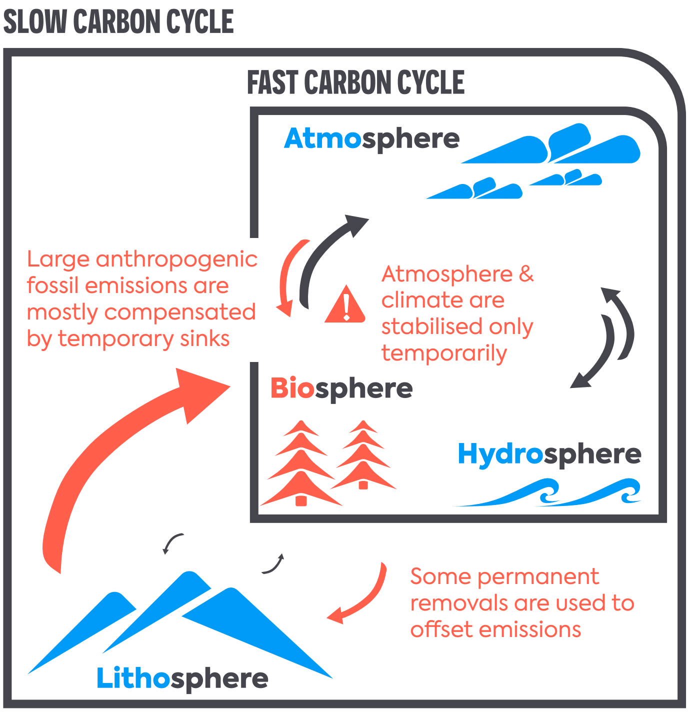


Figure 3: Architecture of the current plans to reach net-zero

20 Lamb et al. (2024) The carbon dioxide removal gap.

21 Allen et al. (2022) Net Zero: Science, Origins, and Implications

22 Dooley et al. (2024) Over-Reliance on Land for Carbon Dioxide Removal in Net-Zero

23 Van Der Woude et al. (2023) Temperature Extremes of 2022 Reduced Carbon Uptake by Forests in EuropeClimate Pledges

24 Nabuurs et al. (2013) First Signs of Carbon Sink Saturation in European Forest Biomass

As illustrated, current net-zero plans could temporarily stabilise the CO_2 concentration in the atmosphere but would fail to rebalance carbon fluxes. These plans would therefore perpetuate the buildup of carbon pools in the biosphere while increasing the risk that these sinks will be reversed. Such a net-zero state, therefore, comes at large risk of reversal and is not sustainable in the long run.

2.3 Reaching durable net-zero

The latest stocktake of the Net Zero tracker[25] reports 148 countries with net-zero targets[26] covering 87% of global emissions and 93% of global GDP. But the plans to reach these targets vary significantly in how they are built, raising legitimate concerns about their relevance to the Paris Agreement's climate goal. The definition of **durable net-zero** brings clarity in this context.[27]

To halt the temperature increase over the coming decades, net-zero CO_2 must be sustained in the long term.[28,29] To do so, **carbon fluxes must be rebalanced** to prevent the continued accumulation of carbon in the fast carbon cycle. One key requirement is to neutralise residual emissions with removals of similar or greater permanence. In practice, this condition means fossil carbon must be returned to long-lasting carbon pools through permanent removals, while biogenic carbon can be returned to the biosphere through photosynthesis.

Additionally, the balancing of non-CO_2 emissions must be of **similar or greater duration/ lifetime**[30] to effectively offset their warming effect. For methane, emissions reductions is the most effective mitigation strategy. Yet, even under ambitious climate policy, some methane will remain hard to abate[31]. Hence, carbon removals could prove useful to address part of the climate impacts of methane for temperature stabilisation.

Finally, **passive CO_2 uptake from natural sinks** cannot be used to neutralise continuing emissions in a durable net-zero state. These passive sinks are not "removals" as per the IPCC definition[32,33] since they do not result from human activities. LULUCF emissions accounting in the EU currently includes both active CDR removal and passive uptake without differentiating them.

Figure 4 illustrates the state of durable net-zero. Carbon fluxes are rebalanced, bringing the main carbon pools back to equilibrium, hence stopping global warming durably.

Durable net-zero is reached when fluxes are balanced and stable. Climate is therefore sustainably stabilised

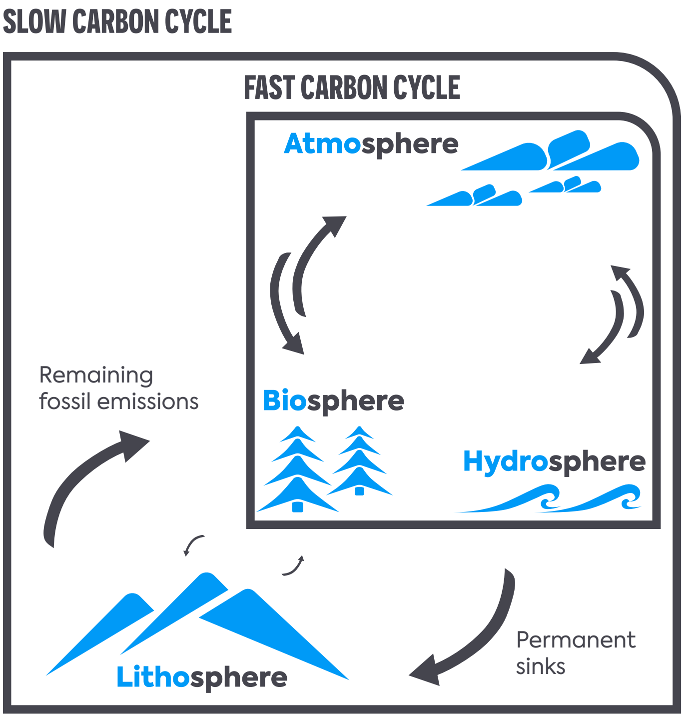


Figure 4: In a durable net-zero state, carbon fluxes are rebalanced and all the carbon pools are stabilised.

25 *Net Zero Tracker (2025)*

26 *With varying degrees of integrity and coverage.*

27 *Fankhauser et al. (2022) The meaning of net zero and how to get it right*

28 *Allen et al., Net Zero: Science, Origins, and Implications. (2022)*

29 *IPCC, Special report on 1.5°C (2018), SPM section A.2.2.*

30 *Allen et al. Net Zero: Science, Origins, and Implications (2022).*

31 *Byers et al., AR6 Scenarios Database. (2022)*

32 *Allen et al., Geological Net Zero and the need for disaggregated accounting for carbon sinks. (2024)*

33 *IPCC, Information note: Removal activities under the Article 6.4 mechanism (2022)*

3. UNDERSTANDING THE LIKE-FOR-LIKE PRINCIPLE

The Like-for-Like **principle** is the practical implication of aiming for **durable net-zero.** It defines the minimum requirements for neutralising residual GHG emissions toward this goal. Importantly, it only applies for neutralisation/compensation purposes (as opposed to other use cases such as contribution)

3.1 Definition

Like-for-Like neutralisation requires balancing anthropogenic GHG sources with removals by sinks of similar or greater permanence than the carbon pool the emissions originate from and/ or the GHG atmospheric lifetime.[34]

The **objective** is to ensure that neutralisation efforts generate an equivalent or superior climate benefit in the long term, compared to the damage they intend to compensate. It also enables rebalancing the carbon fluxes between the fast and slow carbon cycles.

How the LfL principle translates in practice is specific to each GHG, depending on its behaviour once released in the atmosphere and whether the GHG can then be actively removed from the atmosphere. The main GHGs and how they behave are outlined in the section below.

3.2 Using the LfL principle for neutralising greenhouse gases

The main greenhouse gases - carbon dioxide, methane, nitrous oxide and fluorinated gases - have different fates once emitted into the atmosphere due to their varying levels of reactivity (whether transformed or degraded) and the processes by which they can be recaptured/removed. These variations have implications for implementing the LfL principle. The main greenhouses gases and their characteristics are outlined in Table 1.

Greenhouse gas	Durability/ Lifetime[35]	Global Warming Potential over 100 years[36]	Origins	Main processes reducing atmospheric concentrations	Contribution to climate change[37]	Active removal possible	Mitigation strategies
CO_2 Carbon dioxide	Centuries-Millennia, subject to fluxes	1	Fossil and non-fossil	Reabsorption by sinks	66%	Yes	Reduce emissions, Increase removals
CH_4 Methane	12 Years	23	Fossil and non-fossil	Photo chemical degradation (CO_2 as sub-product)	16%	Very early stage	Reduce emissions; Wait
N_2O Nitrous oxide	109 Years	296	Fossil and non-fossil	Photo chemical degradation into NO and O_2	6%	Very early stage	Reduce emissions; Wait
F-gases Fluorinated gases	5-50,000 Years	120-22200	Synthetic	Destruction and artificial decomposition	12%	No	Reduce emissions; Wait

Table 1: Characteristics of the main GHGs defining their fate in the atmosphere

34 Adapted from Allen et al. (2022) Net Zero: Science, Origins, and Implications.
35 IPCC (2021) AR6: The Physical Science Basis
36 IPCC (2018) Special Report on 1.5
37 As shares of global radiative forcing, NOAA, (2023) Annual Greenhouse Gas index

3.3 Neutralising residual CO_2 emissions

Carbon dioxide is largely unreactive but naturally reabsorbed through various processes like photosynthesis, air-sea exchange, or the weathering of silicate rocks. Therefore, the atmospheric CO_2 concentration depends primarily on the relative magnitudes of the fluxes (how much carbon is flowing through) to and from the atmosphere (or the relative strength of sources and sinks), affecting the average residence time of CO_2 molecules.

> ***"Carbon dioxide does not have a specific lifetime because it is continuously cycled between the atmosphere, oceans and land biosphere and its net removal from the atmosphere involves a range of processes with different time scales."***
>
> *TS 2.1, IPCC, AR4, Technical summary (2007)*

For CO_2, direct removal from the atmosphere is possible using CDR methods which allow for direct equivalence; for each molecule of CO_2 emitted, one molecule of CO_2 is removed. A variety of CDR methods are under development, most of them mimicking natural absorption processes.

The LfL principle aims to rebalance carbon fluxes between the short and long carbon cycles. In practice, it requires fossil CO_2 emissions to be neutralised with permanent removals while biogenic CO_2 emissions can also be addressed with biogenic removals.

3.4 Neutralising residual CH_4 emissions

Methane (CH_4) is a powerful GHG and the composition of residual/excess emissions at net-zero is expected to include a larger share of methane than it represents today.[38]

While the removal of atmospheric CH_4 is being researched[39,40] and developed[41], no viable method currently exists at commercial scale to remove it directly from the atmosphere.[42,43,44] (see Table 1). Therefore, CH_4 cannot be neutralised directly, molecule to molecule.

Once released in the atmosphere, CH_4 is reactive to atmospheric components, in particular to hydroxyl radicals (OH). It degrades into CO_2 and water over an average period (or lifetime) of 8 to 12 years[45,46]. Therefore, the impact of CH_4 on climate is composed of a strong short-lived effect for the first ~12 years and a less potent longer-term effect due to the resulting CO_2 molecule.

Using CDR to neutralise the climate impacts of CH_4 involves using equivalence factors. Equivalence factors between CH_4 and CO_2 must be selected carefully depending on the objective and accounting period, especially considering that CH_4 is a much more potent greenhouse gas than CO_2.

38 *Harmsen et al. (2020) The role of methane in future climate strategies: mitigation potentials and climate impacts.*

39 *Liu et al. (2023) Photocatalytic Conversion of Methane: Current State of the Art, Challenges, and Future Perspectives*

40 *Abernethy and Jackson (2024) Atmospheric Methane Removal May Reduce Climate Risk*

41 *Bennu (2025) Destroying Methane, Turning Back the Climate Clock*

42 *National Academies of Sciences, Engineering, and Medicine (2024) A Research Agenda Toward Atmospheric Methane Removal*

43 *Jackson et al. (2021) Atmospheric Methane Removal: A Research Agenda*

44 *National Academies of Sciences, Engineering, and Medicine (2024).*

45 *Saunois et al. (2024) Global Methane Budget 2000–2020*

46 *IPCC (2021) AR6: The Physical Science Basis*

3.5 Determining CH_4 equivalence to CO_2

One proposed equivalence metric is the GWP100, defined as the global warming potential over 100 years and was first suggested by the IPCC in 1990[47] to enable a conversion of greenhouse gases into CO_2 equivalents. While it is the established metric for the national reporting of Parties to the Paris Agreement, the 100-year period is generic and not relevant for all uses. GWP20 (the same metric but over a 20 years period) more closely reflects the characteristics of the short-lived warming effect of a methane emission, delivering 82.5 times more warming than CO_2 over 20 years, but the same limitations apply.[48] A more dynamic metric like the GWP* accounts for the rate of change of a gas in the atmosphere, which is what determines the warming effect in the case of methane.[49,50] Finally, other equivalence approaches are based on the economic cost due to the emission of either gas. The social cost of methane to social cost of carbon ratio would yield similar values as the GWP100[51] or higher depending how the cost is calculated and the type of removals involved. It is worth noting that the appropriate equivalence ratios between GHGs are still subject to debate.[52]

In practice, we propose that the temporary warming effect of residual methane emissions could be balanced out by stacking multiple CDR units to match the warming effect of methane. The difficulty lies in finding the right equivalence metric for such a short timeframe. The newly proposed GWP* could be a candidate. A recent study proposed a ratio between the social cost of methane and the social value of an offset, indicating that 87 units of 30-year removals could effectively neutralise the effects of 1 tonne of methane[53]. However, a scientific consensus on the appropriate ratio still has to be found.

47 *IPCC (1990) Climate Change: The IPCC Scientific Assessment*

48 *IPCC (2021) AR6: The Physical Science Basis*

49 *Allen et al (2024) Geological Net Zero and the need for disaggregated accounting for carbon sinks.*

50 *Lynch et al. (2020) Demonstrating GWP*: A Means of Reporting Warming-Equivalent Emissions That Captures the Contrasting Impacts of Short- and Long-Lived Climate Pollutants."*

51 *Azar et al. (2023) The social cost of methane.*

52 *IPCC (2021) AR6, WG1, Chapter 7, Section 7.6.1.4*

53 *Venmans et al. (2025) Temporary Carbon Dioxide Removals to Offset Methane Emissions.*

Since methane only persists for about a decade, temporary (biogenic) removals could be used to achieve such equivalence and match the duration of the temporary strong warming effect. For the longer-term effect due to the resulting CO_2 molecule, the same rules apply as for CO_2: if the methane is of fossil origin, the resulting CO_2 has to be neutralised with permanent CDR.

3.6 Neutralisation of N_2O and F-gases residual emissions

Nitrous oxide (N_2O) also degrades over time by photolysis and oxidation,[54] but its average lifetime in the atmosphere is longer, about 109 years. The main climate impact of nitrous oxide occurs before it decomposes, but the subproducts of its degradation can also contribute to ozone depletion.[55] These characteristics after decomposition need to be considered to establish equivalences with carbon removals when non-CO_2 pollutants are balanced out at the point of net-zero.

F-gases comprise fluorinated compounds typically used in refrigeration, heat pumps or aerosols. They include hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and other fluorinated compounds. Hydrofluorocarbons (HFCs) represent around 90% of all F-gases. While their atmospheric concentrations are very low, they are potent and persistent GHGs (see Table 1).

Direct removal methods for N_2O and F-gases do not exist. Both gases combine rather long lifetimes and strong warming potentials (see Table 1). They do not involve carbon and are therefore not part of the carbon cycle. Though equivalence factors have also been proposed for these GHG, applying the LfL principle for these gases is more complex and outside the scope of this report.

54 *Tian et al. (2020) A Comprehensive Quantification of Global Nitrous Oxide Sources and Sinks.*

55 *United Nations Environment Programme (2024) Emissions Gap Report 2024: No More Hot Air … Please! With a Massive Gap between Rhetoric and Reality, Countries Draft New Climate Commitments*

4. IMPLEMENTING THE LIKE-FOR-LIKE PRINCIPLE

The LfL principle creates the conditions to reach durable net-zero, a necessary milestone to effectively halt the temperature increase. It is not optional. Yet it raises a series of challenges that need to be addressed to enable its implementation.

4.1 Barriers

Agreeing on permanence

The LfL principle may look like a binary system: permanent versus non-permanent. The reality of CDR is much more nuanced. The permanence of the carbon storage varies across the different CDR methods and sometimes even within a method. Biochar is a good example; its estimated permanence sits in the middle and is highly variable: from decades to millennia depending on its production process and its end use.

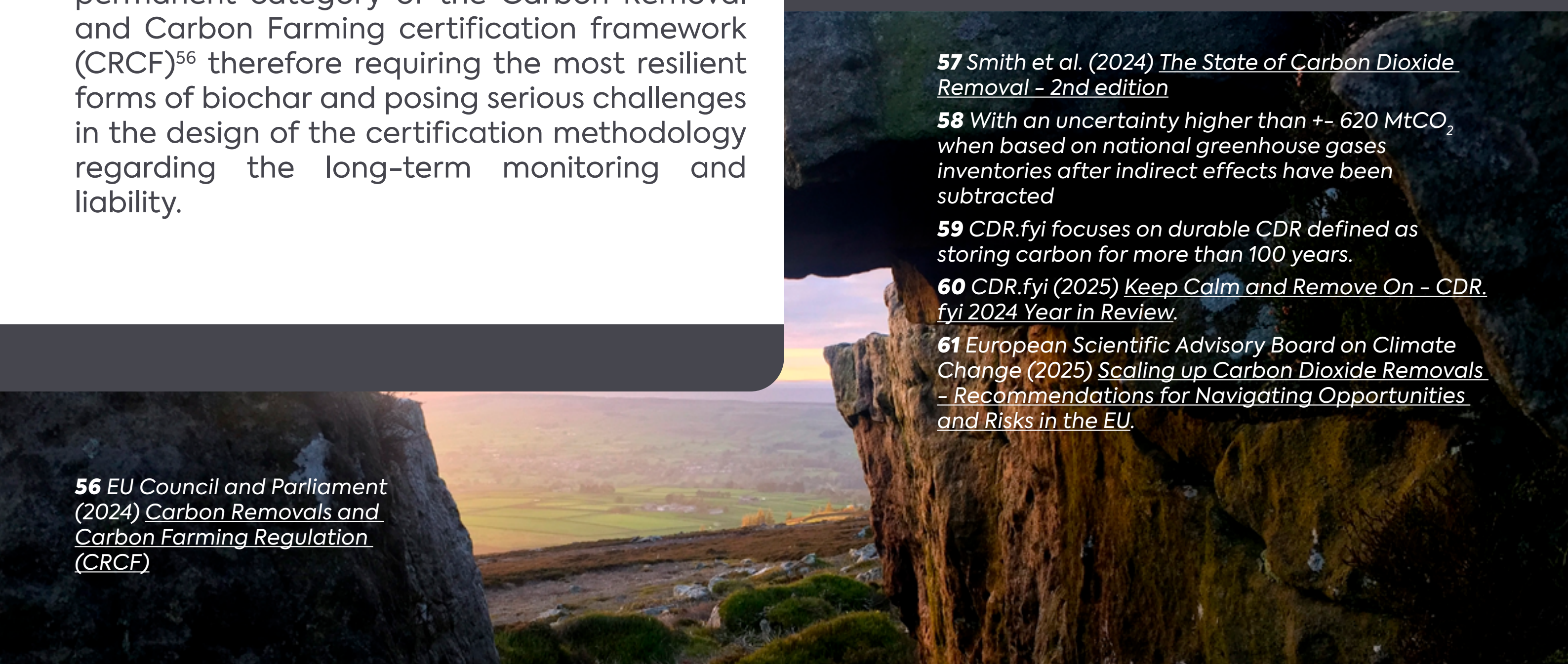
However, implementing the LfL principle requires an agreement between policy makers and regulated entities on what is considered permanent enough to be used to neutralise fossil emissions. Given the stability of the fossil carbon pool over geological timescale, the scientific consensus is that only the most permanent forms of CDR should be used to neutralise residual fossil emissions. In the EU, the regulator eventually included biochar into the permanent category of the Carbon Removal and Carbon Farming certification framework (CRCF)[56] therefore requiring the most resilient forms of biochar and posing serious challenges in the design of the certification methodology regarding the long-term monitoring and liability.

Supply shortage of permanent CDR

In 2024, the State of CDR[57] reported ~2 $GtCO_2$ of total annual removals,[58] with novel CDR representing a mere ~1.3 $MtCO_2$ of which only 0.6 $MtCO_2$ were geologically stored. For the same year, CDR.fyi reported 8 $MtCO_2$ of durable CDR[59] purchased and 318,600 tCO_2 delivered.[60]

The EU is currently planning on having residual emissions of ~400–550$MtCO_2e$/year by 2050, of which ~129–256$MtCO_{2e}$ could be neutralised by permanent removals.[61] There are two orders of magnitude of difference between the global novel (permanent) CDR capacity today and the volumes required only by the EU to neutralise its residual emissions, illustrating a **massive supply gap.**

If compliance with the LfL principle were to be fully mandated overnight at jurisdiction scale, the supply of permanent CDR would fall short of what countries and/or companies would need to comply. The rapid scale up or permanent removals is essential to enable the implementation of the LfL principle, but in the meantime, the lack of supply is a strong limitation that needs to be accounted for.



__56__ EU Council and Parliament (2024) Carbon Removals and Carbon Farming Regulation (CRCF)

__57__ Smith et al. (2024) The State of Carbon Dioxide Removal - 2nd edition

__58__ With an uncertainty higher than +- 620 $MtCO_2$ when based on national greenhouse gases inventories after indirect effects have been subtracted

__59__ CDR.fyi focuses on durable CDR defined as storing carbon for more than 100 years.

__60__ CDR.fyi (2025) Keep Calm and Remove On - CDR.fyi 2024 Year in Review.

__61__ European Scientific Advisory Board on Climate Change (2025) Scaling up Carbon Dioxide Removals - Recommendations for Navigating Opportunities and Risks in the EU.

High price of permanent removals

Another barrier is the high price of permanent CDR. For 2024, CDR.fyi[62] reports prices ranging from 100 to 2000$/ tCO_2 with the weighted average at $320/ tCO_2, down from $490/ tCO_2 in 2023. Meanwhile, conventional (nature-based) removals prices are much lower between 10 and 15$/$tCO_2$ according to Allied Offsets.[63]

Here again, fully applying the LfL principle today would prove incredibly expensive or even impossible for companies with a large share of their residual emissions from fossil origin. The down-costing of permanent removals has already started, as shown by the latest CDR.fyi data. It can be accelerated with supportive policies, but it will take time.

Insufficient demand for biogenic removals

The implementation of the LfL principle also questions the current structure of the voluntary carbon market, where most of the traded credits are biogenic removals. Full implementation of the LfL principle entails swapping and repurposing those biogenic removals - currently used to neutralise fossil emissions - for permanent removals instead. Critics have voiced concerns that the implementation of the LfL principle could therefore, in the short term, translate into a demand drop for much needed biogenic removals, since most of the demand for carbon credits is currently underpinned by fossil emissions.

To follow the LfL principle, these biogenic removals should be repurposed to address residual biogenic emissions, for example from agriculture. Biogenic emissions today represent ~7-12 $GtCO_2eq$/yr, mostly coming from agriculture, land use change and waste. As fossil emissions decrease towards net-zero, the share of biogenic emissions in overall emissions is expected to increase.

The issue is that biogenic emissions are not priced or regulated like fossil emissions, failing to create the necessary incentives and the corresponding demand[64] to effectively repurpose and further grow the biogenic removals needed to address the growing share of biogenic emissions within global emissions volumes.

A competition between biogenic and permanent removals for a limited demand must be avoided by growing the overall size of the addressable market aligned with global CDR needs, including by creating new mechanisms to price biogenic emissions. Carbon Gap welcomes the propositions put forward by the ESABCC in February 2025[64] to better price both emissions and removals in the land sector. This evolution is a key enabler of the LfL principle.

Undefined CDR targets

Targets are key policy measures used to signal the direction of travel and quantified objectives. They are important for holding stakeholders accountable but before that, they are also essential for communicating a **level of ambition** and providing visibility into the future to private actors. Well-specified targets are also essential for establishing **baselines** against which to assess the additionality of CDR activities. Currently, most countries[65] and organisations have net targets, with CDR targets often undefined or not disaggregated between passive uptake, biogenic CDR, and permanent CDR. This lack of specificity in the existing targets results in de facto fungibility of emissions reductions, biogenic and permanent removals, all contributing in unspecified and/or uncapped amounts to the net target.

__62__ CDR.fyi (2024) a Year in Review

__63__ Allied Offsets (2025) VCM 2024 Review & Emerging Trends for 2025

__64__ European Scientific Advisory Board on Climate Change (2025) Scaling up Carbon Dioxide Removals - Recommendations for Navigating Opportunities and Risks in the EU.

__65__ Lamb et al., The carbon dioxide removal gap. (2024)

To support the effective implementation of the LfL principle, countries and private companies need to increasingly adopt separate targets between emissions reductions and removals and "nested" targets, for biogenic and permanent removals (see our brief on separate targets[66]) to reflect the durable net-zero state they aim for and communicate the relative efforts needed on each component.

Carbon accounting rules

To track progress towards the full implementation of the LfL principle, GHG accounting rules need to evolve and require separate accounting between biogenic and permanent emissions and removals. Accounting rules also need to better distinguish natural sinks from anthropogenic CDR, as per the IPCC's definition. This distinction is particularly needed in the LULUCF sector where the net results obscure what is going on with emissions and removals respectively.

The IPCC methodology report on carbon accounting guidelines, expected for 2027, is a key opportunity to mainstream separate reporting in both private and public registries.

4.2 Enabling conditions

Modifications to the existing policy framework are needed to enable the implementation of the LfL principle. Some of them can be achieved in the very short-term by leveraging the revision process of EU regulations in the following ways:

1 **Set separate targets** reflecting the objective of durable net-zero.

The EU and Member States need to adopt separate targets to clarify the relative contributions of emissions reductions and removals to their net-zero targets. They also need to progressively adopt nested targets, that is, specific targets for temporary removals and permanent removals respectively, reflecting the Like-for-Like neutralisation of both residual and historical emissions. While the negotiation of the EU's 2040 target did not allow for the formalisation of separate targets, the EU could still reflect that architecture in the implementation package expected to support the achievement of the -90% objective.

2 **Update GHG accounting rules** to support the granular reporting of the different CDR activities.

The upcoming revision of IPCC's guidelines for GHG accounting will shape how countries and companies will report their climate mitigation efforts in the coming decade. The IPCC must enhance the level of granularity required in the reporting so that temporary and permanent removals are specified in inventories to enable the tracking of progress towards durable net-zero and transparency on whether climate mitigation strategies are compliant with the LfL principle.

3 **Update regulation on biogenic emissions and removals**, notably in the LULUCF sector to create the missing incentives for biogenic removals.

The ESABCC's 2025 report[67] on removals proposes a series of welcome recommendations including that of introducing new instruments to price emissions and reward removals in the LULUCF sector. Such an approach would effectively address the issue listed above and create overdue incentives to use biogenic removals to neutralise biogenic emissions.

66 Carbon Gap (2025) Why Europe needs separate targets for emissions reductions and carbon removals

67 ESABCC (2025) Scaling up carbon dioxide removals – Recommendations for navigating opportunities and risks in the EU

4 **Support supply** with R&I funding, deployment incentives and encourage private investments.

The growth of permanent CDR supply must be accelerated to avoid delaying the implementation of the LfL principle. In our vision for a CDR strategy,[68] we described a policy mix combining upgraded and targeted R&I funding,[69] deployment incentives, and public procurement, alongside leveraging private investments as much as possible to create an array of measures favouring the emergence of a solid permanent CDR supply capacity in Europe. The next Framework Programme (FP10)[70] must provide more and better targeted support to CDR R&I to unlock the full potential of the various CDR methods. The Clean Industrial Deal[71] is the next opportunity to include CDR in the group of strategic approaches to reach EU's climate goals and contribute to the reindustrialisation of the continent.

4.3 Gradual implementation

With all the enabling conditions in place, the supply of permanent CDR will still take some time to scale up, de facto limiting the extent to which the LfL principle can be applied. While it is crucial to enshrine the LfL principle now, a gradual implementation is required to avoid unnecessary market disruptions and unachievable targets in the near future. This timeframe applies both at the country and company level.

Such gradual implementation mechanisms already exist in EU law. For example, the ReFuelEU Aviation initiative proposes a progressive ramp-up of the share of sustainable aviation fuels supplied by EU airports. Similarly, the Net Zero Industry Act[72] has introduced flexibility mechanisms like regulatory sandboxes for a given period to facilitate the adoption of specific technologies. In the private sector, frameworks like the SBTi manage different levels of enforcement to accompany the progressive improvement of companies' mitigation strategies.

Grace period

One option for gradually implementing the LfL principle would be to implement a grace period starting at the entry into force of the principle and lasting for example, five years. In that scenario, EU-based entities would be encouraged, but not obliged, to apply the principle. Following that period, all mitigation strategies in the EU would be mandated to apply the LfL principle.

During the grace period, policy makers should design additional measures at the Member State and EU level to support an increase in permanent removal supply, thus ensuring that by the end of the grace period, permanent CDR volumes will match the demand. On the other hand, countries and companies should transparently report which removal credits they purchased and the source of emissions they intend to balance, proving that they are actively preparing for a mandatory implementation of the principle.

This option has the benefit of giving a clear, tangible, medium-term horizon for the implementation of the LfL principle. However, even with increased public support towards CDR and efforts from entities, there is a risk that the high costs of permanent CDR will deter entities from procuring such credits, making the application of LfL principle highly challenging. This option could also create the risk of a "cliff" effect in permanent CDR demand at the end of the grace period. Furthermore, given the early-stage nature of the permanent CDR industry, it is hard to anticipate a realistic timeframe for the full implementation of the principle.

Such uncertainty, coupled with the risk of a wait-and-see attitude from regulated entities, opens the door to potentially indefinitely postponing the end of the grace period, defeating the entire purpose of this approach.

__68__ Carbon Gap (2024) Envisioning a carbon removal strategy for Europe

__69__ Carbon Gap (2025) Rising to the challenge: Funding CDR research, development & innovation for a net zero competitive EU

__70__ European Commission, (2025) Horizon Europe 2028 - 2034: twice bigger, simpler, faster and more impactful

__71__ European Commission. Clean Industrial Deal (no date) [accessed Sep 2025]

__72__ European Commission: Internal Market, Industry, Entrepreneurship and SMEs, (no date) The Net-Zero Industry Act [accessed Sep 2025]

Increasing percentage obligation

To address some of the shortcomings of the "grace period" option, an alternative could be to introduce an obligation for entities to cover a gradually increasing percentage of their residual emissions following the LfL principle. Such a percentage would increase over time, aiming to reach 100% by a target date.

The option of the increasing percentage has the clear **benefit of implementing a gradual LfL principle obligation from the very beginning**, sending a clear demand signal for permanent carbon removals as soon as the principle is enshrined while delivering a predictable demand signal across the medium and long-term - an essential component to allow the permanent CDR industry to scale-up.

The main challenge this approach creates is that defining the slope of increase is delicate, as it involves multiple moving parameters. It needs to account for both the simultaneous decrease of fossil emissions and the growth of the permanent CDR sector (assumed to be an exponential curve). As a result, the percentage of compliance with the LfL could grow nonlinearly as depicted on Figure 5.

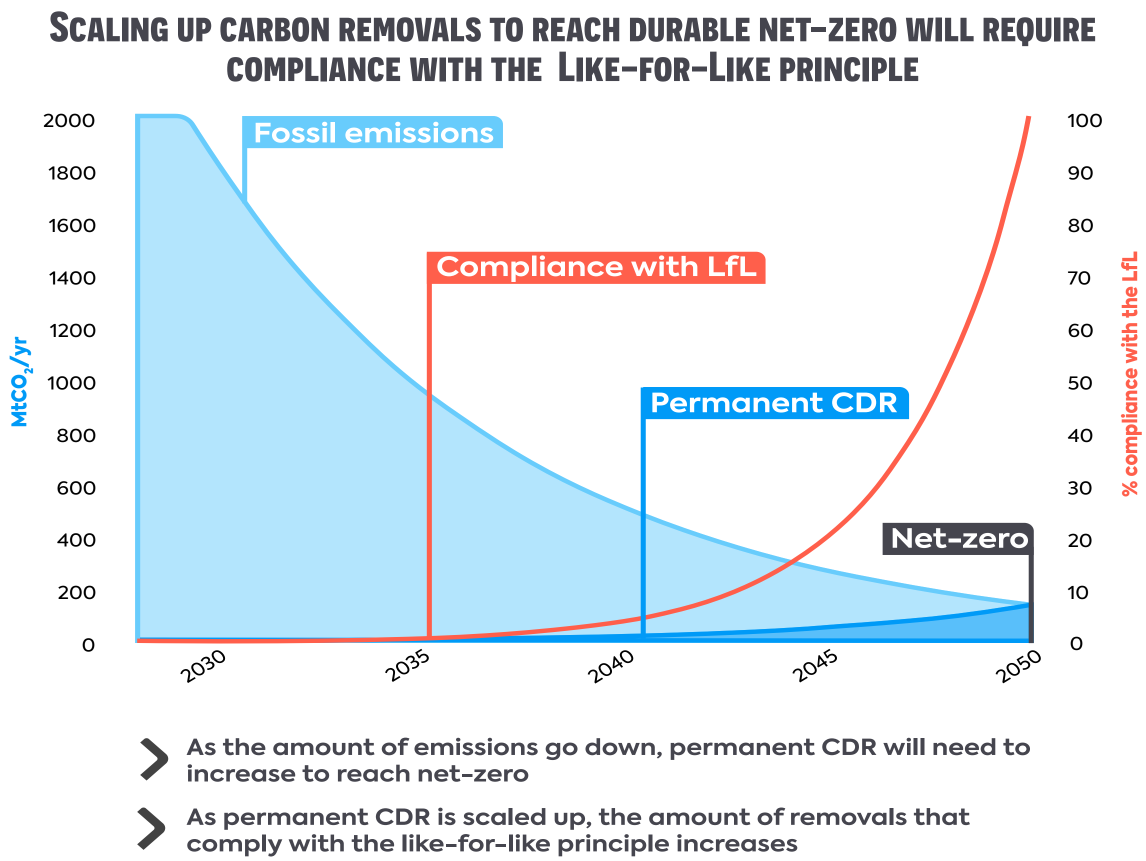


Figure 5: Evolution of the fossil emissions, permanent CDR capacity and resulting percentage of compliance with the LfL. Projected fossil emissions are taken from the EU Commission's impact assessment of 2040 targets[73]. Permanent CDR volumes are projected to grow exponentially until they cover 100% of the residual fossil emissions by net-zero in 2050; The resulting percentage of compliance is depicted in orange and reaches 100% by 2050, following a nonlinear evolution.

A significant mismatch between the real volumes of residual emissions and/or of permanent CDR at any given date would jeopardise the application of this approach. For this reason, the EU should consider some degree of flexibility and a review clause to be sure that the obligation can be adapted over time in case the predictions do not align with the reality of decarbonisation across Europe or the speed of scale-up of the CDR sector.

73 *European Commission (2024) Impact assessment repot on 2040 targets*

Hybrid approach

A third option can be a combination of the first two, with a gradually increasing, but initially indicative, percentage of compliance from the entry into force, paired with a reporting obligation that becomes mandatory after a grace period. This proposed structure could mitigate the risk of the "cliff" effect, with the percentages providing clear guidelines for entities to assess whether they are on track while the reporting allows the regulator to identify those entities accumulating dangerous delays to nudge them back on track.

4.4 Where can the LfL principle be enshrined?

For the EU to reach durable net-zero, the LfL principle needs to progressively become an overarching principle embedded into the complete EU policy mix. In the short term, several policies are being negotiated or revised at the EU level that could provide the first opportunities to enshrine the LfL principle.

The **Green Claims Directive** aims at improving the integrity of environment- and climate-related claims to protect EU consumers from greenwashing and enhance the climate benefits of the carbon credits used to make such claims.[74] The European Parliament's position on this text reflected this logic by including a LfL requirement, allowing companies to neutralise fossil emissions only with permanent removals. This was a major step toward operationalising durable net-zero at the corporate level.

However, progress on the file has stalled: trilogue negotiations were suspended mid-way in 2025 after several Member States withdrew support, leaving the Council unable to confirm its position. The future of the file is therefore uncertain.

The revision of the **European Climate Law** and the adoption of the 2040 climate target also provided a clear option for enshrining the LfL principle, in particular through separate targets; these would specify the relative contribution of gross emissions reductions and removals to the net target, thereby preventing mitigation deterrence. . Nested targets that specify the relative contribution of temporary and permanent removals to the removals target would further strengthen the integrity of the EU's climate strategy and align it with durable net zero.[75]

This architecture gathered significant support from industry, civil society and academics, and was recommended by the European Scientific Advisory Board on Climate Change. Yet, the European Commission's proposal and ensuing political discussions have not embraced this approach.

In 2026, the European Commission is expected to present a legislative and policy package to implement the 2040 target (–90% net GHG emissions compared to 1990 levels) which may provide new opportunities to encode the LfL principle.

Finally, the EU should leverage the upcoming revision of the EU Emission Trading Scheme and the potential integration of removals to enshrine the LfL principle by restricting the integration to only permanent CDR, given that all ETS emissions are from fossil fuels.[76] The revisions of the Land use, land use change and forestry (LULUCF) and Effort Sharing Regulation (ESR) must also be used to improve the management of biogenic emissions creating stronger incentives to reduce them (pricing mechanism) and to neutralise residual biogenic emission with biogenic removals.

Beyond the EU, the recent GGR review led by Alan Whitehead in the UK provided another example (recommendation 1c) of the LfL being increasingly integrated and considered for CDR policy design.[77]

74 *Carbon Gap (2025) How the EU Green Claims Directive can fix corporate climate claims and drive demand for high-quality carbon removal*

75 *Carbon Gap (2025) Why Europe needs separate targets for emissions reductions and carbon removals*

76 *Carbon Gap (2025) Balancing demand incentives with climate integrity: Carbon Gap's views on integrating carbon removals into the EU ETS*

77 *Alan Whitehead (2025) Independent Review of Greenhouse Gas Removals*

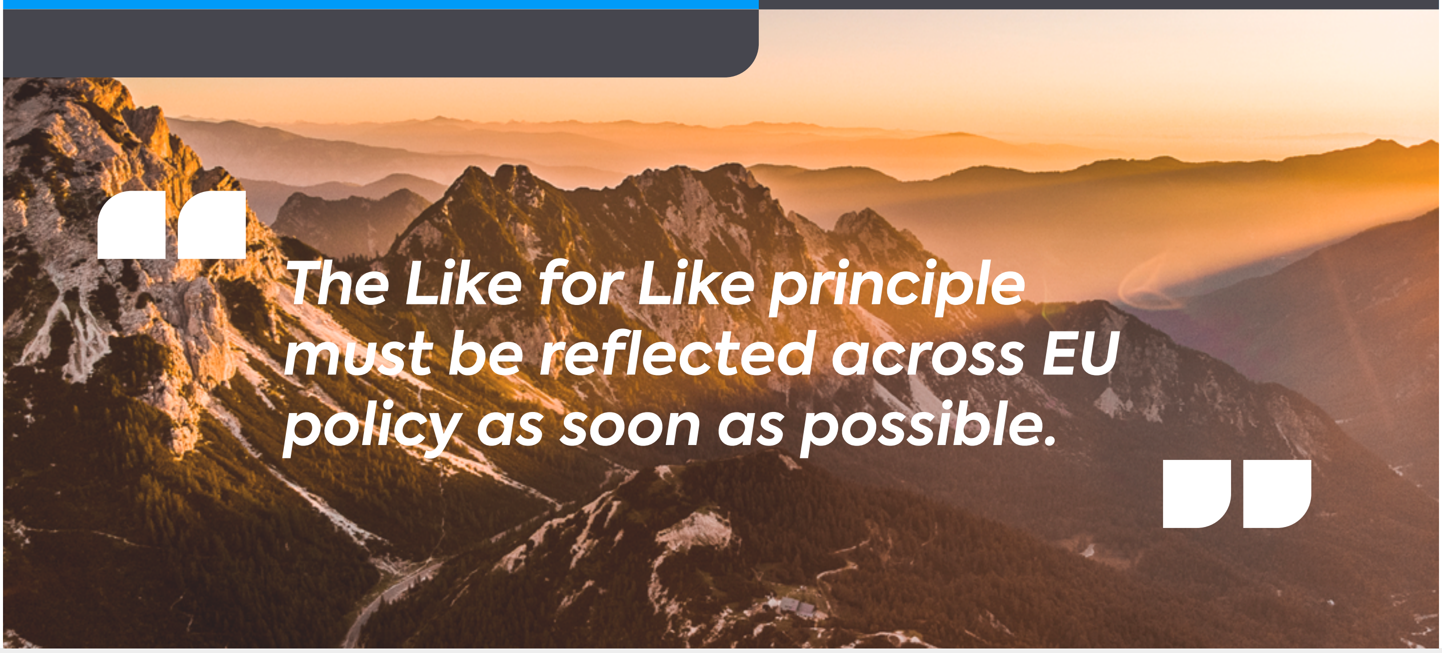
5. CONCLUSION

Delivering on the Paris Agreement and stabilising the temperature increase requires a **durable net-zero state**. The LfL principle is the practical translation of this objective for addressing residual emissions. It aims at rebalancing the carbon fluxes between the fast and long carbon cycles in order to stabilise the carbon pools and effectively neutralise the temporary warming effects of non-CO_2 gases.

The principle applies differently to each of the main GHGs due to their inherent characteristics and the architecture of the natural carbon cycle. **CO_2 residual emissions from fossil origin can only be neutralised with permanent removals. The temporary warming effect of CH_4 can be neutralised using an equivalent amount of temporary removals matching its lifetime**. For other gases, equivalence factors are less well defined making the application of the LfL principle more remote.

Enshrining the LfL principle will boost the integrity and relevance of net-zero strategies, but it will also create a demand signal that permanent removals need to materialise in relevant volumes, clarify the use cases for temporary removals, and strengthen the incentive to cut emissions by making their neutralisation more rigorous and, in the short term, more expensive.

It is urgent to enshrine the LfL principle in law to provide a clear direction of travel and support the refinement of net-zero strategies as soon as possible. Some immediate options for the EU include the revision of the European Climate Law and the upcoming revision of the Emission Trading Scheme. **Carbon Gap recommends reflecting the LfL principle across the EU policy mix as soon as possible but acknowledges the need for a gradual implementation to align with the actual progress of the CDR sector**. Parallel work is also needed to create the enabling conditions for the full implementation, like separate targets, down costing and boosting supply.



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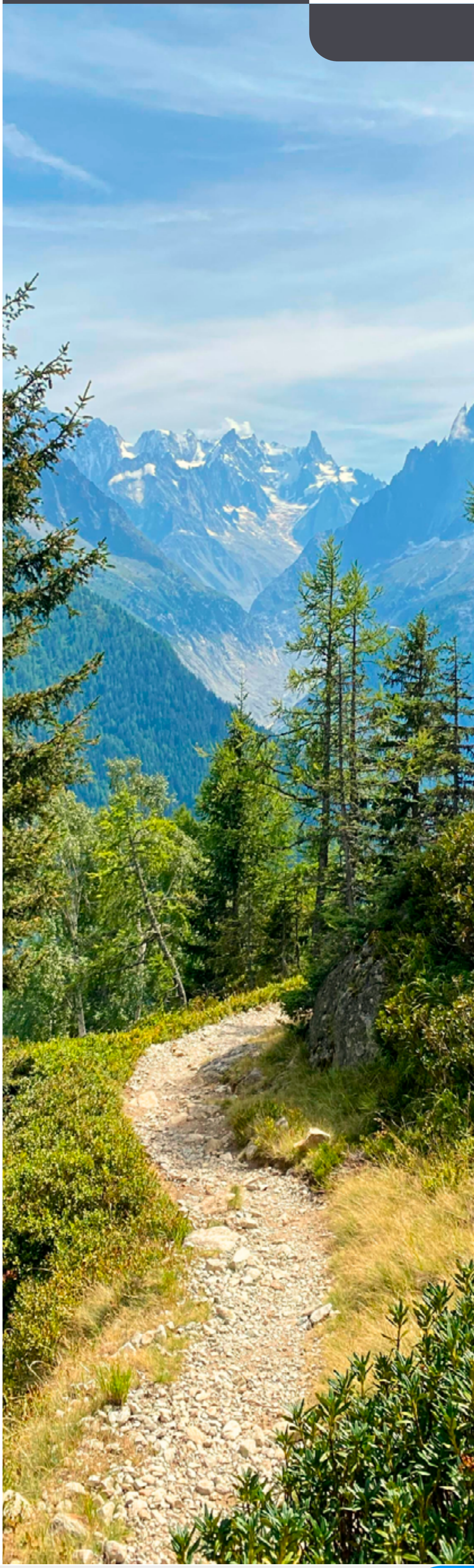

ABOUT US

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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