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CCS hype and hopes sinking fast

- *The use of fossil fuels with CCS is unlikely to be competitive with renewable-based solutions.*
- *The IEA halved its outlook for the use of fossil fuels in association with CCS in just two years, in particular slashing its outlook for gas use with CCS.*
- *Delays, underperformance and technical challenges have a significant impact on CCS costs. Gorgon, the world's largest CCS project, costs about US$138/t$CO_2$ captured, about five times the IEA's estimate for CCS in gas processing.*
- *CCS's role will likely be limited to cases where no alternatives exist.*

Reality check for CCS-fossil fuels combination

Globally, about two-thirds of carbon capture, utilisation and storage (CCUS) capacity is used for fossil gas processing. The remainder is used primarily in fuel transformation, methanol and fertiliser production, and power generation. Notably, about three-quarters of the captured carbon dioxide (CO_2) is then used for enhanced oil recovery (EOR), with only 20% sequestered in dedicated storage. This reflects the most commercially viable applications for CCUS – where there is a revenue stream or a government incentive to invest.

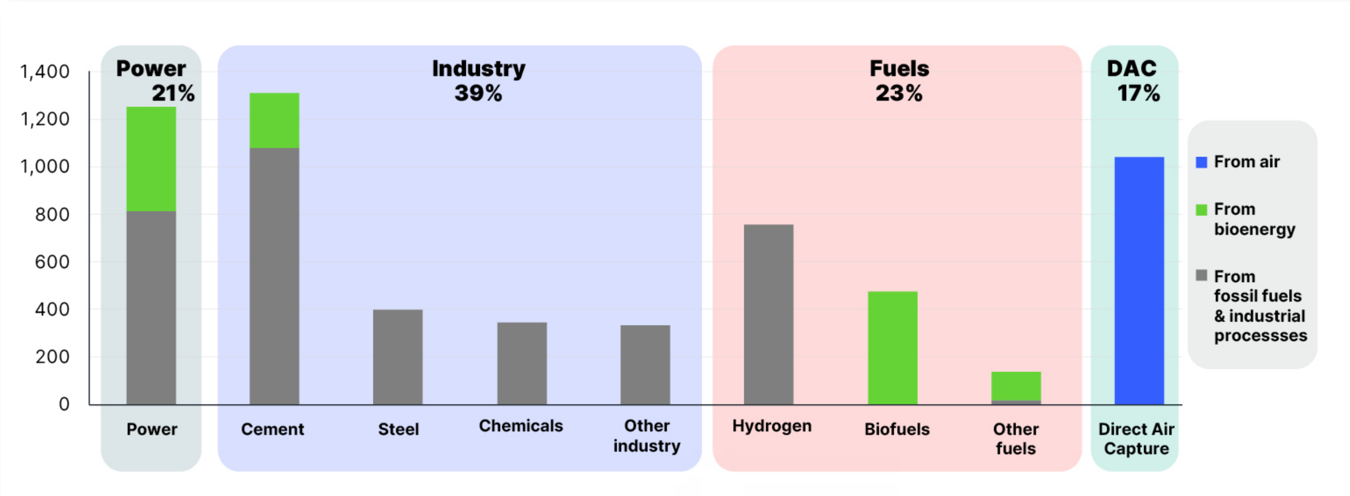
This is at odds with the International Energy Agency (IEA)'s updated Net Zero Emissions (NZE) scenario in which all CO_2 is expected to be permanently stored in order to decrease global greenhouse gas (GHG) emissions (Figure 1). In this scenario, CCS is expected to be used in four main sectors:

- Industry: the largest use with 39% of CO_2 captured, in particular to capture process emissions[1] in the cement sector where limited solutions exist, as well as in the chemicals and steel sectors.
- Fuels transformation: 23% of CO_2 captured, of which about half is used for hydrogen production, and half for bioenergy-based fuels.
- Power: 21% of CO_2 captured, with about two-thirds used in association with fossil fuels, and one-third in association with bioenergy to create "negative emissions" (i.e. by removing CO_2 from the atmosphere).

1 In industry, CO_2 can be created either by burning fossil fuels (combustion emissions) or as a byproduct of a conversion process (process emissions) in the production of cement, chemicals and metals.

- Direct air capture (DAC): 17% of CO_2 captured, which is also expected to deliver negative emissions to counteract delays in emissions reductions.

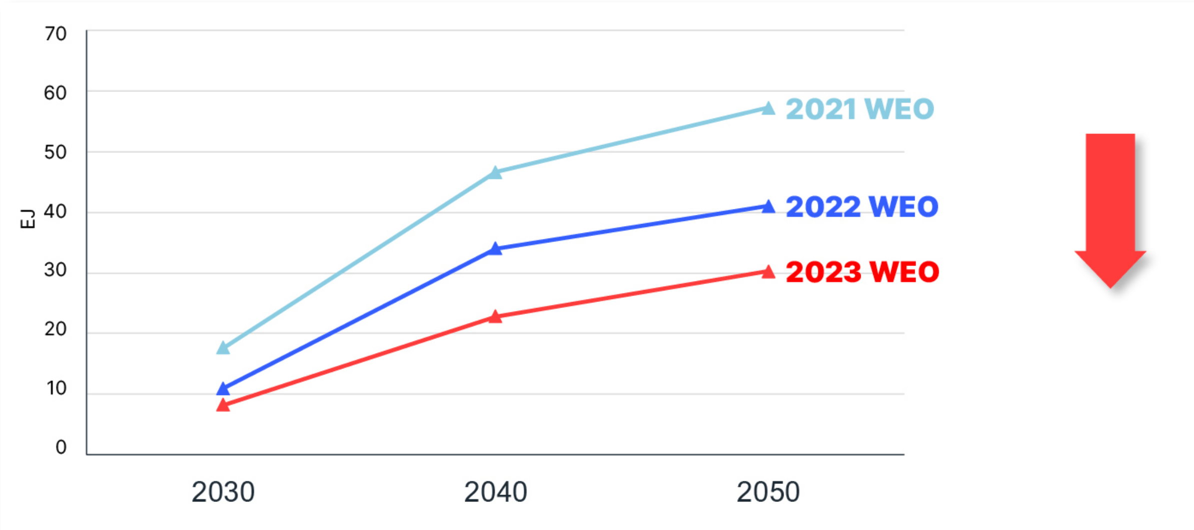
Figure 1: Total CO_2 captured in 2050 in IEA NZE scenario ($MtCO_2$)



Source: IEA, Net Zero Roadmap – 2023 Update

Interestingly, the IEA has already dramatically decreased its outlook for fossil fuel use in association with CCS. Figure 2 shows the global energy supply coming from fossil fuels with CCS in the NZE scenario from the 2021, 2022 and 2023 World Energy Outlooks (WEO). It shows the contribution of fossil fuels with CCS halving by 2040 and 2050.

Figure 2: Contribution of fossil fuels with CCS to global energy supply (NZE)



Source: IEA, World Energy Outlook 2023, 2022 and 2021

Analysing information from the WEO and Net Zero Roadmaps reports (2023 and 2021), we identified the main driver of this decrease is a 57% reduction in the expected use of CCS with fossil gas. Expected coal use with CCS also declines by 15%. This corresponds to a decreased outlook for use of CCS with fossil fuels across a range of applications:

- A 44% reduction in the CO_2 captured in hydrogen production from fossil fuels;
- The near elimination of other fuel transformation from fossil fuels with CCS;
- A 30% reduction in the share of CCS-based equipment in primary steel production and;
- A 47% reduction in fossil gas electricity generation with CCS.

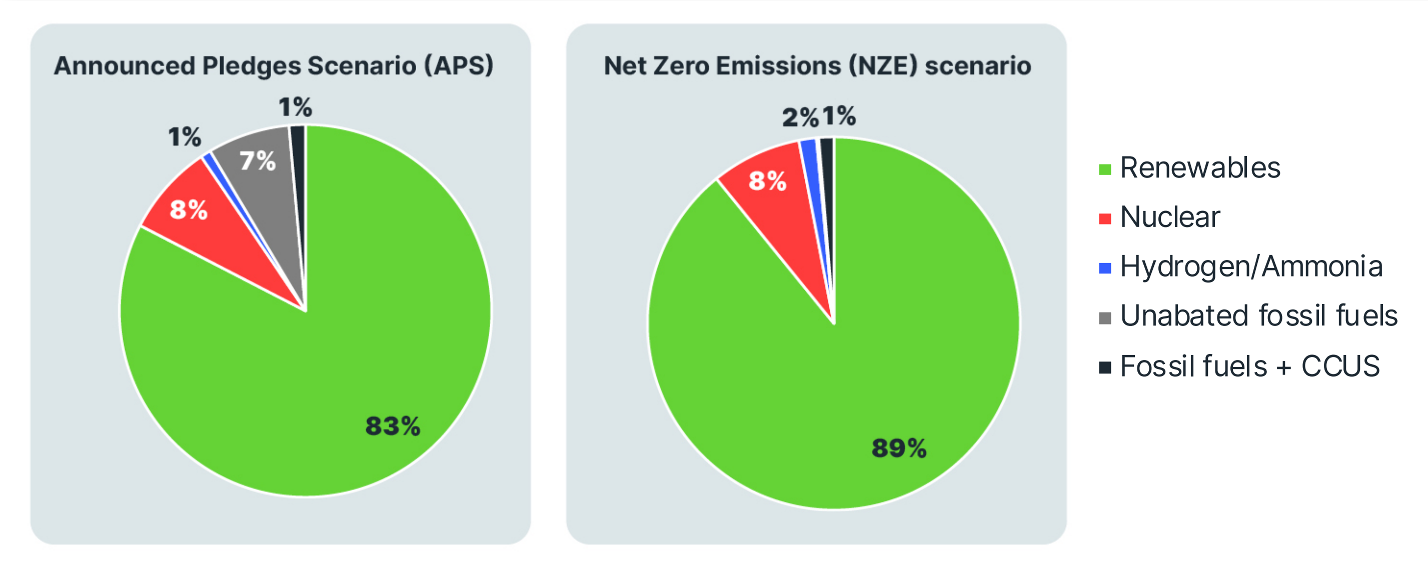
Applications to reduce industrial process emissions (such as in the cement sector), in association with bioenergy and for direct air capture didn't achieve the same decreases.

CCS uncompetitive with alternatives in many sectors

Power sector

In the power sector, CCS is expected to make only a very small contribution to global electricity generation. The IEA expects fossil fuels with CCS will supply about 1.5% of global electricity by 2050 in its NZE scenario as well as in its Announced Pledges Scenario (APS), aligned with about 1.7°C of warming (Figure 3). In the NZE scenario, CCS only comes into play when coal power stations need to be retrofitted before 2040 to meet a global 1.5°C carbon budget.

Figure 3: World electricity generation by 2050, IEA scenarios



Source: IEA, World Energy Outlook 2023

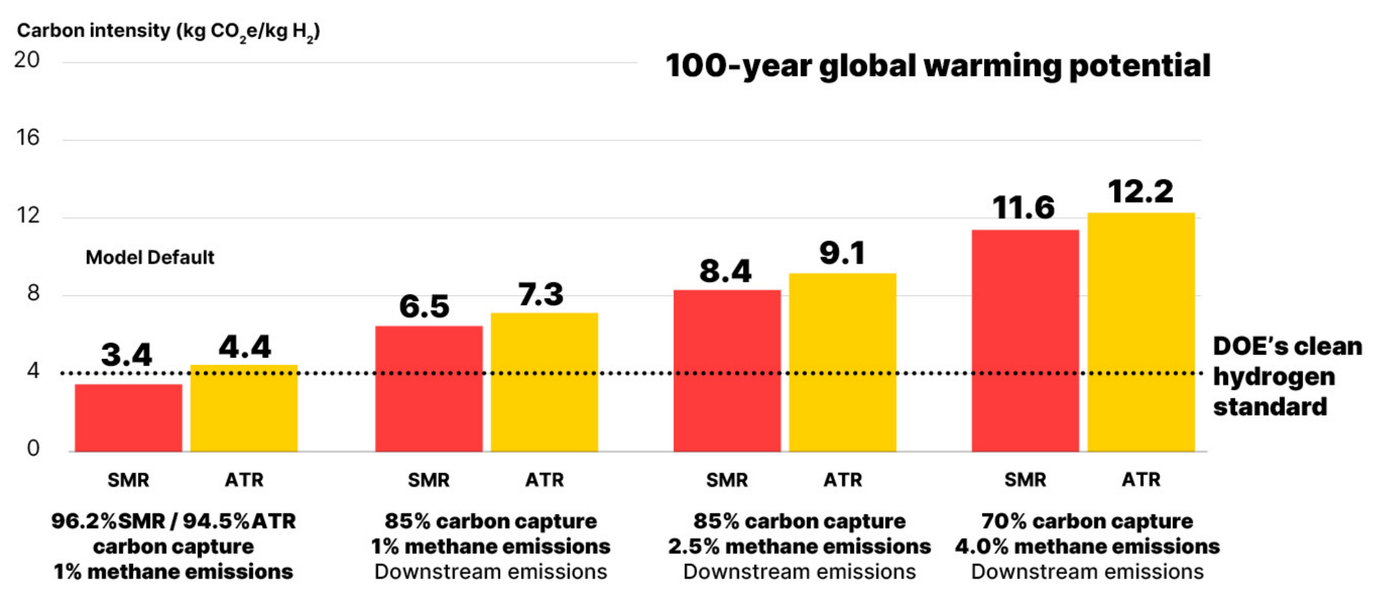
The main reason for CCS's projected decline is cost competitiveness. In the IEA's latest electricity technology cost estimates, even in the NZE scenario, the capital costs of coal with CCS remain very high at about US$3,800 per kilowatt (kW) on average in 2030. This is more than twice as expensive as supercritical coal, as costly as nuclear, and about six times the capital cost of large solar plants. As a result, the levelised cost of electricity (LCOE) generated by fossil fuels with CCS is usually not competitive with renewables even when associated with firming (flexible energy supply sources such as hydrogeneration or batteries that can complement variable renewables).

Hydrogen

There are many blue hydrogen (made from gas with CCS) projects in the pipeline, in particular in the US due to Inflation Reduction Act subsidies. However, IEEFA has examined in detail the carbon intensity of blue hydrogen, and found it is very unlikely to meet clean hydrogen standards. Meeting the US government's standard of 4kg of CO_2 equivalent (CO_2e)/kg hydrogen would require a capture rate of about 95% and fugitive methane emissions of less than 1%. Both those assumptions are heroically optimistic. IEEFA analysis has shown that no CCS project has captured more than 80% of its CO_2 emissions, with most capturing only one- to two-thirds of the CO_2 they produce.

A more realistic fugitive methane emissions rate of 2.5-4% (based on recent peer-reviewed scientific analyses), and capture rates of 70-85% would bring blue hydrogen's carbon intensity to two or three times the standard (Figure 4).

Figure 4: Impact of methane, CCS, emissions on blue hydrogen carbon intensities



Source: IEEFA, based on US Dept of Energy's Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model.

Note: Reflects 100-year global warming potential (GWP) incorporating more realistic assumptions about methane emissions, CO_2 capture rates and downstream emissions.

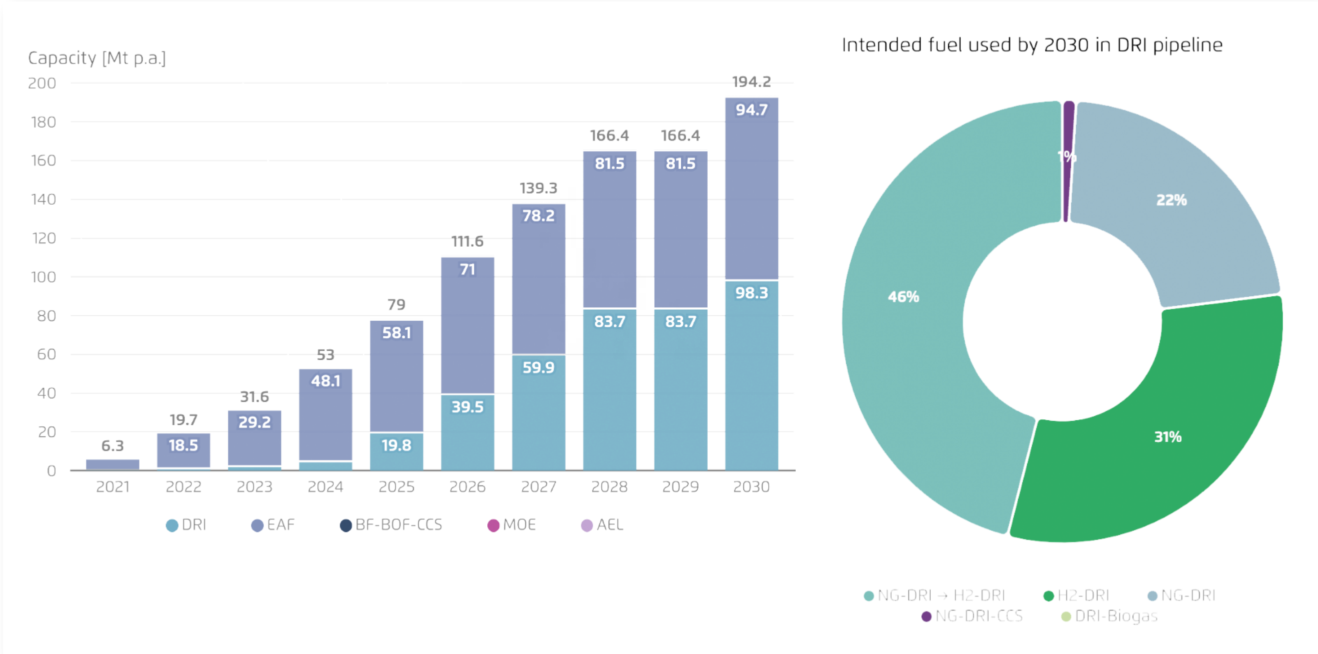
In addition, blue hydrogen's cost advantage over green hydrogen (made from renewable electricity) is expected to be short-lived. Bloomberg New Energy Finance expects green hydrogen will be cheaper than blue hydrogen by 2030 in most markets. It is even expected to reach cost parity with grey hydrogen (made from gas) from existing plants in some markets, including China and India.

Steel

CCS has only been used once at commercial scale in the steel sector – at a gas-based direct reduced iron (DRI) plant in the Middle East where it captured only about a quarter of the plant's emissions. CCS has never been used at commercial scale in coal-based blast furnaces, which are responsible for the vast majority of steel production and emissions. CCS would be much more complex to implement in blast furnaces than in DRI plants, given there are multiple sources of CO_2 and at quite low concentrations.

Only three announced projects plan to use CCS at commercial scale in the steel sector: one in a blast furnace plant, and two in DRI plants. All are at early development stages. Two projects provide information on their projected scale; together they would capture about 1.3 million tonnes of CO_2 ($MtCO_2$) a year, or 0.05% of global steel emissions. In contrast, there has been a flurry of low-carbon steel project announcements (Figure 5). The industry is focusing on increasing the share of recycled steel via electric arc furnaces (EAF) and moving to DRI (also often used in combination with EAF) powered by gas and green hydrogen.

Figure 5: Low-carbon steel project pipeline by technology, year (Mtpa)



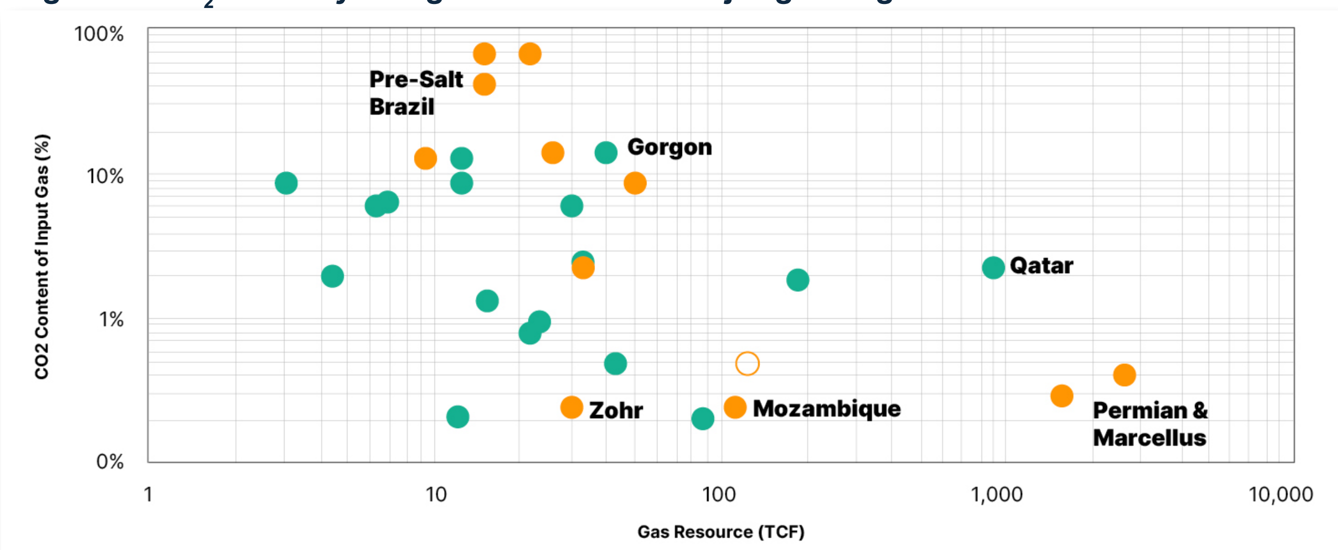
Source: [Agora industry]

Gas processing

CCS is often presented as an unavoidable solution to reduce fugitive CO_2 emissions in gas processing. While this might be true at the project scale, it is less so at the global scale. Instead, the most cost-effective solution is simply not to develop carbon-intensive gas fields.

Not all gas fields are [made equal]. A few large fields have a low CO_2 content, such as in Qatar, which also has the [world's lowest cost of production]. In contrast, some have a very high CO_2 content, including several proposed gas fields in Australia ([Barossa], [Browse] and [Verus]) with CO_2 content ranging from 10%-27%. [IEEFA calculated] the LNG produced from the Barossa gas field (18% CO_2) would produce about 1.5tCO_2e per tonne of LNG. Some fields off the coasts of [Thailand, Malaysia and Indonesia] have CO_2 levels above 40%, and as high as 70%.

Figure 6: CO_2 intensity and gas resource for major global gas fields



Source: [Thunder said energy]

According to the IEA, "today's level of investment in all fossil fuels, including oil and gas, is significantly higher than what is needed in the APS [Announced Pledges Scenario], and double what is needed in the NZE Scenario in 2030." International liquefied natural gas (LNG) trade is increasingly driving new gas developments. IEEFA research has shown that the world is quickly heading towards an LNG supply glut, with liquefaction capacity increasing by 40% in just a few years while demand is declining in major markets and uncertain in others.

In a context of oversupply, IEEFA finds, "Competitive advantages will be mostly derived from the ability to drive costs down to offer lower prices than competitors." This would likely make the cost of implementing CCS prohibitively expensive, particularly for countries such as Australia, which already has one of the highest costs of production globally.

CCS cost estimates likely to increase

CCS's economic competitiveness is likely to worsen as the actual costs of the technology become apparent. The IEA still estimates costs below US$100/t$CO_2$ captured in many sectors. In particular, it estimates that CCS applications in gas processing cost less than US$30/t$CO_2$. However, those estimates seem very optimistic compared with recent experience.

One factor driving up costs is the actual performance of CCS projects. In late 2022, IEEFA conducted a review of 13 global flagship CCS projects, which represented over half of the global CCS capacity and covered a range of applications and countries. The review found that failed or underperforming projects outnumbered successful ones. Two projects failed, one was suspended after four years of operation (recently restarted), five projects materially underperformed their own targets – by about 20% to 50% – and two projects provided no performance data. Only three projects achieved their targets.

IEEFA subsequently reviewed two of those three successful projects based in Norway, and found that they faced significant challenges. In one project, the CO_2 unexpectedly migrated to a previously unknown geological layer, which fortunately contained it, but the extent and integrity of the seam are unknown. The other CCS project had to find a new storage location after only 18 months – at a high cost – after the initial storage site showed acute signs of rejecting the CO_2.

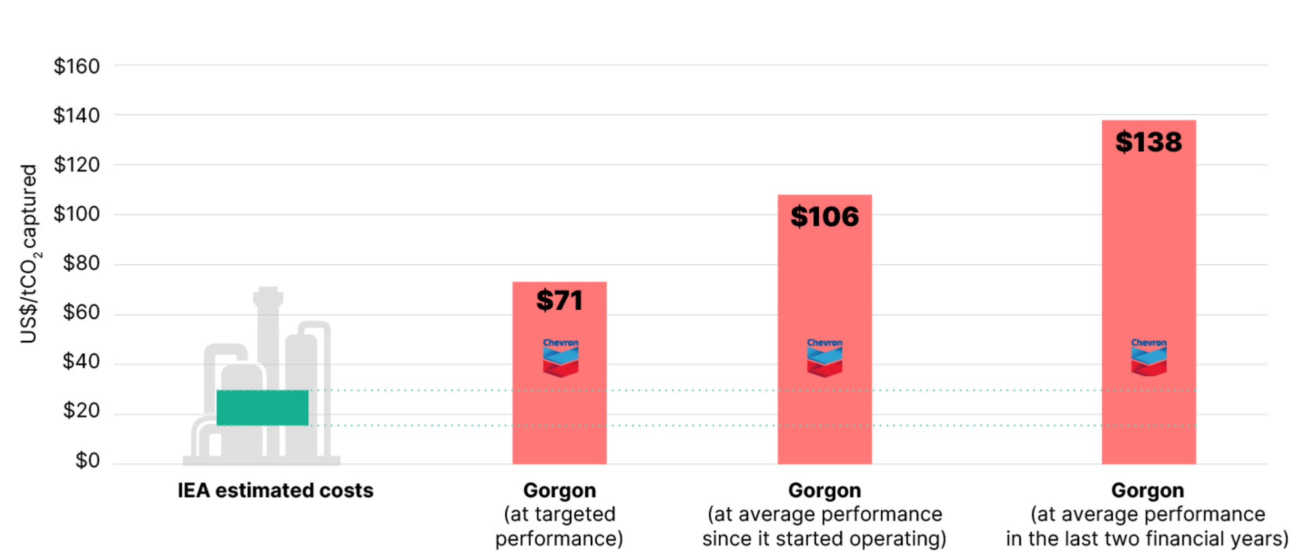
The impact of delays, technical challenges and underperformance on costs is material. For example, we calculated the cost per tonne of CO_2 captured by the Gorgon CCS project, the world's largest CCS project at Chevron's Gorgon LNG facility on Barrow Island in Western Australia. The project originally committed to capturing 80% of the CO_2 it removed from its reservoir on a five-year rolling average from July 2016. However, it only started injecting CO_2 in August 2019, three years behind schedule, and at the end of June 2023 had only captured 43% of the CO_2 removed in five years. In the past two financial years, it also faced significant operational challenges which limited CO_2 injections to about 1.7 MtCO_2 per year, well short of its target of 3.4-4 MtCO_2.[2] Those challenges have also increased capital costs for the project, from A$2.5 billion in FY2019-20 to A$3.2 billion in FY2022-23. Chevron has announced it will make further investments "in the coming years to improve system performance and increase injection rates". (These numbers do not include a A$60m government grant Chevron received for the project.)

On an annualised cost basis, we calculated that the Gorgon project delivered a cost of A$206/t$CO_2$ captured (US$138/t$CO_2$ at September 2024 rates) in the past two years. Since it started

2 All data on Gorgon CCS project performance and costs is based on the project's 2023, 2022, 2021 and 2020 Environmental Performance Reports, as well as the FY2020-21 report to the Low Emissions Technology Demonstration Fund.

operations, the cost amounts to about A$159/t$CO_2$ (US$106/t$CO_2$). Even if it had met its 80% CO_2 capture target since it started operating, the cost would be A$106/t$CO_2$ (US$71/t$CO_2$), still more than double the IEA's estimate for the gas processing sector.[3]

Figure 7: Theoretical vs actual costs of CCS in gas processing (US$/t$CO_2$)



Sources, Chevron and IEEFA analysis

The recent US rule change for power generation will likely drive updated cost estimates in the sector. The EPA's new rule stipulates that existing coal plants operating beyond 2039, and new baseload gas plants, will have to reduce their carbon emissions by 90% by 2032. To do this they will likely rely on CCS. The EPA assessed the cost of the rule to the electricity industry at US$7.5-$19 billion. However, many companies have since warned that the rule is unachievable or would be too costly for consumers. As an example, the East Kentucky Power Cooperative estimated the cost to install CCS at one coal plant alone would be US$10.7 billion after subsidies, on par with the estimated cost to the whole industry.

Increased cost estimates will continue to worsen CCS's competitiveness compared with alternative solutions, and worsen its outlook.

Conclusion

Due to its high cost and low performance, CCS associated with fossil fuels is unlikely to be competitive with renewable alternatives. IEEFA expects the outlook of CCS will continue to decline in coming years, particular for hydrogen and steel applications. CCS is likely to be limited to a niche role, focused on applications where there are truly no alternatives.

3 IEEFA calculation assuming: average annual operating cost of A$25 million based on FY2020-21 data, A$2.5 billion of capital costs in FY2019-20, increasing to A$3 billion in FY2020-21, increasing to A$3.2 billion in FY2022-23 (costs excluding government grant), a 40-year lifespan from FY2019-20, a 10% discount rate for capital costs (lower than the typical 11%-30% hurdle rate reported by large global oil and gas companies), and a US67c exchange rate. CO_2 captured annually: 8.2 MtCO_2 captured to 30 June 2023, 3.4 MtCO_2 captured over FY2021-22 and FY2022-23.

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