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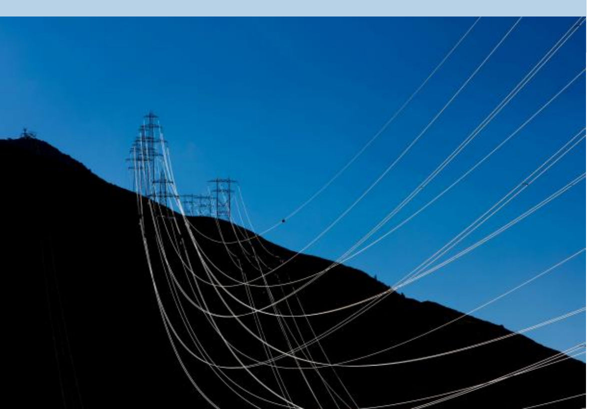
KEY INSIGHTS

• The potential for direct emissions reductions varies across sectors, and **strategies vary within each sector depending on technology costs and availability**.

• In general, the **buildings, industry, and fuels sectors achieve lower percentage reductions than the power and transport sectors**, reflecting their higher marginal abatement costs.

• Electrification and low-carbon fuels can substitute for conventional fuels to reduce emissions, but the **marginal costs can rise steeply for some end-uses**. This leads to carbon dioxide removal use to offset fossil fuel emissions, which can lower costs relative to direct reductions for some end-uses.

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



Sectoral CO_2 Reductions for Economy-Wide Decarbonization

by Geoff Blanford and John Bistline

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

Many companies, states, and countries are setting net-zero emissions goals; however, there are many uncertainties related to potential pathways and technology trade-offs to reach these targets. 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.

Achieving economy-wide net-zero goals requires deployment of low-carbon technologies across electric and non-electric sectors, including industry, fuels, buildings, and transportation. The **potential for direct emissions reductions varies across sectors**, and optimal strategies vary within each sector depending on technology costs and availability (Fig. 1).

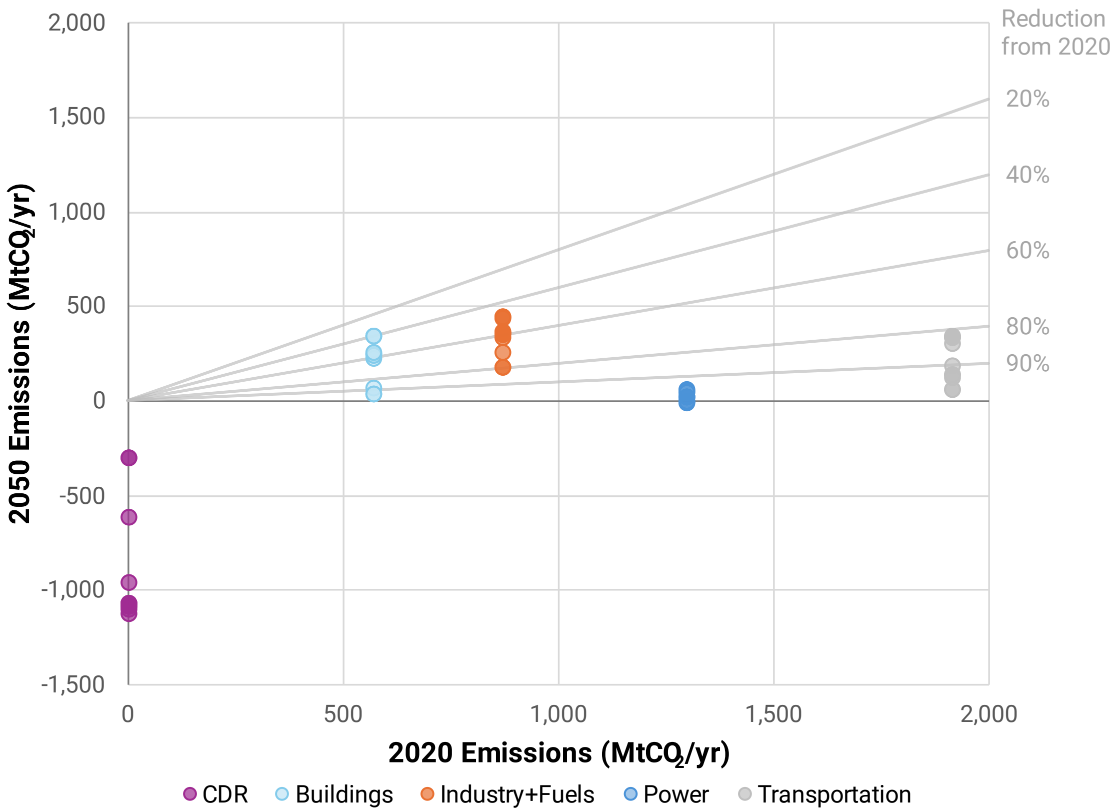


Figure 1. Economy-wide net CO_2 emissions by sector. See the report table for scenario definitions. Data points indicate net-zero scenarios. Diagonal lines indicate percentage reductions in 2050 relative to 2020 at the sector level. CDR = CO_2 removal.

- **In most net-zero scenarios, net power sector emissions are near-zero by 2050**, though some positive emissions remain for infrequently used balancing resources.
- **In the non-electric sectors, direct emissions reductions in net-zero scenarios span a broader range.** In general, the buildings, industry, and fuels sectors achieve lower percentage reductions than the power and transportation sectors, reflecting their higher marginal abatement costs.

Electrification and low-carbon fuels can substitute for conventional fuels to reduce emissions, but the marginal costs can rise steeply for some end-uses, such as space heating in cold climates, high-temperature industrial processes, and transportation segments such as aviation. Carbon dioxide removal (CDR) from bioenergy with carbon capture and storage (CCS), direct air capture (DAC), and natural processes such as afforestation can provide cost-effective options to offset emissions that would be expensive to reduce directly.

In general, the model identifies the least-cost combination of direct reductions and deployment of CDR technologies to meet the target balance between positive and negative emissions. The range of scenarios in this analysis demonstrates how this **balance can depend on uncertain technology and policy variables**. For instance, when CCS is unavailable and the scale of CDR is limited to ~300 $MtCO_2$ from land-based offsets, direct positive emissions must be eliminated wherever possible. In these scenarios, positive emissions are reduced to around 95% of 2005 levels, but marginal costs of achieving the net-zero target approach $1,000/$tCO_2$.

Fig. 2 shows direct sectoral emissions in the context of reductions relative to 2020 across scenarios. Most direct emissions in buildings,

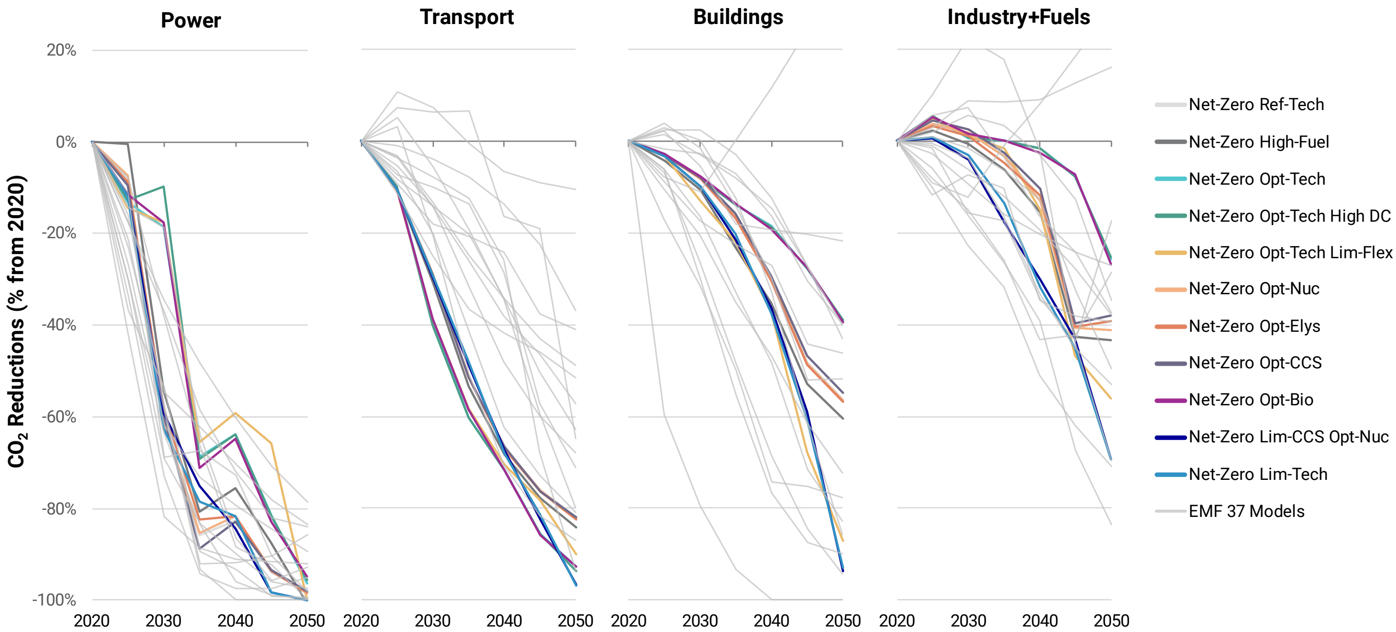


Figure 2. Sectoral CO_2 reductions for U.S. economy-wide net-zero CO_2 by 2050 scenarios. Panels indicate CO_2 reductions relative to 2020 levels for each sector. Scenarios from the LCRI Net-Zero 2050 analysis are compared with Energy Modeling Forum 37 results.

industry, and fuels sectors are related to natural gas use, which has higher substitution costs with electrification and low-carbon fuels than petroleum-based liquid fuels in the transportation sector. Power sector emissions are near-zero in all net-zero cases, although not absolutely zero, as a small amount of gas use remains as a balancing option for variable renewable generation. The **transportation sector exhibits deep reductions in the reference scenario due to electrification** of most on-road segments driven by favorable economics with cost and performance improvements of battery electric vehicles.

These findings are consistent with the emerging literature on reaching net-zero emissions in the U.S. See for example Bistline, et al. (2024), Browning, et al. (2023), and LCRI's model intercomparison of net-zero studies. For instance, Fig. 2 compares sectoral emissions reductions with values from the Energy Modeling Forum (EMF) 37 study of "Deep Decarbonization & High Electrification Scenarios for North America." These comparisons indicate broad alignment with the scenarios in this analysis, albeit with cross-model variation in trends.

For many scenarios, EPRI's analysis generally has lower CDR use and greater direct reductions for many sectors. Net-zero scenarios in REGEN include greater transportation CO_2 reductions than most EMF 37 models due to electrification and low-carbon fuel substitution. Differences are models reflect alternate technological assumptions (e.g., cost, availability), service demand assumptions, as well as deployment constraints and equipment turnover.

FOR MORE INFORMATION

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

CONTACT

Geoff Blanford (lead author)
gblanford@epri.com