Carbon Capture, Utilisation, and Storage: challenges and policy recommendations from the ConsenCUS project

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1 Executive summary

Carbon capture, utilisation, and storage (CCUS) is increasingly in focus as a key contributor to reaching the EU's net zero emissions target. However, major barriers such as lack of regulation and financing, low availability of CO_2 transport and storage infrastructure, and low public awareness continue to pose challenges to the widespread deployment of CCUS technologies. As EU policy begins to address these barriers, the ongoing Horizon 2020 ConsenCUS project provides learnings for additional, lesser-known policy considerations and recommendations for CCUS to play a meaningful role in the transition to net zero.

The findings of the ConsenCUS project so far are summarised in seven policy considerations. Firstly, the environmental implications of CO_2 capture technologies must be appropriately assessed, and environmentally benign, resource-efficient technologies should be prioritised. Secondly, the trade-offs between performance and resource consumption of CO_2 capture technologies must be accounted for, and R&D and deployment must be supported to optimise capture technologies. Thirdly, any CCUS technology developed now must be able to operate in a net-zero world, and the contribution of CCUS projects to climate mitigation, including a full life-cycle assessment of their emissions, must be transparently communicated.

Three other policy considerations reinforced by the ConsenCUS project relate to technology development and deployment. With potential demand for CCUS coming from emitters of different sizes, activity types and locations, modular and scalable CO_2 capture technologies must be prioritised. Further down the value chain, harmonised standards and risk-sharing models for shared CO_2 transport and storage infrastructure must be implemented to support the formation of CCUS clusters. Finally, more R&D and deployment is needed to develop, test, and scale best-in-class CCUS technologies, and comprehensive strategies and funding frameworks to foster research, development, innovation, and demonstration should be set out.

Finally, the meaningful engagement of communities and stakeholders in CCUS projects must be prioritised. Aside from informing the public, capability-building activities can help generate valuable insights from local stakeholders and ensure that CCUS projects are deployed in an impactful, just and sustainable way.

2 The EU CCUS landscape

Carbon capture, utilisation, and storage (CCUS) technologies have come increasingly into focus in recent years, as key options for decarbonizing hard-to-abate industries and meeting the goals of the Paris Agreement.[i] This heightened interest is noticeable in the EU through various policy developments, including a public positioning of the Union in support of CCUS ("no CCUS, no Green Deal"[ii]); the Net-Zero Industry Act, which presents CCUS as a key "net-zero technology" and mandates oil and gas producers to provide CO_2 injection capacity; the revision of the EU Emissions Trading System (EU ETS), which may incentivise investment in CCUS, and others. The EU has also seen a growth of its CCUS project pipeline, supported by national state aid (e.g., in Denmark[iii]) and by EU funding for large-scale projects[iv] and for research and development (R&D)[v]. Some CCUS projects have been designated as Projects of Common Interest, strategically important for Union cohesion.[vi]

Despite this momentum, there are still well-known challenges to deploying CCUS in the EU. The lack of an adequate policy and regulatory framework for CCUS, both at EU level and in most Member States, continues to create investment uncertainty. Investment is further hampered by a lack of funding to support the high costs of CCUS, including the significant energy costs of CO_2 capture. A relative lack of coordination among stakeholders along the CCUS value chain poses difficulties in aligning supply and demand for CO_2: the lack of open-access CO_2 transport and storage infrastructure poses a significant investment barrier to operators exploring CO_2 capture, while the upfront costs of developing storage sites prevent capacity from being made available in the absence of long-term storage customers and without either the cooperation of multiple companies or coordination by the state.[vii] Without such stakeholder coordination, no single company can invest in full-chain CCS on its own. Finally, low institutional capacity to enable CCUS projects leads to low engagement with these technologies, particularly in regions outside of Western and Northern Europe, and public awareness of and interest in CCUS is relatively low.

While recent policies attempt to overcome some of these major barriers to widespread deployment of CCUS, the implications of implementing these technologies must be considered from all angles, including energy and resource consumption, environmental performance, and community engagement. The purpose of this paper is to highlight additional policy considerations and recommendations, based on learnings from the ConsenCUS (CarbOn Neutral cluSters by Electricity-based iNnovations in Capture, Utilisation and Storage) project, a Horizon 2020-funded project.[viii]

3 Learnings from the ConsenCUS project

The ConsenCUS project aims to demonstrate novel CO_2 capture and conversion technologies in the laboratory and at industrial sites from the oil refining, cement production, and magnesite production industries. The project is developing a unified, fully electric module for capturing CO_2 and converting it to potassium formate, a biodegradable product with a wide range of commercial applications.[ix] It also investigates the potential of using different geological formations for temporary or permanent storage of captured CO_2, conducts a life-cycle assessment of the proposed CCUS pathways, models configurations of elements of the CCUS value chain, and studies societal perceptions of CCUS.

As of May 2023, several key findings have emerged from the ongoing ConsenCUS project, whose wider implications may be considered by policymakers in developing upcoming CCUS policies at EU and Member State levels. The first is that **different CO_2 capture technologies have different environmental implications,** which must be considered when deploying CO_2 capture projects. The capture of CO_2 typically relies on the use of solvents, with the most mature capture technologies using amines, volatile substances which can be toxic to the environment (although more research is needed to fully assess the associated risks),[x] and which need a significant amount of heat to be regenerated for reuse in the capture process.[xi] Alternative capture technologies, such as the water-based electrochemical capture method being tested in the ConsenCUS project, use non-toxic, less volatile solvents, improve the rate of solvent regeneration (thus improving resource efficiency), and use electricity (which is more readily available from low-carbon sources than heat, but possibly constrained by availability and competition with other sources of demand, such as the electrification of transport and heating, and green hydrogen production).

Alongside environmental considerations, CO_2 capture technologies must ensure a high capture rate (which may be particularly challenging for emitters such as refineries, whose CO_2 sources are small and dispersed across the industrial site), as well as a high purity of the released CO_2 stream (which reduces the need for a capital-intensive CO_2 purification unit). A second key finding in this sense is that **there are trade-offs between the performance, energy consumption, and resource needs** of CO_2 capture units**.** The energy consumption required for high capture rates ("energy penalty") is well-known,[xii] but other trade-offs must also be considered: for example, adding certain chemicals to the solvents used for capture can increase CO_2 absorption efficiency at the expense of solvent regeneration efficiency, and using electricity means that the rate of regeneration will be limited by the maximum power available at industrial sites. This shows that the applicability of CO_2 capture is dependent on a number of factors, many of which involve trade-offs and increase the complexity of decision-making. This is particularly challenging in jurisdictions where policy dictates a minimum capture efficiency for approved commercial CCUS projects, such as the United Kingdom,[xiii] and where technical and financial bottlenecks for optimising capture units may interfere with upscaling. It also indicates that more R&D, innovation, and deployment of commercial-scale capture projects is needed to optimize a broad portfolio of CO_2 capture technologies and ensure learning for the future development of new technologies.

At the end of the CCUS value chain, a major policy consideration is that different utilisation and storage pathways have different climate mitigation impacts. For example, utilising captured CO_2 in concrete curing will keep it away from the atmosphere for decades or even centuries, whereas incorporating it into a fuel will only delay its atmospheric release by a few months.[xiv] To contribute to climate mitigation, **any CCUS technology developed now must be able to operate in a net-zero world**. CCUS pathways involving the utilisation of CO_2 without permanent storage (e.g., for production of e-fuels) will only contribute to reaching net zero emissions if the captured CO_2 is of biological or atmospheric origin, and if the pathway components (particularly capture) use carbon-neutral energy. As such, novel utilisation pathways for captured CO_2 must involve an adequate assessment of downstream emissions coming from a CCU product, and their ultimate impact on mitigating climate change must be transparently communicated. Furthermore, the deployment of CCS projects should aim to optimise the use of the subsurface and **explore complementarities between CO_2 storage and alternative subsurface uses**, such as hydrogen or natural gas storage, including for more remote emitters[xv]. These complementarities must be investigated early-on, to avoid potentially useful subsurface sites becoming “stranded”. The large suite of end-uses of CO_2 (whether utilisation or storage), coupled with their varying levels of commercial readiness, may generate uncertainty among stakeholders as to what should be done with captured CO_2. At the same time, the EU’s tightening decarbonisation calendar means there is little room for poor carbon accounting, and therefore the accurate assessment of climate mitigation impact of CCUS pathways is a priority. It is crucial to ensure that beyond the revised EU ETS, and at national level, those CCUS pathways and uses of the subsurface being incentivised are those which deliver optimal climate impact.

Further considerations of scalability and modularity of CO_2 capture technologies, as well as the size and location of emitters, increase the complexity of CCUS R&D. As the need for CO_2 capture increases, so will the need for a rapid progression from lab scale to commercial scale of effective, environmentally benign CO_2 capture technologies. This means that there is an additional pressure to develop and test **CO_2 capture technologies which are scalable** (from lab-scale grams of captured CO_2 to potentially hundreds of thousands of tonnes captured by a single unit) **and applicable to different types of emitters**. This is challenging, because the type of industrial activity, size, and location of emitters leads to different capture unit requirements. For example, small- and medium-sized emitters may need less capital-intensive capture technologies, if they are exempt from the EU ETS and thus face more challenges in building a business case based on avoiding emissions costs. If emitters are geographically isolated, they may also benefit from capturing and converting their CO_2 into sellable products on-site. On the other hand, large emitters and those situated near each other (for example, in industrial clusters) may drive demand for capture systems with multi-user capabilities[xvi] and shared transport, utilisation, and storage infrastructure. This creates a different set of challenges, as this shared infrastructure will need to aggregate multiple CO_2 sources and end-uses (whether utilisation or storage), which requires **harmonised specifications and standards, as well as a robust model for sharing risks and liabilities**, which should not fall solely on the public sector.[xvii]

From the point of view of the R&D pipeline of CCUS technologies, the ConsenCUS project also highlights the challenges of bringing these technologies from lab to market, particularly given the required deployment scale. The development of high-performing CCUS technologies **requires significant research, development, innovation**, **and deployment,** including support for procuring expensive specialized components and for bringing low-TRL technologies to market, given the capital and operational costs of CCUS. Although the Net-Zero Industry Act attempts to reduce import dependence for critical technologies and makes provisions for supporting CCUS technologies below a TRL of 8 (including priority access to regulatory sandboxes[xviii]), these may fall short of the investment required to accelerate the pipeline of CCUS R&D.

Finally, findings from the ConsenCUS project so far suggest that **capabilities-focused community engagement is critical for the implementation of CCUS projects**. When engaging communities across Europe, it was found that educational and capability-building activities enabled valuable insights from participants on the drawbacks and potential benefits of local implementation of CCUS. Participants in these activities were sceptical about top-down, one-sided engagement activities, which were seen as untrustworthy and missing vital local information. Issues around transparency and accountability in public and private research collaborations were also raised in some communities. In addition, community members were concerned that they were not informed about CCUS developments in their area and advocated for more outreach activities from the relevant companies and authorities. These findings show that meaningful community engagement must be a key component of CCUS projects, to ensure social acceptance and facilitate a socially optimal implementation of CCUS. Furthermore, integrating capability-building activities such as educational outreach and deliberation workshops into CCUS projects can enable communities and stakeholders to contribute with valuable insights.

4 Policy recommendations

Targeted and well-reasoned policies can help overcome some of the major barriers to deploying CCUS in the EU. An EU-wide strategy for targeted, impactful, and sustainable CCUS deployment and a clear regulatory framework for deployment, building on the EU CCS Directive, could provide investor certainty and stimulate commercial projects. Market creation mechanisms (such as Green Public Procurement for low-emissions products), targeted funding, and a proactive approach from Member States in disbursing national funding and supporting access to EU funds could help close the funding gap, particularly for low-TRL capture technologies. The lack of transportation and storage infrastructure could be overcome by setting clear standards for CO_2 transport, coordinating stakeholders to match CO_2 supply and demand, and increasing accessibility to storage capacity data at EU and Member State level, building on the requirements set by the proposed Net-Zero Industry Act.[xix] Institutional capacity can be built by enhancing knowledge transfer and dedicating resources to competent authorities (at local and national level), while public communication and robust community engagement around CCUS projects can help build public awareness and enhance the transparency of the CCUS project pipeline.

Aside from the above recommendations, the findings of the ConsenCUS project provide additional recommendations for the rapidly evolving EU CCUS policy landscape:

1. **The environmental impact of CO_2 capture and conversion units should be a key criterion** in assessing the impact of EU-wide CCUS targets, and should be robustly integrated into the permitting process for installing these units.
2. **CCUS pathways must be fit for operation in a net-zero world**. The national- and EU-level prioritization of different CCUS pathways and uses of the subsurface **must be grounded in life-cycle assessments of climate mitigation impact,** with underpinning data being made publicly available wherever possible.
3. Any impact assessment of EU-wide and national CCUS strategies should also include **scope 2 and 3 emissions from the entire CCUS chain** and clearly project the demand for carbon-neutral energy of capture units, including how this demand will be met given competing demand from other decarbonization technologies.
4. **The CCUS technology pipeline must be accelerated**, by investing in R&D and deployment for a portfolio of scalable, modular capture technologies that can be retrofitted to multiple types of industrial facilities.

5. Shared CO_2 transport and storage infrastructure **must be subject to rigorous standards and models for sharing liability** from CO_2 sources and end-users connected to the infrastructure.
6. Member States should be mandated to **set out a comprehensive strategy and funding framework for R&D, innovation, and deployment** of CCUS, building on existing EU support and structures such as the Strategic Energy Technologies Plan (SET-Plan), and targeting innovative, efficient, and high-performing technologies.
7. The **meaningful involvement of local communities and stakeholders** should be a key requirement of CCUS projects, and capability-building activities can help generate valuable local insights from stakeholders.

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This policy paper was written by Energy Policy Group (EPG), a partner in the ConsenCUS project, with input from the project consortium.

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