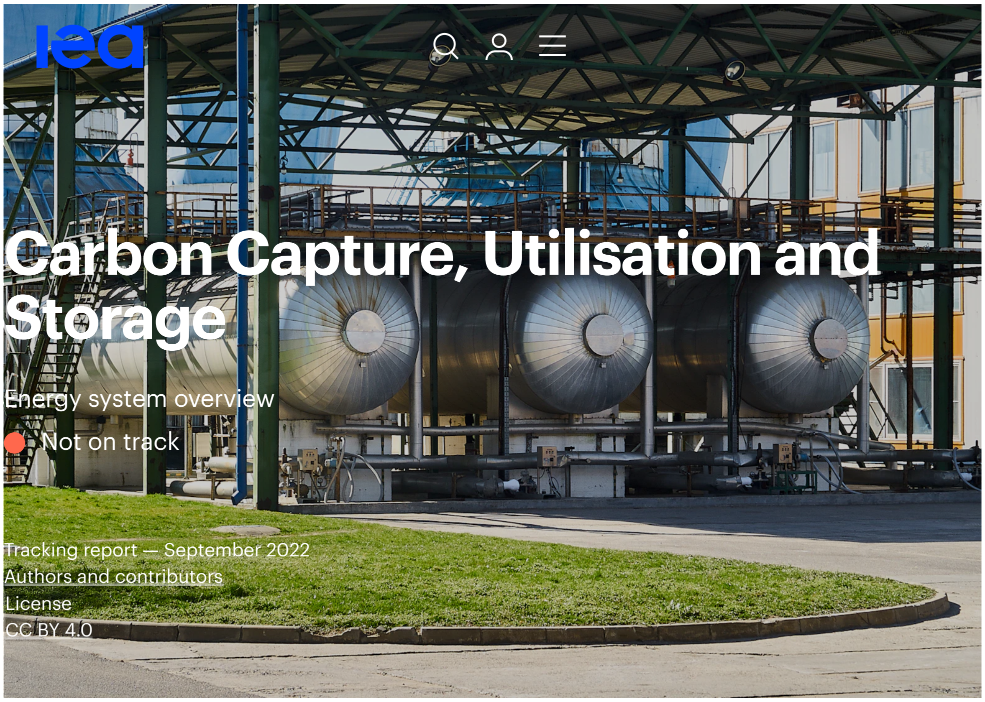

Carbon Capture, Utilisation and Storage

Energy system overview

Not on track

Tracking report — September 2022

Authors and contributors

About this report

Carbon capture, utilisation and storage (CCUS) refers to a suite of technologies that can play a diverse role in meeting
stored.

There are around 35 commercial facilities applying CCUS to industrial processes, fuel transformation and power gener

To translate momentum into action, policy makers should roll out additional policy support, while also ensuring that ap

CO2 capture

CCUS facilities currently capture almost 45 Mt CO2 annually

There are now around 35 commercial capture facilities in operation globally, with a total annual capture capacity of almost 45 Mt CO_2. A number of new capture facilities have come online in recent years, including the Gorgon CO_2 injection project in Australia (2019), two capture facilities linked to the Alberta Carbon Trunk Line in Canada (2020), the first large-scale bioenergy with carbon capture project in Japan (2020), and two capture facilities in China at the Sinopec Chemical plant and at the Guohua Jinjie coal power plant (2021). Around the world, positive final investment decisions (FID) were taken on six CCUS projects in 2021; once operational those projects will capture around 6.5 Mt CO_2 per year.

Capacity of large-scale CO2 capture projects, current and planned vs. the Net Zero Scenario, 2020-2030

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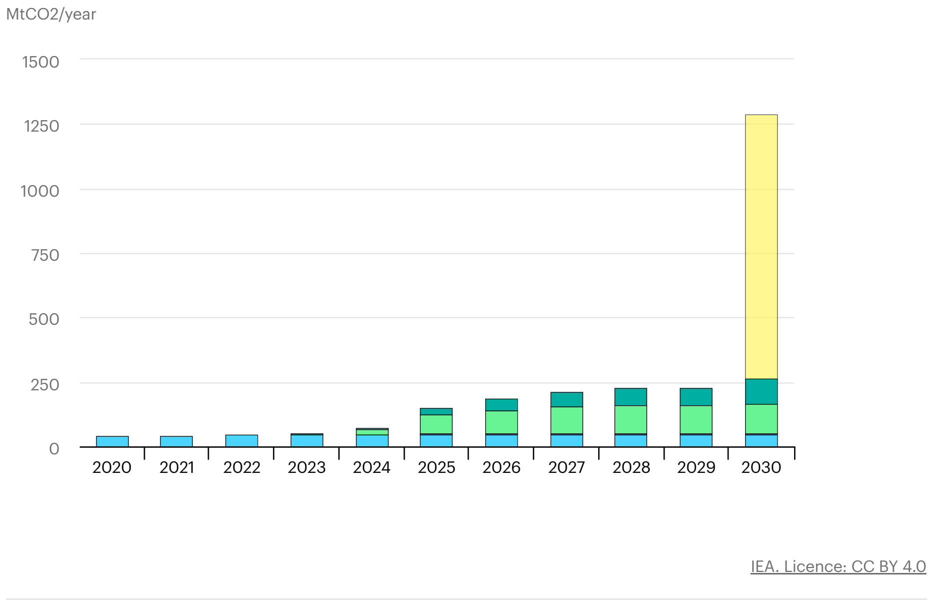

Activity

Progress has been slow, but development is picking up

Since the start of 2018, momentum behind CCUS has been growing. Project developers have announced ambitions for over 200 new capture facilities to be operating by 2030, capturing over 220 Mt CO_2 per year. However, only around 10 commercial capture projects under development have taken FID as of June 2022. Specific CO_2 transport and storage related activities and progress are reported in CO_2 Transport and Storage.

Cite Share

Evolution of the CO2 capture project pipeline, 2010-2022

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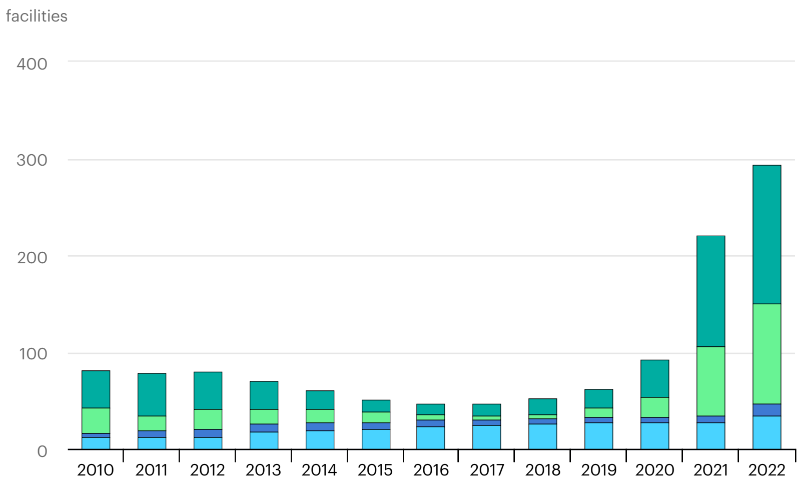

Operating Under construction Advanced development Concept and feasibility

The widespread adoption of economy-wide decarbonisation targets for 2050 is stimulating the diversification of CO_2 capture applications. Currently, around 65% of operating CO_2 capture capacity is at natural gas processing plants, one of the lowest-cost CO_2 capture applications, but new CCUS developments are increasingly targeting other applications. Based on the current project pipeline, by 2030 annual capture capacity from both new construction and retrofits could amount to around 70 Mt CO_2 from hydrogen production, 70 Mt CO_2 from power generation and 20 Mt CO_2 from industrial facilities (cement, steel and chemicals). Bioenergy with carbon capture and storage (BECCS) and direct air capture (DAC) with CO_2 storage are key technologies for carbon removal. Globally, over 40 bioethanol facilities, among the lowest-cost BECCS applications, have announced plans to capture CO_2, and around 15 biomass and waste-fired combined heat and power plants could be capturing around 15 Mt CO_2 by 2030 . The first megatonne-scale DAC plant is scheduled to commence operations in 2024 in the United States.

Plans for CO2 capture facilities are expanding globally

The geographic distribution of CO_2 capture projects in development is diversifying, with projects now being developed in over 30 countries:

- In Southeast Asia, more than 10 projects, most of them announced since January 2020, in Indonesia, Malaysia and Thailand could lead to total capture capacity of around 15 Mt CO_2 per year by 2030.
- In China, the Sinopec Qilu Petrochemical project finished construction in January 2022 and the first Chinese offshore CCUS project, announced in September 2021, finished construction in June 2022.
- In North America, the United States has around 80 projects aiming to be operational before 2030 and could see its CO_2 capture capacity increase by close to a factor of five, from over 20 Mt CO_2 to over 100 Mt CO_2 per year. Canada is also poised to see increased CO_2 capture deployment, with around 15 projects currently in various phases of development.
- In Europe, decarbonisation goals and significant policy support have stimulated CCUS development, particularly in the form of industrial clusters connected to CO_2 storage hubs. Around 50 projects could be capturing close to 70 Mt CO_2 per year by 2030 around the North Sea in Norway, the United Kingdom, the Netherlands, Sweden and Denmark.
- In the Middle East, at least four projects are in development across the region in addition to the four already operating. Earlier this year Bahrain announced plans to deploy CCUS at an aluminium plant – this would be the first application of CCUS to aluminium. In Qatar, construction continues on the North Field East LNG project, which will expand Qatar's CCUS capacity from over 2 Mt CO_2/year to 5 Mt CO_2 by 2050.

Operating and planned facilities with CO2 capture by region, 2022

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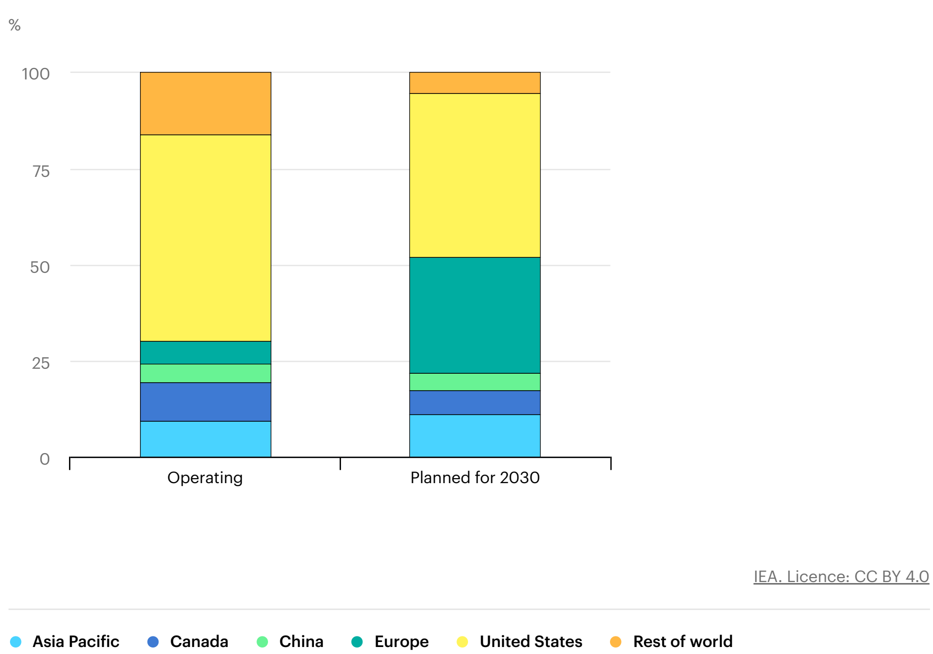

Operating and planned facilities with CO2 capture by application, 2022

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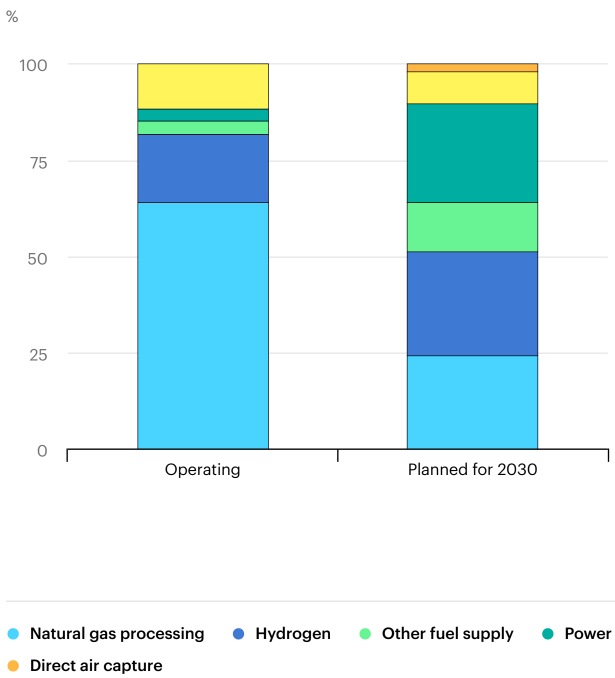

Innovation

Higher CO2 capture rates are possible and will be needed for net zero systems

Higher CO_2 capture rates will be essential for CCUS to play its role in the transition to a net zero energy system. CCUS-equipped power and industrial plants operating today are designed to capture around 90% of the CO_2 from flue gas. While there are no technical barriers to increasing capture rates beyond 90% for the most mature capture technologies, capture rates of 98% or higher require larger equipment, more process steps and higher energy consumption per tonne of CO_2 captured, which increases unit costs. However, initial results based on chemical absorption systems are promising, showing that CO_2 capture rates as high as 99% can be achieved at comparably low additional marginal cost relative to the cost of deploying 90% capture.

Existing projects highlight cost-reduction potential

A feasibility study based on Boundary Dam data and costs suggests that a second-generation capture facility at a coal-fired power plant could be built with 67% lower capital costs. The cost-competitive retrofit of existing plants can be an important mitigation option, especially in regions characterised by a young fleet (the average age of coal-fired power plants in Asia is only 14 years, while the average technical lifetime of a power plant is 40-50 years). Retrofitting these plants with CCUS could address both economic and emissions challenges, allowing them to continue operating while recovering investment and reducing their carbon footprint.

Promising technological innovations are being demonstrated around the world

Several technological innovations that have been proposed to reduce CCUS costs for power generation are now being tested:

- The Drax bioenergy CO_2 capture pilot project is a world-first demonstration capturing CO_2 from a power plant fuelled by 100% biomass feedstock (with plans to move forward with a commercial-scale project by 2027).
- NET Power's 50 MW clean energy plant is the first-of-its-kind natural gas-fired power plant employing Allam cycle technology, which uses CO_2 as a working fluid in an oxyfuel supercritical CO_2 power cycle, significantly reducing capture costs.

CCUS applied to the industrial sector has also made progress:

- A project in France is testing CO_2 capture from steel production (the second operational project globally, after the Abu Dhabi CCS Phase 1 project in the United Arab Emirates, commissioned in 2016).
- Two new operational projects in China are capturing CO_2 from the chemical and the fertiliser sectors respectively.
- In 2020 in Norway, Norcem received funding to implement carbon capture at its cement plant in Brevik. Once operational, this will become the first commercial CCUS project to capture CO_2 from cement production.

While the most advanced and widely adopted capture technologies are chemical absorption and physical separation, other separation technologies under development include membranes and looping cycles (such as chemical looping and calcium looping).

A number of approaches to capturing CO_2 directly from the air are currently under development, with leading technologies relying on solid sorbent filters that chemically bind with CO_2 or on chemical solutions that remove the CO_2 while returning the rest of the air to the environment. Emerging approaches at prototype level include electro-swing adsorption and membrane-based separation.

Policy

The United States and Canada continue targeted policy support for CCUS, while Europe and countries in Asia are stepping up funding and regulatory support

The United States and Canada, which together account for 65% of annual capture capacity, have continued their strong support for CCUS by introducing new targeted policies to drive deployment over the coming years. In other regions, such as Europe and Asia, funding programmes and new frameworks contribute to CCUS support:

- **United States**: The Inflation Reduction Act provides a significant boost for CCUS through the expansion and extension of the 45Q tax credit: the credit amount nearly doubles for CO_2 that captured from power and industrial plants and more than triples for CO_2 that is captured from DAC, and the deadline to qualify for the credit is extended by seven years to 2033. The Infrastructure Investment and Jobs Act provides approximately USD 12 billion across the CCUS value chain over the next five years. Support is offered through a number of policy mechanisms, such as R&D funding, loans and permitting support.
- **Canada**: The 2022 federal budget proposes an investment tax credit for CCUS projects between 2022 and 2030, valued at around 37-60% depending on the type of project.
- **Europe**: The European Union has continued support for CCUS through regional funding programmes (such as the Connecting Europe Facility – Energy and the Innovation Fund) and revisions to cross-border regulations to include CO_2 storage. National subsidy schemes (such as those in Denmark and the SDE++ in the Netherlands) have also supported CCUS projects.
- **Asia**: Korea announced plans to invest up to USD 1.2 billion to develop CCUS technologies by 2030. Around 30% of this investment will be used to assess CO_2 storage resources, with the majority of the remainder earmarked to develop an offshore full-chain CCUS project. In early 2022, Indonesia announced that it is drafting regulations to establish a legal and regulatory framework for CCUS activities – the first of its kind in the region.

Read more about the transport and storage of CO_2.

Policies

Policy	Country	Year	Status	Jurisdiction
Tax Incentive for Carbon Capture Storage	Malaysia	2023	In force	National
Projects to store CO2 in the North Sea	Norway	2023	Announced	National
Enhanced Oil Recovery and CCUS (SB 1314)	United States	2022	In force	State/Provincial
Creation of a Carbon Capture Regulatory Framework (SB 905)	United States	2022	In force	State/Provincial

CCUS Investor Roadmap	United Kingdom	2022	In force	National
Revised national budget 2021-2022: Energy investments	Norway	2022	In force	National

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Recommendations for policy makers

Implement a broad portfolio of policies to stimulate investment in demonstrated and emerging applications

Well-targeted policies and a portfolio of measures can help ensure government efforts to support CCUS deployment are effective and successful in the long term.

Governments should consider complementary policy measures, such as capital grants, regulatory levers, market-based frameworks, public procurement, low-carbon product incentives and tax credits to stimulate investment. A broad portfolio of policies, coupled with the inclusion of CCUS in national energy strategies, can help encourage the deployment of low-cost applications and stimulate investment in higher-cost applications.

Governments have a range of different policies to select from to ensure widescale deployment. For example, feed-in tariffs and contracts-for-difference can encourage CCUS in the power sector, and public procurement programmes and carbon pricing can help make CCUS more competitive in the cement and steel sectors. In designing adequate support schemes for each energy sector, it will be critical for governments to ensure that CCUS is considered in the context of the relative feasibility and cost-effectiveness of other options.

Encourage the development of transport and storage infrastructure

CO_2 transport and storage infrastructure must be ready prior to or, at least, alongside CO_2 capture projects in order to stay on track with net zero goals. CO_2 capture plants take between three and five years to build, while the assessment and development process for CO_2 storage can take much longer. If the pace of storage development falls behind the pace of capture development, as is currently the case, the risk of cross-chain default and project cancellation increases substantially.

Governments can encourage the development of multi-user CO_2 transport networks and storage hubs with supportive policies and the coordination of authorisation, permitting and environmental review requirements. Policy makers will need to think about a host of regulatory considerations, such as whether open-access requirements should be put in place, how liability should be handled and what costs can be passed through to users of the shared infrastructure. Spatial planning should be used to prevent clashes between stakeholders with activities in the same geographic regions – for example spatial overlaps can occur with offshore wind, CO_2 storage and fisheries. They can also consider whether state-owned enterprises should have a role in developing such infrastructure or in conducting pre-competitive exploration for storage development.

Recommendations for the private sector

Develop business models to support CO2 management

New business models and deployment approaches for CO_2 management are emerging and can facilitate rapid CCUS scale-up. These include:

- A shift from building standalone full-chain CCUS projects with integrated transport and storage infrastructure to developing multi-user infrastructure. Such infrastructure can capitalise on the economies of scale present in both transport and storage infrastructure and can reduce commercial risk.
- Developing "as-a-service" business models for CO_2 capture, transport and storage wherein each part of the chain is offered as third-party operated services. This can support the wider deployment of CCUS technologies by shifting capital costs to service providers, thereby allowing emitters to focus on their primary activity. Companies with CCUS-related intellectual property and/or expertise can also benefit from this business model as it may allow them to develop new business lines and revenue streams.
- Exploiting new and existing options for CO_2 use to provide a revenue stream to CCUS facilities. However, the limited market size of CO_2 uses means dedicated storage should remain the primary focus of CCUS deployment to reach net zero.

Boost innovation to reduce costs and widen the CCUS portfolio

R&D investment in emerging CCUS applications can ensure they become commercially deployed in key sectors, such as heavy industry (cement, steel and chemicals), CO_2 use for synthetic fuel production and carbon removal. While innovation can play a major role in reducing capture costs (which typically account for almost 75% of the total cost of CCUS), R&D efforts should not only focus on individual CCUS steps, but also on their successful integration. Innovation should extend beyond classic R&D to encourage the standardisation and modularisation of CCUS equipment in order to drive down costs and offer CCUS as a solution to smaller emitters.

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- Iain MacDonald, Shell
- Nirvasen Moonsamy, Oil and Gas Climate Initiative

Related sectors & technologies

Bioenergy with Carbon Capture and Storage	More efforts needed
CO2 Capture and Utilisation	More efforts needed
Direct Air Capture	More efforts needed
Industry	Not on track
Electricity Sector	More efforts needed
Oil and Natural Gas Supply	Not on track

Analysis

All analysis

Legal and Regulatory Frameworks for CCUS

An IEA CCUS Handbook

Technology report — July 2022

CCUS in Clean Energy Transitions

Flagship report — September 2020

Tracking Clean Energy Progress

Assessing critical energy technologies for global clean energy transitions

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