

White Paper

Carbon Capture and Utilisation

The Role of Bio-CCU in Reducing Carbon Emissions



Liquid Wind

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Executive Summary

Carbon Capture and Utilisation (CCU) technologies can contribute to reducing carbon emissions by converting captured carbon dioxide (CO₂) into feedstock for new products such as fuels, chemicals, and building materials, thereby reducing the need for virgin fossil carbon. This White Paper provides a comprehensive overview of CCU's environmental impact, integration into existing industrial processes, regulatory frameworks supporting its deployment, and benefits for various stakeholders, including investors, policymakers, commercial offtakers, and emitters of biogenic CO₂.

1. Introduction

This section introduces CCU and its role in reducing carbon emissions. It highlights the urgency of climate action and outlines how CCU can strengthen industrial resilience, create jobs, and improve energy security in Europe.

2. Understanding CCU

This part explains the role of CCU and how it differs from Carbon Capture and Storage (CCS). It clarifies the distinction between fossil-based and biogenic sources of CO₂, outlines the main carbon capture technologies used today — including post-combustion, pre-combustion, oxy-fuel combustion — and explores various utilisation pathways, such as producing fuels, chemicals, building materials, and plastics.

3. Environmental Impact of CCU

By transforming captured CO₂ into valuable products, CCU supports a circular carbon economy. Its local utilisation promotes industrial symbiosis, where emissions from one industry become resources for another, while also reducing logistics-related emissions. This approach not only creates a more efficient and sustainable system but also advances key Sustainable Development Goals (SDGs).

4. Regulatory and Policy Landscape

This section reviews the current regulatory and policy frameworks affecting the adoption of CCU technologies, with a focus on European initiatives like the EU Fit for 55 package, Renewable Energy Directive, and sector-specific policies such as FuelEU Maritime and ReFuel Aviation. It outlines existing incentives, identifies policy gaps, and discusses the challenges that hinder CCU deployment.

5. CCU Development and Scalability

This section highlights key innovations in CCU technologies aimed at improving efficiency and scalability. While many technologies are still in early stages, they show great promise for reducing emissions and producing valuable by-products. Scaling these technologies globally requires overcoming challenges in production, infrastructure, and regulation, with digital tools like AI helping to optimise operations and enhance scalability.

6. Conclusion and Call for Action

This section summarises the White Paper and provides actionable recommendations for key stakeholders, including investors, policymakers, companies, and emitters of biogenic CO₂. It emphasises the need for collaborative efforts to accelerate the adoption of CCU technologies and outlines specific actions that each stakeholder group can take to support the transition to a sustainable, circular carbon economy.

1. Carbon Capture and Utilisation

1.1 The Role of Bio-CCU in Reducing Global Emissions

The Paris Agreement sets ambitious targets to limit global warming to well below 2°C, aiming to cap the increase at 1.5°C. To meet these goals, global CO₂ emissions must be reduced by about 50% by 2030, ultimately reaching net-zero by 2050. This requires a substantial transformation across industries, with carbon capture strategies playing a key role in reducing carbon emissions — whether by permanently storing captured CO₂ underground, to prevent it from being released into the atmosphere (CCS), or by using it as feedstock for products like fuels, chemicals and building materials (CCU) and thereby reducing the need for virgin fossil carbon.

According to the World Meteorological Organization (WMO)'s State of the Global Climate 2024 report, the concentration of CO₂ in the atmosphere reached 420 parts per million (ppm) in 2023, which is the highest level in 800,000 years¹. These alarming figures call for an “all-hands-on-deck” approach: not only cutting new emissions but also making better use of the carbon already in circulation. This is where Carbon Capture and Utilisation (CCU) becomes especially important.

The goal of this White Paper is to give a better understanding of CCU by examining its environmental impact, its integration into existing industrial systems, the regulatory frameworks supporting its deployment, and the value it brings across industries.





1.2 Societal Benefits from CCU

Accelerated Climate Transition

The Intergovernmental Panel on Climate Change (IPCC) highlights the importance of carbon capture in its 6th Assessment Report². Both CCU and CCS are identified as key strategies in achieving net-zero emissions. The IPCC notes that CO₂-based fuels and feedstocks, such as synthetic methane, methanol, diesel, jet fuel, and other hydrocarbons, represent drop-in solutions with limited new infrastructure needs. For chemical production, a life cycle approach involving plastics recycling, fuel switching, and CCU will be essential for reducing emissions.

Strengthened Industrial Competitiveness

The use of sustainable carbon as a resource in key industrial sectors — such as chemicals, fuels and building materials — offers an opportunity to build a new circular economy industry in Europe that supports climate goals, creates high-quality jobs, and strengthens long-term economic resilience.

To achieve net-zero emissions by 2050, the EU Commission estimates that approximately 280 million tonnes of CO₂ will need to be captured by 2040 and around 450 million tonnes by 2050. Of this, 33% of the captured CO₂ would need to be used for products by 2040 (about 90 million tonnes of CO₂) and 45% by 2050 (around 200 million tonnes of CO₂). The Commission also estimates this will help create between 75,000 and 170,000 jobs³.

Increased Security of Supply

A secure energy supply is essential for Europe's competitiveness. Growing geopolitical tensions have made energy security an increasingly urgent priority. The EU's concept of "strategic autonomy" aims to reduce critical dependencies, especially in energy⁴.

CCU supports the transition by enabling domestic production of products such as eFuels — using locally sourced raw materials — that strengthen supply security. As fossil fuel availability becomes more uncertain, domestically produced fuels made using CCU can strengthen Europe's energy independence and security. NATO has identified energy as a strategic issue, and has promoted the development of synthetic fuels, including eFuels produced through CCU, as a contribution to military and civilian energy security⁵.

2. Understanding CCU

2.1 CCU vs. CCS: Key Differences

Carbon Capture and Storage (CCS) and Carbon Capture and Utilisation (CCU) are complementary strategies for managing carbon emissions. While both involve capturing CO₂, they differ in what happens to the carbon afterwards.

CCS focuses on the permanent storage of CO₂. Once captured, it is compressed and transported to geological formations like depleted oil and gas reservoirs or deep saline aquifers, where it is stored securely and indefinitely. Because the CO₂ is removed from the atmosphere and kept out of the carbon cycle, CCS has an immediate impact on atmospheric CO₂ levels and plays a key role in achieving net-zero by 2050.

CCU converts captured CO₂ into valuable products such as synthetic fuels, chemicals, and building materials. By turning emissions into a resource, it supports a circular approach to carbon use and gives the CO₂ a renewed purpose. Although the carbon is eventually re-released (e.g., when a fuel is burned), CCU helps avoid the extraction and use of new carbon thereby reducing overall emissions.

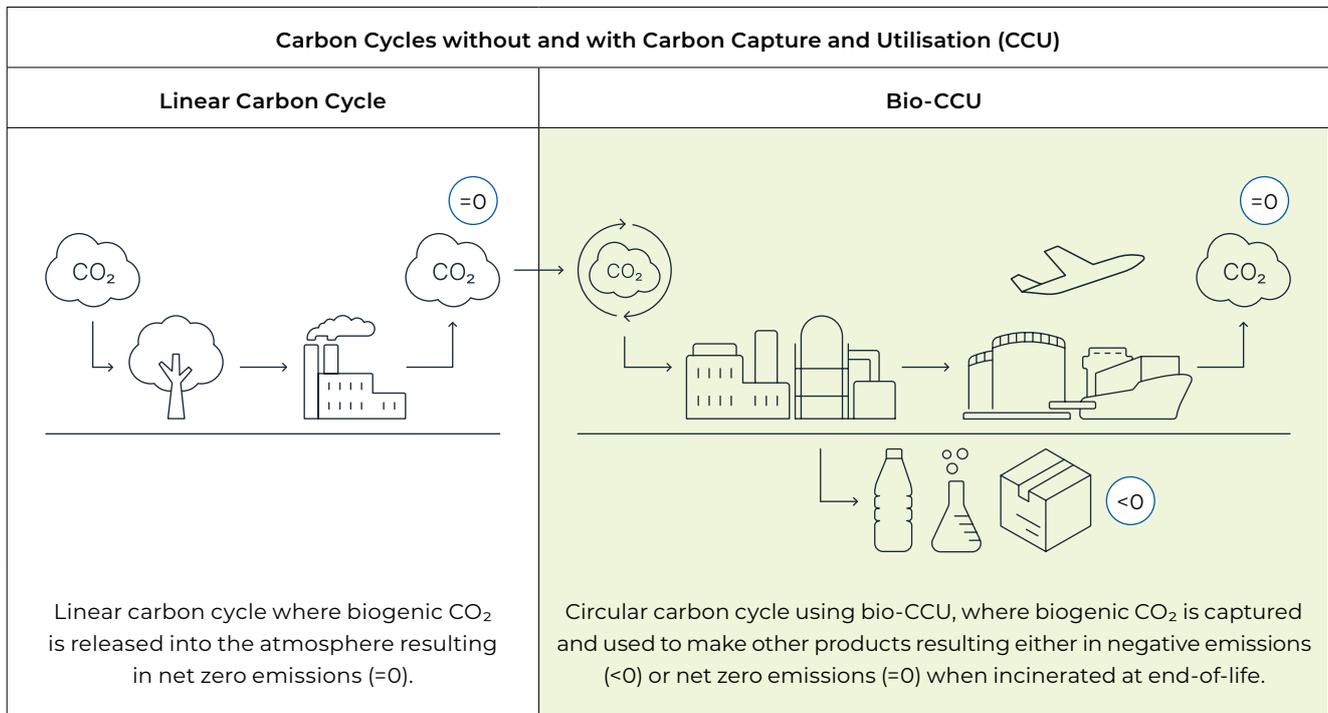
2.2 Distinguishing Biogenic and Fossil Sources of CO₂

CO₂ comes from different sources, and before exploring its use in CCU in more depth, it's important to clarify the difference between biogenic CO₂, which comes from biomass like plants, wood or organic waste, and fossil CO₂, which is released by burning coal, oil, or gas.

Biogenic CO₂ is part of the natural carbon cycle. As plants grow, they absorb CO₂ from the atmosphere through photosynthesis. This same CO₂ is later released when the biomass is used — for example through combustion, decomposition, or industrial processes. If the biomass is sustainably sourced, this cycle is considered carbon-neutral, since the CO₂ released was originally taken from the atmosphere. Capturing this type of CO₂ for storage or use is referred to as Bio-CCS or Bio-CCU. When applied specifically to bioenergy production, as BECCS (Bioenergy with Carbon Capture and Storage) or BECCU (Bioenergy with Carbon Capture and Utilisation).

Fossil-based carbon capture, by contrast, deals with CO₂ emitted from fossil fuel combustion or industrial processes. While it can reduce emissions and support net-zero strategies — particularly when the captured CO₂ is permanently stored — it does not reduce fossil fuel dependency if fossil carbon continues to be extracted and used.

This distinction is especially relevant when evaluating the environmental impact of carbon capture strategies. For clarity, and unless stated otherwise, this White Paper refers to Bio-CCU and Bio-CCS simply as CCU and CCS.



2.3 Main Carbon Capture Technologies

Carbon capture technologies are highly versatile and can be used across various industries to reduce emissions. Different technologies capture CO₂ at different stages of emission and from a wide range of feedstocks, including fossil fuels, biomass, and industrial byproducts. The relevance and effectiveness of each approach depend on factors like the purity, concentration, location, and intended end use of the captured CO₂.

For bio-based carbon capture, which captures CO₂ from renewable sources like biomass, three key technologies are typically applied:

- Pre-Combustion Capture:** Often used in hydrogen production, this method separates CO₂ from hydrogen through gasification before combustion. The resulting CO₂ is typically in a concentrated and high-pressure state, which is well-suited for CCS, as it can be efficiently separated, compressed and stored in underground reservoirs. For CCU applications, it often requires additional processing to meet strict purity and composition standards. This is because the captured CO₂ may contain impurities such as hydrogen sulphide or carbon monoxide and may also need conditioning to align with the specific requirements of downstream conversion technologies.
- Oxy-Fuel Combustion:** Burns biomass using pure oxygen instead of air. This produces a flue gas primarily composed of water vapour and a high concentration of CO₂. With fewer gases to isolate, the CO₂ is easier to extract once the water vapour is removed, reducing the need for complex separation processes. This method produces a relatively pure CO₂ stream and is well-suited for both CCS and CCU. Its high CO₂ concentration simplifies conditioning for downstream applications, though specific purity requirements for CCU may still necessitate some additional treatment.
- Post-Combustion Capture:** Captures and separates CO₂ from flue gases using solvents, solid adsorbents, membranes, or cryogenic separation. By producing a relatively pure CO₂ stream, post-combustion capture is highly suitable for CCU applications, where the captured CO₂ can be converted into synthetic fuels, chemicals, and other products. For CCS, the CO₂ can be compressed and stored in underground reservoirs.

Additional carbon capture technologies, which capture CO₂ from atmospheric or fossil-based sources include:

- **Direct Air Capture (DAC):** Captures CO₂ directly from the ambient air using chemical methods. Because atmospheric CO₂ concentrations are low — about 419 parts per million (ppm), or 0.0419% of the air by volume⁶ — this method is more energy-intensive than capturing from industrial flue gases, where CO₂ levels range between 4–15%. Despite these challenges, DAC can be deployed flexibly near utilisation sites, such as for fuel production, carbon-based products, and mineralisation. As technology develops, improvements are being made to reduce energy consumption, increase efficiency, and lower costs. To remain competitive, DAC relies on access to large amounts of low-cost renewable energy.
- **Direct Ocean Capture (DOC):** This technology removes dissolved CO₂ from seawater, using the ocean's natural ability to absorb carbon from the atmosphere. The process typically involves drawing seawater into a system where electrochemical treatment shifts the carbonate balance, converting bicarbonates into gaseous CO₂ for separation. By reducing the concentration of carbon in seawater, the ocean becomes able to absorb additional atmospheric CO₂ to re-establish equilibrium. Although still in early development, it holds potential for large-scale uptake.
- **Onboard Carbon Capture (OCC):** Enables ships to capture CO₂ emitted during voyages, preventing its release into the atmosphere. It typically involves separating CO₂ from exhaust gases using solvent-based or other capture systems, and storing it onboard in gas or liquid form. The captured CO₂ can later be offloaded at shore-based facilities for long-term storage or utilisation, for example as liquid CO₂ in industrial applications. OCC offers a transitional solution for reducing emissions from ships that continue to run on conventional fuels, supporting maritime climate goals while infrastructure for alternative fuels is scaled.

2.4 CO₂ Utilisation and Applications

Once captured, CO₂ can be transformed into a variety of valuable products, effectively turning a waste stream into a resource. Key applications include:

- **Fuels:** Captured CO₂ can be used to produce synthetic fuels, providing a sustainable alternative to fossil fuels. These fuels are particularly relevant for hard-to-decarbonise sectors such as aviation and shipping which demand fuels with high energy densities. This pathway allows for emission reductions without requiring significant changes to existing fuel infrastructure.
- **Chemicals:** CO₂ can be converted into chemicals such as eMethanol, to be used in the production of plastics, solvents, and fertilisers. This not only provides a way to replace fossil feedstocks but also helps reduce the carbon intensity of industrial supply chains.
- **Building Materials:** Mineralisation of CO₂ can produce stable carbonates, which can be used to create sustainable building materials. This method helps reduce the environmental impact of construction and infrastructure projects, supporting long-term sustainability.
- **Plastics:** CO₂ can also be used to produce bioplastics or synthetic polymers, offering a more sustainable alternative to conventional petroleum-derived plastics. These materials can be used in packaging, consumer goods, and various other applications, reducing dependence on fossil fuels and minimising the environmental impact of plastic waste.

3. Environmental Impact of CCU

According to the International Energy Agency (IEA), CCU technologies could account for up to 15% of the emission reductions needed to achieve global net-zero goals by 2070⁷. This is particularly important given the challenging nature of decarbonising sectors like heavy industry, aviation, and shipping, which rely heavily on carbon-intensive processes.

3.1 Carbon Circularity: Enabling Sustainable Carbon Use

By capturing CO₂ from industrial emissions and using it as a feedstock for new products, CCU helps shift away from the traditional linear model of resource use — where materials are extracted, used, and discarded without recycling. Instead, CCU promotes a closed-loop system, where carbon is continuously reused, reducing the need for virgin raw materials like fossil fuels and minimising the environmental impacts of their extraction. This approach helps avoid the environmental degradation typically associated with resource extraction, such as mining, drilling, and other harmful practices.

To fully deliver on the environmental and resource-efficiency benefits, CCU must be powered by renewable energy like solar, wind or hydropower and, ideally, use biogenic CO₂ sourced from sustainably managed biomass or organic waste. This combination ensures a truly circular carbon economy, where emissions are captured, reused, and integrated into new products without introducing additional fossil-derived carbon into the atmosphere.

Moreover, as emphasised in the European Commission's Circular Economy Action Plan, CCU promotes industrial symbiosis — where emissions from one industry serve as a resource for another, enhancing overall efficiency and supporting a circular economy⁸. This local utilisation of CO₂ also eliminates the need for long-distance transport for carbon sequestration, which reduces logistics-related emissions, contributing to both efficiency and lower environmental impacts throughout the supply chain.

3.2 The Carbon Footprint of eMethanol

CCU plays a critical role in producing synthetic fuels as sustainable alternatives to fossil fuels, in sectors like shipping and aviation. One such example is eMethanol, a liquid eFuel created from captured CO₂ and renewable hydrogen.

The Methanol Institute's report Carbon Footprint of Methanol⁹, includes life cycle assessments (LCAs) of various methanol pathways. The report found that production from renewable sources, such as from biomethane, solid biomass, municipal solid waste, and renewable energy, has a low carbon footprint, with most of these pathways achieving 10-40 g CO₂ eq/MJ, whereas CCU fuels, like eMethanol produced using solar energy can be as small as about 4.4 g CO₂ eq/MJ. In comparison, conventional methanol production typically has a carbon intensity in the range of 50 to 100 gCO₂ eq/MJ or even higher.

Similar findings were published in the EU Joint Research Center's Well-to-Tank report v5¹⁰, which provides carbon footprint values for a wide range of fuels. The table on the next page (page 10) provides examples of these values. The difference in emission values in the reports occurs because different emission factors were assigned to the renewable electricity input.

Fuel and Pathway	Well-to-Wake Value (gCO ₂ eq/MJ)	Absolute Reduction (gCO ₂ eq/MJ)	Reduction Potential %
eMethanol	1.7	89.3	98%
Waste Cooking Oil Biodiesel	14.9	76.1	84%
Sunflower Biodiesel	44.7	46.3	51%
HVO from Rape Seed	50.1	40.9	45%
HVO from Palm Oil	73.3	17.7	19%
HVO Waste Cooking Oil	16	75	82%
Waste Wood Fischer-Tropsch Diesel	13.7	77.3	85%
Farmed Wood Fischer-Tropsch Diesel	16.7	74.3	82%
Fischer-Tropsch from Black-Liquor Gasification	10.4	80.6	89%
Waste Wood Methanol	13.5	77.5	85%
Farmed Wood Methanol	16.2	74.8	82%
Biomethane - Municipal Organic Waste (CBM)	9.5	81.5	90%
Synthetic Methane (SLNG) from Renewable Electricity	6.7	84.3	93%
Synthetic Methane (SLNG) Gasification of Wood Chips	28.6	62.4	69%
Synthetic Methane (SLNG) Gasification of Waste Wood	25.3	65.7	72%

Well-to-Wake Values based on [EU JEC Well-to-Tank report v5](#). (Fossil comparator @91g/MJ)

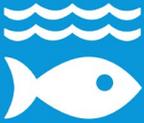


While studies may provide default carbon footprint values for different fuel types and feedstocks, these values should not be used as a general rule when assessing fuels. Instead, fuels, particularly low-carbon alternatives, should be assessed on a plant-specific basis in order to account for differences in upstream processes and to incentivise sustainable practices. This will provide a more accurate and comprehensive view of a fuel's environmental impact.

3.3 Supporting the UN Sustainable Development Goals

The UN Sustainable Development Goals (SDGs) are a set of 17 global objectives established by the United Nations in 2015, designed to address the world's most pressing challenges by 2030. These goals cover a broad spectrum, from ending poverty and hunger to promoting sustainable industries and combating climate change.

CCU supports the following SDGs:

 <p>7 AFFORDABLE AND CLEAN ENERGY</p>	Supports the production of renewable energy-based synthetic fuels (e.g., eMethanol), providing cleaner energy alternatives for hard-to-electrify sectors like aviation and shipping.	 <p>9 INDUSTRY, INNOVATION AND INFRASTRUCTURE</p>	Drives innovation in carbon capture technologies, enhancing industrial efficiency and enabling the development of sustainable infrastructure.
 <p>11 SUSTAINABLE CITIES AND COMMUNITIES</p>	Contributes to reducing emissions in urban areas by providing cleaner energy and alternative building materials, supporting more sustainable cities.	 <p>12 RESPONSIBLE CONSUMPTION AND PRODUCTION</p>	Fosters a circular economy by converting CO ₂ into valuable products, reducing reliance on virgin fossil resources, and minimising industrial waste.
 <p>13 CLIMATE ACTION</p>	Captures and repurposes CO ₂ , helping to reduce overall emissions and supporting global climate action efforts, especially in industrial decarbonisation.	 <p>14 LIFE BELOW WATER</p>	Mitigates climate change impacts like ocean acidification by reducing CO ₂ emissions, supporting marine ecosystem health.
 <p>15 LIFE ON LAND</p>	Helps mitigate climate change impacts on terrestrial ecosystems and promotes sustainable land management practices.	 <p>17 PARTNERSHIPS FOR THE GOALS</p>	Encourages collaboration between industries, governments, and organisations, promoting partnerships for innovation and global sustainability goals.

4. Regulatory and Policy Landscape

The successful deployment of CCU technologies depends on a supportive regulatory and policy environment. Key initiatives, such as the Fit for 55 package and various industry-specific regulations, create frameworks for their adoption. However, from a European context, there are policy gaps and barriers that hinder progress, and further alignment of policies and enhanced support mechanisms are necessary to foster CCU's growth.



4.1 Current European Regulations Affecting CCU

The EU Fit for 55 package aims to reduce greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. This comprehensive legislative framework includes several directives and regulations that drive the deployment of CCU, such as the Renewable Energy Directive (RED III), FuelEU Maritime, and ReFuel Aviation.

- The **Renewable Energy Directive** aims to increase the share of renewable energy sources in the EU's overall energy mix.
- **FuelEU Maritime** seeks to reduce greenhouse gas emissions from the maritime sector by establishing requirements for the use of renewable and low-carbon fuels in shipping.
- **ReFuel Aviation** aims to accelerate the adoption of sustainable aviation fuels (SAFs) by setting binding targets for their use in the aviation sector.

The production of renewable fuels through CCU technologies will be vital for Europe to meet these objectives.

In conjunction with the launch of the Clean Industrial Deal, The European Commission has announced several upcoming initiatives that may contribute to the demand for CCU-related products, including a Chemical Industries Package, which will recognise the strategic role of the chemicals sector and of critical molecules, and a Sustainable Transport Investment Plan, which will outline measures to prioritise support to specific renewable and low-carbon fuels for aviation and waterborne transport¹¹.

4.2 Policy Gaps and Barriers

Despite the progress, several policy gaps and barriers impede the growth of CCU technologies:

- **Lack of recognition in the EU Taxonomy:** CCU is not yet recognised as a sustainable economic activity in the EU Taxonomy. This means investors are not provided with the legal certainty that could accelerate private investments.
- **Limited incentives:** While European energy- and transport policy initiatives like RED, FuelEU Maritime, and ReFuel Aviation create a market for eFuels produced with green hydrogen and CCU, some CCU methods lack incentives or rules. Using captured carbon to make chemicals is not rewarded in the EU, preventing the shift to sustainable carbon sources in this industry. Several member states have called upon the European Commission to put forward a policy package on sustainable carbon for the chemical industry, which should include policies on market creation and sustainable carbon availability.
- **Challenges with mixed CO₂ streams:** Other regulatory challenges, pertaining to RED, include the utilisation of mixed streams of CO₂ containing both biogenic and fossil CO₂. The current regulatory framework makes it challenging to utilise such streams, meaning Europe risks missing out on significant production potential for bio-CCU.
- **EU ETS implementation issues:** It is also becoming evident that national authorities face challenges when implementing EU ETS, providing contradicting guidance on the allocation of free allowances and the responsibility for surrendering allowances in CCU projects involving both producers and users of fossil CO₂.
- **Insufficient public funding:** There is a lack of public funding for CCU projects. In 2025 the European Commission announced the adoption of a new State aid Framework to support the objectives of the Clean Industrial Deal. The Draft Clean Industrial State Aid Framework (CISAF) is suggested to make it possible for EU member states to provide support for, among others, carbon capture technologies.

5. CCU Development and Scalability

Continuous innovation is essential to advancing CCU technologies, optimising energy usage, improving operational efficiency, and reducing costs. As industries strive to meet stringent sustainability goals, a variety of emerging technologies are showing great promise in not only mitigating emissions but also generating valuable by-products.

5.1 Key Areas of Innovation in CCU

Electrochemical Conversion

This technology uses renewable electricity to convert CO₂ into fuels and chemicals. One prominent application is the conversion of CO₂ into carbon monoxide, which can then be used to synthesis synthetic fuels and valuable chemicals. This process is critical for scaling up the production of sustainable fuels, but achieving the necessary production volumes for global impact remains an ongoing effort due to technological and economic factors.

Bioengineered Organisms

Genetically modified microbes and algae are being researched to convert CO₂ into biofuels or bioplastics. These biological processes are still largely in the pilot stages but have the potential to offer more sustainable, lower-energy alternatives to traditional chemical methods.

Advanced Catalysts

Research into catalysts that improve the conversion of CO₂ into valuable products is ongoing. These advancements aim to make the electrochemical reduction of CO₂ more efficient, especially under lower temperatures and pressures. While these catalysts show promise in lab settings, their commercial readiness and performance at larger scales need to be further tested.

Solid Sorbents

New solid sorbents are being developed for use in high-temperature industrial settings such as cement or steel production. These materials improve the efficiency of CO₂ capture while minimising energy consumption. As industries like cement and steel are significant contributors to global emissions, the integration of solid sorbents into these sectors could significantly reduce their environmental impact. Pilot programs are currently exploring their full potential, especially in large-scale applications.

Carbon Mineralisation

This process involves converting CO₂ into stable minerals, such as carbonates, which can then be used in construction materials. While carbon mineralisation provides potential long-term CO₂ storage, it is often viewed as a form of carbon sequestration rather than direct utilisation.

Artificial Photosynthesis

Still in the research phase, this technology mimics natural photosynthesis to convert CO₂ and sunlight into carbohydrates or fuels. It offers a sustainable approach to both carbon sequestration and renewable energy production.

5.2 The Road to Scalability

Efforts to scale CCU solutions include the development of modular designs, as well as improvements in infrastructure and supply chains. Digitalisation, including the use of AI and machine learning, is helping optimise CCU operations, enhance monitoring, and drive efficiencies across the value chain. However, scaling requires overcoming barriers related to production capacity, regulatory frameworks, and cost competitiveness compared to existing fossil-fuel-based systems.

5.3 Integration with Renewable Energy

The integration of renewable energy sources like wind, solar, and hydropower into CCU technologies is essential to reducing emissions. As renewable energy costs fall, the economic feasibility and efficiency of CCU technologies will improve. However, intermittency issues related to fluctuations in wind and solar output present challenges to maintaining consistent operation of CCU systems.

To mitigate these challenges, advancements in energy storage technologies and grid management are crucial. Large-scale storage solutions, such as batteries, pumped hydro storage, or compressed air energy storage, will be key to ensuring a stable supply of energy for CCU systems during periods of low renewable generation. Additionally, smart grid solutions that can balance demand and supply in real time will be important for optimising the integration of renewable energy into CCU value chains.



6. Conclusion and Call for Action

By converting captured CO₂ into valuable products such as fuels, chemicals, and building materials, CCU technologies drive the transition toward a circular carbon economy. They offer a practical solution for hard-to-abate sectors to lower emissions and achieve sustainability targets. However, realising the full potential of CCU depends on continuous innovation, cross-sector collaboration, and a supportive policy framework.

To ensure CCU technologies scale effectively and become an integral part of broader climate strategies, we call on key stakeholder to take action:

For Investors

- **Invest in Innovation:** Support companies developing and deploying CCU technologies. Your investment can drive innovation and bring scalable solutions to the market.
- **Evaluate Long-Term Returns:** Consider the long-term environmental and financial returns of investing in CCU projects, which contribute to global sustainability goals.

For Policymakers

- **Develop Supportive Policies:** Advocate for policies that incentivise CCU innovation and provide financial support for research and development.
- **Shape Regulatory Frameworks:** Engage with industry stakeholders to create regulatory frameworks that facilitate the adoption of CCU technologies and ensure their integration into national and international climate strategies.

For Commercial Offtakers and End Users

- **Adopt Sustainable Practices:** Incorporate CCU-derived products into your supply chain to reduce your carbon footprint and support sustainable practices.
- **Collaborate with CCU Providers:** Partner with companies that offer CCU solutions to enhance your sustainability profile and meet regulatory requirements.

For Biogenic CO₂ Emitters

- **Implement CCU Solutions:** Integrate CCU technologies into your operations to capture and utilise biogenic CO₂ emissions, turning waste into valuable inputs for sustainable products.
- **Leverage Financial Opportunities:** Take advantage of government subsidies, tax breaks, and grants available for CCU projects to reduce costs and improve profitability.

By taking these actions, you can help accelerate the transition to a sustainable, circular carbon economy and contribute to global efforts to mitigate climate change.

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References

- ¹ World Meteorological Organization (WMO). *State of the Global Climate 2024*. 2024.
<https://wmo.int/publication-series/state-of-global-climate-2024>
- ² Intergovernmental Panel on Climate Change (IPCC). *Summary for Policymakers, Sixth Assessment Report*. 2023
https://www.ipcc.ch/site/assets/uploads/2023/03/Doc5_Adopted_AR6_SYR_Longer_Report.pdf
- ³ European Commission. *Commission Staff Working Document on CO₂ Capture Estimates*. 2024.
<https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX%3A52024DC0062>
- ⁴ European Parliament. *Strategic Autonomy in the EU: Challenges and Opportunities*. 2023.
https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/747099/EPRS_BRI%282023%29747099_EN.pdf
- ⁵ European Network of Security and Cooperation in Energy (ENSECCOE). *Synthetic Fuels and Security of Supply*. 2023.
<https://www.enseccoe.org/publications/synthetic-fuels/>
- ⁶ National Oceanic and Atmospheric Administration (NOAA). *Climate Change: Atmospheric Carbon Dioxide*. 2024.
<https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide>
- ⁷ International Energy Agency (IEA). *CCUS in Clean Energy Transitions*. 2024.
<https://www.iea.org/reports/ccus-in-clean-energy-transitions>
- ⁸ European Commission. *Circular Economy Action Plan*. 2020.
https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en
- ⁹ Methanol Institute. *Carbon Footprint of Methanol*. 2022.
https://www.methanol.org/wp-content/uploads/2022/01/CARBON-FOOTPRINT-OF-METHANOL-PAPER_1-31-22.pdf
- ¹⁰ European Commission Joint Research Centre (JRC). *Well-to-Tank Report*. 2020.
<https://op.europa.eu/en/publication-detail/-/publication/a857087a-fe0c-11ea-b44f-01aa75ed71a1/language-en>
- ¹¹ European Commission. *Fit for 55 Package*. 2024.
<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52024DC0062>

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