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CCS Ladder 2.0

A Brief Summary

POLICY BRIEF
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DISCLAIMER

The CCS Ladder, co-authored by E3G and Bellona, is a framework for assessing the climate value of different CCS applications in Europe

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Introduction

The *CCS Ladder* is a framework for assessing the climate value of different CCS applications in Europe. Its goal is to provide a granular industry-wide evaluation of CCS applications, ranking them based on their climate mitigation impact using transparent criteria.

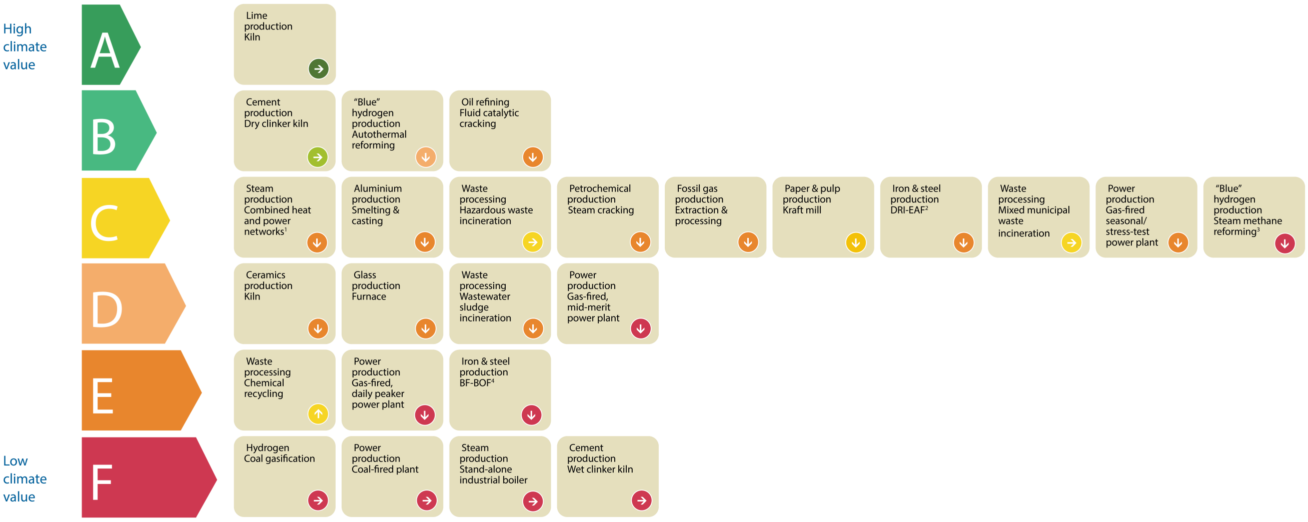
The Ladder was born from the observation that discussions of CCS lacked nuance, often treating it as a single technology with clear opponents and proponents. The framework was therefore developed to help place CCS in the broader landscape of decarbonisation tools. It aims to inform strategic prioritisation of CCS by highlighting the benefits and trade-offs of different CCS applications, especially in relation to other available climate mitigation tools.

However, the ladder <u>DOES NOT</u>:

- Assess the value of specific projects or installations, only types of applications;
- Outright condemn the use of CCS in any specific case or single project;
- Claim to be a conclusive analysis, since its underlying criteria and assumptions may change over time;
- Serve as a direct funding guide, given that the climate value of a CCS application does not automatically justify awarding it financial support.

The briefing was updated in 2026 as the *CCS Ladder 2.0* to reflect changes in policy, technology and political context. Indeed, the competition between CCS and other decarbonisation tools is changing. The operational cost of CCS remains uncertain, and while renewable energy and electrification are accelerating, they also face their own hurdles, as does renewable hydrogen. Europe's political context has also shifted away from long-term climate action, with policy makers increasingly preoccupied with short-term competitiveness, defence and reducing public spending, which makes it all the more important to prioritise the most cost-effective investments in decarbonisation.

2030



Notes: Coloured arrows indicate changes in relative ranking from 2030 to 2050 (up, down or stable. The ladders do not express how much CCS should or will be deployed in any application, nor whether CCS is the only or preferred mitigation lever. All applications assessed have at least some technological and non-technological mitigation alternatives, including those applications with higher rankings. Please see Box 1 for guidance on how to interpret and use the CCS ladders.) BF-BOF – blast furnace-basic oxygen furnace; CCGT – combined-cycle gas turbine; 2 DRI-EAF – direct reduced iron-electric arc furnace; OCGT – open-cycle gas turbine;
1 For example, in chemical clusters; 2 Fossil gas-based; 3 For example, for ammonia production; 4 Coal-based.

2050

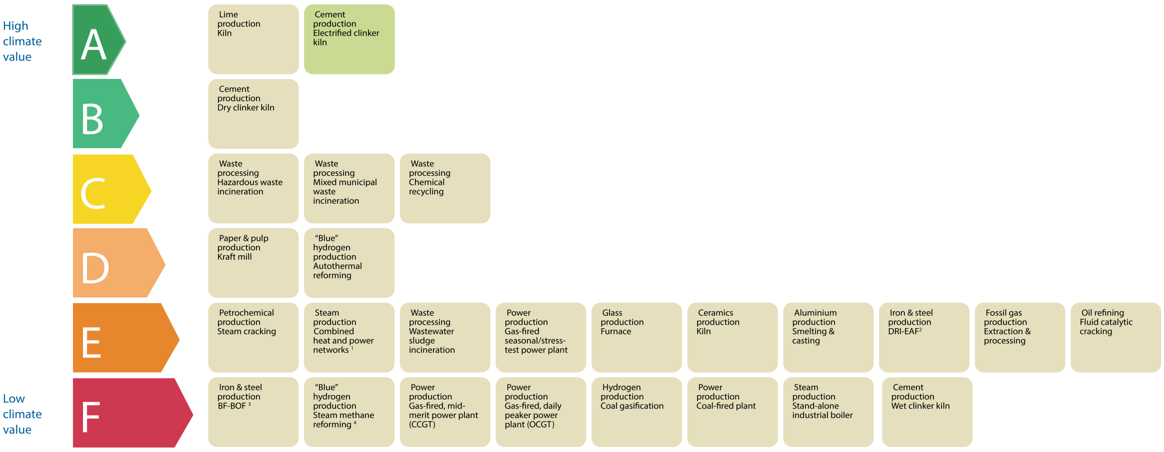


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Figure 1. CCS ladders: *climate value of carbon capture and storage by industrial process (2030 and 2050)*

Insights from the CCS ladder

Methodology

The CCS Ladder 2.0 uses the following three criteria to assess the climate value of each CCS application:

- **Competition from alternatives** (double weight)[1]: are there other credible and scalable ways to decarbonise this industrial production route?
- **Mitigation potential**: can CCS deliver deep, durable emission reductions for this industrial production route?
- **Feasibility**: how practical is it to deploy and scale CCS for this industrial production route?

Each CCS application is scored against these criteria by drawing on internal analysis, published studies and targeted stakeholder feedback. This score is then translated into an A-F ranking to form the ladder itself.

An important component of the methodology is the time horizon: to show how the role and climate value of CCS could evolve over time, each application is assessed for both 2030 and 2050. This results in two ladders, which rank the climate value of the same CCS applications in 2030 and 2050:

- The 2030 Ladder highlights production processes where CCS must have an impact in the near future and where CCS is needed to keep emissions on track during a transition period;
- The 2050 Ladder shows the no-regret CCS applications that will require it now and over the foreseeable future, serving as the critical anchor points of CCS infrastructure build-out.

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[1] Double weight is given to "Competition from Alternatives" to reflect that CCS is not impact-free: it requires significant transport and storage infrastructure, increases energy use, and – where fossil fuels remain – can prolong upstream and downstream impacts. CCS should not be the go-to solution where scalable, cost-effective alternatives exist; it sits lower in the mitigation hierarchy for that reason. The double weighting ensures this principle is well reflected in the assessment.

Cross-cutting takeaways

The CCS Ladders provide valuable insights that should be considered when designing CCS policy in Europe:

1. The sectors where CCS may be most critical are not always those where deployment is easiest or cheapest, e.g. due to small site sizes, limited technical capacity, or distance from infrastructure. Conversely, applications where CCS can be relatively feasible may have limited climate value or rapidly developing decarbonisation alternatives.

   Furthermore, climate value alone should not automatically translate to public support. Depending on the business case, technical capacity and political acceptability, applications with similar scores could warrant different types of intervention – ranging from enabling support and infrastructure coordination to regulatory obligations and managed phase-down conditions.
2. CCS will have an increasingly narrow and targeted role to play in mitigating emissions, focusing on the applications that offer the highest climate value, such as cement and lime production.
3. The relative climate value of CCS is expected to decline over time for many industrial processes if alternatives deliver. In most sectors, the rise of cheaper alternative mitigation technologies with stronger climate benefits should gradually diminish the role of CCS. However, this is not universal: for activities such as lime production, hazardous-waste incineration and clinker production in the cement sector, carbon capture will probably need to play a considerable role to deliver near-full decarbonisation.

Sectoral deep dives

Alongside the cross-sectoral overview mentioned above, the *CCS Ladder 2.0* also provides deeper analyses of CCS applications in different industrial sectors. These sectoral deep dives explain why applications occupy their respective positions on the 2030 and 2050 Ladders and show how the role of CCS varies within industries and over time. The key findings are as follows:

- Some applications offer high climate value as CCS will be essential in addressing process emissions[2] in these industries (e.g. cement, lime);
- Many applications offer structurally low climate value as alternatives are already available or are expected to outcompete CCS (e.g. power production, certain iron, steel and hydrogen processes);
- Most applications are only a transitional measure, have moderate climate value or face competition from alternatives under certain conditions (e.g. paper and pulp, glass, ceramics).

The following applications were chosen to illustrate these findings.

Cement and lime production

Ranking:

2030: A-B **2050: A-B**

Together, lime and cement production account for 115–125 $MtCO_2$ emissions per year across Europe. Both sectors are particularly difficult to fully decarbonise because a large share of their emissions come from the production process itself. When limestone ($CaCO_3$) is heated, it undergoes a chemical reaction called calcination, which releases CO_2 from the raw material ($CaCO_3 \rightarrow CaO + CO_2$). In cement production, these process emissions account for the majority of overall emissions.

Lime is particularly dependent on CCS given its widespread use in other industrial activities and the limited availability of alternative decarbonisation options. However, lime is produced in smaller, geographically dispersed kilns that are often located far from planned CO_2 transport and storage infrastructure. The sector will therefore require coordinated support mechanisms and accessible infrastructure to enable its decarbonisation.

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[2] Process emissions arise from chemical reactions and raw materials inherent to a given process rather than fuel combustion. As such, they cannot be abated by changing fuels or electrifying processes, meaning that they will occur even after other decarbonisation methods have been implemented. Examples include cement and lime production or metal smelting and refining.

Cement production has access to a broader range of mitigation measures, particularly through resource substitution and efficiency improvements. However, achieving deep decarbonisation will still hinge on capturing process emissions from calcination. As with the lime sector, coordinated infrastructure development, regulatory reform, and industrial planning will be needed to maximise the sector's decarbonisation and ensure that smaller sites and installations are not left behind.

Iron and steel production

Ranking:

2030: C-E **2050: E-F**

Steelmaking is responsible for roughly 145 $MtCO_2$ emissions per year across Europe, mostly coming from aging, coal-fuelled plants (known as BF-BOF). Recent trends show increased investment in alternative steel production methods (known as DRI-EAF), some of which can deliver major reductions in CO_2 emissions, but their development remains uncertain.

CCS offers limited value for BF-BOF steel. This application leaves high residual emissions on top of significant upstream methane emissions from metallurgical coal mining. It also faces high energy demand and strong competition from hydrogen-based routes and risks extending the lifetime of coal-based assets.

For DRI-EAF steel, CCS could be used to mitigate emission from fossil gas-based processes, but at a high cost, uncertain long-term viability and risks of fossil lock-in. On the other hand, DRI-EAF pathways based on renewable hydrogen have higher mitigation potential but themselves require accelerating hydrogen deployment while accepting some transitional solutions to avoid delaying CO_2 emissions cuts.

The role of CCS in steel will thus depend on industrial strategy choices. Long-term CCS dependence can be reduced by targeting support for DRI-EAF plants strategically located near abundant, affordable renewables and hydrogen, bolstered by a liquid market for low-carbon iron.

Petrochemical production

Ranking:

B

C

E

2030: B-C **2050: E**

The petrochemical industry encompasses upstream fossil-gas extraction, oil refining, and petrochemical production through steam cracking, which represent around 185 $MtCO_2$.

These processes generate continuous, concentrated CO_2 streams, which can be efficiently captured, and CCS may be the only mitigation lever to address the emissions at site level. However, these on-site emissions represent only a small share of the total climate impact of petrochemica production. While the real long-term solution lies in reducing fossil-product demand, petrochemical emissions will remain large enough that excluding them from early CCS deployment could jeopardise Europe’s interim climate targets.

Oil refining ranks relatively high on the 2030 CCS Ladder because refineries are large, concentrated sources of CO_2 where carbon capture is technically feasible and can deliver substantial reductions in direct emissions. However, CCS only addresses emissions from the refining process itself. The vast majority of lifecycle emissions from oil products occur downstream when fuels are combusted in transport, heating and industry. As a result, while CCS can significantly reduce refinery emissions, it only mitigates a limited share of the total climate impact of oil products. Looking ahead, electrification, efficiency improvements and modal shifts are expected to steadily reduce demand for refined fossil fuels. In the longer term, any remaining refining capacity is likely to be focused on producing bio-based or synthetic feedstocks, further narrowing the role and climate value of CCS in the sector.

This assessment is almost identical for fossil gas extraction and processing, where long-term decarbonisation ultimately depends on the decline of gas demand through renewable energy deployment, increased efficiency and electrification.

Similarly, CO_2 emissions for petrochemicals relying on steam cracking (e.g. plastics, fibres, and solvents) occur downstream, which limits the benefits of CCS. Long-term decarbonisation will therefore require a shift to non-fossil carbon feedstocks, which remains speculative at this stage, and reduced demand for primary products.

Overall, CCS brings most value in managing near-term emissions as long as it does not undermine the structural transition away from fossil energy and feedstocks.

Gas-fired power production

Ranking:

2030: C-E **2050: E-F**

Gas-fired electricity generation still represents one-sixth of electricity generation and roughly 150-190 Mt CO_2 emissions per year, but demand is expected to fall dramatically over the coming decades as renewables continue to expand, and flexibility and storage solutions mature.

While the broad trend is clear – CCS for gas power generation is expensive, misaligned with system needs and has limited climate value – differences in gas plants types their specific roles in operations bring some nuance to the discussion.

CCS can technically reduce emissions from gas-fired power plants, particularly those operating at high utilisation rates. However, these are precisely the plants expected to be increasingly displaced as renewables, storage, interconnection and demand-side flexibility expand. While CCS could also be applied to residual peaking, seasonal or stress-test plants, their low operating hours would make carbon capture infrastructure costly and underutilised, while risking continued dependence on fossil gas. As a result, the overall climate value of CCS in the power sector is expected to decline over time as cleaner alternatives mature and scale.

The role of gas-fired power generation in Europe is expected to decline as renewables, energy storage, interconnection and demand-side flexibility continue to scale. Public policy should therefore prioritise accelerating these solutions and reducing both the volume of gas generation and its influence on the power system. While some residual gas-fired capacity may remain necessary for seasonal or security-of-supply purposes, applying CCS to these plants would be costly, result in inefficient use of CO_2 transport and storage infrastructure, and risk prolonging dependence on fossil fuels. Where residual emissions persist, alternative approaches such as renewable fuels, low-carbon hydrogen or compensatory removals may offer a more credible long-term pathway than widespread deployment of CCS on gas-fired power generation.

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