Carbon Capture and Storage: Essential and Cost-Effective

Key Points

Stopping climate change will be hard. Deep cuts in global CO₂ emissions must occur soon, but rising energy demand will probably increase emissions.

- By 2050, the IPCC tells us that CO₂ emissions must fall to 60% to avert a 2-degree Celsius rise in the Earth’s temperature. By the end of the century, CO₂ emissions must essentially fall to zero.

- But these cuts must take place while global energy demand rises. By 2040, global energy consumption is projected to increase 28%.

Carbon capture and storage (CCS) is vital and essential to meeting 2050 climate goals.

- CCS is the only technology with large-scale abatement potential for many industrial sources. Industrial sources account for about 25% of global CO₂ emissions.

- CCS works on both industrial and electric plants. Together, these sectors account for 54% of the total U.S. CO₂ emissions.

- Projections by the International Energy Agency show CCS will need to account for 6,000 million tonnes of CO₂ reduction worldwide by 2050. That’s more CO₂ than emitted today in the entire U.S.

- CCS is among the least expensive options to cut carbon dioxide, especially when used with enhanced oil recovery (EOR).
The Climate Challenge

Stopping climate change will be hard. Deep cuts in global CO₂ emissions must occur soon, but rising global energy demand at the same time may increase emissions.

The Intergovernmental Panel on Climate Change (IPCC) concludes that greenhouse gas emission must be reduced by 40 to 70% by 2050, and must be zero or below in 2100.¹ Cuts from the electric sector must be even deeper. The IPCC concludes that electric sector emissions must reach zero CO₂ emissions by 2050 and negative emissions by 2100.²

The International Energy Agency (IEA) also reaches a similar conclusion- we need a 50% reduction in CO₂ emissions from the total energy sector by 2050 while “the power sector becomes virtually decarbonized.”³

To complicate matters, these reductions must be achieved while total energy consumption rises. According to IEA, total global energy use is expected to grow 28% by 2040, including a 40% increase in the electric sector.⁴

Emissions Sources and CCS

IEA calls carbon capture and storage (CCS) “vital” and “essential,” accounting for about 14% of the CO₂ cuts (6,000 million tonnes) in 2050 needed to avoid temperature increases of 2 degrees Celsius.⁵ CCS is important because it reduces CO₂ emissions from two of the largest sectors: industrial and electric. In the United States, these two sectors account for 54% of the emissions, as shown below.

Carbon capture works on both the electric and industrial sectors which together account for 54% of US CO₂ emissions.
While many options are available to cut carbon dioxide in the electric sector, CCS is the only technology with large-scale abatement potential for many industrial sources. That's because the emissions from many critical industries arise not simply from burning a fossil fuel to produce steam or electricity to run the industrial plant, but because CO₂ is an inescapable by-product of the chemical reactions that manufacture glass, iron, steel, aluminum, fertilizers, cement, and paper.

CCS is the primary technology available for cement (8% of global CO₂ emissions⁶), fertilizer production (3-5% of global CO₂ emissions⁷) and steel (5% of global CO₂ emissions⁸). Its importance is one reason why IEA concludes, “CCS represents the most important new technology option for reducing direct emissions in industry…”⁹

The table below ranks CO₂ emissions by country, and shows the importance of industrial emissions. If China’s industrial emissions (about 3,300 Mt) were their own country, they would rank 3rd overall. If the industrial emissions (937 Mt) in the U.S. could be separated into their own country, they would rank 6th.


**CCS Costs**

The avoided cost of carbon dioxide is a standard measure used to compare the effectiveness of different carbon reduction options. It is defined as “the cost of reducing CO₂ emissions to the atmosphere while producing the same amount of product from a reference plant.”¹⁰
For CCS, the avoided cost of carbon dioxide is represented by more than one number. That’s because CCS can be applied to different industries and fuels, and because the captured CO₂ can be stored in either saline formations or used to recover oil in aging petroleum fields.

Generally, it’s cheaper to capture CO₂ when its concentration in the emissions is high. Therefore, in industries where the CO₂ emissions are relatively “pure” (e.g., ethanol, natural gas processing, ethylene oxide), the avoided cost of CO₂ is lower than in electric power plants where the CO₂ concentration in the flue gas is relatively low. Even within the category of electric power plants, natural gas plants have a lower CO₂ concentration in the flue gas than coal plants, and so the avoided cost of CO₂ is higher in gas plants than coal plants.

The choice of storage also impacts the avoided cost of carbon dioxide. When CO₂ is sold by a source for enhanced oil recovery, the revenue offsets some (but usually not all) of the costs of capture and transport. This lowers the avoided cost of carbon dioxide relative to saline storage.

The figure below shows the avoided cost of carbon dioxide for selected industrial and electric power plant applications. From left to right, the bars representing the avoided cost of CO₂ grow larger as the concentrations in the emissions become more dilute. The figure below also shows two cost bars. The smaller bars reflect CO₂ sales for EOR (assuming $60 per barrel oil) while the larger bars reflect the avoided cost of CO₂ if the source must pay to store the CO₂ in saline formations. As the figure shows, EOR can reduce CCS costs significantly.

\[ \text{CO}_2 \text{ Avoided Costs for Industrial and Power Plants ($/tonne)} \]

The figure below compares the avoided cost of carbon dioxide for various technologies within the electric sector, including CCS with saline storage. As the figure shows, CCS compares quite favorably to other CO₂ abatement options.

**Avoided cost of CO2 for plant in the U.S. ($/tonne)**

Cost of electricity is also a frequently used measure of carbon abatement within the electric sector. The figure below shows the levelized cost of electricity (LCOE) for various technologies, including plants equipped for CCS with saline storage.

**Levelized Cost of Electricity for Plants in the U.S. ($/tonne)**

As the figure above shows, CCS-equipped plants compare favorably with other low-carbon electricity options. One issue with LCOE as a measure of cost is that it does not effectively account for differences between intermittent resources like wind and solar and dispatchable generation such as coal, gas or nuclear. LCOE measures of wind and solar ignore costs incurred when these sources are unavailable. These costs include additional balancing, additional transmission and shadow generating capacity.

Accounting for the availability limitations of solar and wind can change the ranking of CCS relative to wind and solar. Van den Broek, et. al, compared costs of NGCC-CCS with intermittent offshore wind, solar and photovoltaic resources on the same baseload playing field, correcting for additional balancing, transmission and back-up needed by intermittent sources. They examined potential future cost reductions and a variety of back-up technology options. They then developed four stylized low-carbon systems and examined them in 2020, 2030 and 2040. The authors concluded that the system with the lowest LCOE and the lowest avoided cost of carbon was NGCC-CCUS.

**Source:** Global CCS Institute, *The Costs of CCS and Other Low-Carbon Technologies in The United States* 2015 Updated July 2015 Page 9.
Conclusions

Carbon capture and storage is essential for addressing climate change. Projections by the International Energy Agency show CCS will need to account for 6,000 million tonnes of CO₂ reduction worldwide by 2050. That’s more CO₂ than emitted today in the entire U.S.

CCS is the only practical large-scale option to address industrial emissions, which account for almost 25% of global CO₂ emissions. CCS also works on other large stationary sources such as electric power plants. Over half of the CO₂ emissions in the United States come from the electric power and industrial sectors.

CCS is a cost-effective way to abate CO₂ emissions. While costs vary by industry and application, the avoided cost of capture is comparable to other low carbon options, especially when emissions are stored using EOR.

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ii IPCC, page 28.


