ESCA Back Pocket Insights

Role of Carbon Management Technologies in U.S. Economy-Wide Decarbonization Pathways

by Geoff Blanford and John Bistline

KEY INSIGHTS

• Model results suggest that **carbon capture and storage can play key roles in emissions reductions**, but the extent and composition **depend on technological and policy uncertainties**.

• **Electricity demand increases significantly over time in all scenarios** due to data centers, electrification, and other loads. However, scenarios without CCS entail much higher demand due to electrolytic hydrogen.

• **Technology optionality enables affordability.** Carbon prices span \$170-300 per ton CO_2 across most net-zero scenarios but can approach \$1,000/tCO_2 in scenarios without CCS.

This brief is based on the report "LCRI Net-Zero 2050: Sensitivity Analysis and Updated Scenarios" published on epri.com

Analysis evaluates technology strategies for achieving economy-wide net-zero CO_2 emissions in the U.S. by 2050, including the role for carbon management.

Carbon management technologies could be important elements in achieving net-zero CO_2 emissions across the economy; however, technological and policy uncertainties make the extent of this role unclear. This analysis uses EPRI's REGEN model to investigate a range of technology sensitivities and recent developments, including evolving policy incentives and emerging trends in data center electricity use.

The analysis includes scenarios related to:

- Technology availability and cost assumptions for advanced nuclear, electrolysis, carbon capture and storage, and bioenergy
- Fuel price uncertainty
- Limited flexibility in how far individual sectors and regions are required to reduce direct emissions under an economy-wide target
- U.S. Inflation Reduction Act (IRA) incentives

More detail on scenario and analysis assumptions can be found here.

Model results suggest that carbon capture and storage (CCS) can play a key role in economy-wide decarbonization, but the **extent of deployment spans a wide range depending on policy and technology assumptions** (Fig. 1). Total capture rates range from 100-2,200 million metric tons of CO_2 annually across net-zero scenarios in 2050.

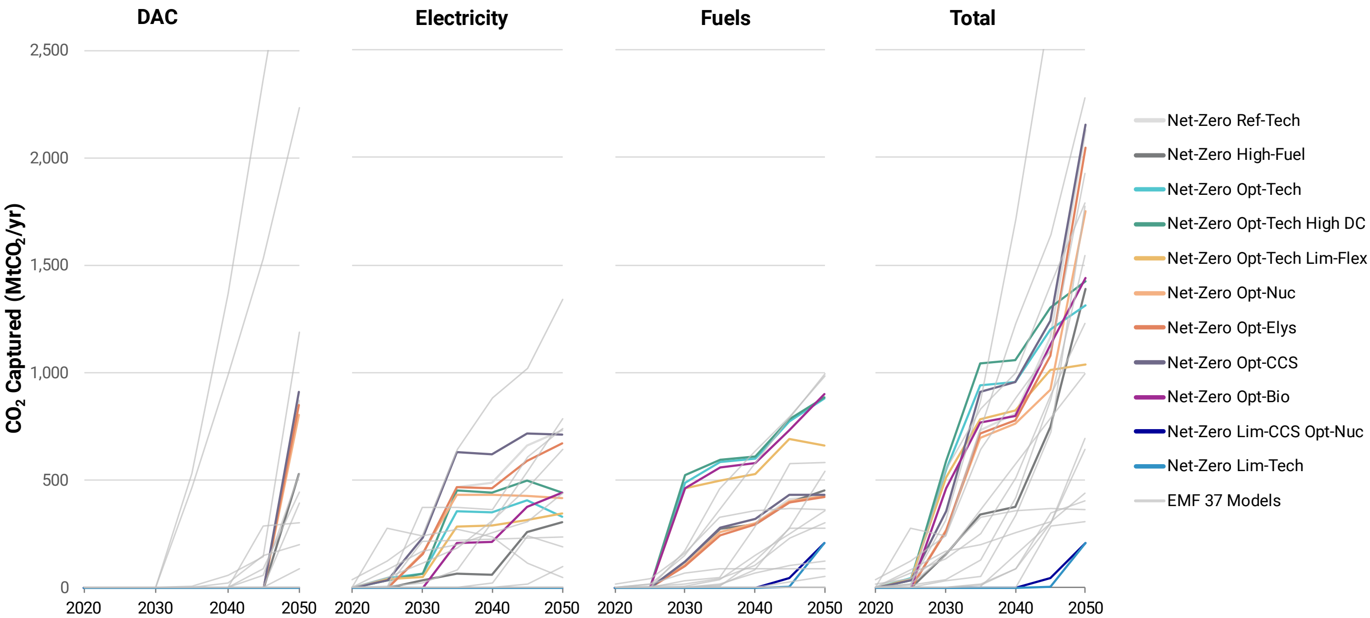

Figure 1. Captured CO_2 for U.S. economy-wide net-zero CO_2 by 2050 scenarios. Scenarios from the LCRI Net-Zero 2050 analysis are compared with Energy Modeling Forum 37 results across models. Total includes captured CO_2 from DAC, electricity, fuels, and industrial process.

Captured CO_2 exceeds 1,000 $MtCO_2$/yr for all scenarios except for cases that specifically limit CO_2 storage. CCS generally increases as the net-zero target is approached, but some CCS is deployed for electricity generation and fuels production in the 2030s due to expiring IRA incentives and state-level policies.

Although net emissions reach zero by 2050, direct positive **emissions are not entirely eliminated in any scenario, as they are offset by CO_2 removal (CDR) options**. The model identifies the least-cost combination of direct reductions and CDR deployment to meet the net-zero target. Under this strategy, more expensive direct reductions are avoided when a less expensive CDR option is available. Positive emissions remain in sectors where the marginal cost of substituting away from fossil fuels is highest, including high-temperature industrial heat and aviation.

The range of scenarios demonstrates how this balance can **depend on technological and policy uncertainties**. With optimistic assumptions about bioenergy and CCS, there is more deployment of biofuels for CDR and replacement of petroleum-based liquid fuels for transport. With more pessimistic assumptions about bioenergy, there is less substitution away from petroleum in non-electrified transportation segments, and direct air capture (DAC) is used to provide CDR offsets, albeit at a higher cost.

In all analysis scenarios, **electricity demand increases significantly over time**, representing a fundamental departure from recent history. Growing electricity demand comes from the proliferation of data centers, end-use electrification, and other loads. **In scenarios without CCS, hydrogen from electrolysis plays a much larger role** as both a direct substitute to conventional fuels and an input to synthetic hydrocarbon fuels.

These findings are consistent with the literature on reaching net-zero emissions in

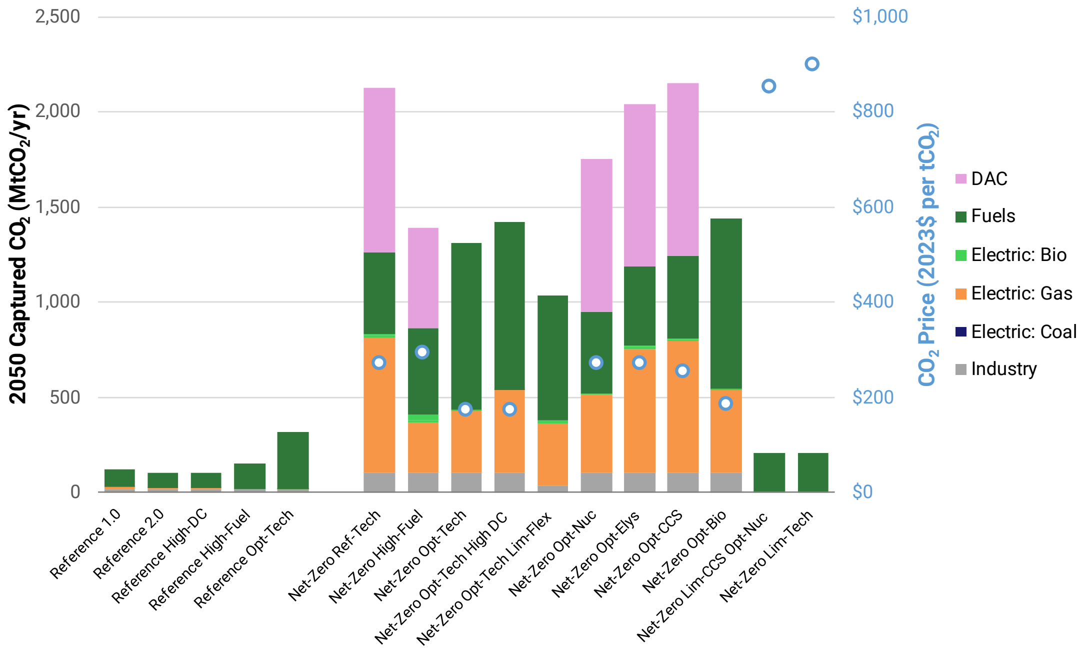

Figure 2. Captured CO_2 in 2050 by source across scenarios. See the report table for scenario definitions across reference (left) and net-zero (right) scenarios. DAC = direct air capture. The fuels category includes biofuels, hydrogen, and ammonia.

the U.S. (e.g., Bistline, et al., 2024; Browning, et al., 2023). For instance, Fig. 1 compares captured CO_2 from REGEN scenarios with values from the Energy Modeling Forum (EMF) 37 study. There is considerable overlap in ranges of captured CO_2 across REGEN and EMF 37 scenarios.

When CCS is unavailable, direct positive emissions must be eliminated wherever possible, remaining only in certain industrial activities such as chemicals and cement where non-fossil alternatives are not considered. In these scenarios, positive emissions are reduced to around 95% of 2005 levels with lower fossil fuel use, but marginal **costs of achieving the net-zero target increase considerably in scenarios without CCS** and approach \$1,000/tCO_2 (Fig. 2), which is an indicator of the stringency of the cap given the costs and availability of technologies. The lowest carbon prices, around \$170/tCO_2, occur in scenarios with optimistic bioenergy assumptions, as these cases enable greater deployment of biofuels and associated CDR for lower cost. In scenarios with reference bioenergy assumptions and CCS available, the carbon price resolves to a higher level, around \$270/tCO_2, reflecting the assumed levelized DAC cost in 2050, which supplements CDR from bioenergy with CCS.

The **composition of captured CO_2 varies across policy and technology scenarios** (Fig. 2). Large shares of CCS are deployed for fuels production (especially biomass-based liquid fuels that create negative emissions flows), gas-fired electricity generation, and DAC. CCS deployment is much lower in current policies reference scenarios, where CCS is primarily driven by 45Q incentives for fuels production and some power sector deployment from state emissions and clean electricity policies.

FOR MORE INFORMATION

Read the full report: "LCRI Net-Zero 2050: Sensitivity Analysis and Updated Scenarios."

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