ConsenCUS

The future of industrial carbon management in the EU: findings from the Horizon 2020 ConsenCUS project

This project has received funding from the European Union's Horizon 2020 research and Innovation programme under grant agreement N°101022484. This press release reflects only the author's view and the European Climate, Infrastructure and Environment Executive Agency (CINEA), under the powers delegated by the European Commission, is not responsible for any use that may be made of the information it contains.

1 Executive summary

Industrial carbon management (ICM) has seen an increasing uptick in supportive policies, commercial-scale projects, and innovation action in the EU in recent years. Policy frameworks under the Net Zero Industry Act (NZIA), the Clean Industrial Deal, and the ICM Strategy are poised to further direct resources towards ICM projects as part of the EU's technological portfolio for achieving climate neutrality by 2050. Despite these promising advances, important barriers remain in the deployment of ICM at pace and scale in Europe.

With many of the challenges faced by ICM being increasingly acknowledged by policymakers, the ongoing Horizon 2020 ConsenCUS project can provide additional policy insights. As an innovation action, it brings learnings for the roll-out of ICM, but also for the advancement of innovation in net-zero technologies in general. These findings are summarised in five policy recommendations and complement those issued in a previous policy paper published under the ConsenCUS project.

Firstly, the EU will require a balanced approach to supporting ICM technologies, both enabling next-generation technologies and deploying existing mature technologies. Secondly, the EU's research and innovation (R&I) frameworks must acknowledge the importance of demonstrating, not just developing, innovative ICM technologies, and allocate appropriate financial resources to demonstrator projects. This must include an appreciation of fostering "learning-by-doing", providing resource flexibility to react to unexpected challenges and aligning project success indicators with the long timelines for demonstrating new technologies in real operational conditions, including permitting requirements and technical challenges. Thirdly, policies and mechanisms to mitigate the high energy costs faced by industry, while still maintaining climate ambition, will be essential to ensure the operational feasibility of carbon capture.

Fourthly, support for ICM demonstration and deployment must acknowledge the trade-offs between technology characteristics such as cost, environmental footprint, capture efficiency, energy consumption, scalability potential, and others. Finally, R&I frameworks for developing and demonstrating ICM technologies must be relatively unbureaucratic and allow flexibility for project consortia to recruit expertise with minimal administrative constraints, supported by appropriate human and knowledge resources from EU agencies to match the scale of the EU's ambitions on ICM. This will help ensure that ICM not only contributes to EU climate neutrality, but also to the reduction of an innovation deficit which has placed the Union in a challenging position with regards to its competitiveness.

2 Industrial carbon management is unfolding rapidly in the EU

Industrial carbon management (ICM), broadly comprising carbon capture and storage (CCS) and carbon capture and utilisation (CCU) technologies, is a key point on current agendas for climate change mitigation. It is a complex and long value chain involving processes for capturing, transporting, utilising, and/or storing carbon dioxide (CO_2), each one with multiple technological options with associated economics, environmental credentials, energy balance, and public concerns. In general, ICM technologies are relatively scarcely deployed at commercial scale worldwide, and remain extremely expensive, with high capital costs and significant operational costs, particularly due to the energy consumption of capture units. As a result, public policy is key in rolling out ICM at scale and targeting it at industries and sites where it is the most cost-effective solution for decarbonising competitively.[i]

Recent years have seen a significant uptick in policy efforts around ICM in the European Union, as well as various Member States (MS). The adoption of the Net Zero Industry Act (NZIA) and publication of the ICM Strategy[ii] have pinpointed CCS and certain types of CCU as projects of strategic importance to delivering the EU's climate goals. The NZIA includes a European goal of developing 50 million tonnes (Mt) of injection-ready CO_2 storage capacity by 2030, with the development obligation falling on hydrocarbon producers, proportionate to their oil and gas production levels. The forthcoming adoption of the EU's 2040 climate target, currently set at a 90% reduction of GHG emissions compared to 1990 levels, relies on a substantial amount of CCS, including carbon removals through direct air capture with carbon storage (DACCS), a promising but costly technology with very limited commercial deployment.[iii] Rolling out ICM technologies will therefore play an important role in ensuring deep emissions cuts in hard-to-abate sectors, such as cement and chemicals production, as well as enabling the EU's commitment to net negative emissions after 2050.[iv]

Surrounding the NZIA, the last two years have also seen an uptick in ICM project and policy activity in the EU. Since 2023, three Final Investment Decisions were taken – one on the Porthos ICM project in the Netherlands,[v] and two as part of the Northern Lights project (the entering of Hafslund Celsio waste-to-energy plant into Phase 1 of the project,[vi] and the decision to launch Phase 2).[vii] The Innovation Fund, the EU's most important public funding instrument for large-scale ICM projects, has supported an increasing number of capture, utilisation, and storage projects, including projects around the North Sea (such as Denmark's Accsion project[viii]) as well as the Mediterranean Basin (such as Greece's IFESTOS and Croatia's KOdeCO Net Zero[ix]). This marks not only an increase in the deployment of ICM projects, but also a slow expansion of their geographical spread from the North Sea basin. The geographical expansion is also reflected in the emergence of cross-border ICM projects, with the most recent list of candidate Projects of Common Interest (PCIs, cross-border projects judged to be of strategic importance and eligible to access EU support under the Connecting Europe Facility) featuring 19 proposals, including in southern Europe (such as the Madoqua project of Spain and Portugal, and the Prinos-Apollo CO_2 CCS project involving Greece, Croatia, Slovenia, Italy, France, Cyprus, and Bulgaria[x]). Finally, the EU's Clean Industrial Deal, a wide-ranging strategy for transforming European industry, foresees a broad set of legislative and non-legislative measures aimed at increasing industrial competitiveness while reducing emissions, which may directly or indirectly support ICM, for example through the designation of labels for low-carbon cement or other construction products suitable for carbon capture.

Commercial-scale deployment of mature ICM technologies is critical but is not the only puzzle piece for the future of European industry. As highlighted in Mario Draghi's 2024 report on EU competitiveness,[xi] CCS is one of the technological portfolios where the EU has a competitive edge compared to other geographies. Cementing a leadership position in research and innovation (R&I) for CCS and CCU can bring competitiveness benefits to the EU's emerging cleantech sector, whose total value could be as high as €117 billion/year by 2030.[xii] As such, funding R&I for ICM could enhance the EU's competitive edge, if a balanced approach is adopted to ensure competitiveness benefits while maintaining attainable goals for advancing ICM projects. Recent discussions on scaling down the EU's 2040 emissions target[xiii] may set the scene for an increased need for deep decarbonisation in the decade immediately preceding 2050, including a massive rollout of ICM projects. If this materialises, an uptick in R&I for ICM now will be all the more important to ensure that the 2040s and 2050s see the deployment of high-performance, cost-effective ICM.

Overall, there appears to be a growing acceptance of ICM amongst policymakers as a contributor to the EU's climate neutrality goals, particularly for the decarbonisation of heavy industry. However, ICM projects are extremely complex, and their rollout brings to light various challenges in innovating, demonstrating, and operationalising the associated technologies. In this context, this policy paper reflects on the Horizon 2020 ConsenCUS (**CarbOn Neutral cluSters by Electricity-based iNnovations in Capture, Utilisation and Storage**) project. The project's aim is to demonstrate novel CO_2 capture and conversion processes in three different industries and countries in the EU, research novel CO_2 storage media, conduct comprehensive assessments of public perception, and model potential cross-sectoral, cross-country ICM clusters. Due to close in 2025, the project offers a wealth of insights on ICM, as well as on the process of innovating, demonstrating, and deploying the associated technologies. The following section reflects on these learnings and suggests several recommendations for policymakers, building on the insights of a previously published policy paper.[xiv]

3 Insights from the ConsenCUS project

In the current policy context, given the substantial advancements in ICM made by some partner countries in the ConsenCUS project (including the Netherlands, the United Kingdom, Denmark, and Greece), it is timely to reflect on learnings from the project and ensure its legacy by creating actionable recommendations to policymakers.

The ConsenCUS project involves major innovation action, namely developing new methods for capturing CO_2 and converting it to useful products. It also involves the demonstration of these technologies at three industrial production sites in the cement, oil refining, and magnesite industries – all owned by large companies navigating the requirements for transitioning to net zero emissions, including a phase-out of free emissions allowances under the EU Emissions Trading System (EU ETS) and an increasing demand for low-carbon products. One first key learning from this project is that the future of European ICM **will necessarily involve a balanced approach**, focusing both on deploying existing ICM technologies to target industries, and on demonstrating next generation technologies, to ensure a robust contribution of ICM to the EU's climate neutrality goals. To meet the NZIA's ambitious near-term target for CO_2 storage development, industries will require financial support to deploy commercially available carbon capture solutions now and at scale. At the same time, the EU's pipeline of innovative ICM technologies requires significant funding to enable demonstration in real-world conditions and increase the portfolio of available solutions for the coming decades. The costs of such demonstration projects are an order of magnitude higher than technology R&D projects, and require significant flexibility to "engineer out" unforeseen challenges when moving from the lab to demonstration sites.

Given that the demonstration of new technologies represents the last "stress test" for innovations in a real operational environment, a broadening of funding for demonstration activities will be necessary. This means both an increase in the number of funded demonstration projects, as well as an increase in project-specific funding to reflect the much higher costs of technology demonstration, compared to research and development. Moving beyond technologies at demonstration stage, the main bottleneck for commercially deploying relatively mature technologies, such as amine-based capture, is to create a favourable investment environment that allows deployment across a diversity of relevant industries. As such, **a "two-track" approach could be deployed**, whereby the most mature technologies receive incentives for deployment, and innovation-focused funding is disbursed to demonstrate a broader range of innovative technologies, preparing them for deployment in the decades to 2050. A portfolio approach should be adopted, as relying on a small number of technologies comes with significant risks, regardless of whether the technologies in question are mature or not. Designating support for ICM will be particularly important in the context of ongoing negotiations of the next Multiannual Financial Framework (MFF – the EU's budget) and shifting spending priorities in light of the current geopolitical reality.

ICM technology demonstration is still a complex process, with technical challenges and an overall small window of time in R&I projects to achieve performance indicators while still fostering learning-by-doing. In some cases, these technologies may be too early-stage to deliver commercial-scale cost-efficient ICM – yet they are crucial as testbeds for the innovations that can serve to achieve the deep emissions reductions required across the EU in the decades to come. Given the importance of efficiently moving new technologies from lab-scale to demonstrator-scale, future ICM R&I frameworks must **allow sufficient financial headroom and time to “engineer out” the inevitable challenges that come with demonstrating and scaling innovative ICM technologies**. Demonstrator projects must have sufficient time to obtain all relevant permits for installing said technologies, cope with challenges in commissioning, cope with the inevitable operating challenges, to, while still allowing ample runtime to record sufficient high-quality data during demonstration cycles. Technology scale-up is challenging, and over-optimism must be avoided, given that often what may appear as a technological breakthrough at lab stage may be difficult to demonstrate in real operational conditions. At the same time, this demonstration is crucial for industrial operators to learn by doing and build up their capacity to secure commercial-scale ICM projects. As such, EU R&I funding should move away from an “innovation-only” focus and respond to the need for feasible while innovative technologies to reach deployment readiness, through well-resourced demonstrator projects.

Demonstrating the ConsenCUS technologies during Europe’s ongoing energy price crisis, which has seen energy-intensive industries face electricity bills sometimes two to three times higher, and gas bills up to five times higher, than their US counterparts,[xv] has reinforced **the potential challenge of access to affordable, clean energy** to supply the ICM value chain. The energy footprint of capture units also comes with implications for the life-cycle emissions of ICM, and for this reason the ConsenCUS capture technology is electrochemically-based, using electricity as an energy vector that is easier to decarbonise than heat. However, the supply of affordable, clean electricity in sufficient quantities to capture units (and, more broadly, of clean energy to the ICM value chain) is vulnerable to current high prices, particularly given that electricity prices are affected by those of natural gas. It is not always possible for industrial producers to generate energy on-site for their CO_2 capture plants, and if said energy is to be renewable, it will require either capture solutions that can easily ramp up and down to cope with intermittency (including congestion or oversupply of renewable energy), or flexibility solutions to enable continuous energy supply. This is yet another argument for the need to demonstrate a broad range of capture technologies, ensuring robustness in the face of potentially volatile energy prices.

The energy consumption of CO_2 capture (and more broadly of ICM technology chains) is one of many technology characteristics, between which there are often trade-offs. For example, electrochemically-based CO_2 capture (such as the technology demonstrated in ConsenCUS) has several advantages over conventional methods including being electrically-powered, using inorganic, non-volatile solvents, having potentially high capture efficiency, and relying on commercially available components and equipment with a clear path for upscaling. It also produces high-purity CO_2, an important aspect for downstream use or storage. At the same time, the use of inorganic solvents for CO_2 capture comes with higher energy consumption than traditional, amine-based capture methods. These trade-offs show a need for continuous innovation to improve the technical performance parameters of ICM, also leveraging the ongoing developments happening in other fields (for example, electrochemistry, including batteries and fuel cells) and engaging established industries, such as fuel cell and membrane developers, in R&I projects for ICM. Future support of ICM innovations should acknowledge the potential trade-offs between **energy performance, environmental footprint, life-cycle costs, scalability and supply chain robustness**, rewarding technologies which have the potential to perform well for a particular use case.

Last but not least, **EU funding frameworks exhibit several characteristics which may pose additional challenges to advancing ICM**. Firstly, the lower funding rates offered to for-profit organisations may decrease companies' interest in participating in R&I projects, given that many of them are small and medium enterprises or start-ups. Secondly, there is a general aversion to subcontracting in EU R&I projects, which may prohibit the contracting of engineering companies to ensure the design, construction, and commissioning activities necessary for successful pilots. Finally, the governance of R&I funding frameworks would benefit from a reduction in red tape, increased knowledge-sharing, and engagement of financial and human resources to match the scale of the ICM challenge. As highlighted in the Draghi report, the "human resource" aspect of R&I funding is essential; for ICM, it will be crucial for R&I projects to be supervised, managed, and conducted based on an understanding of the challenges of demonstrating novel technologies in real-world environments and the flexibilities that this requires, rather than just on achieving project indicators.

The six challenges mentioned above are profiled against a set of existing challenges to ICM development. A continued overall low market readiness for ICM is exacerbated by the lack of CO_2 infrastructure, funding competition with other emerging industrial decarbonisation methods,[1] regulatory gaps, and public acceptance issues. Substantial investments are still required in infrastructure, with **significant gaps in mid-stream (transport) infrastructure** which may jeopardise an ICM value chain where other components are investment-ready. **Funding and financing gaps still remain**, with projected EU ETS prices often insufficient to cover the life-cycle cost of ICM, and **regulatory frameworks still require clarification and proactive engagement from authorities**, including local authorities designated to provide the relevant permitting, particularly in eastern European countries. The NZIA provisions on accelerating permitting timelines for ICM are promising, but their implementation will require **an increase in institutional capacity** across the board in countries with current low deployment of ICM. An uptick in human capital is also required for buildout of transport and storage infrastructure, with the **oil and gas industry playing a key role** given the transferability of knowledge and skills from hydrocarbon production to CO_2 storage.

Challenges in developing ICM also relate to data, risk management, value chain analysis, and public engagement. Subsurface data availability (including for southeast European countries such as Romania and Greece), competition over use of the underground, potential over-estimation of CO_2 storage potential and technology availability, and the lack of incentives for pre-appraisal of CO_2 storage sites all **pose continued challenges to the development of CO_2 storage sites**. The derisking of CO_2 handling across the entire value chain requires **tailored**

[1] For example, the production of steel using direct reduction of iron based on renewable hydrogen. It should be noted that some of these competing technologies benefit from favourable subsidy regimes in certain geographies.

standards to avoid cost inefficiencies from additional purification and risk mitigation requirements, particularly if the CO_2 in question crosses borders. The need to **assess ICM technologies across the entire value chain** still remains, including the potential for temporary CO_2 storage to support flexible CO_2 utilisation (which research from this project shows to be subject to large uncertainties[xvi]), and for developing high value-added products based on captured CO_2. Finally, **public acceptance of ICM still remains a relative unknown**, but with showstopping potential if not addressed. This may be exacerbated in Just Transition areas with a rich hydrocarbon production history, which are suitable candidates for the development of CO_2 storage while facing social challenges in the transition away from emissions-intensive economic activities. Integrating social research into large-scale R&I projects, and dedicated public dialogue into commercial projects, will be essential.

4 Policy recommendations

The EU has made significant strides in developing ICM in just a few short years, but the innovation, demonstration, and deployment of these technologies still face challenges that could be addressed by policies at EU and national levels. The Clean Industrial Deal foresees a range of market creation mechanisms and uptick in funding for decarbonising industry which could benefit ICM deployment, but it must be matched by a proactive approach from Member States to disburse national funding through competitive schemes, such as Carbon Contracts for Difference tailored to the novelty and uncertainty still surrounding ICM. A set of clear CO_2 transport standards, equitable distribution of CO_2 storage obligations under the NZIA to ensure geographical balance of ICM across Europe, and investment in regional transport networks could all serve to increase confidence from emitters assessing the risk of being a first mover in carbon capture. Increased technical assistance and knowledge transfer to enhance institutional capacity, particularly in regions where ICM is still nascent, can help build up institutional capacity, and EU guidelines on community engagement and public awareness can help set firm expectations for transparent public dialogue and avoid social backlash.

Beyond the above recommendations, which have been highlighted numerous times in Brussels and in national capitals, the findings and experience from the ConsenCUS project sketch five broad policy needs.

1. Adopt a **balanced approach to supporting ICM development**, supporting both the demonstration of next generation technologies and deployment of mature technologies to plug the EU innovation deficit while advancing ICM goals.
2. Acknowledge the **significant funding needs of demonstrator projects**, compared to technology R&I, and **allow sufficient financial headroom and time** to “engineer out” demonstration challenges and foster learning-by-doing.
3. Roll out **time-bound supportive policies and mechanisms for reducing industrial energy costs**, to mitigate the high operational costs of carbon capture in the context of the current energy crisis.
4. Acknowledge the trade-offs between technology characteristics such as **life-cycle emissions, capture efficiency, energy consumption, and scalability**, rewarding technologies that perform well against essential criteria for a particular use-case.
5. Enhance innovation capacity by **removing red tape, improving governance, and adjusting funding requirements** to match the reality of demonstrating new ICM technologies at scale.

This policy paper was authored by Energy Policy Group (EPG), which is part of the ConsenCUS project consortium.

5 References

[i] E3G, 2023. Carbon Capture and Storage Ladder

[ii] European Commission, 2024. Towards an ambitious Industrial Carbon Management for the EU

[iii] Bruegel, 2024. Europe's 2040 climate target: four critical risks and how to manage them

[iv] European Commission, 2021. European Climate Law

[v] Porthos, 2023. First CO2 storage project in the Netherlands is launched

[vi] NTB, 2025. Carbon capture in Oslo becomes a reality!

[vii] Equinor, 2025. Investing NOK 7.5 billion in expansion of the groundbreaking Northern Lights CCS-project

[viii] Aalborg Portland, 2025. Carbon Capture and Storage.

[ix] CCS Europe, 2023. Innovation Fund supports CCS projects

[x] European Commission, 2025. Consultation on the list of Projects of Common Interest (PCIs) in CO2 networks

[xi] European Commission, 2024. The future of European competitiveness: Part A – A competitiveness strategy for Europe

[xii] https://www.statista.com/topics/11797/cleantech-in-europe/#topicOverview

[xiii] Politico, 2025. EU exploring weaker 2040 climate goal

[xiv] Energy Policy Group, 2023. Carbon Capture, Utilisation, and Storage: Challenges and recommendations from the ConsenCUS project

[xv] European Central Bank, 2025. How enduring high energy prices could affect jobs.

[xvi] Andrianov et al, 2022. Selection of temporary storage strategy and description of uncertain parameters or processes.