BRIEFING

Towards climate neutrality

European Parliament

Sustainable carbon cycles

Promoting removal, storage and recycling

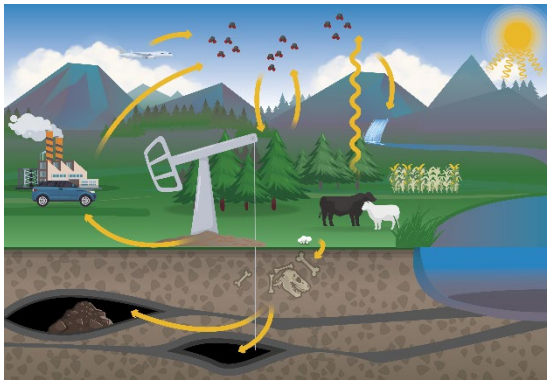
SUMMARY

The European Union (EU) is legally bound by the Climate Law to reach climate neutrality by 2050 and deliver negative emissions from that year on. To do so, carbon emissions must be significantly reduced and any remaining greenhouse gas (GHG) emissions balanced, and subsequently exceeded, by sequestration or removals, to limit and ultimately reverse the warming of our planet.

In its December 2021 communication on sustainable carbon cycles, the Commission outlined various approaches to capture and store or sequester carbon dioxide emissions, or capture already released carbon dioxide directly from the atmosphere to reduce the concentration and thereby its warming effect. Various solutions, both technology- and nature-based, are being brought forward to this end. A key challenge will be to ensure permanence of carbon dioxide removals, whether in underground geological storage or through actively managed natural processes, such as carbon farming and management practices in the land use, land-use change and forestry sectors.

Many products today, such as plastics and chemicals, are produced using virgin fossil-based carbon resources. The Commission therefore also aims to push for product and process innovation to substitute current fossil-based feedstock with sustainably sourced bio-based materials, or through the circular economy, to ensure that carbon integrated in products is recycled and remains stored. More CO_2 transport infrastructure is essential to increase the reuse of captured carbon.

At the end of 2022, the Commission plans to put forward a legislative proposal on a European framework for the certification of carbon removals, which could lead to a market for carbon removals, further incentivising measures to increase carbon sequestration and storage. Ensuring high environmental integrity and adequate monitoring and reporting frameworks is crucial, while also taking into account potential trade-offs or co-benefits of potential solutions.



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Introduction

The EU has set itself, with the adoption of the EU Climate Law, the legal obligation to deliver a climate-neutral economy by 2050 and deliver negative emissions thereafter. To prioritise direct emission reductions, the EU Climate Law sets a limit on the role played by net carbon emissions removal, towards the 2030 target of a 55 % reduction in net emissions compared with 1990. However, for 2050 and beyond, hard-to-abate emissions will need to be balanced by removals to deliver the obligation to achieve neutrality and subsequent negative emissions. Some sectors or subsectors have emissions that are considered difficult or impossible to eliminate, even in the long term. Agriculture is one of the primary sectors where this challenge is present, but transport (especially long haul, aviation and shipping) and some industrial processes are also considered likely to have remaining emissions. Many of the products and manufacturing processes in our economy today rely on fossil-based carbon. This includes, in particular, plastics, pharmaceuticals, chemicals and construction materials such as cement and steel. One should not confuse carbon (C), which is an atom and an element in the periodic table, and carbon dioxide (CO_2), which is a molecule made out of one atom of carbon and two oxygen atoms. CO_2 is produced, for example, when products containing carbon (such as fossil fuels) are burnt in the presence of oxygen. Another key natural process is that of photosynthesis, which is the way plants, with the help of sunlight, absorb CO_2 from the atmosphere and split it into carbon and oxygen; the oxygen is released back into the air and the carbon, together with water and minerals drawn from the ground, enables plants to grow.

The April 2022 Working Group III report of the Intergovernmental Panel on Climate Change (IPCC) states that carbon dioxide removals (CDR) are necessary, with sectoral emissions reduction trajectories determining scale and timing in terms of deployment. With over half of the carbon used in the economy coming from fossil-based sources, the Commission has taken a broader view on the cycles involving carbon and carbon emissions, publishing a communication in December 2021.

The communication (COM(2021) 800) on sustainable carbon cycles lays out how the Commission aim to close the loop on our economy's need for carbon, particularly fossil-based, as a material or feedstock for products through a reuse, reduce and recycle or substitution approach. Furthermore, it addresses CO_2 emissions, looking to increase natural carbon sinks and technological carbon capture, with possible links to utilisation in value chains. As such, the Commission will seek to establish new business models and support innovation while putting an economic value on carbon removals, storage and utilisation to create a market to drive the expansion of CDR.

Types of carbon cycle

Carbon cycles in the Commission communication include natural or technological processes involving either CO_2 emissions or carbon as a raw material. The processes manage and potentially reduce carbon emissions into the atmosphere in three distinctly different ways:

- use – increasing recycling or reuse of carbon feedstock in **products and processes**
- removal – CO2 sequestration by way of **natural processes**
- storage – via at source or direct air **capture of carbon** or **carbon storage products**.

Whereas atmospheric carbon removal – such as through natural carbon sinks or direct air capture (DAC) with storage – reduces the GHG concentration in our atmosphere, point source carbon capture and storage (CCS) – such as from chimney stacks or during the manufacturing process – does not reduce GHG levels, but avoids increasing them.

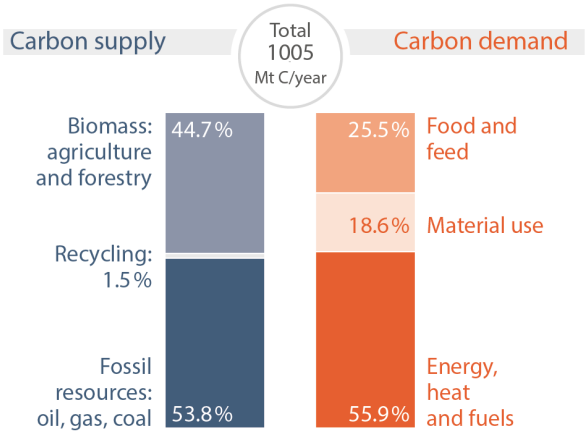
Each of the three processes on how to manage carbon in our economy – be it use, removal or storage – contains diverse approaches that are currently at different stages of implementation, with some yet to be further developed in terms of their market- or technology-readiness level. Integrating the focus on substitution and recycling of carbon into products and processes links industrial policy and climate policy by promoting circularity in resource flows, which in turn can deliver climate and environmental benefits. A 2021 EPRS briefing presents the range of nature-

based or technological CDR solutions. The Commission communication, though broadly encompassing various options for CDR, focuses specifically on short-term actions to promote new business models to incentivise **carbon farming practices** and on upscaling the sustainable capture, recycling, transport and storage of carbon by fostering **new industrial value chains**.

Use – Substitution and recycling of carbon

Carbon as a raw material permeates our economy, and over half of the carbon we use still comes from fossil sources (see Figure 1). Ensuring circularity by recycling or reusing carbon – sourced from waste streams, sustainable biomass or carbon capture – in products, or substituting fossil-based carbon with another material through industrial innovation, could reduce the overall demand for virgin fossil-based carbon and reduce associated GHG emissions. The chemicals industry is the only user of fossil-based carbon for non-energy purposes; in 2018, this amounted to 73.2 million tonnes (Mt) C from fossil resources, according to the 2021 carbon economy report. To address this, the Commission has set the target that, by 2030, sustainable non-fossil sources should cover at least 20 % of carbon use for chemical and plastic products. In its technical assessment accompanying the communication, the Commission further highlights the need to make progress on advanced low carbon biofuels, biogas, biomethane and synthetic fuels to substitute fossil fuels, especially in hard-to-electrify transport sectors such as shipping and aviation. In construction, the substitution of GHG-intensive with bio-based materials is noted, along with the added value of such products delivering a carbon pool of sequestered carbon with delayed emissions, depending on their lifecycle.

Figure 1 – Carbon flows EU-27 (2018)



Note: only recycling of materials and energy is considered here, not recycling of biomass.

Source: EPRS illustration based on COWI et al., Carbon economy report, 2021.

Removal – Carbon farming: A focus on the land manager

Nature-based solutions (NBS) usually include afforestation, reforestation and forest management measures, carbon sequestration in soils, wetland restoration or peatland rewetting, agroforestry and conversion to permanent grassland of cropland or fallow land. The current climate policy framework incorporates NBS primarily under Regulation (EU) 2018/841, adopted following the Paris Agreement, which covers GHG emissions and removals from land use, land use change and forestry (LULUCF). In 2019, the total carbon sequestration capacity[1] of the EU LULUCF sector had decreased by 20 % compared to 2005, a trend which accelerated from 2013. Emissions from agriculture, as an economic sector, are covered under the Effort-sharing Regulation (ESR) (EU) 2018/842. Both regulations are currently under revision[2] as part of the 'Fit for 55' package to align the EU's legislative framework with the EU Climate Law's 2030 targets.

The distinction between NBS generally and carbon farming can easily become blurred. The focus of carbon farming is not necessarily limited to agricultural farms but includes 'actors of the land sectors' – thus potentially extending to land owners and forestry actors. Officially announced in the 2020 farm to fork strategy, the carbon farming initiative was also mentioned in the 2021 EU forest strategy. Whereas many NBS provide carbon sequestration as a public good ecosystem service[3] without a market value, carbon farming aims to increase land management practices that ensure carbon sequestration by way of the market. Managing carbon pools at the level of the land manager involves actively supporting the natural carbon sequestration processes (focusing on the living biomass, (dead) organic matter, and soils), thereby removing atmospheric CO_2 and protecting

carbon stocks. The management practices simultaneously improve conditions for biodiversity and soil fertility due to increased amounts of organic carbon. The carbon farming document accompanying the Commission's communication highlights the most effective examples of practices, while the accompanying technical assessment provides an overview of their mitigation potential. Carbon farming can also incorporate practices to reduce other GHG fluxes, such as methane (CH_4) and nitrous oxide (N_2O), relevant to agriculture. As highlighted in a recent study by Ecologic Institute and IEEP, two headline practices – livestock and manure management, and cropland and grassland nutrient management – could be focus areas.

The market value of carbon farming can be based on either **action-based** or **result-based** payments or a mix of the two (examples of existing schemes are presented in the abovementioned study). Action-based payments can provide financial security at land manager level, but there is uncertainty regarding the mitigation outcomes. Examples of actions or area-based support for carbon farming practices are the common agricultural policy (CAP) eco-schemes. Their implementation depends on individual Member States' CAP strategic plans, approved by the Commission. Result-based payments give flexibility to the land manager over choice of methods, but cause greater uncertainty concerning return on investment, which depends on the mitigation outcomes. Conversely, it can deliver a higher level of credibility to carbon farming actions, due to the verified outputs. A 2021 technical handbook on implementing a result-based carbon farming mechanism, prepared for the Commission, explores the potential of such schemes through five thematic case studies from across Europe. A prerequisite for result-based payment schemes is a robust and transparent monitoring, reporting and verification (MRV) framework.

The communication includes a target to ensure verified emission and removal data by 2028 for every land manager and to deliver 42 $MtCO_2$-equivalent carbon farming land use net removals by 2030.

Storage – Technological solutions to capture and store carbon

The communication presents the role of technology-based solutions (TBS). CCS can play a key role in reducing the quantity of CO_2 released into the atmosphere by capturing it at source and storing it. Capturing CO_2 directly from the atmosphere using direct air capture with carbon storage (DACCS), or using biomass, which has sequestered CO_2, to produce bioenergy with carbon capture and storage (BECCS), are presented as ways to deliver negative emissions. By 2030, the Commission has set the target that DACCS should reach 5 $MtCO_2$ per year.

DAC uses chemical solutions which bind the CO_2 and release the air back into the atmosphere. The method involves either passing the captured air through filters with solid sorbents or using a liquid chemical solution. The process is scalable, which provides flexibility in implementation, and DAC offers a solution to emissions from distributed sources; however, as a recent paper concludes, the technologies are still nascent and require further research and demonstration efforts to lower risk and reach scale. With the first commercial DAC plant launched in 2017, in Switzerland, 19 DAC plants are currently operational, according to the 2021 tracking report of the International Energy Agency (IEA). Most of these are small-scale and sell the captured CO_2 for use. A large-scale plant (DAC1) is scheduled to begin operating in the United States by 2024, starting with a 0.5 $MtCO_2$/year removal capacity, to be increased to 1 $MtCO_2$/year of DACCS. Challenges to overcome for the expansion of DAC involve the heat and energy needs of processes to capture and store the CO_2, as well as the area of land needed for a large-scale plant. For liquid processes, water needs are significant, and transport infrastructure and energy needs depend on whether the captured CO_2 is to be stored permanently or sold for use in products.

The CCS project pipeline took a dive over the last decade, with researchers pointing to the impact on planned CCS projects from the shift away from coal-fired power stations. An unstable policy landscape, public perceptions and a lack of progress on mapping geological storage opportunities are also noted to have affected deployment. The 2021 Global Status of CCS shows the diverse industry application of CCS projects globally, and reported 27 facilities with a capture capacity of 36.6 $MtCO_2$/year in operation, with projects in development surging 48 % from 2020 to 2021,

forecasting a total capture capacity of 149.3 mtCO_2/year.[4] CCS is a proven technology and recognised as essential to curbing hard-to-abate emissions by industry. To deliver negative emissions through DAC or BECCS, the permanent storage aspect of CCS will be needed. Strong regulations and a clear policy direction, with further efforts to reduce perceived risks related to transport and storage, are highlighted in the above publications as key factors for progress.

Business and climate opportunities

While the climate crisis fuels the need for CDR, the Commission communication on sustainable carbon cycles is one of the most direct examples of why the European Green Deal should be considered a growth strategy. Research carried out by Ecologic Institute and IEEP has shown that carbon farming practices can provide benefits in terms of improved soil health, decreased soil erosion, reduced water use and improved conditions for biodiversity while also ensuring more efficient use of fertilisers, which in turn protects surface and groundwater resources. Yet, the knowledge and incentive levels to adopt these practices do not compete with the perceived costs and complexity of implementing some of the changes. For carbon capture technologies, however, the main players so far have been within the oil and gas industry, where various carbon-pricing regimes, combined with the sector's own use of the captured CO_2 for enhanced oil recovery, provide the economic incentive needed to invest in capture technology. Though uptake was slower than expected in the last decade, market analysts are expecting unprecedented growth for the carbon capture utilisation and storage (CCUS) market of almost 14 % annually, leaping from a global market value of US$1.9 billion in 2020 to US$7 billion in 2030. This growth is driven by countries' climate policies and carbon pricing, combined with industry net zero pledges and improvements in both costs and infrastructure. New value chains and products, implementing circularity in carbon flows, will also support this development.

As shown in Figure 1, in 2018 the EU economy required roughly one billion tonnes of biogenic or fossil carbon. Over half of this went towards energy purposes, while a quarter went to food and feed production. Almost 19 % went towards the production of various materials, including textiles and fibres (1 %), animal bedding (11 %), pulp and paper (14 %), construction and furniture (28 %), and chemicals and plastics (46 %). Only 7 % of the carbon needed for chemicals and plastics are of biogenic origin, and it is the only sector to use fossil resources for non-energy purposes. By supporting innovation, cascading principles and implementing circular economy policies, the Commission hopes to improve Europe's autonomy in terms of resource needs. Replacing imported virgin fossil-based carbon with reused captured carbon or using bio-based alternatives could reduce import dependency. The Commission is positive about the potential of the bioeconomy, both in terms of growth and climate impact, but points to the need for further integrated assessments on potential trade-offs and research to determine bio-based products' storage potential.

The IEA net zero 2050 report forecasts 1.6 billion tonnes (Gt) CO_2/year captured globally by 2030, rising to 7.6 GtCO_2 annually in 2050. During a recent presentation, an IEA representative stated that carbon capture in 2050 represents an industry with over US$400 billion in revenue, forming part of the trillion-dollar industry of CCUS. Early 2022 statements showed both ExxonMobil and Occidental Petroleum estimating a US$4 trillion CCS market by 2050. In August 2022, the world's first commercial contract for cross-border transport and storage of CO_2 was signed between the Yara fertiliser company and the Norwegian Northern Lights project. Northern Lights, the transport and storage part of Norway's Longship CCS initiative, is co-owned by Shell, Equinor and Totalenergies.

The rise of carbon markets

The increased focus on the need for climate action has not only resulted in countries' pledges to lower emissions but also triggered commitments by cities and companies worldwide. Net Zero Tracker's Stocktake 2022 shows a surge in net zero commitments from 2020 to 2022. To deliver on such commitments, several companies have started to invest directly in NBS, mainly forest-based, to offset their emissions, or purchase certified offset certificates. Increased demand for certified

carbon offsets have led to a proliferation of voluntary schemes and approaches to deliver these. The global voluntary offset market doubled in value and volume from 2017 to 2018 and is expected to reach US$200 billion by 2050. Ensuring a high level of environmental integrity in certifying and trading carbon offsets is essential to avoid greenwashing and the risk of undermining climate action. Certified offsets must be real, additional, permanent, leakage-proof and avoid double-counting, and the quality or assurance of each of these aspects should be transparent to the buyer. A 2021 report evaluated 12 certification mechanisms, showing significant differences in administrative costs, certification methodologies and approaches to different types of removals. The Commission's 2022 work programme includes a legislative proposal for a carbon removals certification scheme by the end of 2022. At the 2021 climate conference (COP26) in Glasgow, an agreement was reached on Article 6 of the Paris Agreement, including Article 6.4 on a new formal United Nations mechanism for trade in certified emission reductions. Some researchers estimate that the overall Article 6 breakthroughs may trigger annual US$1 trillion financial flows for climate action by 2050. The specific Article 6.4 market mechanism is, however, expected to take years to become operational.

Policy initiatives, obstacles and trends

In 2005, the EU was the first major emitter to establish an emissions trading system (ETS), effectively putting a price on carbon emissions. According to the International Carbon Action Partnership (ICAP), 25 ETS are in operation globally, with the latest additions being those of the United Kingdom and China. An additional 22 are under development or being discussed. Reforms to align several of the ETSs with net zero targets have pushed up carbon prices, which in turn supports climate mitigation actions, including CCUS investments. Several of the Long-Term Low Emissions and Development Strategies (LEDS) submitted under Article 4 of the Paris Agreement mention carbon capture solutions. The 2009 CCS Directive seeks to ensure a coherent European framework, yet some EU Member States do not authorise CCS. Some ETSs allow carbon offsets towards compliance, further supporting investment in NBS. As a sectoral first, the carbon-offsetting scheme CORSIA is being implemented for international aviation, whereby airlines in participating countries must buy carbon credits to offset their CO_2 emissions from international aviation, if above a certain level. Allowing offsets towards compliance requires a certain permanence of the certified sequestration. In the case of the Californian ETS, which allows for forestry offsets, its integrity has been questioned with recent increases in wildfires. In 2021, the United States launched the Carbon Negative Shot to support further development of technological solutions for CDR. In April 2022, an alliance of private investors launched the advance market commitment (AMC) fund Frontier in an attempt to accelerate the development and deployment of CDR technologies; the fund has US$925 million to purchase permanent carbon removals between 2022 and 2030. The Mission Innovation platform includes missions to deliver, by 2030, annual CDRs of 100 $MtCO_2$ and, through innovation, replace 10 % of fossil-based fuels, chemicals and materials with bio-based ones.

The Commission's communication kicks off the process to broaden the market base from industrial CO_2 emissions, covered by EU ETS, to add value to a broader range of carbon cycles within sectors or processes of the economy. The first mention of this broad idea was found in the 2020 new circular economy action plan and carried further in the Commission's 2030 climate target plan, which notes the need to facilitate industry decarbonisation pathways and ensure circularity through EU certification schemes on GHG performance of low-carbon basic materials and carbon removals.

The 2021 synoptic review of carbon removal solutions prepared by the Austrian environment agency analyses the status of both NBS and TBS, including existing standards and MRV frameworks. Examples of standards to support uptake include the French Label Bas-Carbone and the standard of German public-private partnership MoorFutures for peatland rewetting, recently expanded to Lithuania, as well as the many voluntary CDR certification methods and schemes linked to voluntary carbon markets. The Commission stresses the need for further analysis and integrated life cycle assessments to ensure a future EU certification scheme of high environmental integrity, to be coupled with stringent MRV requirements. Furthermore, to support the reuse of carbon from carbon capture, support for the expansion of CO_2 transport infrastructure is considered essential.

European Parliament, Council and EESC positions

As stated in the resolution ahead of the 26th climate conference in Glasgow (COP26), the European Parliament gives priority to direct emission reductions over removals. Despite the primary focus on direct emission reductions, Parliament has acknowledged the need for CDR. In the 2019 COP25 resolution, Parliament called for greater action in implementing commercial-scale industrial CCS as well as DACCS, and reiterated the importance of natural carbon sinks and the significant role of farmers through carbon farming practices. In its 2021 resolution on the new circular economy action plan, Parliament reiterated the role of a circular economy in industrial decarbonisation and called on the Commission to establish a regulatory framework for certification of all nature-based and technological carbon removal solutions, including CCUS.

The Committee on the Environment, Public Health and Food Safety (ENVI) has been preparing an own-initiative report (2022/2053(INI)) on the topic of sustainable carbon cycles. At the ENVI meeting on 11 July 2022, the draft report was presented by the rapporteur, Alexander Bernhuber (EPP, Austria). The final ENVI vote on the report is to take place in early November 2022.

On 7 April 2022, the Council adopted conclusions regarding the Commission communication on sustainable carbon cycles. The Council recognised the need for financial support alongside the CAP to ensure incentives for the agriculture sector to adopt climate-friendly practices. The Council also highlighted the need to take an integrated approach to carbon farming, as agriculture emits other GHGs such as methane and nitrous oxide. Support was given to the idea of an expert group of farmers and foresters to work together with the Commission. The Council stressed the need for information, advice and training for land managers and to ensure a system of high environmental integrity, particularly regarding impacts on biodiversity. The need to create a system that is not too complex and flexible enough to integrate future carbon removal solutions was noted.

During its May 2022 plenary, the European Economic and Social Committee (EESC) adopted its opinion on the Commission communication. The EESC stressed the important role of the land sector and the need to evaluate solutions to its overall impact, be it increased biomass demand or the sustainability of permanent CO_2 storage. The important role of the land sector and the need to secure the commitment of farmers and workers to a transition in practices was noted, also to improve the resilience of rural areas and the overall food system. The EESC finds that the CAP should support this transition, but carbon storage should not be a condition for CAP support.

Expert analysis and stakeholder views

The high energy needs of DACCS and the definition of the concept of 'permanence' when debating storage of carbon emissions have often been raised by a range of experts. For NBS, non-permanence is a major point of debate in the context of increasing occurrences of wildfires and deforestation, with droughts also a risk to sequestration in wetlands. A recent policy brief from the non-profit Bellona Foundation examines three approaches to managing differences in the permanence of CDR solutions.

The director of the World Resources Institute (WRI) has warned of a possible overreliance on BECCS in IPCC scenarios, pointing to the risk of land competition. Climate Action Network Europe (CAN Europe) noted similar issues as a CarbonMarketWatch representative presenting on the topic in February 2022, noting key concepts being mixed in the communication regarding carbon removals versus emissions reductions, and a lack of consideration of biomass sustainability issues and overall reversal risks. CAN Europe also found it problematic that the communication could be seen to promote offsetting, when direct reductions should have priority. Similar criticism of promoting offsets have been brought forward by French non-governmental organisation (NGO) Réseau Action Climat in their analysis of the French standard 'Label Bas-Carbone', which they argue provides the agricultural sector with a compensation tool and not a framework to promote improvements through direct emission reductions. CAN Europe urged the Commission to proceed with caution on a CDR framework.

In their response to the public consultation launched by the Commission, the European Environmental Bureau (EEB) NGO outlined specific NBS to be deployed, stressing that NBS should be the priority, after direct emission reductions, and pointed to the cost, energy, and land issues related to other CDR technologies, saying that CCU is merely a delaying measure. Pointing to the linear nature of EU agri-food systems, the EEB makes recommendations on a hierarchy for biomass use, including cascading principles.

Several responses from business associations, including the European Federation of Energy Traders (EFET) and the Negative Emissions Platform (NEP), call for any future certification frameworks for CDR to be integrated into the EU ETS and advocate a focus on TBS to avoid the risk of non-permanence associated with NBS. From the forestry and agriculture sectors, Copa-Cogeca, the European State Forest Association (EUSTAFOR) and the European Federation of the Parquet industry (FEP) call for the potential of their industries to be unlocked to deliver natural carbon sinks, storage through bio-based products and reductions through material substitution, and not just to be offsets for other sectors. Finally, EuropaBio focuses on the need to support the bioeconomy through cutting-edge technology, in particular biotechnology, to promote sustainable carbon cycles.

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ENDNOTES

1 The concept of GHG stock and flows is relevant here. Emission flows are the total emissions emitted and those sequestered/captured by natural processes. Today, the overall concentration of CO_2 in the atmosphere, the stock, is increasing as nature's carbon sink function cannot keep up with the increase in emissions from human activities.

2 For more information, see the EPRS legislation in progress briefings on revising the LULUCF and Effort-sharing Regulations.

3 In economics, a public good is a commodity or service that is provided without payment to all members of a society.

4 For an updated overview of all CCS facilities and projects, see the CO_2RE database run by the Global CCS Institute.

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