FLORENCE
SCHOOL OF
REGULATION

ROBERT SCHUMAN CENTRE

POLICY BRIEF

The role of CCUS on the EU road to climate neutrality

Highlights

The EU has decided to achieve carbon neutrality by 2050. While energy efficiency and renewable energy must and will remain the foundation of the EU's future energy priorities, carbon capture, utilisation and storage (CCUS) will be necessary to achieve this 2050 objective, notably during the transition. In some sectors with hard-to-abate greenhouse gas (GHG) emissions, such as cement, this is the only option for decarbonisation, and in other energy-intensive areas it will be needed for affordable GHG reductions during the energy transition period. CCUS using biomethane could also deliver negative emissions and be an important carbon sink. Finally, the use of carbon capture and storage (CCS) for producing low-carbon hydrogen could provide significant cost savings, again during the energy transition.

Despite the implementation of Directive 2009/31/EC 'On the geological storage of carbon dioxide,' the use of CCUS has been slow. Strong leadership by the European Commission is needed.

The adoption of a European Strategy for CCUS and a European Commission initiative to catalyse CO2 infrastructure could provide this necessary step change.

Issue 2022/04
January 2022

Authors

Christopher Jones, Professor, European University Institute
Andris Piebalgs, Professor, European University Institute

Introduction

The EU needs a timely and wide deployment of CCUS technologies to meet its Green Deal objectives.[1] However, while virtually all decarbonisation scenarios rely on large quantities of CCUS by 2050,[2] the EU still lacks the political momentum and legal and policy framework necessary to kick-start investments and allow CCUS to live up to expectations.

The development of a CCS grid and storage will be an EU-wide challenging endeavour involving significant regulatory risk for investors, which will need to commit billions of euros, and technical innovation. There is a need for a new robust regulatory and legal framework, and the commitment of very significant European funding from the ETS Innovation Fund and the CEF, and major funding from the Member States, notably from ETS revenues, will be essential. Without action by the Commission in the next few years, CCS risks falling into a 'valley of death,' as investments will not be able to be amortised in time, given that it is to a significant extent a 'transition technology.' Indeed, the Commission itself has recognised that CCUS technologies will not be available at competitive prices before 2035 or 2040 if a conducive regulatory framework is not put in place at the EU level[3]. In addition, studies indicate that CO2 storage capacity is available. The third Report by the European Commission on Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide identifies more than 100Gt storage capacity in the EU.[4] The Norwegian Petroleum Directorate has published a carbon dioxide storage Atlas in Norwegian Continental Shelf indicating 70 Gt storage capacity in the Norwegian North Sea.[5] The Dutch CCS Porthos project is advancing to transport industrial carbon dioxide emissions in Rotterdam for storage in an empty gas field more than 3km beneath the North Sea.[6]

There are a number of reasons why the EU will need CCS to meet its decarbonisation goals:

1. Sectors with hard-to-abate emissions

Meeting net-zero objectives requires tackling emissions across all sectors, including those that are the most difficult to abate, such as in energy-intensive industry (which accounted for 20.5% of Europe's CO2 emissions in 2019[7]). In these sectors, alternatives to fossil fuels are either prohibitively expensive (such as electricity to generate extreme heat) or even do not exist (in the cement industry, for instance).

Significant additional efforts will be required to decarbonise industrial sectors between 2030 and 2050, when the EU's climate neutrality ambition will require industry to reduce its emissions by around 90-95% compared to 1990 levels.[8] For most of these sectors, deployment of affordable CCUS technologies is the only way to reasonably meet the objectives on time.

In practice, **some sectors will simply not be able to achieve net-zero emissions without CCUS**. Cement production is a prime example: two-thirds of the CO2 emissions in the cement industry are process emissions (i.e. they result from the manufacturing process and are not associated with fossil fuel use), which means that even if cement kilns could be electrified or use zero-carbon hydrogen, these process emissions would persist. Therefore, with no demonstrated alternative way of producing cement, CCUS is effectively the only operation to decarbonise the sector.[9]

---

[1] See European Commission (2018), In-depth analysis in support of the Communication COM(2018)773 "A Clean Planet for all – A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy" (available here), p. 61; IPCC (2018), Special Report on Global Warming of 1.5 degrees Celsius, available here; IEA (2020), CCUS in Clean Energy Transitions, available here; IRENA (2020), Reaching Zero with Renewables, available here.

[2] Tsiropoulos, I., Nijs, W., Tarvydas, D. and Ruiz Castello, P., Towards net-zero emissions in the EU energy system by 2050, EUR 29981 EN, Publications Office of the European Union, Luxembourg, 2020, available here. This JRC technical report provides a comparison of 8 scenarios achieving more than 50% reductions in GHG emissions by 2030, and 16 scenarios aiming at climate neutrality by 2050 similar to the ambitions of the 'European Green Deal.'

[3] European Commission (2018), op.cit., section 9.4.2.7. The Commission specifies that "CCS for instance enters in significant numbers only by 2040 with carbon prices at that time of €200/tCO2 or more. Deployment of such solutions requires the necessary energy and CO2 infrastructure to be in place when the related technologies have been proved at scale. At the same time a supporting regulatory framework is necessary that will promote the deployment of such technologies, both on the production side, but also on the side of demand, creating for example lead markets for low carbon products."

[4] Com(2019) 566 final.

[5] CO2 Atlas for the Norwegian Continental Shelf.

[6] www.porthosco2.nl

[7] IEA (2020), Energy Technology Perspectives 2020, Special Report on Carbon Capture, Utilisation and Storage, available here, p. 135.

[8] European Commission (2018), *op.cit.*, section 9.4.2.7.

[9] IEA (2020), Energy Technology Perspectives 2020, Special Report on Carbon Capture, Utilisation and Storage, available here, p. 23.

Energy uses in energy-intensive industries. There are limited alternatives to CCUS for reducing emissions from energy use in a number of energy-intensive industries such as steel and chemicals in the medium and long term. This results from both technical and economic considerations.

In technical terms, for example, CCUS in the steel and chemicals sectors can be implemented quickly. While, for example, the hydrogen-based direct reduced iron (DRI) route for making steel, which reduces emissions substantially, could emerge as a technically possible alternative to CCUS, this is not technologically mature and depends on the availability of large quantities of cheap clean hydrogen.

In economic terms, based on current estimates of levelised costs of production for commercial-scale plants, producing one tonne of steel via CCUS-equipped DRI and innovative smelting reduction processes is typically 8-9% more expensive than today's main commercial production routes, but the hydrogen-based DRI route typically raises costs by around 35-70%.[10] The story is similar in the chemicals sector. Clean hydrogen as a feedstock for ammonia and methanol production could become an alternative to CCUS, but in most regions today it is considerably more expensive than applying CCUS to existing or new plants. The cost of CCUS-equipped ammonia and methanol production is typically around 20-40% higher than that of their unabated counterparts, while the cost of electrolytic hydrogen routes is 50-115% higher.[11]

The pace of CCUS deployment in industry is currently very limited, emphasising the need to get the ball rolling as quickly as possible. According to the IEA in its Sustainable Development Scenario, by 2030, at the global level the cement industry alone will need one CCUS-equipped cement facility coming online every week between now and 2030, accelerating to almost 6 a month on average in the period 2030-50. Much of this capacity is retrofitted to existing plants or ones currently under construction. To achieve this will require a massive expansion of CO2 transport and storage infrastructure.[12] The EU is leading the world in renewable energy and hydrogen, but falling behind in CCS.

Similar figures can be quoted for other energy-intensive industries, which, as mentioned above, account for more than 20% of total EU emissions. ETS prices are highly unlikely to increase to the level needed to enable these industries to competitively invest in any important decarbonisation solution alternative to CCS before 2040 at best. Without a functioning CCUS system in the short-to-medium term, they will simply not, therefore, be able to significantly decarbonise. The Commission's proposed reform of the ETS, combined with a CBAM, envisages that these sectors will become exposed to the ETS in a few years. Without a functioning CCS option, they will have to pay for allowances, but have very few, if any realistic, concrete options to significantly decarbonise. In this scenario the ETS will cause them to increase processes but not save GHG.

The power sector. Many of the plants responsible for CO2 emissions could be operating for decades to come. For instance, the average age of a European gas-based power plant is 17 years, against an average technical lifetime of around 50 years. These plants (and others under construction or planned) could potentially emit more than 25 Gt of CO2 between 2019 and 2070 unless they are retrofitted with CCUS or retired early.[13] These plants will progressively move to providing balancing rather than base-load power, as the level of renewable energy in the electricity mix increases. Zero-carbon alternatives to the use of natural gas combined with CCS exist, notably clean hydrogen. However, these are far more expensive alternatives than natural gas plus CCUS, they will fail to use non-amortised existing assets and would use valuable hydrogen in an end-use that fails to meet the 'energy efficiency first' principle (the scarce clean H2 should first be used to displace grey hydrogen and to replace fossil fuels in transport, for example).

In 2018, when it had a RES share of its electricity market of around 38%, Germany paid more than €700 million in compensation for curtailed renewable electricity production.[14] Its current (pre-Green Deal) RES-E target for 2030 is 65%.

---

[10] IEA (2020), *op. cit.*, p. 64.

[11] *Ibid*.

[12] *Ibid*., p. 67.

[13] *Ibid*., p. 136.

[14] Bundesnetzagentur, Monitoring Report 2019, 27 November 2019, available here, p. 161. See also IEA (2020), Germany 2020, available here, pp. 30-31.

It is fairly self-evident that the EU will need a lot of low GHG balancing power moving towards 2050, and that existing gas OCGTs combined with CCS is by far the cheapest and most readily available option. Without a ready cost-effective CCS network, this will not develop and the EU will need to go straight to high-cost (hydrogen) solutions, and either the cost of balancing will be far higher than it need be or low/zero GHG balancing power will be unavailable in the required quantity. Neither of these options are attractive.

There are other industries where CCS will also be important, for example natural gas processing. However, simply based on the two examples above, it becomes clear that without a functioning CCS network in the short-to-medium term, it will be very difficult to decarbonise these industries at scale during the next 20 years and beyond.

2. A cost-effective pathway for low-carbon hydrogen production

The European Commission adopted a Hydrogen Strategy in July 2020, which has been endorsed by the Council and Parliament.[15] It sets out ambitious targets, with the aim of producing up to 10 million tonnes of renewable hydrogen in the EU by 2030. Although no precise targets are set for 2050, it is commonly accepted that the EU will require at least 50 Mt of clean hydrogen by that date, and probably considerably more.

The Commission has adopted a ‘renewable hydrogen first’ approach in its policy and legislative proposals. Some Member States, notably Germany, have mirrored this approach, for example in its initial support scheme design, although the new coalition government has recognised that low-carbon hydrogen will need to play an important transition role. Others, such as the Netherlands, have adopted a more technology-neutral approach. While it remains to be seen how the market and technology will develop, a number of drivers indicate that, notwithstanding this political preference, if the EU is to meet its hydrogen and Green Deal objectives in a cost-effective, timely and affordable manner we will need significant quantities of low-carbon hydrogen produced from steam methane reforming combined with CCS.

Today, blue hydrogen is projected to be appreciably cheaper than green hydrogen, in the order of €1/kilo or more.[16] The competitiveness of green hydrogen depends on cheap electricity supplies. Competitiveness with blue hydrogen is often projected because of the low and falling costs of new RES capacity in excellent locations. However, hydrogen production will not pay the low and falling costs of new RES capacity in excellent locations, but the overall forward electricity market price. If one can produce cheap RES electricity, why sell it below the market price for hydrogen production if you can sell it more profitably for electricity supply? To catalyse the production and sale of just 10 Mt of green hydrogen at a €1/kilo price disadvantage compared to blue hydrogen would require additional subsidies of €10 Bn per year, with limited GHG benefit. Given that Member States’ ‘green’ budgets will be constrained post-European Recovery Plan funding, they may well wish to use this €10 Bn for energy efficiency investments if this price differential indeed emerges.

Furthermore, a convincing recent academic study argues that in reality there will not be enough incremental renewable electricity capacity to meet all the needs of electrification (coal and nuclear closure), transport, buildings and industry over the coming decade and beyond, and still have enough for large-scale green hydrogen produc-

---

[15] See the Commission's Communication “A hydrogen strategy for a climate-neutral Europe” published on 8 July 2020, available here. See Council of the EU's conclusions, "Towards a hydrogen market for Europe" published on 11 December 2020, available here. See the European Parliament's resolution of 19 May 2021 on "A European Strategy for Hydrogen," available here.

[16] IEA (2020), *op. cit.*, p. 24. The IEA indicates that "*Today, the cost of CCUS-equipped hydrogen production can be around half that of producing hydrogen through electrolysis powered by renewables-based electricity (which splits water into hydrogen and oxygen). The costs of electrolytic hydrogen will certainly decline over time, with cheaper electrolysers and renewable electricity, but CCUS-equipped hydrogen will most likely remain a competitive option in regions with low-cost fossil fuels and CO2 storage resources. CCUS also offers an opportunity to address emissions from existing hydrogen production that almost exclusively relies on natural gas and coal and is associated with more than 800 MtCO2 each year.*" In addition to being more cost-efficient, IOGP argues that blue hydrogen is greener than hydrogen produced with electrolysers connected to the grid: "*In the EU, in 2016, average electricity emissions per MWh were 296 kg CO2. Production of hydrogen from electricity with such a CO2 intensity would result in an emission rate of 15 kg CO2 per kg of hydrogen. If the hydrogen was produced from natural gas with average European upstream and midstream CO2 emissions combined with CCS, the emission rate would be 2 kg of CO2 per kg produced hydrogen. CO2 emissions are therefore 7.5 times lower for hydrogen produced from natural gas with CCS. Outlooks from the European Commission’s strategic long-term vision and IRENA’s Outlook for Europe give a corresponding ratio in the range of 4.6 to 4.9. It can therefore be assumed that emissions from hydrogen production from grid average electricity will be above that from natural gas with CCS well beyond 2030*" (IOGP (2019). The potential for CCS and CCU in Europe is available here, p. 7). See also https://fsr.eui.eu/publications/?handle=1814/68977

tion (which requires massive amounts of electricity).[17]

In this light, it is far from certain that green hydrogen will be able to meet the EU's low and zero-carbon needs for hydrogen in the medium term. Pyrolysis and electrolysis hydrogen may be the long-term answer, but there are very strong grounds to conclude that 'blue' hydrogen will certainly need to play an important role at least until 2050.

Evidently, the availability and cost of natural gas will play an important role in this respect. However, the IEA believes that investment decisions in natural gas systems and stronger contracting activity in 2021 would ensure a sufficient medium-term supply of natural gas and improving supply availability is expected to already moderate H2 2022 prices.[18] While, therefore, it makes absolute sense to use very significant R&D&I support to make sure electrolysis technology is mature when large quantities of cheap RES-E are available, the EU will almost certainly need blue hydrogen to meet its objectives. Without readily available and cost-effective CCS, the EU will deprive itself of this option.

3. Policy recommendations

It flows from the above that CCS will need to constitute an important part of the EU's Green Deal delivery.

The EU needs a detailed plan to get the CO2 grid built and to develop adequate storage, indicating where this will be, when and what the grid will look like, how to finance it and what the stable regulatory regime to finance it should be.

In its 'Fit for 55' package and communications the Commission has focussed on 'end-game' technologies and long-term solutions. This is of course necessary – we need the technologies and infrastructure in place to meet the full 2050 decarbonisation deadline.

The Commission therefore needs to provide the same level of leadership, vision and determination regarding CCS as it has regarding hydrogen. In concrete terms we suggest the following:

- **Adopt a European Strategy for CCUS and legislative package.** This would have the form and level of ambition similar to the Hydrogen Strategy, announce clear targets and deadlines, commit to developing a CCUS Alliance (similar to the hydrogen, battery and microelectronics examples) and commit to new legislative proposals on CCUS. It would act as a catalyst for major action by industry and mark a step-change in EU and Member State determination to deliver a cost-effective CCS network.

- **Advance the work on CO2 infrastructure, for example by preparing a study on storage and point sources and including storage in the TEN-E framework.**

- **Undertake a detailed analysis regarding the development of a 'no-regrets' CO2 grid in close collaboration with EU TSOs and their representatives (notably ENTSOG).** This would need to take account of the fact that most CO2 that will need to be stored will come from energy-intensive industry, and a correlation between 'hydrogen clusters' and their CO2 equivalent is likely to exist.

- **Upscale support for CCUS.** Commit more for R&D&I from the Horizon and ETS Innovation funds, and commit to use the proposed possibility for contracts for difference in the increased ETS Innovation fund for green steel, cement and chemicals based on CCUS (or based on technology-neutral tenders).

- **Follow developments in pyrolysis hydrogen.** Pyrolysis (or 'turquoise' hydrogen) is a CCU technology producing zero or even negative-carbon hydrogen using renewable electricity as the energy source, with solid carbon as the by-product. The solid carbon can be used as an industrial feedstock (pigments, tyres, electronics), potentially as a soil improver (thus actually reducing and capturing CO2 and being an ideal 'circular economy' candidate) and as graphite in battery production (meeting EU goals for self-sufficiency in sensitive materials).

---

[17] R. BELMANS, P. CARLO DOS REIS, P. VINGERHOETS (2021), Electrification and sustainable fuels: Competing for wind and sun, available here.

[18] IEA (2021) Global Gas Security Review 2021.

Conclusions

CCUS must be a key part of the EU's decarbonisation strategy. It is largely a transition technology and unless it can succeed in capturing and permanently storing 100% of emissions from certain applications has relatively little role to play post-2050. Based on currently foreseeable technology, it will still have some role post-2050. There is currently no solution to decarbonising cement other than CCS for example, and technological innovation may enable 100% capture of CO2, but current assumptions are that the CO2 grid will need to be largely amortised by 2050. This is one of the reasons why a sense of urgency is needed. The CCS grid can neither be a stranded asset nor an argument for grandfathering positive emission technologies post-2050.

The Florence School of Regulation

The Florence School of Regulation (FSR) was founded in 2004 as a partnership between the Council of the European Energy Regulators (CEER) and the European University Institute (EUI), and it works closely with the European Commission. The Florence School of Regulation, dealing with the main network industries, has developed a strong core of general regulatory topics and concepts as well as inter-sectoral discussion of regulatory practices and policies.
Complete information on our activities can be found online at: fsr.eui.eu

Robert Schuman Centre for Advanced Studies

The Robert Schuman Centre for Advanced Studies (RSCAS), created in 1992 and directed by Professor Brigid Laffan, aims to develop inter-disciplinary and comparative research on the major issues facing the process of European integration, European societies and Europe's place in 21st century global politics. The Centre is home to a large post-doctoral programme and hosts major research programmes, projects and data sets, in addition to a range of working groups and ad hoc initiatives. The research agenda is organised around a set of core themes and is continuously evolving, reflecting the changing agenda of European integration, the expanding membership of the European Union, developments in Europe's neighbourhood and the wider world.

www.eui/rsc

Published by
European University Institute (EUI)
Via dei Roccettini 9, I-50014
San Domenico di Fiesole (FI)
Italy

doi:10.2870/30583
ISBN:978-92-9466-143-2
ISSN:2467-4540
QM-AX-22-004-EN-N

Co-funded by the
Erasmus+ Programme
of the European Union