The role of carbon capture and storage in limiting warming to 1.5C

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Key Findings

- Only one out of the existing 26 operational CCS projects is in the power sector. Majority of existing CCS projects are in oil and gas sector as a part of enhanced oil recovery
- Retrofitting existing fossil fuel assets with carbon capture and storage (CCS) is being proposed as one option to reduce the amount of emissions already locked in by existing infrastructure
- Plummeting cost of renewables is eroding the economic incentive for retrofitting existing fossil fuel power plant with CCS, and in most cases, earlier retirement of assets would be more economically efficient than retrofits
- CCS technology for captured carbon dioxide from power plants remain stagnant and costly
- The mismatch between available geological formation for storage and water availability further constrains the availability of CCS as a solution for existing fossil fuel assets

Existing fossil fuel infrastructure will put 1.5°C out of reach

Energy infrastructure has extremely long lifetimes. Coal and gas-fired power plants have historically operated on average 39 and 36 years, respectively. If all energy infrastructure continue to operate until the end of their typical lifetime, the cumulative emissions between 2020-2050 would amount to 650 Gt CO_2, according to the IEA net zero by 2050 report. This is 30% more than the remaining carbon budget, estimated at 500 Gt CO_2, that is consistent with limiting global warming to 1.5°C (with a 50% likelihood) by the IPCC Working Group I report. As a result, alignment with 1.5°C requires no new coal, gas or oil extraction, and existing demand for unabated coal is expected to decline by 98% to just 1% of total energy use by 2050.

The electricity sector accounts for more than 50% of the total emissions from existing assets, 40% of which comes from coal-fired power plants alone. Therefore, existing assets face four main choices in order to stay within the remaining carbon budget:

1. Accelerating retirement (in scenarios that limit warming to 1.5°C, global coal and gas power generation's operational lifetime are shortened to 9 and 12 years, respectively),
2. Reducing utilisation,
3. Switching to low carbon fuel sources, and/or
4. Retrofitting with carbon capture and storage (CCS)

Carbon capture retrofits cannot compete with plummeting cost of renewables

As of 2021, the costs for solar PV and onshore wind are increasingly undercutting the operating costs of existing coal-fired power plants. Data from the IRENA Renewable Cost Database show that between 2010 and 2020, the cost of electricity from utility-scale solar photovoltaics (PV) fell 85%, followed by concentrating solar power (CSP; 68%), onshore wind (56%) and offshore wind (48%). Since 2010, a cumulative total of 644 GW of renewable power generation has been added to the global energy system at a lower cost than the cheapest fossil fuel-fired option in that year.

Retrofitting plants with CCS is very costly, CCS for coal or gas electricity generation facilities are almost double the capital cost of power generation projects without CCS. Rapidly falling costs in wind and solar energy are eroding the economic value of CCS as a mitigation option by up to 96%, according to a paper published by the Grantham Institute.

The Boundary Dam CCS power plant project in Canada is the only commercially operational coal power station. The technology is installed on one 110MW boiler (small in comparison to typical project sizes of 500MW). Its cost of $1.5 billion, of which $800 million was for the installation of the CCS process and the remaining $500 million for retrofit costs. Leaked internal memo from November 2014 suggests the project has "serious design issues", having suffered numerous technical problems in its first year and only running at an average of ~30% capacity in 2021. Since its operation in 2014, it has only captured 4.3 Mt of CO_2, in comparison to its total CO_2 capture capacity of 1 Mt p.a.

CCS is an extremely energy intensive process, and the higher fuel requirement for the CCS process adds further to the operational costs of plants. The only other operational CCS project for the power generation sector, Petra Nova, was shut down in 2020 as a result of high operational cost. A 2017 study looking at potential applications of CCS on Indian power plants has estimated that the costs of electricity would increase by 63-76%.

While renewable energy is expected to continue to decline in cost, CCS development has remained stagnant in the last 30 years. Currently there are only 26 operational CCS projects in the world, with only one facility in the power generation sector. On the carbon storage side, the vast majority (20 out 26) projects use the captured carbon dioxide for enhanced oil recovery (EOR), rather than permanent geological storage. Captured carbon dioxide used for EOR undermines emissions cuts, where emissions from burning recovered oil could more than offset the benefits of capturing the carbon dioxide in the first place, by a factor of up to three. Research indicates that tonnages of CO_2 injection are often overestimated, while in reality, many injection rates are much lower, or facilities have stopped injecting sooner than is reported.

The additional capital and operational costs increase the cost of electricity, which can create cost barriers to energy access in developing countries. As such, CCS deployment should focus on removing CO_2 from the atmosphere and capturing CO_2 in industry for permanent geological storage, rather than retrofitting to fossil fuel power generation.

Water and geological storage further constrain the application of CCS retrofits

The availability of large volume, permanent, geological reservoirs is critical for the cost effective removal and storage of CO_2. The amount of storage space accessible is still to be determined at a global scale. Not only does storage need to be permanent, it also needs to be close to or within transportable distance from the point of emissions to make projects viable. The mismatch between the locations of existing power plants and geological location of underground storage is one of key barriers to retrofitting the global fleet of power plants. A study of Indian emission sources indicates that only 14% of Indian emissions are in sites that are located within a range of 100km from geological sink locations.

CCS is a resource-intensive technology requiring a large amount of water for operations. It has been estimated that CCS can increase power plants' water withdrawal by 175% and water consumption by up to 150%, in comparison to plants without CCS. With climate change, regions already prone to water scarcity may experience worsening periods of drought, further limiting the deployment of CCS in power plants in those regions.