FACTSHEET

Institute for Energy Economics and Financial Analysis

CARBON DIOXIDE REMOVAL (CDR)

Climate pathways are very optimistic relative to what the technology can deliver

KEY FINDINGS

- Nature-based processes account for almost all current carbon dioxide removals, with engineered removal delivering around 0.02% of the total in 2025.
- Annual carbon dioxide removals would need to rise about 5,400-fold between 2025 and 2050 for bioenergy with carbon capture and storage (CCS), and about 13,000-fold for direct air capture with CCS, to reach the median of pathways assessed by the Intergovernmental Panel on Climate Change that limit warming to 2°C or below.
- Engineered removal depends on CCS and inherits its technical and cost risks. The US's ADM Decatur bioenergy with CCS plant was out of action for 11 months following a storage breach.
- Direct air capture with CCS costs USD400–2,500 per tonne, against an EU carbon price of around USD99 per tonne and a global average of just under USD21 per tonne.

WHAT IS CDR?

Carbon dioxide (CO_2) removal takes CO_2 out of the atmosphere and stores it durably. Most carbon reduction pathways rely on CDR to balance residual emissions and limit warming. However, today's engineered removals are minuscule relative to the volumes required in future pathways. Most of the planned engineered removals depend on carbon capture and storage (CCS) and thus inherit its technical, cost and delivery constraints.

THE TWO MAIN FORMS OF CDR

Nature based and environmental	Engineered and technology based
Uses biological or natural processes to draw down CO_2: afforestation and reforestation, soil carbon, and peatland or coastal wetland restoration. These methods account for most measured CDR, but land availability and carbon saturation limit scale, while fire and drought threaten permanence.	Uses engineered processes to capture CO_2 and store it in underground reservoirs. The largest modelled routes are bioenergy with CCS (BECCS), and direct air capture with CCS (DACCS). Both require capture, compression, transport and geological storage. DACCS also needs substantial low-carbon energy.

Source: State of CDR report.

CURRENT REMOVALS ARE DOMINATED BY NATURE

The 2026 State of CDR report estimates nature-based methods removed 2.2 gigatonnes (Gt) of CO_2 in 2025, while engineered removal (taken here as BECCS and DACCS only) was 0.5 megatonnes (Mt) of CO_2, or 0.02% of the total.[1,2]

1 The State of Carbon Dioxide Removal report. 2026.
2 The report's novel CDR category is larger, at around 2MtCO_2, as it also includes biochar, enhanced rock weathering and coastal wetland management.[1] This note uses the narrower definition because 2050 pathways depend on engineered removals.

THE SCALE-UP IMPLIED BY 2050 PATHWAYS

Using 2025 removals as the baseline, the 2050 pathways imply a sharp scale-up in both technologies. BECCS rises roughly 1,800-fold in the International Energy Agency (IEA) Net Zero Emissions by 2050 Scenario and 5,400-fold at the median of Intergovernmental Panel on Climate Change (IPCC) pathways that limit warming to 2°C or below. For DACCS, the IEA pathway implies about 650,000 times 2025 levels, against about 13,000 times at the IPCC median, although the IPCC range is exceptionally wide and extends to roughly 1.16 million times. The divergence between the two technologies largely reflects the base each is growing from: BECCS has a small but established operating base, whereas DACCS has almost none. These are modelled pathway levels rather than forecasts. The contrast also reflects different scenarios.

2050 PATHWAY ASSUMPTIONS AGAINST 2025 DELIVERED REMOVALS

2050 pathway	BECCS	Scale-up	DACCS	Scale-up	Basis
IEA NZE	0.9Gt	1,800x	0.98Gt	650,000x	Single scenario[3]
IPCC AR6, median	2.75Gt	5,400x	0.02Gt	13,000x	Median of pathways[4]
IPCC AR6, upper	9.45Gt	18,500x	1.74Gt	1,160,000x	95th percentile

Source: IEA, IPCC AR6 WGIII, State of CDR report, IEEFA analysis.
Note: NZE = Net Zero Emissions by 2050 Scenario. AR6 = Sixth Assessment Report. Scale-up is measured against 2025 delivery of 0.51MtCO_2 for BECCS and 0.0015MtCO_2 for DACCS.

ENGINEERED REMOVALS RELY HEAVILY ON CCS

The engineered label can make options sound more mature than they are. BECCS from bioethanol fermentation is commercially deployed and has a technology readiness level (TRL) of 9, but biomass combustion with CCS remains at demonstration stage (TRL 7). DACCS is also uneven: Solid sorbent systems are classed as commercial (TRL 9), while liquid solvent and other routes remain at pilot or earlier stages (TRL 6–7 and TRL 4–6 respectively).

Route	Maturity	Cost/constraint
BECCS from ethanol	TRL 9, commercial	ADM Decatur: USD28.35/t capital plus operating cost, which is not a lifecycle or net removal benchmark.[5]
BECCS from biomass combustion	TRL 7, demonstration	Current: USD75–300/t. Potential long term: USD40–125/t. Sustainable biomass, land and water, and CCS chain costs constrain scale.
DACCS solid sorbent	TRL 9, commercial	USD400–2,500/t gross, levelised. Many estimates omit transport and storage. Economics depend on low-carbon energy and utilisation.
DACCS liquid solvent/other	TRL 6–7, pilot; other routes, 4–6 early	No established commercial economics. Dilute CO_2 makes capture energy intensive. Low-carbon heat and power, plus transport and storage, add further requirements.[6]

Source: The State of CDR report unless otherwise referenced.

3, IEA. Direct Air Capture: A key technology for net zero. Revised October 2024. Note: The Net Zero Emissions by 2050 Scenario has 2050 direct air capture of approximately 980MtCO2 and BECCS plus DACCS combined of approximately 1.9GtCO2. The BECCS figure shown is the implied residual.
4, IPCC. Climate Change 2022: Mitigation of Climate Change. Working Group III Contribution to the Sixth Assessment Report. Chapter 12. Note: Medians and fifth to 95th percentile ranges across assessed pathways limiting warming to 2°C or below.
5, IEA Bioenergy. Deployment of BECCUS Value Chains in the United States.
6, The State of Carbon Dioxide Removal report: Chapter 10. 2026.

A capture price is not a full-chain cost. According to the State of CDR report, indicative estimates put compression at USD10–30/t, large onshore pipelines at a few dollars per tonne per 100 kilometres, and shipping 1Mt/year over 1,000 kilometres at USD20–30/t. Onshore storage is estimated at a few dollars to under USD25/t, and offshore storage at USD5–55/t.[7] New storage sites and infrastructure have uncertain costs that vary by scale and location. These sites must be in place ahead of the capture plant rather than alongside it.

The gap between nameplate capacity and actual removal is visible in operation. In 2025, three US BECCS facilities together removed about 0.51MtCO_2. ADM Decatur in Illinois stopped injecting in September 2024 after problems were found with its deep monitoring wells. It restarted in August 2025 under an updated federal Administrative Order of Consent, some 11 months later.[8] Climeworks operates two DACCS plants, Orca and Mammoth, both in Iceland. Neither has performed as intended since opening, which the company attributes in part to early mechanical problems and to conditions in the field, such as ice and snow freezing mechanisms.[9]

CARBON PRICES ARE SIGNIFICANTLY BELOW REMOVAL COSTS

Carbon pricing is the mechanism that would, in principle, fund removal at scale. Direct carbon pricing currently covers 29% of global greenhouse gas emissions, and the average price across all schemes in operation is just under USD21/t.[10] The EU Emissions Trading System, which is the largest carbon market and among the highest priced, traded at €88/t in October 2026 (around USD99/t).[11] Buyers contracting direct air capture have paid a median of around USD650/t, which sits inside the reported cost range but well above any traded carbon price.

CARBON PRICES AGAINST THE COST OF ENGINEERED REMOVAL

Measure	USD/t	Basis
Average carbon price worldwide	21	All carbon taxes and trading schemes in operation, covering 29% of global
EU Emissions Trading System	99	€88/t on 12 October 2026, converted at USD1.12 per euro
Assumed cost of removal, upper bound	300	Upper end of the IPCC AR6 central assumption, the lower end being USD100
Direct air capture, lower cost	400	Lower end of the reported cost range today
Direct air capture, price paid	650	Median disclosed price across contracted transactions[12]
Direct air capture, upper cost	2,500	Upper end of the reported cost range today

Source: World Bank, ICE, cCarbon, State of CDR report, IPCC AR6 Working Group III, IEEFA analysis.

The EU ETS does not cover engineered removals, so there is no route by which an emission allowance price funds a tonne of removal. The European Commission's July 2026 review proposes to change that indirectly, by auctioning 250 million additional allowances and having a public body purchase permanent removals with the proceeds. That proposal has not been adopted.[13] Global carbon pricing revenues were around USD107 billion in 2025,[14] against an annual cost running into the trillions were removal to be delivered at the scale the 2050 pathways assume.

7, The State of Carbon Dioxide Removal report: Chapter 10. 2026.
8, ADM Statement. 29 August 2025.
9, Swissinfo.ch. Why Swiss carbon-removal start-up Climeworks faces serious headwinds. 22 May 2025.
10, World Bank. State and Trends of Carbon Pricing 2026.
11, GMK Center. European carbon prices rose to €88/t in October. 15 October 2026.
12, cCarbon. Carbon Dioxide Removal Series: Direct Air Capture | Market Compass. 27 May 2026.
13, Carbon Gap. EU Emissions Trading System.
14, World Bank. State and Trends of Carbon Pricing 2026.

CONCLUSION

Most engineered CDR in climate pathways depends on CCS: capture, compression, transport and durable storage. Some parts of the chain are technically established, but the operating base is small, costs remain unsettled and delivery falls far short of pathway scale. BECCS also depends on sustainable biomass, and DACCS on large supplies of low-carbon energy. CDR is an uncertain complement to rapid emissions cuts, not a substitute for them.

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The Institute for Energy Economics and Financial Analysis (IEEFA) provides independent, evidence-based financial analysis of global energy markets, investment trends, and policies. IEEFA's work helps investors, policymakers, regulators, communities and the media better understand risks, opportunities and market dynamics shaping the energy transition.

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