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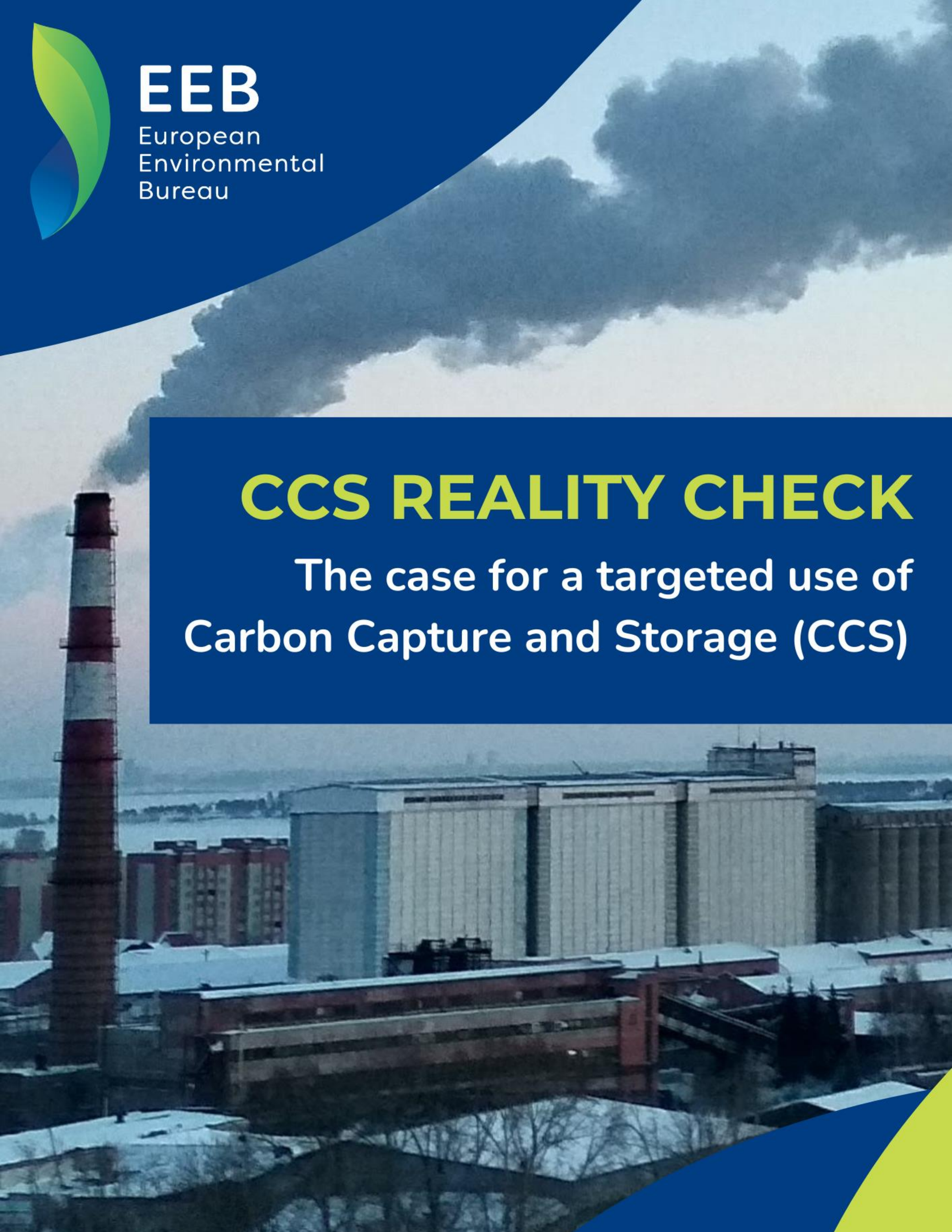
# CCS REALITY CHECK

## The case for a targeted use of Carbon Capture and Storage (CCS)



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# The case for a targeted use of CCS

## Introduction: Realities, risks, and priorities

While the effects of climate change are increasingly evident, it is necessary to use all tools available to mitigate its effects and reach climate neutrality by mid-century. According to the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA), a certain amount of Carbon Capture and Storage (CCS) will be needed at global level to get net-zero greenhouse gas (GHG) emissions by 2050.

Nevertheless, the track-record of CCS deployment and achievements in the last decades tells a story of overpromising and under-delivering. It suggests caution before relying on CCS as a silver bullet to fix our decarbonisation problems. Even though already in 1991 CCS was depicted[1] "*as a promising solution for the near term*" and, in any case, as an "*interim priority*", so far it has not played a significant role to help the decarbonisation of carbon-intensive industrial activities. While the EU Joint Research Centre (JRC) reports only 3 full-scale CCS projects to date, the Global CCS Institute refers to 41 operational CCUS facilities at worldwide level, mainly linked with fossil fuels extraction and with a $CO_2$ capture capacity of 49M tonnes per year.

The IPCC considers CCS **the least efficient and one of the most expensive climate mitigation options** in 2030. Using it as the main decarbonisation lever will impact the deployment of renewable energy and electrolysers for green hydrogen in the next decades, as well as other more cost-effective decarbonisation strategies such as increased energy and material efficiency, product circularity, electrification of industrial processes and shifts towards low-carbon products and fuels. It would also add pressure on water bodies and keep air pollution at the same levels as today, with potential additional amounts of pollution released due to the so-called energy penalty and upstream emissions in the fossil fuels value chains. Moreover, it risks perpetuating the extraction and use of fossil fuels, which in turn cause the emission of several pollutants and land exploitation and thus slow down the transition out of fossil fuels by creating lock-in effects.

Regarding costs, according to an assessment of real-world evidence on CCS projects made by the University of Oxford[2], it would be prudent for policymakers and businesses to assume that CCS will continue to be as expensive as it is today, particularly when not associated with fossil fuels extraction as fossil gas processing or Enhanced Oil Recovery (EOR).

**Safety concerns are subject to site-specific geology conditions** and require continued monitoring and readiness in case of **leakage risks,** which must be foreseen for an undetermined amount of time, at least multiple centuries. It is questionable whether it is possible to build such an ambitious and long-lasting alarm system to prevent the disastrous release of millions of tonnes of stored $CO_2$ in the atmosphere. Such never-

[1] CO2 reduction and removal: Measures for the next century

[2] Bacilieri, A., Black, R., & Way, R. (2023). Assessing the relative costs of high-CCS and low-CCS pathways to 1.5 degrees. Oxford Smith School Working Paper 23-08.

ending monitoring system will be very expensive and add expenses to a technology that will benefit very little of learning effects, its technology being used for decades already.

CCS will not have any impact on fighting pollution generated by combustion of fossil fuels or feedstock, rather it will **aggravate air quality problems** due to additional energy to be used to allow the capture of $CO_2$.

Rather than creating an overreliance on CCS, a cascade of priorities must be devised to privilege the most effective decarbonisation options and drive industrial processes away from combustion of fossil fuels or use of fossil feedstock. Such **cascade of priorities should guide policymaking** and should enforce circular economy, energy and material efficiency strategies at sectoral level, prioritising substitution of materials, electrification and, only as last resort allowing for CCS for emissions that cannot be avoided with the above-mentioned strategies.

In any case, storage of $CO_2$, either in products or in storage basins, must be permanent, meaning that multiple-centuries sequestration from the atmosphere must be ensured; if it cannot be guaranteed, its use as a feedstock to be later emitted into the atmosphere should never be supported by climate policies or public funding. The role of CCS is to mitigate climate change, not to turn a problem into a commodity.

# Why we need a targeted approach to CCS

## CCS cannot help to get our mid-term climate targets

According to the IPCC[3], even if implemented at its full potential, CCS will **account for only 2,4% of the world's carbon mitigation by 2030** due to its low effectiveness and high cost. Other options such as fuel switching, material and energy efficiency and enhanced recycling have not only a higher mitigation potential but are also cheaper.

In the EU, only the emissions of the three top $CO_2$ emitters (refining of mineral oil, production of cement clinker, and production of pig iron and steel) amount to around 425M tonnes of $CO_2$ per year[4]. Even if the EU will manage to implement the target of 50 million tonnes of injection capacity per year in the Net-Zero Industry Act (NZIA), it will only happen from 2030 onwards and only address 12% of the $CO_2$ emissions of those three sectors.

According to the Haut Conseil pour le Climat[5], an independent body in charge of assessing public activities regarding climate action in France, the goal of France of to capture 4 to 8 Mt of $CO_2$ "*looks ambitious".* This ambitious goal only represents between 13% and 26% of the $CO_2$ emissions from the above-mentioned sectors.

[3] IPCC, 2022, Sixth Assessment Report
[4] European Environment Agency, EU Emission Trading System data viewer (2022 data)
[5] Haut Conseil pour le Climat, 2023, Avis sur la stratégie de capture du carbone, son utilisation et son stockage (CCUS)

## The actual $CO_2$ capture rate is generally worse than expected

In general, **it is assumed that CCS can remove 85-90% of the $CO_2$** released after combustion, leaving unsolved the problem of dealing with 15-10% of emissions that CCS cannot capture. According to a Senior Research Engineer at the Massachusetts Institute of Technology, getting capture rates above 90% is exponentially expensive: the closer a CCS system gets to 100% efficiency, the harder and more expensive it becomes to capture additional carbon dioxide[6]. Moreover, according to a study released by the Institute for Energy Economics and Financial Analysis (IEEFA)[7] analysing the actual capture rate of 16 existing projects, no existing project has consistently captured more than 80% of $CO_2$. **The average capture rate of such projects is around 49%**, with some only at 10-17%, which is particularly problematic.

An analysis by ARIA[8] on the Al Reyadah CCS project in the United Arab Emirates has found that it could capture only 13,6% of the $CO_2$ emitted by the steel mill it serves, with additional GHG emissions occurring up and downstream. The fact that the $CO_2$ captured is used for EOR further compromises the climate performance of Al Reyadah.

**More transparency is needed** to fully understand the actual achievable capture rate of CCS on the long term not only in terms of $CO_2$ captured at the stack, but also in terms of what is done with the captured $CO_2$. For instance, using the $CO_2$ for EOR projects results in significant re-emission of $CO_2$ into the atmosphere, as enhanced oil recovery sites can have retention rates below 30%. Also, producing hydrogen from fossil gas with CCS can release more GHGs than burning fossil gas directly due to methane leakage. In contrast, producing hydrogen with electrolysis driven by renewable energy results in no emissions[9].

## CCS never reduces air pollution; rather, it increases the emissions of pollutants and pressure on water bodies

By only taking care of $CO_2$, the use of **CCS leaves untouched the problem of reducing air pollution from combustion processes.** Air pollutants not captured by CCS equipment from fossil or bioenergy plants include CO, $NO_x$, $SO_2$, organic gases, mercury and other heavy metals, black carbon, particulate matter, and other aerosol components[10]. Waste incinerators are still the primary source of dioxin emissions[11]. Such pollutants will simply continue to be emitted, regardless of the presence of CCS equipment, not reducing their impact on public health and the environment. On top of that, further toxic waste will be generated using the solvents for capturing the $CO_2$.

**Not only does CCS not reduce air pollution but**, by requiring additional energy to capture, compress, and transport the $CO_2$, **it leads to increased emissions of other pollutants.** This additional amount of energy used to operate CCS is called energy penalty and varies depending on the specific technology and

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[6] MIT Climate Portal: How efficient is carbon capture and storage?
[7] IEEFA, https://ieefa.org/ccs
[8] ARIA, 2023, The shaky foundation of the UAE's carbon capture strategy
[9] Thomas Longden, Fiona J. Beck, Frank Jotzo, Richard Andrews, Mousami Prasad – 'Clean' hydrogen? – Comparing the emissions and costs of fossil fuel versus renewable electricity-based hydrogen, Applied Energy, Vol. 306, Part B, 2022.
[10] Mark Z. Jacobson, The health and climate impacts of carbon capture and direct air capture, Energy Environ. Sci., 2019, 12, 3567
[11] European Environmental Agency, Persistent organic pollutant emissions

application. According to the IPCC[12] it is generally in the range of 13-44%, leading to additional emissions and increased costs.

Moreover, by promoting the combustion of fossil fuels due to a high use of CCS, upstream emissions and environmental damages due to the extraction of fossil gas and coal will continue. On the other hand, shifting towards non-combustion alternatives reduces air pollution and land degradation due to mining.

CCS also increases the pressure on water bodies for the cooling of fumes and the cleaning of filters. An estimated volume of at least 1,71 $m^3$ of water per tonne of captured $CO_2$ is required for coal power plants, 2,59 $m^3$ for gas power plants, and 4 $m^3$ for Direct Air Capture Systems (DACCS)[13]. According to the IPCC[14], water withdrawals for CCS are 25–200% higher than plants without CCS due to energy penalty and cooling duty. In case of water scarcity, it is possible that CCS equipment must be switched off.

## CCS costs are generally underestimated

According to a study by the University of Oxford[15], neither the CCS industry nor the IEA have ever systematically assessed costs linked to CCS deployment. Only approximations are present in literature showing that, for the same CCS project, cost estimates made by different bodies can differ by 65%. Other cost uncertainties regard storage and storage maintenance costs, for which there is limited real-world experience. The Oxford study shows that, in general, literature indicates that the costs of CCS are usually underestimated, while **technological progresses are overestimated**.

The evidence gathered by the University of Oxford also suggests that **the learning effect, which usually brings the cost of technologies down, is unlikely to happen for CCS**, mainly because its equipment consists of mature engineering components such as steel pipes and gas pumps. Regarding the capture equipment, the main technology in use (amine scrubbing) has been used for almost a century, indicating that significant cost reductions should already have happened.

The precited JRC report[16] highlights that costs vary much; that they can be anywhere between 13€ and 103€ per tonne of $CO_2$ depending on the industry and $CO_2$ concentration. Transport and storage costs can also vary significantly depending on distance, volume, geographical location and storage conditions. The French Agence de la Transition Écologique (ADEME) estimated the capture and storage costs for the French industry to vary between 69€ and 143€ per tonne of $CO_2$eq[17].

At the EU level, as stated by industrial operators active in the cement sector[18], the costs associated with a widespread CCS development are very high. Using the cement sector as an example, only connecting the more than 200 clinker producers in the EU to a trans-national CCS network would require a financial effort of billions of euros; only operationalising the NZIA injection capacity target (50M tonnes by 2030) would

[12] IPCC, 2022, Sixth Assessment Report
[13] Haut Conseil pour le Climat, 2023, Avis sur la stratégie de capture du carbone, son utilisation et son stockage (CCUS)
[14] IPCC, 2022, Sixth Assessment Report
[15] Bacilieri, A., Black, R., & Way, R. (2023). Assessing the relative costs of high-CCS and low-CCS pathways to 1.5 degrees. Oxford Smith School Working Paper 23-08.
[16] EU Joint Research Centre, 2023, Carbon Capture, Utilisation and Storage in the European Union
[17] ADEME, 2020, Le Captage et Stockage géologique du CO2 (CSC) en France
[18] Ecocem's answer to the Industrial Carbon Management strategy

require up to 10,5 billion €[19]. Such a financial commitment would likely come from the public purse, given the fact that, for instance, 40% of the EU clinker producers are medium or small enterprises with no possibility to spend that much on CCS infrastructure. CCS could clearly **divert scarce public money from much more mature and effective available solutions**.

## More CCS means higher costs of renewable energy

The same Oxford study shows an important side-effect linked to a large and unfocused deployment of CCS. Decarbonisation pathways foreseeing a high use of CCS will cause higher prices of renewable energy technologies (solar and wind) and electrolysers than low-CCS pathways.

How does it work? Low-CCS pathways deploy more solar, wind and electrolysers earlier, so the cost of these technologies comes down faster. As well as creating cheap and early emissions reductions, faster deployment of renewable energy and electrolysers makes even more substitution of fossil fuel technologies possible at lower cost than in high-CCS pathways. This effect is likely to be found also for energy storage. On the other hand, **high-CCS pathways** foresee a higher use of fossil fuels, consequently **slowing down the deployment of renewable energy sources and electrolysers** and, as a result, **reducing their learning effect** and increasing their costs.

In a nutshell, high-CCS pathways would carry the risk of perpetuating the use of fossil fuels, with all the risks associated.

## Financial viability of CCS without fossil fuels extraction is unproven

At the end of 2023, only 41 CCS projects were operational worldwide[20]. Out of the 41, 15 operational projects are linked to the extraction of fossil gas[21], while 29 use the captured $CO_2$ to facilitate the extraction of oil with a process called Enhanced Oil Recovery (EOR)[22]. To date, only 6 operational projects are active in Europe; the two largest ones (Snøwhit and Sleipner in Norway) facilitate the processing of fossil gas. In other words, today **CCS is financially intertwined with the fossil fuels industry**, which facilitates its financial viability but contributes to emit more $CO_2$ rather than preventing or reducing emissions.

CCS business case far from the revenues of the fossil fuels industry is still to be demonstrated. In the EU, the presence of a carbon market is not helping its case; even the power sector, which does not benefit from free carbon emissions and is subject to higher $CO_2$ prices, is continuing to deploy renewable sources at high rates instead of betting on CCS.

## $CO_2$ storage safety requires long-term commitment

[19] European Commission Staff Working Document: Investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity
[20] Global CCS Institute, 2023 Global Status of CCS
[21] To produce marketable natural gas when the extracted raw gas contains too much CO2.
[22] Enhanced oil recovery is the extraction of crude oil from an oil field that cannot be extracted otherwise through the injection of gases, including CO2. EOR enhances the oil production rate from fields that have passed the maximum output rate.

When captured $CO_2$ is injected to increase the extraction of oil in EOR projects, 70% of the injected $CO_2$ is released back into the atmosphere[23]. But even when the idea is to pick storage basins to store $CO_2$ indefinitely, the actual $CO_2$ retention ability over prolonged periods of such basins is unpredictable.

According to a study by IEEFA[24] on the literature describing the well-established Sleipner and Snøhvit projects in Norway, **neither the performance nor the integrity of storage sites can be guaranteed**, whether ex ante or over time. The literature review indicates that:

- Both projects have seen unexpected behaviours of the stored $CO_2$ that might have led to leakages.
- Extensive studies are required at site-level; the learning effect is small due to the unique geology of each site.
- Monitoring programs would need to continue indefinitely to assure the permanent sequestration of $CO_2$ long after storage sites' closure. Earth geology is dynamic, and the long-term impacts of man-made storage are unpredictable.
- Contingency plans should be prepared and budgeted for, meaning that the necessary equipment and personnel must remain available not only during the site operations, but also after its end of life for an indefinite amount of time.

Finally, the two projects (with a combined storage capacity of 1,7 Mtpa of $CO_2$) are way smaller than the ones proposed at the EU level (250 to 350 Mtpa by 2050 according to the EU Industrial Carbon Management strategy[25]) or at global level. Given that, for instance, the EU storage targets require multiple times the capacity of the Sleipner and Snøhvit projects, it is highly questionable whether it is possible to deliver such storage capacity with the level of safety required to store big amounts of $CO_2$ for centuries. Given these premises, it is far from clear whether CCS can be scaled safely and efficiently and where the economic resources for such a long-term commitment will come from.

## CCS as a last resort

The use of carbon capture technologies should be the last step in a cascade of priorities aimed at decarbonising industry.

### First priority: circular economy, energy and material efficiency

The implementation of circularity and efficiency strategies at sectoral level would automatically reduce the amount of $CO_2$ emitted in the atmosphere through a more optimal use of resources[26], and thus a reduction of embedded emissions in those materials, while sparking new business models.

[23] Thomas Longden, Fiona J. Beck, Frank Jotzo, Richard Andrews, Mousami Prasad – '[Clean' hydrogen? – Comparing the emissions and costs of fossil fuel versus renewable electricity-based hydrogen](), Applied Energy, Vol. 306, Part B, 2022.
[24] IEEFA, 2023, Norway's Sleipner and Snøhvit CCS: Industry models or cautionary tales?
[25] This refers to a leak published on 17.1.2024.
[26] Efficiency strategies are conditioned by the so-called rebound effect (Jevons paradox). Nevertheless, such a paradox exists whatever the strategy used to save energy, materials, etc.

For instance, the cement sector has the potential to reduce its $CO_2$ emissions by 50-60% using low-clinker cements[27], with some industrial players even producing cement with no clinker. Low-clinker or 0 clinker cements are cost-effective and maintain the same functionality as classic Portland cement[28]; its widespread use would greatly reduce the need for CCS in the cement sector, which is one of the sectors with hard-to-abate emissions that will likely need CCS to reach net-zero emissions. $CO_2$ emissions resulting from cement amount to 103 Mt[29] in the EU. It is simply easier, safer, and more cost-effective to design a CCS infrastructure for 41 Mt $CO_2$ or less instead of 103.

A report by Material Economics[30] states that **a more circular economy can cut emissions from heavy industry** (steel, cement, plastics and aluminium) **by 56%** by 2050 through higher re-circulation of materials (60% of potential emission savings), higher efficiency (19% of potential emission savings) and circular business models (21% of potential emission savings).

Similarly, according to a study by Agora Industrie and Systemiq[31] focusing on Germany, **climate targets** can be **achieved faster, cheaper, and with less energy consumption through circular economy** than scenarios only foreseeing the decarbonisation of primary production. With a combination of decarbonised primary production and circular economy measures in the energy-intensive value chains of steel, cement, and plastics, cumulative GHG emissions can be reduced by 25% by 2045, transformation costs by 45%, and energy consumption by 20%.

**Waste management strategies have a high potential to reduce emissions from carbon-intensive sectors;** this should be the first step, before considering tackling any residual emissions with CCS. For instance, municipal waste management recycling rates are surging throughout the EU: the average EU recycling rate is 48,7%, with peaks of 67,8% in Germany and 60,8% in Slovenia[32]. Further improvements are possible to reach the EU target of 65% by 2035: even in Member States with highly developed waste management systems such as Germany, the non-sorted waste collected at households contains almost 67,5% of materials that can be recycled, with the potential to save between 10,2 and 23,2 Mt $CO_2e$ per year[33] (up to 21% of the total 2020 EU waste sector emissions). CCS can play a role in the incineration of hazardous waste but the same principles apply: prevention and recycling should be prioritised.

## Second priority: Switching industrial processes towards electrification and phasing out combustion of fossil-based feedstocks

The replacement of combustion processes with electrification with renewable electricity is another powerful way to reduce $CO_2$ emissions without recurring to CCS.

While a decade ago CCS was envisaged to reduce $CO_2$ emissions from the power sector, that has not happened, and nowadays **renewable energy is displacing fossil fuels and related emissions with no**

[27] Alliance for Low-Carbon Cement and Concrete, 2022, Fast-Tracking Cement Decarbonisation
[28] 90% of CO2 emissions of Portland cement comes from clinker production.
[29] European Environment Agency, EU Emission Trading System data viewer (2022 data)
[30] Material Economics, The circular economy, a powerful force for climate mitigation
[31] Agora Industrie & Systemiq, 2023, Resilienter Klimaschutz durch eine zirkuläre Wirtschaft
[32] Circular Economy Monitor Flanders, 2021 data
[33] Zero Waste Europe, Join position paper on mandatory implementation of CCS in municipal waste incinerators

**need of capturing them**. Going into 2024, the EU is generating more renewable power than ever. Preliminary data gathered by the Fraunhofer Institute[34] shows that renewables accounted for nearly 44% of the EU's 2023 power production, while the share of fossil fuels dropped below 32%.

We should be able to tell the same story for **steelmaking**. As stated above, the first priority should be to give more prominence to the scrap-based route with Electric Arc Furnaces and reduce the amount of steel we need through circular economy measures. The remaining needed steel coming from iron ore (primary route) should be produced with electrified processes, namely Direct Reduced Iron (DRI) powered by renewable hydrogen and renewable electricity, instead of blast furnaces with CCS. DRI is on the brink of becoming commercially viable[35] and almost completely displaces fossil fuels when used with renewable hydrogen and renewable electricity.

The shift to electricity-based processes is widely applicable to other **energy intensive processes** such as:

- **Downstream processes** (ferrous metals processing): certain energy intensive production steps such as hot rolling or casting can be fully electrified.
- **Foundries:** cupola furnaces can be substituted by electric kilns like induction type or EAF furnaces.
- **Ceramic production:** in the EU at least 4 kilns are reported to operate on electricity run kilns instead of fossil gas.

The main reason that hampered the reluctance of switch to electrification to materials were low carbon prices and the presence of free-allocated CO2 emissions, the lack of internalisation of other air pollution damage costs and, in some cases, lack of stable electricity supplies due to grid issues.

## Last priority: use of carbon capture only for residual and "unavoidable emissions" and only with permanent storage

The two paragraphs above give an idea of the emissions that should be declared as "unavoidable" and that, consequently, should be potentially captured and permanently stored. It is often said that **unavoidable emissions are associated with "hard-to-abate" sectors** (steel, cement, chemicals, etc.), **but such a definition is misleading** because it does not take into account the different kinds of emissions within an industrial process (e.g. from combustion or from chemical reactions), the potential of circular economy and efficiency practices, nor the technological developments of these sectors and the internalisation of external costs of inaction.

For instance, steelmaking is usual referred as "hard-to-abate", but the sector is evolving: according to Agora Industry and the Wuppertal Institute steel production meets the requirements to be a "fast-to-abate" sector due to a combination of new technology availability, minor impact on the costs of final products made with green steel, the possibility to use zero-carbon electricity, and the potential for a quick transition (early 2040s)[36]. The same is true for the other sector examples (see examples cited above).

[34] Fraunhofer, Energy charts
[35] The Hybrit project in Sweden plans to market low-carbon steel in 2026.
[36] Agora Industry & Wuppertal Institute, 2023, 15 insights on the global steel transformation

## Defining “unavoidable emissions”: some examples

There are different ways to define “unavoidable emissions”, all of them trying to distinguish the emissions that we should simply avoid by, for instance, stopping burning fossil fuels from the ones we should accept and then capture and store away.

In the debate around the Net-Zero Industry Act, the Environment, Public Health and Food Safety Committee of the European Parliament proposed a definition based on the following principles: unavoidable emissions are the ones generated when no direct emission reduction options are available after the best available techniques are applied, demand-side reduction measures are applied, and the state-of-the-art of technologies are considered[37]. This is a general definition and does not provide details on which industrial processes emit unavoidable emissions.

A more nuanced proposal comes from think tanks E3G and Bellona: the so-called “CCS ladder”[38]. It assesses the added value of different CCS use cases for different industrial processes having in mind two horizons: 2030 and 2050. The ladder is built according to the following criteria: competition from alternative technologies (to CCS), the mitigation potential of CCS, the feasibility of carbon capture, and the source of $CO_2$. Even though the ladder overestimates the use of CCS for waste incinerators and still considers coal-fired power plants as potential targets for CCS, it has the merit to nuance the debate, highlight differences in climate-value about CCS use, and help to focus resources on only certain sectors for which CCS is key to get net-zero.

Another definition proposal comes from the Haut Conseil pour le Climat[39], and it is based on the following principles: concentration and capture rate of $CO_2$, geographical concentration of emitters, type of emissions (combustion or process), alternatives to CCS, evolution of the sector, and weight of the sector emissions with respect to the total $CO_2$ emissions of France. The methodology is centred on the French industrial landscape; while being useful on many aspects, including an assessment of the evolution of the market demand of each sector, it lacks considerations on circular economy and efficiency practices as alternatives to CCS.

## So, what are “unavoidable emissions”?

The picture sketched in the previous paragraphs shows that there are many alternatives to CCS to decarbonise our industry. Many technologies and techniques to avoid producing $CO_2$ in the first place are viable and their deployment should be prioritised when it comes to public funds spending. With no presumption of being exhaustive, we try to summarise what “unavoidable emissions” could look like.

**For energy generation,** 100% of $CO_2$ emissions are avoidable. Under no circumstances CCS should be used, the only priority is to deploy non-combustion based renewable electricity as quickly as possible. When it comes to bioenergy with CCS (BECCS), not only is its deployment clearly constrained by the availability of biomass, but the production of biomass for this specific purpose would raise major concerns regarding

[37] Opinion of the Committee on the Environment, Public Health and Food Safety on the NZIA (2023/0081COD)
[38] E3G & Bellona, 2023, Carbon Capture and Storage Ladder
[39] Haut Conseil pour le Climat, 2023, Avis sur la stratégie de capture du carbone, son utilisation et son stockage (CCUS)

land grab, biodiversity and food security. Large-scale deployment of BECCS would drive unsustainable levels of land-use change and biomass use that are incompatible with the objectives to increase carbon sequestration in soils and vegetation and would hinder ecosystem restoration[40].

**For steelmaking,** the combination of circular practices, material and energy efficiency strategies, a higher use of scraps, and the implementation of Electric Arc Furnaces (EAF) and DRI with renewable hydrogen allow to reduce the sector's $CO_2$ emissions to nearly zero without implementation of CCS. While capturing $CO_2$ produced in blast furnaces might lower emissions to 0,9 tonnes of $CO_2$ per tonne of crude steel (assuming high $CO_2$ capture rates), EAFs and DRI with renewable hydrogen bring $CO_2$ emissions down to almost 0[41].

**For cement production,** a certain amount of CCS is needed to allow the sector to become net-zero. But its use should come after the deployment of more cost-effective and ready-to-implement alternatives, such as the use of low-clinker, which has the potential to reduce $CO_2$ emissions by 50-60% without CCS. Circular and material efficiency practices, 0-clinker cement and the development of electrified cement kilns would bring down emissions further. The use of CCS should be targeted only for specific co-incineration facilities serving purposes beyond waste treatment (e.g. cement kilns).

**For waste incineration,** the general rule to reduce emissions is to prevent waste and recycle. when it comes to mixed municipal waste to most materials and, thereby, the related emissions of the incineration process can be considered avoidable through either preventing waste in the first place or by recycling, following the waste management hierarchy. A further way to decrease the amount of mixed waste that must be incinerated is to sort it by using "leftover mixed waste sorting" techniques (LMWS); a combination of LMWS and CCS would result in higher recycling rates, higher levels of $CO_2$ emissions reduction and a much lower average cost per unit of $CO_2$ reduction than where CCS is deployed without LMWS (63-84€ per tonne of avoided CO2 with LMWS against 122-143€ with CCS)[42]. Therefore, all measures to prevent and recycle municipal waste must be applied before CCS can be considered for any residual emissions. Moreover, attention needs to be paid to the systemic risks that CCS poses to a circular economy: further investments in incineration facilities may reinforce technological lock-in effects that lead to stagnating recycling rates and little incentive for waste prevention. Not without reason are investments in incineration facilities deemed unsustainable according to the Taxonomy Regulation due to the harm they cause to achieving the goal of a circular economy. Accordingly, the application of CCS for municipal waste incineration requires careful consideration.

When it comes to plastic production, according to a report by Systemiq[43] focusing on plastics used in packaging, household goods, automotive, and construction, with circularity solutions the quantity of plastics that need to be incinerated or put in landfills could reach only 9% by 2050, with 78% of plastics waste that can be managed through elimination of unnecessary plastics, reuse and recycling. Such circularity scenario would reduce 80% of end-of-life plastic disposal and reduce $CO_2$ emissions by 65%.

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[40] See the EEB recommendations for carbon removals
[41] Material Economics, 2021, Steeling demand
[42] Zero Waste Europe, 2024, Materials or Gases? How to Capture Carbon
[43] Systemiq, 2022, Reshaping Plastics

## Storage must be permanent

$CO_2$ must be considered as a dangerous pollutant, not a commodity. This not only means that its production should be avoided in the first place, but that its storage should be permanent and safe. The use of $CO_2$ as a feedstock to be later emitted into the atmosphere should never be supported by climate policies. But what does "permanent storage" mean? How do we define "permanence"?

First, since CCS is meant to play a role in the fight against climate change, its storage must be an effective mitigation measure. According to the IPCC[44], carefully selected sites can store $CO_2$ underground for long periods of time: it is **considered likely that 99% or more of the injected $CO_2$ will be retained for 1000 years.** Other approaches consider shorter timeframes, but in general a time horizon of multiple centuries is considered as a good definition of permanent storage. Such a long timeframe presents the challenge of setting up monitoring and contingency plans for storage sites to be able to work for centuries.

$CO_2$ might also be bound in products. The EU ETS Directive[45] states that $CO_2$ emissions permanently chemically bound in a product so that they do not enter the atmosphere under normal use and do not enter the atmosphere under any normal activity taking place after the end of the life of the product are not subject to allowances surrender. Such definition opens the problem of permanency of $CO_2$ in products: are there products able to store $CO_2$ for centuries? How is it possible to practically prove and certify that $CO_2$ emissions will remain bound in products for centuries?

Again, this challenge is difficult to solve. On the other hand, we know what are the products that do not store $CO_2$ for amounts of time relevant for tackling climate change, like fuels, plastics, fertilisers. As a rule of thumb, unless $CO_2$ storage is guaranteed for amounts of time allowing to address climate change (in the order of centuries), the utilisation of $CO_2$ in applications where it is emitted to the atmosphere should never be presented as carbon neutral nor supported with public finance[46].

# Policy recommendations

Public money is scarce and should be used wisely to serve the public interest. CCS should be treated as an expensive and valuable resource, to be used carefully and not as the main option to decarbonise. Instead, many voices today are advocating for additional subsidies for CCS technologies, pushing for a deployment of a technology that cannot be the main solution when it comes to fight climate change, while being well recognised to create lock-in effects for the extraction of fossil fuels. Our answer to these voices is simple: if public policies are needed to deploy CCS, it must be used for the public interest, meaning that:

- CCS must serve the EU ambition to become climate neutral by 2050 and **not perpetuate the burning of fossil fuels** or continued use of fossil feedstocks. The final goal must always be to achieve a system entirely based on renewable energy/feedstock, industrial processes based on non-combustion, and an efficient use of resources.

[44] IPCC, 2005, Special Report on Carbon dioxide Capture and Storage
[45] Directive (EU) 2023/959 amending Directive 2003/87/EC
[46] Bellona, answer to Industrial Carbon Management public consultation

- CCS, as for any "end of pipe" option, **must be used as a last resort**, only for industrial processes that cannot decarbonise with other means and after all other decarbonisation routes are used: use of renewable electricity, electrification, material substitution, energy and material efficiency, and circularity.
- **CCS must not counter other environmental policies**, such as pollution and waste prevention and reduction at the source through increased circularity and energy and material. Investment in CCS should always be subordinated to the evidence of higher and earlier investments in more effective solutions at plant, corporate and national levels.
- **The contribution of the oil and gas sector** to the implementation of CCS must be substantial and long-term; it must take responsibility for the climate change it has fuelled and provide storage sites sustaining their long-term management for free. Even a focused use of CCS would require a copious amount of money and expertise for the deployment of the necessary infrastructure and the long-term monitoring of the storage sites to address potential leakages. This would align with the polluter pays principle not yet fully developed as highlighted by a recent report of the European Court of Auditors[47].
- **Capture rates of each CCS project must be carefully measured** and made publicly available. Projects with capture rates under 90% should not be supported by public policies. Any issue leading to lower than 90% capture rate must result in termination of operations until the capture rate is restored or, alternatively, the emitter must pay for the uncaptured emissions according to the EU ETS carbon price.
- CCS must be safe and subject to **monitoring and contingency protocols** able to be activated along multiple centuries.
- $CO_2$ must be **permanently stored**, meaning that its use as a feedstock or bound in products with retention time lower than multiple centuries must not be supported by public policies.

[47] European Court of Auditors, Special Report 12/2021: The Polluter Pays Principle: Inconsistent application across EU environmental policies and actions