RSC PP 2024/02
Robert Schuman Centre for Advanced Studies
Florence School of Regulation

POLICY PAPER

The role of CCS in the EU - thoughts on a possible Road Map for the next Commission

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ISSN 1830-1541

Published in September 2024 by the European University Institute.
Badia Fiesolana, via dei Roccettini 9
I – 50014 San Domenico di Fiesole (FI)

Italy

With the support of the Erasmus+ Programme of the European Union

The European Commission supports the EUI through the European Union budget. This publication reflects the views only of the author(s), and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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Abstract

In the Commission's Industrial Carbon Management Strategy it acknowledges the importance of CCUs, and that without it the EU will not succeed in its Green deal and Net Zero ambitions. In her speech before the Parliament and the Political Guidelines outlining the next Commission's priorities, the importance of CCUS for the Clean Industrial Deal is highlighted by President Von der Leyen. In this article the author looks at the challenges in developing a 'fit-for-purpose' CCUS value chain in time to meet the EU's needs, and suggests a tentative road map of actions that the next Commission may consider taking.

Keywords

Industrial Carbon Management, Carbon Capture, Usage and Storage, Industrial Clean Deal

Acknowledgements

My thanks to my colleagues at the Florence School of Regulation for their input and suggestions in this paper, notably Alberto Pototschnig, Andris Piebalgs, Jean-Michel Glachant, Leonardo Meeus and Ronnie Belmans. The opinions, and any inaccuracies remain, however, those of the author.

Executive Summary

The EU's Industrial Carbon Management Strategy recognizes that without CCS, the EU will not be able to achieve its climate ambitions. Three categories of CCS may be identified:

'No-choice CCS': unavoidable process emissions such as those from cement production, and, at a later stage of the decarbonisation cycle, negative emissions achieved through CCS to balance the GHG emissions that the EU is unable to avoid.

'Options where CCS seems to be cost effective (at least for a certain transition period, and possibly longer): The Carbon Border Adjustment Mechanism (CBAM) enables the EU to progressively expose its energy intensive industry to the full effects of the ETS, eliminating free allowances. By 2034, the relevant CBAM sectors (iron and steel, cement, hydrogen, fertilisers,) will therefore be fully exposed to the effects of the ETS. For some of these companies, CCS is the only currently technically feasible or economically reasonable option to decarbonising; without this they will simply need to buy ETS allowances or relocate. Chemicals and other energy intensive sectors may be brought into the CBAM in the future, at which point they will also progressively lose their free allowances, at which point they will fall into this category at least for some products.

'Additional options for the use of CCS': For electricity generation to balance RES, it remains to be seen whether the use of existing combined-cycle gas turbines (CCGTs) combined with CCS would be a more cost-effective solution compared to new hydrogen generation facilities using RES H2 or other sources of flexibility. Low-carbon hydrogen may in certain cases be a more cost-effective decarbonisation option for the EU compared to renewable hydrogen, especially when produced in the EU.

Building a 'no-regrets' CO_2 network at scale and on time does not have to grandfather polluting technologies or create stranded investments. New investments in CCS seek to capture and permanently store at least 90% of CO_2 emissions. By combining sustainable biomethane into the natural gas feedstock, and assuming that methane leakage can be avoided, CCS can ensure completely decarbonised end-products (steel, cement, electricity, hydrogen…). Blending using e-methane is also an option. By increasing the blended percentage above 10%, a potential negative-carbon option emerges. In any event, a 'no-regrets' grid, properly designed, will be needed to permanently store negative emissions towards the later stage of the decarbonisation cycle.

The EU will therefore need a cost-effective 'no-regrets' CCS value chain to be in place by the time that the ETS price rises to match the cost of CCS for industry (estimated to be around €150-200/tonne) and when CBAM industry is fully exposed to the effects of the ETS (2034). If the 'no-regrets' grid is not in place by that date, industry will not be able to decarbonise, and will be forced instead to buy ETS allowances - thus raising costs for steel, cement, fertilisers etc. for EU citizens and industry, but not necessarily reducing GHG emissions in these sectors[1].

But **the key challenge for the EU in this respect** is that, until this 'ETS price/CCS cost' tipping point is reached when ETS allowances are eliminated, industry will have too limited an incentive to invest in the capture facilities required for CCS, or to sign long-term CO_2 transport and storage contracts that infrastructure investors need to de-risk investments.

Without specific action at EU and Member States level to catalyse the building of the CCS value-chain on an 'anticipatory investment' basis, by the time that it becomes essential, the grid will therefore not be in place. The EU therefore risks that its climate ambitions lead to an unsustainable situation because it will have imposed a high ETS cost on its industry and citizens, with potential job losses and industrial delocalisation, instead of transforming these energy-intensive sectors. Given that existing CCS projects such as Porthos in the Netherlands take as much as 10 years to develop,

1 Unless other, potentially more costly transformations of these industries, were supported via State aid earlier than expected.

action is urgent.

In many respects this problem of the need for anticipatory investments - resulting from a situation where there *is* certainty that an infrastructure value chain will be required in future, but there *is no* certainty as to the needed scale, location, and timing of that infrastructure, is similar to that seen regarding hydrogen. Solutions will be required for CCS that are similar (but not identical) to those that are emerging regarding the future hydrogen grid.

A roadmap for driving CCS investment in the EU is proposed, which is considered more in detail in the conclusion to this paper, but may be summarised as follows:

Data Collection: There is an urgent need for further concrete data on the cost of CCS, including its relative cost compared to other decarbonisation options and the cost of using CCS to achieve zero or negative GHG electricity and hydrogen. This data will form the basis for sound EU CCS policy and grid planning/investment.

Planning: Based on the data collected, the anticipated CCS infrastructure needs can be refined over time. This will enable the development of a 'no-regrets' CCS grid, evolving as more data becomes available, based on detailed market-testing. This should factor-in the possibility to use repurposed gas pipelines, especially the low-calorific grid in Northern Europe which is being rapidly decommissioned.

In this context the 'no-regrets' element of the grid planning is important. Based on extensive market testing - asking energy intensive companies whether, and at which ETS price they would be willing to sign long-term CCS transport and storage agreements - it would be possible to design such a grid.

On this basis, (i) in the context of the NECPs, Member States may determine how they will ensure that a 'no-regrets' CCS grid is developed through a combination of carbon contracts for differences and state guarantees for anticipatory infrastructure investments, and (ii) a framework for the development of a CO_2 Ten Year Network Development Plan should be established, and actors encouraged to develop a 'no-regrets' CO_2 grid model prior to this.

Carbon Contracts for Differences (CCFDs) and/or state guarantees for anticipatory grid investments. Without state action, the CCS grid will develop too late to be compatible with its decarbonisation aims and the full impact of the ETS on CBAM sectors, given the decade or more needed from planning to entry into operation. This may be resolved through a combination of an accelerated train of CCFDs and state guarantees for anticipatory infrastructure development, implemented within the context of a CCUS IPCEI. Germany and the Netherlands have taken the lead here; the Commission should follow by establishing a 'Carbon Bank' financed by the ETS Innovation Fund and/or the future Competitiveness Fund that has been announced by President von der Leyen.

UK and Norway Involvement: For a rational EU CCS system to emerge, the CO_2 storage capacity of the UK and Norway will be essential. Efforts should be made to bring Norway under the NZIA, negotiate a CCS agreement with the UK, and ensure that all other relevant rules are adapted so that CCS applies seamlessly between the EU and these countries.

Regulatory Certainty: Companies building CO_2 grids and storage at scale will need to de-risk their investments, notably through long-term CO_2 transport and storage contracts with industrial emitters. They will need to be sure that any future regulatory framework, applying TPA to such infrastructure, does not undermine the validity of such agreements. A 'fast-track' legislative proposal could be put forward by the Commission in the short-term to propose mechanisms to accelerate regulatory certainty for CCS infrastructure investments, while the wider CCS framework - similar to the recently agreed gas and hydrogen package - is negotiated.

Accelerating planning procedures: Whilst the EU has taken action to ensure that Member States implement accelerated planning procedures for essential investments in RES, there are no such provisions regarding CCS. The abovementioned future proposal on establishing a regulatory framework for the CCS grid and storage would be good opportunity to do so.

Establishment of CO_2 Purity and Other Relevant Standards: Standards for CO_2 purity and other relevant aspects will need to be established, for example via CEN.

Clarification on the Treatment of State Guarantees: It remains to be seen whether private companies are able to shoulder the risk of leaks by CO_2 storage infrastructure and insure for this, which should evidently be the 'default' option. Clarification could be provided on this, and, if relevant on the State aid treatment of state guarantees for the risk.

Introduction of a Mass Balancing and Certification System: A mass balancing and certification system for CO_2 will need to be introduced, which could, for example, be included in the Commission proposal for a regulatory framework for CO_2 grids.

Finalisation of the ratification of the amendment to Article 6 of the London Protocol[2] to allow for cross border transportation of CO_2 for sub-seabed CO_2 storage.

This suggested Roadmap provides a basis for consideration regarding possible priorities for the next Commission. It is not exhaustive, and the various Working Groups of the ICM Forum are identifying other needed actions.

1. Why we need CCS and why is it urgent?

The Commission's Industrial Carbon Management Strategy marks a sea change in its approach to CCS. It is a formal recognition by the Commission that without CCS, the EU is unlikely to reach its climate ambitions as set out in the Climate Law.

In President von der Leyen's confirmation proceedings[3] before the European Parliament and the accompanying Political Guidelines[4], she committed that her first priority for her next mandate would be "*prosperity and competitiveness*" regarding the Green Deal, a technology neutral energy and Green Deal policy, and a *"Clean Industrial Deal"* in particular for energy intensive sectors. If indeed CCS is the most cost-effective option for decarbonising certain of these sectors, it should be treated by the next Commission as such and be prioritised. Not least, as explained below, not to give CCS the necessary policy priority would be potentially prejudicial to the competitiveness of EU industry compared to imports in CBAM sectors.

Three different categories of CCS that the EU will/may need can be identified, which may be categorised as being from certain to probable:

2 https://www.iea.org/reports/carbon-capture-and-storage-and-the-london-protocol.
3 https://neighbourhood-enlargement.ec.europa.eu/news/statement-european-parliament-plenary-president-ursula-von-der-leyen-candidate-second-mandate-2024-2024-07-18_en.
4 https://commission.europa.eu/system/files/2020-04/political-guidelines-next-commission_en_0.pdf.

1.1 First, CCS will be a 'no-choice' option for certain decarbonisation needs:

- unavoidable process emissions - for example in the cement industry where large quantities of CO_2 are emitted when turning limestone into lime, which accounts for two-thirds of emissions from cement production[5]. There is no other viable decarbonisation solution than capturing and storing these emissions (or their use in products permanently storing CO_2[6]).
- removals of CO_2, or 'negative emissions' - the EU's Climate Law commits to 'net zero', meaning that any residual emissions in the EU must be compensated by negative carbon actions - capturing and permanently storing either biogenic emissions from sustainable biomass, or via direct air capture. According to the Commission's Industrial Carbon Management Strategy, to achieve the EU's climate ambitions, 280 MT of CO_2 will have to be captured and permanently stored by 2040 and around 450 million tonnes by 2050.

Just focusing on these emissions represents an important and urgent challenge. Scaling up a CO_2 capture, transport and storage industry in this timeframe, for just these 'no-option' needs, will be challenging.

1.2. Second, there will also exist 'cost-effective' CCS needs.

Until recently, the EU has struggled with the question 'how to decarbonize energy intensive industry covered by the ETS in the light of the problem of carbon leakage?' Should the EU fully expose its energy intensive industry to the ETS, requiring them to pay a carbon price which their overseas competitors do not pay, the likely consequence is that the EU industry would become uncompetitive compared to imports, losing market share, and delocalising. The EU has attempted to overcome this problem by introducing the Carbon Border Adjustment Mechanism, or CBAM.

The CBAM enables the EU to progressively expose its industry to carbon pricing by gradually removing free ETS allowances and impose an equivalent carbon charge on imports. It has initially decided to introduce the CBAM in the iron and steel, cement, fertilisers, hydrogen and electricity sectors.

The reduction of free ETS allowances on EU industry and the imposition of the equivalent CBAM charge on imports will be progressively introduced from 2026, with free allowances for EU industry reduced by 10% by 2028, 48.5% by 2030 and being removed altogether by 2034. Assuming an ETS price of €100/tonne, these industries would therefore have to pay roughly €10 per tonne of CO_2 emitted in 2028, €50/tonne in 2030 and €100/tonne in 2034. Energy intensive companies in CBAM sectors in the EU will therefore have to progressively decarbonise or pay the auction cost for ETS allowances for the CO_2 that they emit.

In determining the effect of this change on CCS, the next questions are therefore, (i) what ETS price will be needed to convince these energy intensive industries that will be fully exposed to the ETS by the mid-2030s to invest in CCS (i.e., buy capture equipment and sign long-term transport and storage agreements?), (ii) would they use CCS to decarbonise, or is there another better, cheaper, or legally mandated decarbonisation option for them? and (iii) what is the likely ETS price they will have to pay by the mid-2030s?

5 Ali Abdelshafy, RWTH Aachen, Martin Lambert, Prof. Dr. Grit Walther, 2011. The role of CCUS in decarbonizing the cement industry: A German case study. OIES. https://doi.org/10.1016/j.cemconres.2011.03.019.
Boakye, K., Fenton, K., Simske, S., 2023. Machine Learning Algorithm to Predict CO2 Using a Cement Manufacturing Historic Production Variables Dataset: A Case Study at Union Bridge Plant, Heidelberg Materials, Maryland. Journal of Manufacturing and Materials Processing 7, 199. https://doi.org/10.3390/jmmp7060199.

6 This paper only discusses CCS not CCU. Permanently capturing and storing emissions in products is equally important, but it is outside the scope of this analysis.

(i) what ETS price will be needed to convince the energy intensive industries that will be fully exposed to the ETS by the mid-2030s to invest in CCS (i.e., buy capture equipment and sign long-term transport and storage agreements)?

Whilst assessing full value chain costs for CCS remains challenging, due to factors such as the effect of economies of scale, the questionable availability of onshore storage at scale, and the possibility of currently unforeseeable technological developments, projections typically place the cost of CCS for energy intensive industry and electricity generation between €70 to €250/tCO_2[7], with the largest volumes potentially available at less than €120/tCO_2. Whilst these figures are confirmed when informally discussing this question with project developers[8], which typically put current full value chain cost in the range of €150-200/tCO_2, robust and detailed public data available on this is limited.

(ii) would the energy intensive industries that will be fully exposed to the ETS by the mid-2030s use CCS to decarbonise, or is there another better, cheaper, or legally mandated decarbonisation option for them?

Certain energy intensive industries will have the choice to decarbonize through electrification or through the use of renewable hydrogen. However, for other sectors, the use of these options is likely to be either technologically infeasible or an economically unreasonable decarbonisation option. Independent data, for example from the IEA[9] and others[10], argue that for certain energy-intensive industries, electrification/clean hydrogen to replace fossil fuel use is either technically very challenging or a very expensive option compared to CCS. Whilst a CCS cost of €70 to €250/tCO_2 is significant, these figures are typically lower than the expense of constructing entirely new technological value chains and broadly compatible with medium-term ETS price forecasts[11].

The level of data available on this issue is however limited, and further efforts to provide additional transparency would be valuable as a policy-making input. What can be said with confidence is that for much of the industry covered by their CBAM, as well as for those prime candidates for future inclusion in the CBAM (chemicals and refining….), it is not possible to find analysis indicating that the option of using existing plant combined with CCS is likely to be a *more* expensive option for decarbonisation at scale than building new capacity using RES-E and/or RES H2.

(iii) What ETS price will the energy intensive industries that will be fully exposed to the ETS by the mid-2030s have to pay, and will it be enough to convince them to invest in CCS?

In 2024 the ETS price has ranged between approximately €52-100/tonne[12]. Until early 2021, it was far lower - it hovered around €20. However, in 2021 it rapidly increased to around €100/tonne. The driver behind this rapid increase was the EU's decision, in 2021, to adopt a legally binding GHG reduction target of 55% for 2030. The Climate Act enshrining this in law was adopted in June 2021, but it was already clear earlier in that year that the Climate Act would be agreed as well as the level of ambition (i.e., 55%).

7 Toby Lockwood, 2023. Mapping the cost of carbon capture and storage in Europe. https://www.catf.us/2023/02/mapping-cost-carbon-capture-storage-europe/.

8 Based on discussions with project developers and the author of this paper.

9 https://www.iea.org/commentaries/is-carbon-capture-too-expensive.

10 https://www.sciencedirect.com/science/article/pii/S2211467X18300634; https://www.sciencedirect.com/science/article/pii/S2211467X18300634; https://zeroemissionsplatform.eu/wp-content/uploads/Overall-CO2-Costs-Report.pdf.

11 Monna Dimitrova, 2024. 2030 EUA price predictions: expert analysis of 3 scenarios. https://www.homaio.com/post/2030-eua-price-predictions-expert-analysis-of-3-scenarios.

12 Carbon Price Tracker | Ember (ember-climate.org).

ETS traders understood that (i) to achieve the 2030 GHG reduction target of 55%, the ETS sectors would need to contribute strongly, (ii) due to the Climate Act, the EU had a legal obligation to bring the ETS into line with the 55% GHG reduction commitment, (iii) this would lead to a rapid increase in the ETS price, and thus (iv) financial gains could be made by buying ETS allowances, rapidly pushing prices up. Whilst the actual ETS reform with a GHG reduction trajectory of 62% - in line with the headline GHG reduction 55% requirement - came later, its 'direction of travel' was already clear in 2021, and traders reacted accordingly.

During the next Commission the EU will need to adopt its GHG reduction target for 2030-2040. It will then need to update the ETS, so that the reduction of allowances is compatible with the 2040 GHG reduction commitment. President von der Leyen stated in her confirmation speech before the European Parliament that she stands by the 90% GHG reduction that the existing Commission suggested[13].

Irrespective of whether the final 2040 GHG reduction target ends up at 90% (Member States may favour a less ambitious figure), to achieve the chosen percentage the EU's energy intensive industry (and its electricity mix) will need to be (quasi) completely decarbonised. Given the emissions that will be impossible to abate by 2040 (agriculture, buildings, air and maritime….), without decarbonising the ETS industrial and electricity sectors there is no way to make even an 80% GHG reduction target remotely credible. This analysis is confirmed by Commission modelling on which it based its 90% suggestion[14].

Thus, in 2025-2026, we can expect that the next Commission will formally table a new 90% GHG reduction proposal for 2040. This (or a somewhat lower target) will probably be agreed by the Council and Parliament by around 2028/2029. Based on the above experience, once this is agreed, we can expect traders to identify that the ETS will be reformed accordingly, and push up the ETS price to a new, higher, range and the end of the 2020s/early 2030s.

The current trajectory of the ETS foresees that there will be no allowances auctioned after 2040 - ETS sectors will need to be fully decarbonised by that date. If this were to be confirmed, ETS sectors would only be legally allowed to emit GHG after this date if they had previously bought and 'banked' allowances for later use - but these banked allowances would also soon run out. Even if the ETS were extended beyond 2040 - not envisaging a total elimination of emissions in these sectors - the level of allowances auctioned would surely be reduced drastically and would be phased out quickly in the second half of the subsequent decade.

The only logical conclusion of this (admittedly high-level) analysis that one can draw is that:

- Towards the end of this decade/early 2030s the ETS price is likely to jump again. It is beyond the scope of this article (and the authors' capacity) to speculate on the likely level of the increase, but logic dictates that it will be significant.
- By 2034, the sectors covered by the existing CBAM (steel, cement, fertilisers, hydrogen, electricity), as well as those that will be covered by its eventual reform (chemicals, refining….), will be fully exposed to the carbon pricing effects of the ETS.
- Thus, by the middle of the next decade these companies will need to either stop emitting CO_2 or pay the (likely high) ETS price. Importers of these products will need to do the same.

13 https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2040-climate-target_en#:~:text=In%20February%202024%2C%20the%20European,by%202040%20relative%20to%201990.

14 See, for example, the Commission's analysis of how a 90% GHG reduction could be achieved per sector (energy, industry, buildings….). https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2040-climate-target_en#:~:text=In%20February%202024%2C%20the%20European,by%202040%20relative%20to%201990.

- By 2030 or shortly after, the ETS price is therefore reasonably likely to be in the range where CBAM sector companies would have an economic interest in investing in CCS rather than buying allowances. By 2034, with the removal of free allowances, CBAM industry will be fully exposed to this higher ETS price. Before that date, however, as such companies are only progressively fully exposed to the ETS, they are likely to have more incentive to buy allowances than to invest in CCS. Unless action is therefore taken to drive 'anticipatory investment' in the CCS value chain, it will not be built in time for when it is needed by industry by around 2034 (this problem is considered in more detail below).

1.3 Third, there exist a number of potential additional uses of CCS.

There are a number of potential applications for CCS that may become highly relevant in the context of the EU Green Deal should President von der Leyen's promise to the European Parliament of a Green Deal focused on "*prosperity and competitiveness"* being characterised by *"technology neutrality"* be translated into effective policy:

Electricity generation: by 2040, to achieve any credible GHG reduction target, the EU's electricity mix will need to be (quasi) carbon free. Clearly, RES will make up the lion's share of generation, with nuclear contributing in a number of Member States. However, with very high RES levels - around 80% of the electricity mix, significant balancing power will be required.

To date, the Commission has focussed on renewable hydrogen as the future solution to provide longer-term and seasonal balancing. But in a 'technology neutral' energy policy scenario, the use of existing CCGTs combined with CCS is another potential solution to consider as an alternative to new hydrogen generation facilities using RES H2 or other sources of flexibility.

New CCS investments aim at a 90% CO_2 capture rate and if one mixes bio-genic/renewable methane into the natural gas used to power the turbines at a level of 10% or more, this will logically lead to zero- or even negative carbon power, assuming that methane leakage can be avoided with the bio or e-methane used for blending.

Whether this approach - using existing CCGTS/OCGTs combined with CCS (and at a later stage mixing bio-genic/renewable methane into the natural gas used) - is a more cost-effective option than building entirely new solutions such as hydrogen turbine-based capacity using renewable hydrogen remains to be seen.

Low carbon or 'blue' hydrogen. Until now the Commission, and the EU more widely, has taken a technology-specific approach to its hydrogen policy - the RED III targets for industrial hydrogen and the ReFuel Aviation and (to a lesser extent) Maritime Regulations, for example, adopt a clear choice for renewable hydrogen over low-carbon or nuclear produced hydrogen.

If a 'technology neutral' energy policy does emerge during the next Commission, whilst it remains to be seen which form of hydrogen is the most cost-effective, studies indicate that low-carbon hydrogen may well be a more cost-effective decarbonisation option for the EU compared to renewable hydrogen produced in the EU[15]. Again, mixing bio/e-methane into the natural gas feedstock can potentially produce zero- or even negative GHG 'blue' hydrogen[16].

15 https://fsr.eui.eu/publications/?handle=1814/76564.

16 Rosa, L., Mazzotti, M., 2022. Potential for hydrogen production from sustainable biomass with carbon capture and storage. Renewable and Sustainable Energy Reviews 157. https://doi.org/10.1016/j.rser.2022.112123.

Interesting in this context is the Platts Ammonia Price Chart[17] which illustrates monthly averages of fossil fuel (grey), low-carbon (blue) and renewable (green) ammonia prices across a range of geographies and delivery options. This indicates that the cost of importing blue ammonia into the EU from the Middle East is roughly 10% more than the cost of grey ammonia from the same region, whereas green ammonia from the same region is roughly three times the price.

Given the REDIII's legally binding hydrogen target - where Member States have to ensure that 60% of the approximately 8 MT of industrial hydrogen consumed in the EU will be renewable in nature by 2035 - this technology-specific renewable hydrogen target looks as if it might be an expensive policy choice based on this data.

1.4. This leads to a logical and unavoidable conclusion - action on developing the 'no-regrets' CCS grid and storage is really important and urgent.

Based on all these indications, it is clear that by the mid-2030s, the EU will need a large-scale CCS value chain for some if not all these end-uses.

Further work needs to be undertaken to quantify the likely timing, origin and volumes of CCS that will need to be captured and stored/used, and this should feed into a detailed planning exercise, based on a cautious approach involving market-testing to identify a 'no-regrets' grid. But the policy and political conclusion that must be drawn from this is clear - CCS at scale is crucial to meeting the EU's climate ambitions, as well as the need to decarbonise its energy intensive industry in a cost-effective and technology neutral manner, consistent with any sensible definition of the Commission's future Clean Industrial Deal.

Building CO_2 transport and storage at scale requires significant investment and time. For example, the Porthos project[18] in Amsterdam, one of the largest projects in the EU to reach final investment decision, envisages the permanent storage of 2.5 MT CO_2 per year, storing 37 MT CO_2 over a 15-year period. The project received €102M in grants from the EU's CEF fund, and the offtakers - Air Liquide, Air Products, ExxonMobil and Shell - received subsidies from the Dutch SDE++ fund to bridge the difference between their ETS exposure and the total CCS costs via carbon contracts for difference (CCFDs). The project started in earnest well before 2018 when the feasibility study was completed and is expected to enter into service in 2026. Thus, this 'flagship' project will have required around 10 years between conception and completion. This use of large-scale public money is justified due the early stage of development of the CCS value chain and the need to scale up technology, but a different financing approach will be needed to fund the wider CCS value chain.

Based on this experience, if we want to have the needed 'no-regrets' grid and storage in place for when the EU's CBAM industry is fully exposed to ETS costs - 2034 - we should already be in the planning phase for the needed investments and capacity. In fact, we are already well behind.

17 https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/051023-interactive-ammonia-price-chart-natural-gas-feedstock-europe-usgc-black-sea.

18 https://cdn.catf.us/wp-content/uploads/2023/02/20091740/CATF_PorthosFactsheet_English_02.27.23.pdf.

2. The investment problem and the risk of a 'lost-decade'.

Imagine the following conversation between the Chief Sustainability Officer (CSO) of a cement or fertiliser company and its CEO in 2024. The CSO says *'by the mid-2030s we will be fully exposed to the ETS, which will probably be around €150/tonne. I have calculations that show that we can probably install CO_2 capture and sign long-term transport and storage contracts for around this amount. We should commit today to these investments to be ahead of our rivals.'*

The CEO will surely reply *'can you be sure that the ETS will be at that level? If the US fails to adopt a climate charge/tax over the next decade, will the EU then be able to politically commit to expensive net-zero policies given the competitive disadvantages that this will entail compared to the US and others? Is it not better and cheaper for us to simply continue to buy ETS allowances until we can be certain that the ETS price will remain above €150? Let's wait.*'

This is the Catch-22 of the EU's CCS challenge. We absolutely need to have a cost effective 'no-regrets' CCS grid and storage in place by the mid-2030s at the latest, but until it is economically needed by industry (i.e. when (i) the CCS cost/ETS price tipping-point is reached (which may be even before 2030) and (ii) free ETS allowances are fully phased out), no industrial emitter will rationally invest in capture facilities and sign the long-term CO_2 transport contracts needed to finance the grid. It is more rational for them to wait and buy ETS allowances until (i) the CBAM/free allowance elimination is fully phased-in (2034), and (ii) one can be certain that the ETS price will remain above the CCS cost/ETS price 'tipping-point'.

Thus, without regulatory intervention of some kind, it is inevitable that the CCS grid will not be built sufficiently early to meet the EU's climate and competitiveness objectives, and the EU risks a 'lost decade' of underinvestment in CCS that is incompatible with its climate and competitiveness objectives.

3. If the EU simply relies on the ETS to drive CCS development, what is likely to happen?

The following key consequences are likely to occur under this scenario:

- Aside from investment in 'flagship' projects that are subsidised by governments (see for example the level of subsidy in the Dutch Porthos project, in the form of capital grants and CCFDs for companies committing to long-term capture and storage), energy intensive companies are unlikely to commit to CCS unless and until the ETS price/CCS cost 'tipping point' occurs, which, assuming that the ETS price increases significantly in the coming years, would be around 2034 when ETS allowances are fully phased out.
- Potential investors in CO_2 transport pipelines are likely to have difficulties securing long-term agreements for the use of assets, which will be needed to de-risk projects before the mid-2030s.
- Investments in storage - notably those made by oil and gas companies subject to the CCS storage obligation under the Net-Zero Industry Act - will be unlikely to be able to secure usage agreements before the ETS 'tipping point' is reached, putting into question the short to medium-term viability of investments.
- By the time that companies in CBAM sectors (or, potentially, also those wishing to produce blue hydrogen/ammonia or CCS-based balancing power), need a cost-effective CCS network, it is unlikely to be in place. Given the long lead times for investments, it will then take a significant period to develop the necessary infrastructure.

- In the meanwhile, EU industry covered by the CBAM will need to pay for ETS allowances for emissions, increasing product cost in the EU's CBAM sectors (steel, iron, cement, fertilisers…), but not necessarily reducing GHG emissions in these sectors, unless potentially more costly transformations of these industries (with RES-E or RES-H2) would be supported earlier than expected via State aid or unless industry relocates (see also next bullet point).
- If non-EU competitors in CBAM sectors have access to cost-effective CCS networks, they will be able to export to the EU and avoid CBAM payments. The UK is moving ahead quickly on CCS[19], as is Norway[20], Canada[21]. The US IRA gives strong support for the development of CCS. Where companies outside the EU have access to CCS solutions cheaper than the CBAM/ETS cost, they will be able to 'out-compete' EU companies, which will lose market share and close capacity in the EU.
- During the period before the CCS cost/ETS price 'tipping point' is reached and ETS allowances are phased out by 2034, unless they are incentivised to invest in CCS through specific government support, CBAM industries will pay the cost of ETS allowances, but this will only result in increased costs of their products for EU citizens and industry but no GHG savings in these sectors.

4. Is CCS only a transition technology, or to what extent could it be a long-term 'Net-Zero' climate and industrial solution for the EU?

A new CCS project will typically seek to capture 90% of CO_2 emissions from an industrial facility, although the number will vary notably depending on the concentration of CO_2 in the plants' emissions.

Thus, it may be argued that CCS is a transition technology, and (i) it is therefore better for energy intensive industry and other uses such as balancing electricity to invest in 'end-use' net-zero technologies, such as RES-E/RES H2, even if this is more expensive in the short-term (i.e. 2030-2050), and (ii) we should only invest in CCS for unavoidable process emissions (cement etc.) and negative emissions.

However, this is an oversimplification:

- If we do not invest to develop CO_2 grids and storage and use it where CCS is a more cost-effective decarbonisation option for certain sectors than RES-E or RES H2, then imports from countries that have invested in CCS will be cheaper than EU-produced decarbonised products using more expensive options.
- On the other hand, if we do develop a cost-effective CCS network - ideally cheaper than that of our major competitors - this can result in a competitive advantage for EU-based production when selling into EU markets in CBAM sectors. Developing a cost-effective CCS value chain is therefore an intrinsic part of any technology neutral 'Clean Industrial Deal'.
- As we move closer to 2050, CCS will be essential for negative emissions. Thus, with careful planning of the grid and storage, as technology develops and 'true net zero' options may emerge for energy intensive industry, the CCS capacity built for industry during the transition phase can be taken over for negative emissions.

19 The Carbon Capture and Storage Infrastructure Fund: an update on its design (May 2021) (accessible webpage) - GOV.UK (www.gov.uk).
20 https://www.regjeringen.no/en/topics/energy/carbon-capture-and-storage/id86982/.
21 https://natural-resources.canada.ca/climate-change/canadas-green-future/capturing-the-opportunity-carbon-management-strategy-for-canada/canadas-carbon-management-strategy/25337.

- For unavoidable process emissions from cement etc., even if CCS may never be a true net-zero option (based on current technological solutions it is not possible to capture 100% of the CO_2 emitted), there is no currently foreseeable option. Closing down EU industry and importing the products that produce CO_2 elsewhere, and then declaring the EU 'carbon neutral', should not be viewed as a credible option.
- When using CCS for capturing and storing emissions from the use of fossil fuels, for example for creating heat, 90% of the CO_2 can typically be captured and stored for new investments using existing technology. On this basis, if one would burn a 90% natural gas/10% sustainable biogas fuel mix, the residual 10% of CO_2 emissions that are emitted would be balanced out by the 10% of negative emissions, making the result 'net-zero'[22]. This assumes that when using biogas or e-methane, methane emissions during the production/supply value chain can be avoided - in any event they would need to be taken into account. If one uses 20% sustainable biogas, the resultant industrial process is logically 'net-negative' from a GHG perspective.

Based on this logic, by mixing increasing percentages of bio-methane into the natural gas feedstock, CCS could be a potential option for zero/negative carbon electricity, hydrogen, steel, fertilisers etc.

This is not to say that this is a 'magic bullet' for the EU's climate objectives. There is precious little data on the cost of such an approach, or the availability of sufficient sustainable biogas to make this option mainstream, or methane leakage under this scenario. It is, however, certainly relevant, and the need to develop data in this respect as part of a technology- neutral Industrial Clean Deal seems self-evident.

Thus, CCS can and will be an important part of a long-term net-zero EU economy. The question how big the part it will play in the long-term will depend on cost and technology developments. But the clear conclusion is that a carefully planned 'no-regrets' CCS value chain will not be a lost investment, but a 'no-regrets' decarbonisation option for the EU.

5. So what are the options to address the CCS 'Catch-22' challenge?

There are two actions that the EU is taking at present to address this challenge:

- Providing capital and other grants to 'flagship' projects. These are valuable, and enable experience to develop, but given the budgetary implications, capital grants will not be a solution to the wider CCS 'Catch-22' problem, given its scale and cost. Even if the needed funds would be theoretically available, this would not be a rational, cost-effective support mechanism, as it would not be dynamic in nature, linking subsidies to the ETS price.
- The Net-Zero Industry Act[23]. Whilst the main aim of the Act is to provide targets and support to the production of 'net-zero technologies' within the EU, it also focuses on CCS. It (i) sets an EU target for CO_2 storage in the EU by 2030 - 50 MT, (ii) provides measures to increase the level of transparency regarding the availability of potential storage sites in the EU, and (iii) provides a generally worded obligation on Member States to take appropriate measures so that the infrastructure to supply this 50 MT of storage is built in time.
- Most significantly, however, Article 23 of the NZIA places a legal obligation on companies that have produced oil and gas in the EU between 2020-2023 to build CO_2 storage to contribute to achieving this 50 MT target by 2030. The storage to meet this obligation must be built in the EU. Where for example a company has produced 10% of the oil and gas produced in the EU over the last three years, it has a legal obligation to build 10% of the 50 MT target by 2030,

22 Rosa, L., Mazzotti, M., 2022. Potential for hydrogen production from sustainable biomass with carbon capture and storage. Renewable and Sustainable Energy Reviews 157. https://doi.org/10.1016/j.rser.2022.112123.

23 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401735.

i.e., 5 MT.

- Member States have a general obligation under EU law to enforce EU obligations, for example through dissuasive penalties. Thus, whilst enforcement of this obligation is not without difficulty (which Member State is responsible for enforcing which part of any given company obligation?…), and there are a number of economic and practical challenges to companies in meeting this obligation (not least, 2030 is only 6 years away….), this creates a strong obligation that should lead to at least a large part of this 50 MT target being met.

However, these two measures, as well as the general policy statements and measures adopted by the Commission in recent years, will not create the economic or legal conditions that will lead to the establishment of a cost-effective, fit-for-purpose and 'no-regrets' CCS network to solve this 'Catch-22' challenge. Additional measures are necessary.

Investors in the CCS value chain (transport and storage (excepting the investment obligation under the NZIA)) are unlikely to invest significantly unless they are guaranteed that the assets will be used - they need long-term transport and storage agreements to de-risk investments. Once these agreements are in place, they will need a long period to implement the investment.

Users of the CCS value chain are unlikely to sign long-term transport and storage agreements unless and until this ETS/CCS cost tipping point is reached. However, once the tipping point is reached, they will be willing to pay any amount lower than the ETS price for the full CCS value chain.

The solution to this problem is therefore for the EU and the Member States to step in, to de-risk the investments in the CCS value chain, ensuring that a 'no-regrets', fit-for purpose, cost-effective grid and storage is available at scale and in time for when it is needed.

There are two potential forms of mechanisms that could deliver such de-risking - the tendering of carbon contracts for differences, or the provision of state guarantees for anticipatory investments.

5.1. Carbon Contracts for Difference.

Under a carbon contract for difference mechanism ('CCFD'), the Commission/Member States would tender to provide the needed support for (CBAM) industry to decarbonise by a given amount by a given date (which may, for example, mirror the CBAM phase-in date and the consequent withdrawal of free allowances). Companies would bid-in the subsidy required compared to the ETS price to decarbonise by the specified amount[24].

As a hypothetical example, a cement company would undertake due diligence with CCS value chain suppliers and determine that it could decarbonise at a cost of €150/tonne (this may be by CCS or other means - a CCFD should be technology neutral in nature). It would receive the difference between the prevailing ETS price and €150/tonne.

Based on this, the cement company would have the legal guarantees necessary to sign long-term capture, transport and storage agreements for application from in 2034 (or earlier), that would in turn enable infrastructure companies to invest and ensure that the CCS value chain is delivered in time.

The CCFD tender could indicate that it would only apply at a future date, say 2034, in which case, assuming that the ETS price is at least as high as the strike price at that point, the Member State would in fact pay nothing - the mechanism would be a guarantee, not a subsidy. Should a Member State so decide, the CCFD tender could equally apply earlier, before the CCS cost/ETS price tipping-point is reached, in order to accelerate the decarbonisation of industry, and, potentially, give it a competitive advantage as free allowances are phased out.

24 A good overview of how CCFDs work can be found at https://henrike-hahn.eu/files/upload/aktuelles/dateien/Study_CCfD_Henrike-Hahn_6.2022.pdf.

Such mechanism would imply potential State aid and would therefore need to be approved by the Commission.

The question whether a CCFD mechanism should ideally start application when one would expect the CCS cost/ETS price 'tipping point' to be reached, or earlier so that the gradual implementation of the CBAM also leads to decarbonisation, is a question of choice, budget, and policy. If the CCFD payment mechanism is not applied before the expected CCS cost/ETS price tipping-point, CBAM companies will need to progressively pay more for ETS allowances until the CCFD mechanism enters into force, but in the meanwhile they are less likely to invest in CCS, passing on the cost of allowances to EU citizens/companies. But, as mentioned above, to avoid this will require subsidies (between the strike price and the prevailing ETS price) to be paid from state budgets.

There are good grounds for an accelerated CCFD mechanism to put EU industry on a 'fast-track' decarbonisation route, ensure that the industry contributes strongly to achieving the 2030 and certainly 2040 GHG reduction targets, and for industrial policy reasons.

Germany launched its first major call for carbon contracts for differences in March 2024, focussed on the paper, glass, steel and chemical industries, with a funding volume of €4 bn[25]. The total funding will be in the double-digit billions[26]. The Netherlands has also implemented CCFDs covering CCS in the context of its SDE++ mechanism[27].

Should Member States choose to provide this 'pre-tipping point subsidy' to EU companies, and that this is approved under the State aid rules (as is the case for the German and Dutch support), this would give the recipients a competitive advantage over imports in the event that the latter do not receive equivalent subsidies. The opposite also applies - the EU will need to be vigilant that competitors in CBAM sectors do not receive subsidised access to CCS. Indeed, this will be an important issue not just during the pre-tipping point transition period, but also thereafter.

5.2 State Guarantees for Anticipatory Investments.

To develop the Hydrogen grid, Germany has chosen to provide the operators of its future H2 grid (gas TSOs) with state guarantees to underpin the anticipatory investments that are needed to develop the grid at the scale and timeframe needed for expected future demand.

Under this approach, the TSOs propose the grid investments that they believe to be necessary to meet future hydrogen demand. In the short term, revenues from transmission fees will not be sufficient to finance the costs of building this grid, but as the volumes of hydrogen transported increase over time, future revenues are expected to make the investments financially viable over the grids' lifetime. Germany therefore provides a state guarantee regarding these future revenues, based on which the TSOs can borrow the required funds. If the expected volumes and revenues do occur, the state never pays anything. If the volumes and revenues do not, however, develop, the state steps in in the future to cover the shortfall. The Commission has approved this mechanism under the State aid rules[28].

Such an approach could also be applicable for the development of CO_2 grids, assuming that the future operator of the CO_2 grid can be identified. Note in this context that like with respect to hydrogen, much of the future CO_2 grid may be expected to be made up from repurposed natural gas pipelines. However, the prospect for CCS might be less uncertain than for H2, which makes the 'cost' of the guarantee lower and, possibly allows pre-booking of capacity by operators of hard-to-abate

25 https://www.bmwk.de/Redaktion/EN/Pressemitteilungen/2024/03/20240312-first-round-of-carbon-contracts-for-difference-launched.html.

26 https://www.klimaschutzvertraege.info/lw_resource/datapool/systemfiles/agent/ewbpublications/f7531bfd-eb98-11ee-8b39-a0369fe1b6c9/live/document/2403_EN_BMWK-FAQ_Klimaschutzvertraege.pdf.

27 https://henrike-hahn.eu/files/upload/aktuelles/dateien/Study_CCfD_Henrike-Hahn_6.2022.pdf.

28 https://ec.europa.eu/commission/presscorner/detail/en/ip_24_3405.

sectors.

This approach may equally be relevant for CO_2 storage - whilst the EU has gone down the road of mandating storage investment by pool and gas companies in the short-term, this may be an option to consider should this mechanism prove to be an insufficient long-term approach.

6. What are the challenges to implementing a CCFD mechanism covering the EU's CBAM sectors?

Assuming that the ETS price indeed increases in line with the analysis above, the main issue should not be cost. Providing that the strike price/guarantee for the CCFD is set at the expected CCS/ETS tipping point based on robust data, the CCFD guarantee should never be called upon. This issue is therefore one of liability rather than cost, (subject to the caveat that as discussed above, there are strong grounds to tendering CCFDs before the tipping-point is reached, in which case subsidies are required).

By providing well-designed CCFDs, the Commission or Member States would therefore essentially give a state guarantee that in principle should never be called upon. However, there is no guarantee that this will not be the case, in whole or part. The ability of the Commission/Member States to provide CCFDs therefore rests in large part on their willingness, and fiscal ability, to assume this risk. In this context it should also be noted that such CCFDs can be expected to be 'one-way', so that they result in liability for Member States, but not a potential revenue source[29].

Total GHG emissions in ETS sectors in 2023 were 1,126,557,459 tonnes of CO_2[30]. This puts into perspective the potential cost of such a guarantee and the possible need to focus on certain strategic CBAM sectors when providing CCFDs. For example, in 2020, greenhouse gas emissions caused by the chemical reaction in the production of cement in the EU were about 114 MT, roughly 2.5% of all EU emissions[31]; the steel industry is responsible for around 5% of CO_2 emissions in the EU.

7. Should the Commission tender for CCFDs using EU funds - 'an EU 'carbon bank'??

The Commission currently operates a 'Hydrogen Bank'[32] which it uses to tender for renewable hydrogen, using ETS revenues from the ETS Innovation Fund.

There is no reason why it should not develop a similar instrument - a 'Carbon Bank' - to tender for CCFDs for CBAM industry. On the contrary, there are strong grounds to argue that the Commission should do this - not just that it could make a significant difference in terms of the funds/guarantees needed, but by way of example and precedent to catalyse action at Member State level where most of the CCFD guarantees will need to emerge.

29 Where the CCFD strike price is higher than the ETS price, clearly the Member State will need to fund the difference.
However, what if it is other way round, and the ETS price becomes higher than the CCFD strike price - should companies then pay the difference to Member States? In principle this is not the case. If the ETS price is higher than the strike price, the company does not receive additional income or windfall that it should per se surrender to the Member State - it simply avoids paying the higher price for ETS allowances than the strike price.
The company does, however, have an indirect potential benefit - any competitors (such as possible importers) that do not have a CCFD and do not have access to a cost-effective CCS grid will not be able to decarbonise as cheaply, or at all. They may only have the solution of buying more expensive ETS allowances (or CBAM payments) to cover their emissions, which will be passed onto their product cost.
Thus, if the marginal supplier that sets the market price does not have access to CCS, the company covered by the CCFD system - with consequent access to cost-effective CCS - will receive a 'windfall' profit from the higher market price. On this basis, theoretically, the Member States should seek to recoup these 'windfall profits'.
However, calculating this will be pretty much impossible, and so in reality, a CCFD is likely to be one way.
30 https://www.homaio.com/post/what-is-the-eu-ets-emissions-data-published-in-2024.
31 https://carbonmarketwatch.org/wp-content/uploads/2022/11/CMW_Decarbonising-Cement.pdf.
32 https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/european-hydrogen-bank_en.

In her speech to the European Parliament in her confirmation hearing, President von der Leyen announced that in the next EU budget she would propose a *"Competitiveness Fund"* that, *inter alia,* will invest in new IPCEIs. The Commission announced its intention to launch a CCUS IPCEI in its Industrial Carbon Management Strategy. Whether this Competitiveness Fund emerges, and its scope and size, remains to be seen. However, it may be an important additional source of EU-level funding.

8. Which is the better option - carbon contracts for difference or a state guarantee for anticipatory investments by infrastructure operators.

One of the key aims of either measure is to catalyse the required investments in the 'no-regrets' CCS infrastructure, to ensure that it is available at the latest when ETS prices rise to the level that make it essential for the ETS industry that do not receive free allowances and for which CCS is a valid decarbonisation option.

It may also be needed before this 'tipping-point' if Member States take the view that they wish 'accelerated decarbonisation' in these sectors and provide CCFDs that enter into application before this ETS price/CCS cost price tipping-point is reached, becoming an active subsidy and not just a state guarantee.

Either mechanism can be a valid option to achieve the first of these two possible objectives, and both have advantages and drawbacks:

- CCFDs may be seen as a more technology neutral option than a state guarantee for anticipatory investments - a company would opt for whatever decarbonisation option is cheaper to eliminate emissions. They are a more market-based instrument that should avoid over-compensation, and in fact - if properly designed and focussed at providing guarantees at the projected 'tipping-point' - they should, in theory, never lead to the state actually providing funds. However, the potential issue of fiscal liability will be important.
- State guarantees for anticipatory network investments are a more technology-specific choice, but they will guarantee that a 'no-regrets' network of the agreed size will be built, which only indirectly results from the CCFD choice and is thus uncertain. It does however require the state to decide how big the grid will be and who will be responsible for building it.

The two mechanisms are not mutually exclusive - if state guarantees for anticipatory network development are granted, this will guarantee that a CCS grid is available in due time, reducing risk for the companies bidding for CCFDs. Thus, in fact there are good reasons for the Commission/ Member States to follow a dual track approach.

9. What are the other actions that will be needed to enable the CCS value chain to develop at the needed scale and time frame?

Whilst creating the basic financial conditions necessary for the development of the EU's CCS full value chain is obviously the most important and difficult issue to solve, a number of additional challenges remain that will need to be addressed by the next Commission, which include the following:

- The **regulatory framework for CCS infrastructure** is required to provide the legal security necessary to invest. The Commission has indicated its intention to consider tabling a legislative proposal on this issue at the early part of its next mandate.
- **The urgent need for a CCS agreement with Norway and the UK, to ensure competitive CO_2 storage costs and to deal with consequences from the NZIA and the ETS**.

The Net Zero Industry Act requires companies to invest in CO_2 storage that is located in the EU. However, the question may be raised whether, because offshore CO_2 storage at scale is likely to be relatively cheap and plentiful in UK and Norwegian offshore waters, notably in depleted gas fields, excluding these from the NZIA obligation will create a sub-optimal EU CO_2 storage system.

On this basis, requiring companies to invest in storage in the EU under the NZIA, and excluding that in Norway and the UK, may mean that these companies have to invest in assets that are more expensive to develop and operate than in the UK and Norwegian offshore areas.

When companies sign long-term CO_2 transport and storage contracts in the future, they will obviously look to the cheapest supplier. If this is storage developed in Norwegian/UK offshore waters, then companies owning storage in the EU following a NZIA obligation will be 'out competed' and may therefore either have to close the facility or to sell capacity at a loss.

Whichever way one looks at this, it would make great sense for the EU to have access to CO_2 storage where it is cheapest.

In principal Norway is legally obliged to implement the NZIA as a part of its EEA obligations - the Act is adopted under an Internal Market legal base. However, one may legitimately question whether the CCS storage obligation in the NZIA can legitimately be considered to be a Single Market related act. Thus, uncertainty exists whether Norway will be covered by the NZIA investment obligation. In any event, the next Commission and the EU has every interest in (i) fast-tracking clarity on Norway's participation in the NZIA and the availability of storage for EU CO_2 in its waters, and (ii) commencing discussions on an EU-UK agreement on energy issues and notably mutual recognition on CCS storage.

At the same time, the issue of the treatment of CO_2 under the ETS needs to be reconsidered. At present, only when the CO_2 is stored in the EU/EEA can the avoided emissions be deducted from a companies' GHG 'account' - if it is stored outside the EU a company must nonetheless buy ETS allowances to cover the emissions.

- **Liability for CO_2 leakages from storages.** Should CO_2 leak from storages, someone must pay the ETS price for every tonne leaked. This leads to questions (i) who should be liable - the original emitter or the storage operator? (ii) whether insurance is available? and (iii) whether Member States should provide sovereign guarantees, and should this be allowed under EU -State aid rules? Whilst available data indicates that storages should be very reliable indeed[33], with tiny leakage probability, and that insurance may be available, this remains an issue that will need to be addressed.

- **Rules on CO_2 standards.** There is a trade-off that will need to be solved: if lower CO_2 purity standards are set (e.g., allowing higher moisture content), the costs of repurposing existing gas pipelines to carry CO_2 increase (moist CO_2 is corrosive). Standards need to be determined as soon as possible.

- **Permitting procedures for CCS,** unlike for RES-E, have not been looked into at EU level. Any action that can ensure that such procedures are accelerated as far as possible should be considered.

- **Certification and mass balance:** At the early stage of CCS development, we can expect to see isolated projects such as Porthos, where the CO_2 captured and stored is within a closed loop. As the network develops, this will be more difficult - CCS operators can be expected to develop an interconnected system with different actors, implementing a more efficient portfolio

33 John Alcalde et all, *"We calculate that realistically well-regulated storage in regions with moderate well densities has a 50% probability that leakage remains below 0.0008% per year, with over 98% of the injected CO2 retained in the subsurface over 10,000 years"*. Nature: https://www.nature.com/articles/s41467-018-04423-1.

approach. At this stage an EU certification mechanism similar to that seen regarding hydrogen will be required.

- Equally, 'green CO_2' from sustainable biogenic sources will become increasingly valuable when, in the mid-2030s, it is no longer possible to use CO_2 from ETS sectors when making renewable transport fuels from hydrogen. In order to make the transport of this 'green CO_2' efficient, it would be sensible to implement a mass balance system and EU data base for CO_2, based on the hydrogen model, enabling a refinery remote from a source of qualifying green CO_2 to use local ETS-based CO_2 and sequestrate the green CO_2 molecules. To prevent fraud, a mechanism based on the EU data base/mass-balance system for hydrogen would be valuable.
- The international movement of CO_2, especially when stored outside the EU, requires ensuring compatibility with **the London Protocol[34].** Member Sates need to ratify the amendment to Article 6 of the Protocol to ensure that necessary quorum is reached for it to enter into force.

5. Conclusion: a possible Roadmap for driving CCS investment in the EU.

Based on the above analysis, the following step-by-step process is proposed. Action on these issues is urgent if the EU is to have the assets in place needed to meet its decarbonisation goals in a cost-effective manner and in a time-frame compatible with its climate ambitions.

Step 1: Data, Data, Data.

There is a lack of concrete data collected by the Commission on which it is basing its energy policy proposals, on the cost of CCS, including the relative cost of CCS compared to other decarbonisation options, the cost per tonne of CO_2 saved, and the cost of using CCS in a manner that lead to truly zero-carbon or even negative carbon end products - industrial, electricity, and hydrogen. This is not a good basis for a sound EU energy and climate policy, and inevitably leads to making politically driven choices for certain decarbonisation options.

Given President von der Leyen's commitment to technology neutrality and the Clean Industrial Deal, one would expect that the Commission seeks such data as a matter of urgency.

Not least, robust data on the following issues would be very valuable as a basis for policy making:

- The estimated cost of CCS for industry covered by the ETS, especially CBAM sectors, where relevant divided on a sector-by-sector basis, per tonne of carbon saved.
- The comparator, based on the use of alternative 'end-use' decarbonisation technologies (RES-E, RES H2…) for those industrial sectors where alternatives are a realistic technological decarbonisation option. This should take into account all relevant factors such as the potential additional cost of new plant and equipment under both scenarios, and the CO_2 cost of the ETS option vs the 'net-zero' technology one.
- The estimated additional cost for CCS should, at a later stage of the decarbonisation cycle, it be decided to blend sustainable biomethane/e-methane into the natural gas feedstock, to render the resultant product truly zero-carbon, or even negative carbon. This should take a full value-chain approach and factor in methane leakage in the production and transport of biogas and e-methane.

34 https://www.iea.org/reports/carbon-capture-and-storage-and-the-london-protocol.

- The estimated relative cost of producing balancing electricity based on (i) existing CCGTs plus CCS compared to (ii) new-build hydrogen-based capacity using renewable H2, taking into account all relevant factors such as the potential additional cost of new plant and equipment under both scenarios, and the CO_2 cost of the ETS option vs the 'net-zero' technology. Additional data should consider the picture if biomethane/e-methane were to be blended into the natural gas feedstock, to render the resultant electricity truly zero-carbon, or even negative carbon.
- The estimated cost of blue vs green hydrogen, both produced in the EU and imported, including the CO_2 cost of residual (non-captured) CO_2 emissions in the blue hydrogen option. Again, additional data should consider the picture if biomethane/e-methane were to be blended into the natural gas feedstock to deliver a zero-carbon, or even negative carbon option.
- A realistic assessment of the expected need for CCS for negative emissions over time.

The ability to determine very precise data on these issues obviously faces a significant number of challenges, such as: (i) the economies of scale of a larger, integrated, CO_2 system are difficult to calculate, (ii) unforeseeable technological developments, and (iii) company confidential data. Nonetheless, much greater transparency than exists can surely be provided.

Step 2 Planning

In dealing with data that emerges when planning a 'technology neutral' decarbonisation policy with respect to CCS, it is of course essential not to fall into the trap of simply developing an alternative technology-picked decarbonisation policy.

However, on the other hand, if the EU does not catalyse anticipatory investments in CCS grids and storage to ensure that they are in place in time for when they are required, it will fail in its decarbonisation and competitiveness objectives.

Based on emerging data, it should be possible to refine the anticipated CCS infrastructure needs over time, and progressively develop a reliable 'no-regrets grid model'.

To develop such a 'no-regrets' grid, market testing by the Commission, ACER, and/or NRAs would appear to be a valid approach, to determine which industries would be likely to use a CO_2 grid, and what ETS price would incentivise them to do so. This should not be an impossible exercise, as it would at least initially be focussed on CBAM sectors. On this basis a fact-based view of the size, required temporal development, and geography of a 'no-regrets' grid would be able to be developed.

Inter alia, this would need to factor in the use of repurposed pipelines, not least the low-calorific network in Northern Europe (where much of the EU's energy intensive industry is concentrated), which is currently undergoing decommissioning.

The Commission's Joint Research Centre has produced an initial model[35] that attempts to identify an "*optimal CO_2 transport network from an investment cost perspective*", which provides a useful starting point, that additional data can assist in further developing. The study finds that the future European CO_2 transport network could reach a length of 6,700-7,300 km by 2030 and might extend to between 15,000 and 19,000 km by 2050. Its deployment could cost between about EUR 6.5 billion and EUR 19.5 billion by 2030, rising to between EUR 9.3 billion and EUR 23.1 billion in 2050.

35 JRC Publications Repository - Shaping the future CO2 transport network for Europe (europa.eu).

Under the EU grid planning framework, notably under the TEN-E Regulation, CCS infrastructure can qualify as a PCI, and then potentially qualify for CEF funding. However, there is no Ten-Year Network Development Plan (TYNDP) mechanism for CCS. TYNDP plans, that exist for electricity and natural gas, and now are to cover hydrogen, are prepared via an ENTSO, with the opinion of ACER and then implemented by national transmission system operators. It would therefore be opportune to amend the TEN-E to envisage a CCS TYNDP.

Amending the TEN-E will obviously take some time and will not happen in practice before 2027-2028. As occurred with respect to the hydrogen grid, it would be appropriate to encourage a grouping of potential CO_2 network operators to already start work on the future 'No-regrets EU CO_2 Grid model', prior to the revision of the TEN-E Regulation. In practical terms this would probably need to be a grouping of natural gas TSOs, ensuring the participation of other relevant actors, such as ACER, and oil and gas companies developing/considering offshore infrastructure.

Potential timing of such a planning process may look something like:

- In early 2025 the Commission, in the context of the CCUS IPCEI, tenders for a series of studies intended to provide greater transparency regarding the relative costs and needs for CCS infrastructure with first results delivered by the end of the year. Member States and industry take accompanying initiatives.
- By mid-2025 the Commission proposes a revision of the TEN-E Regulation.
- By mid-2026 a first model grid has been developed by industry, with an option delivered by ACER.

Step 3 Bring the UK and Norway on board.

To have a rational EU CCS system, the storage capacity of the UK and Norway will be essential.

In the case of Norway, this means bringing them under the NZIA and ensuring that all other rules are adapted so that CCS applies seamlessly with the EU, from a technical, legal and economic viewpoint.

In the case of the UK this is obviously more complicated. Nonetheless, this is an area where there should be common ground and, given the scale and urgency of the challenge (not least ensuring that the storage constructed based on the NZIA obligation is cost-effective), there are good grounds for fast-tracking such an agreement as a predecessor to a wider agreement on energy and climate issues (which inevitably would require more time).

Step 4 Regulatory certainty

If a company is to build CO_2 grids and storage at scale, they will need to de-risk them, either through long-term CO_2 transport and storage contacts with industrial emitters, or state guarantees that the projected long-term income stream from anticipatory investments will be realised, or through a combination of both.

If a company totally or partially de-risks the investment through long-term agreements with emitters, the issue of regulatory certainty regarding these contracts becomes paramount. If regulated or even negotiated TPA becomes required regarding the assets they build, and they have already sold 100% of the capacity of the assets on long-term contracts, they may bear a risk that the national regulatory authority will require that some of that capacity is auctioned in applying TPA, making it impossible to honour the long-term contracts.

Thus, ensuring regulatory certainty on this issue will be important in the near future. The Commission has indicated that it is actively considering proposing a CO_2 infrastructure regulatory legal framework at the start of the next Commission, but any such proposal will not enter into force until the end of this decade, making an interim solution to provide legal certainty to infrastructure built in the meanwhile important.

The Commission could, in 2025, propose a simple regulatory solution aimed at fast-tracking Council and Parliament approval, for example allowing NRAs to determine the appropriate regulatory framework to new infrastructure on a case-by-case basis with Commission approval, based on Commission guidelines, using a procedure similar to that contained in Article 36 of the Gas Directive[36], and benefiting from experience, for example regarding hydrogen. Each case could be dealt with on its own merits, for example allowing full reservation of capacity to the operator or accepting that say 75% - of the capacity could be sold long-term, leaving the test to be auctioned off on a yearly basis, to avoid market foreclosure.

Step 5

This legislative proposal would also be an appropriate place to propose mechanisms, based on those for RES investments in the RED III Directive, to accelerate planning procedures for CCS infrastructure investments, which may however also be dealt with in a separate legislative proposal, enabling its speedy adoption by the Council and Parliament.

Step 6

An accelerated train of carbon contracts for differences consistent with EU's decarbonisation targets, combined with state guarantees for infrastructure developers, within the context of a CCUS IPCEI.

Germany and the Netherlands already have mechanisms in place for tendering CCFDs. An early initiative by the next Commission to support this process and commit, initially trough a 'Carbon Bank' funded by the ETS Innovation Fund, could have an important catalytic value.

Thus, based on accelerated work on an IPCEI, involving as many Member States as possible, such CCFDs could make a major difference. This would need to be coordinated with potential state guarantees for anticipatory investments.

Via the abovementioned planning process, this would ideally be combined with the roll-out of guarantees for anticipatory investments in a 'no-regrets' CO_2 grid.

As part of the biannual progress report that Member States must submit on their National Energy and Climate Plans[37], it would be opportune for the Commission to insist that each Member State identifies its coherent plan, based on the abovementioned additional data generated by the Commission, using a combination of CCFDs and anticipatory investment guarantees and any other relevant measure, that will guarantee that a fit-for-purpose CO_2 infrastructure will be in place in a time frame compatible with its climate and energy ambitions.

Step 7

The establishment of CO_2 purity and other relevant standards, for example via CEN.

36 This suggestion is outlined in more detail in https://fsr.eui.eu/publications/?handle=1814/76181.
37 Article 17 of the Governance Regulation, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1999.

Step 8

Clarification on the treatment of state guarantees for the risk of leaks by CO_2 storage infrastructure, for example via a Commission communication.

Step 9

The introduction of a mass balancing and certification system, which would presumably be included in the abovementioned Commission proposal for a regulatory framework for CO_2 grids.

This is obviously a non-exhaustive list of needed actions, and the various Working Groups of the ICM Forum[38] (previously 'CCUS Forum') are identifying others, but it hopefully provides a basis for consideration regarding possible priorities for the next Commission.

38 https://energy.ec.europa.eu/topics/carbon-management-and-fossil-fuels/industrial-carbon-management/icm-forum-and-working-groups_en.

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