Support to the coordination of national research and innovation programmes in areas of activity of the European Energy Research Alliance

SUPEERA

Policy Brief

Sustainable Carbon Cycles

CHALLENGES AND OPPORTUNITIES AHEAD

Setting the scene

Three years after the launch of the European Green Deal, the European Union has made substantial steps forward in its efforts to promote the green transition. The publishing of the Fit for 55 package in 2021 is the most telling example of this endavour and the finalisation and roll out of the legislative proposals therein contained in the next years will be crucial to attaining the 2030 and 2050 EU climate goals.

The year 2022 also marks a crucial moment for European research, and the EU in general. It will not only signal the halfway of the current European Commission and European Parliament terms, but it will also see the Horizon Europe Missions – new instruments designed to reduce the distance between citizens, researchers, policymakers and local government - at work, after being launched in 2021.

These efforts will be invalidated without the active participation and support of the research community as only by combining state-of-the-art research with careful policymaking the EU will be able to reach its ambitious goal of becoming climate neutral by 2050. The research community has a pivotal role to play in this process, supporting identified political priorities with empirical findings and developments. It can also advise policymakers on the way forward through fundamental research, particularly focused on low TRLs, to advance breakthrough technologies, materials, and systemic approaches. Crucial in this effort will be the participation of the industrial sector, without which developments will be unattainable. In particular with the new objectives posed by REPowerEU, a close interaction between research, industry and Member States will be more fundamental than ever.

In the context of the SUPEERA project, a series of policy briefs are currently being developed to identify concrete R&I challenges in EU policies relevant to the energy research community. The final goal is to support the achievement of the Clean Energy Transition (CET). This Policy Brief will focus on the EC Communication on Sustainable Carbon Cycles launched in December 2021, having as a main goal to create resilient and sustainable carbon capture, storage and use practices in the EU.

The EC Communication on Sustainable Carbon Cycles

The EC Communication on Sustainable Carbon Cycles of last 15 December 2021 introduces the EU's objective to implement sustainable and resilient carbon cycles in Europe, in accordance with the indications given by the International Panel on Climate Change and its reports on the status of global climate[1]. As stated by the EU Commission, this could be achieved by reducing the EU's reliance on carbon (by improving efficiency of building, transport and industries), recycling carbon to be used in place of fossil carbon, and upscaling carbon removal solutions that capture and store CO2, either through nature-based or industrial solutions.

The table below summarises the main R&I challenges of the Communication, divided following the structure of the document:

Key priorities	Identified R&I challenges
Role of carbon farming	1. Reverse the decline in carbon removal by forests and return to above 300 MtCO2eq removed annually (pre-2013 levels) 2. Establish a proper and functioning system of incentives for land managers to increase carbon removals and protect carbon stocks 3. Enable key stakeholders in sustainable carbon management to deliver on recovery of biodiversity and nature protection 4. Enhance the potential for carbon farming practices to provide co-benefits on biodiversity and ecosystem services 5. Facilitate knowledge and access to carbon farming opportunities for land managers, by facilitating and tailoring training and advisory services 6. Standardise the methodologies and rules for monitoring, reporting and verifying (MRV) 7. Carbon farming initiatives should contribute to the increase by 42 Mt CO2eq of the land sink that is required to meet the objective of 310 Mt CO2eq net removals by 2030 8. Harmonise forest-related information across the EU 9. Facilitate the installment of a demonstration network on climate-smart farming 10. Fully exploit the potential of digital technologies and data technologies for more accurate, cost effective and efficient estimates of carbon emissions 11. Provide solutions to enhance resilience and protection of EU coastal areas 12. Increased knowledge and data on blue carbon quantification
Industrial capture, use and storage of carbon	1. Improve the climate performance of buildings, being able to reduce overall emissions of the construction sector while storing substantial amounts of carbon 2. Develop scientifically sound methodologies, with the objective of acknowledging carbon storage in all European frameworks related to the climate performance of products 3. Develop innovative projects that replace energy-intensive materials, such as cement and steel, with bio-based materials and products. 4. Improve solutions to turn the CO2 from a waste to a resource and use it as feedstock for the production of chemicals, plastics or fuels 5. Bring down the costs of producing methanol from CO2, opening the road to the production of a large range of chemicals such as ethylene or propylene 6. Study the potential of depleted oil and gas reservoirs and saline aquifers to store billion tonnes of CO2 in offshore sites 7. Ensure that at least 20% of the carbon used in the chemical and plastic products should be from sustainable non-fossil sources by 2030 8. Remove and permanently store 5Mt of CO2 annually from the atmosphere by 2030 9. Improve the infrastructure capacity for transport and storage of CO2

[1] April 2022 Working Group III report of the Intergovernmental Panel on Climate Change (IPCC) - https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf#page=48

	10. Develop an efficient system for the traceability of captured CO2 that can track how much fossil, biogenic or atmospheric CO2, respectively, is transported, processed, stored and potentially re-emitted to the atmosphere each year

Sustainable Carbon Cycles plans open the door to the future of emissions management

Planet Earth is heating up, there is no doubt about it and there is ever less doubt on the fact that humans have sped up the process leading to global warming, according to the latest reports from the IPCC[2]. In particular, the emissions of damaging gases like CO2 and CH4 (methane) have proved catastrophic in leading to higher average temperatures across the world. So much that, in order to prevent further degradation of the environment, and to support the larger efforts aiming at a clean energy transition[3], we will need not only to develop renewable energy systems as such, but also think about how to capture, store and use the excessive carbon emissions that we produce.

This is the aim of the EC's communication, which focuses on the sustainability of carbon cycles in the EU. Proper management of carbon cycles can answer Europe's need for carbon, particularly fossil-based, as a material or feedstock for products through reuse, reduce and recycle or substitution approach. The Communication mentions the need to increase the presence and use of natural carbon sinks, and discusses the position of carbon capture in the process. The link with energy technologies can be then directly made with CCUS (Carbon Capture, Use, and Storage) developments. The technology has made giant leaps forward in the past decades, and offers today a valuable contribution to the clean energy transition and the attainment of the Green Deal goals in the EU.

Capturing CO2 directly from the atmosphere using direct air capture with carbon storage (DACCS), and using biomass, which has sequestered CO2, to produce bioenergy with carbon capture and storage (BECCS) are the two best known methodologies of technology-based carbon capture.

Direct air capture with carbon storage is probably the most mainstream technology known to the public, when it comes to CCS developments. DACCS uses chemical solutions which bind the CO2 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. There are presently 19 DACCS plants operating worldwide, capturing more than 0.01 Mt CO2/year[4]. The number is expected to grow, as the hopes of many nations worldwide are ever more pointing to negative emissions technologies according to IPCC reports. However, increasing DACCS operations will create a new challenge: energy demands. According to recent studies, machinery absorbing CO2 from the air could grow to require as much as a quarter of the total energy

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[2] https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

[3] EERA (2021), White Paper on the Clean Energy Transition, European Energy Research Alliance, Brussels

[4] Mihrimah Ozkan, Saswat Priyadarshi Nayak, Anthony D. Ruiz, Wenmei Jiang, Current status and pillars of direct air capture technologies, iScience, Volume 25, Issue 4, 2022, 103990, ISSN 2589-0042, https://doi.org/10.1016/j.isci.2022.103990 (https://www.sciencedirect.com/science/article/pii/S2589004222002607)

supply by 2100[5]. Given the important potential of the technology, it will be therefore crucial for researchers to address how this could impact energy systems.

Bioenergy with carbon capture and storage (BECCS) is the other major sector in the field. Here, investment needs vary differently across the technology spectrum. According to the IEA[6], bioethanol is an up-and-coming leader in the field, but further BECCS applications lack the proper policy landscape to grow further. Among the developments most needed in the field, we can single out instruments to reduce high upfront costs, long payback periods, biomass supply sustainability and the further development of transport and storage infrastructures. R&D areas of interest for future technologies, in need of public and private investment, include advanced gasification for hydrogen production, low-energy-penalty capture technologies, and solid-adsorption capture through metal organic frameworks[7]. At the same time, the relationship between BECCS and land use must be further explored, as models show that relying heavily on BECCS could require land areas up to five times the size of India devoted to growing the biomass needed[8].

To boost the development of the technology, the availability of data will be fundamental. The collection of key data along the whole CCS value chains will give legislators, researchers and industry alike a better grasp of the real impact of carbon removals and environmental impact. Key areas of focus include accounting and verification of the feedstock biogenic carbon content in waste-to-energy and co-firing applications, the permanence of CO2 storage and reversal risk, and carbon dioxide removal (CDR) allocation across multi-stakeholder, cross-boundary BECCS value chains[9].

Infrastructure could prove to be one of the most crucial topics in the years to come. Decisions on the location of CCS operations bases are subject to multiple and complex factors, that need to consider carefully the historical problems of social acceptance of CCS processes in populated areas. The point on infrastructures is key if we consider that according to estimations, a single plant with an absorbing capacity of 1Mt CO2/year would require an area of 0.2 km2, equivalent to 28 soccer fields. In addition, for a liquid solvent DAC technology today to capture one ton of CO2 nearly 1–7 tons of water are used and, in some cases, this may reach 13 tons[10]. More research will be needed, as the need to make the technology more appealing and reasonable to society will have a great impact on its potential for development. Still, there is

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[5] Realmonte, G., Drouet, L., Gambhir, A. *et al.* An inter-model assessment of the role of direct air capture in deep mitigation pathways. *Nat Commun* 10, 3277 (2019). https://doi.org/10.1038/s41467-019-10842-5

[6] IEA (2022), *Bioenergy with Carbon Capture and Storage*, IEA, Paris https://www.iea.org/reports/bioenergy-with-carbon-capture-and-storage, License: CC BY 4.0

[7] IEA (2022), *Bioenergy with Carbon Capture and Storage*, IEA, Paris https://www.iea.org/reports/bioenergy-with-carbon-capture-and-storage, License: CC BY 4.0

[8] Alexander Popp, Katherine Calvin, Shinichiro Fujimori, Petr Havlik, Florian Humpenöder, Elke Stehfest, Benjamin Leon Bodirsky, Jan Philipp Dietrich, Jonathan C. Doelmann, Mykola Gusti, Tomoko Hasegawa, Page Kyle, Michael Obersteiner, Andrzej Tabeau, Kiyoshi Takahashi, Hugo Valin, Stephanie Waldhoff, Isabelle Weindl, Marshall Wise, Elmar Kriegler, Hermann Lotze-Campen, Oliver Fricko, Keywan Riahi, Detlef P. van Vuuren, Land-use futures in the shared socio-economic pathways, Global Environmental Change, Volume 42, 2017, Pages 331-345, ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2016.10.002.

[9] IEA (2022), *Bioenergy with Carbon Capture and Storage*, IEA, Paris https://www.iea.org/reports/bioenergy-with-carbon-capture-and-storage, License: CC BY 4.0

[10] Mihrimah Ozkan, Saswat Priyadarshi Nayak, Anthony D. Ruiz, Wenmei Jiang, Current status and pillars of direct air capture technologies, iScience, Volume 25, Issue 4, 2022, 103990, ISSN 2589-0042, https://doi.org/10.1016/j.isci.2022.103990.

also a technical side to the problem: building an interconnected network for emitters will be a major challenge for the EU as a whole. Different steps along the value chains also suffer from forced distance, including challenges in connecting different industrial complexes[11].

The future of CCS also includes the possible pathways related to using the captured CO2. As shown in an analysis by our SUPEERA Partners, Finnish research organization VTT, the carbon reuse economy can profoundly impact many different aspects of life. These range from chemicals and materials derived from CO2 and food products. Most interesting for the purposes of this document and community, however, are CO_2-derived energy carriers and fuels. The authors argue that, in a future where CO2 capture and fossil-free energy will be cheap processes, the value network for using CO2 to produce sustainable fuel production will be a strong component in the clean energy world. Still, they say, this value network can already start today by supporting innovative processes, such as modular decentralised production of hydrocarbon fuels from carbon dioxide and hydrogen, or boosting the biomass to liquids (BTL) process by low-carbon hydrogen[12].

To conclude, the proposal for a certification of carbon removals from the EU published last 30 November[13] is a significant push forward in the direction of CCUS developments. Improving the EU's capacity to quantify, monitor and verify carbon removals will create the conditions for stable classification of best practices and points of strength in carbon value chains. This higher transparency and accountability will strongly enhance the attractiveness of the sector for investors and stakeholders, therefore keeping the sector growing where it is needed and where it is most successful. However, important will be to continue encouraging research on lower TRLs for CCS, as many technologies of tomorrow risk otherwise remaining closed in a lab.

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[11] IEA (2022), *Bioenergy with Carbon Capture and Storage*, IEA, Paris https://www.iea.org/reports/bioenergy-with-carbon-capture-and-storage, License: CC BY 4.0

[12] Lehtonen, J. (Ed.), Järnefelt, V. (Ed.), Alakurtti, S., Arasto, A., Hannula, I., Harlin, A., Koljonen, T., Lantto, R., Lienemann, M., Onarheim, K., Pitkänen, J-P., & Tähtinen, M. (2019). The Carbon Reuse Economy: Transforming CO2 from a pollutant into a resource. VTT Technical Research Centre of Finland. https://doi.org/10.32040/2019.978-951-38-8709-4

[13] European Commission's Proposal for a Regulation on an EU certification for carbon removals. https://climate.ec.europa.eu/document/fad4a049-ff98-476f-b626-b46c6afdded3_en

Conclusions

The EC Communication on Sustainable Carbon Cycles is one of the cornerstones of the future legislation contributing to the objective of climate neutrality by 2050 in the EU. The potential of carbon removals to protect and regenerate biodiversity and the environment will be crucial for the EU in managing emissions, soils, and energy applications.

Still, the Communication opens up challenges and focus points for research and innovation, mainly regarding CCUS applications. Infrastructure, data and social impact will all need to be carefully assessed and developed to be exploited at full potential. The research performed in these areas will bring to light new capacities, new skills and new innovations that will bring us closer to making our environment more sustainable. Still, the imperative remains: research must be taken up, not only by industry but also by policymakers, as a serious player in the fight against global warming. Funding is a starting place, but it cannot be all. In particular, when it comes to CCS technologies, more is needed: permitting, market interventions and value chain-oriented strategies. All of these realms are beyond the reach of researchers, who need serious and targeted interventions from the other actors in the field.

Nonetheless, the promises are bright: CCUS is being developed at a faster pace than ever, and positive signals from the markets shall keep the technology up and running, giving the necessary momentum to build a stronger and more resilient conducive environment for the years to come. In connection with the REPower EU Plan, great expectations are being put on CCS to deliver on carbon removals, a cleaner atmosphere and new solutions for materials, soils and energy.

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