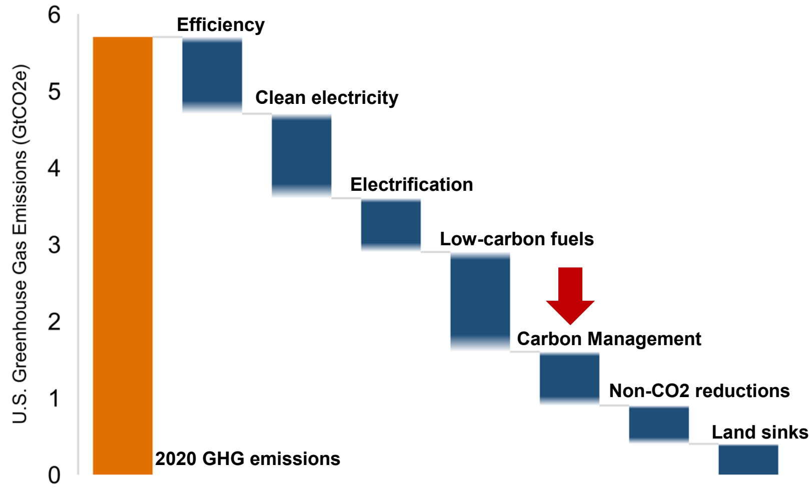
Summary for Policymakers:
Carbon Management in Net-Zero Energy Systems

U.S. goals to achieve a stable climate

To avert the worst impacts of climate change, the Biden Administration has set a goal of achieving net-zero greenhouse gas emissions by no later than 2050. Experts across the U.S. government and at the International Energy Agency broadly agree that the priority strategies to achieve this goal include energy efficiency, clean electricity, and electrification, which are estimated to enable at least *half* of the emissions reductions required. There is less clarity around the additional strategies needed to fill the gap.

Drivers of emissions reductions by 2050
Adapted from: *The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050 (2021)*



One set of potential solutions, known as *technological carbon management*, would enable the removal of carbon dioxide from the atmosphere or emissions-intensive facilities. Common technological carbon management solutions include carbon capture and storage (CCS) at point sources (e.g. power plants, factories); direct air capture (DAC); bioenergy with carbon capture, utilization and/or storage (BECCUS). Carbon dioxide can be stored in geologic formations underground or utilized as a feedstock for low-carbon materials or synthetic fuels. While these technologies all have the potential to help reduce climate warming, they exist at different levels of technological readiness and cost, and may lead to a variety of potential environmental, economic, and community impacts. Several common questions include:

- *How important is carbon management to achieving net zero in the United States?*
- *How much carbon management would be required under different scenarios of resource costs and availability?*
- *Would carbon management lead to the lock-in of inefficient fossil fuel plants?*
- *What should policymakers do to get ready for the potential deployment of these technologies?*

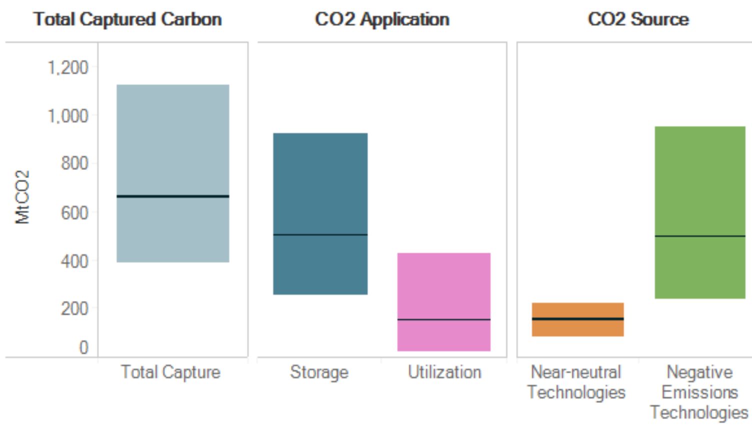
Evolved Energy Research ("Evolved"), a leading energy systems modeler, has explored a series of scenarios to shed light on these technologies' potential, and to inform strategic planning and innovation investment in federal policy. Here we summarize insights and policy recommendations from their analysis: **Carbon Management in Net-Zero Energy Systems.**

How can a model help us understand the role of carbon management?

Model results are not predictions of what will happen, but they can provide insights on how the energy system could respond in different pathways to net zero. Evolved created a "Core Net-Zero" (CNZ) scenario in which they model the evolution of the U.S. energy system under a declining limit on annual emissions (with an exogenous treatment of non-CO_2 gases on a CO_2 equivalent basis), which hits a 50% CO_2 reduction below current levels by 2030 and net-zero CO_2 by 2050. They then test 20+ alternative scenarios to understand a broad range of potential technological outcomes and pathways to net zero, tweaking assumptions such as renewable energy costs or fuel prices that could affect carbon management uptake.

The model deployed used a "least-cost" optimization approach and was not designed to consider other factors like political will, public health, and distributional equity considerations. It also focused on the dynamic modeling on net-zero carbon dioxide, a common practice in energy modeling, but one that omits a full consideration of non-CO_2 emissions reductions (such as methane, NOx, SOx, and other short-lived pollutants). Nonetheless, these insights provide a sense of the key variables that will shape the decisions and policy frameworks that would enable the most positive outcomes and avoid the greatest risks.

Key findings from the analysis



1. Carbon management is likely a necessary ingredient to achieve net-zero scenarios. Though the model relied on significant contributions from energy efficiency and clean electrification, significant carbon management was deployed in all the main scenarios, requiring between 400-1,100 million metric tons of CO_2 capture by 2050 (between 7%-20% of gross U.S. emissions today). Excluding carbon management from the model altogether led to extraordinary levels of renewables development and biomass use that would likely be technically challenging and politically infeasible, such as requiring the utilization of 1 billion tons of biomass for low-carbon fuels (an optimistic estimate of all biomass produced in the United States).

2. Innovation across the carbon management supply chain can lead to an enhanced suite of options. From direct air capture (DAC) to CO_2 utilization for synthetic fuels in shipping and aviation, innovation can accelerate the viability of a wider suite of technologies. Given the many uncertainties that shape the path forward, creating more options is a high-impact investment.

3. Assuming the other elements of a clean energy transition are in place, carbon management isn't expected to extend the life of polluting fossil fuel plants in the long term. There are concerns that removing carbon from point sources (e.g., power plants, factories) could prolong the life of old, polluting fossil fuel facilities. The Evolved model suggests that CDR options (DAC, BECCUS) strongly outcompete point-source CCS by 2050, driven by their greater versatility and falling costs in a system with other significant clean energy deployments. However, this outcome relies on progress decarbonizing other sectors (including the deployment of an additional 600 GW of renewable electricity by 2050), and doesn't obviate the need for carefully designed policies to ensure CCS deployments and its incentives do not act as fossil fuel subsidies in the immediate and medium-term.

4. Policymakers should also consider investing in existing technologies to prepare for a net-zero energy system. The model drives approximately three-quarters of captured CO_2 from CCS and DAC to geologic storage, with the remainder utilized to produce low-carbon synthetic fuels in the CNZ scenario. The U.S. does not lack technologically-feasible geologic storage capacity. However, significant levels of research, planning and investment would be required today to enable the deployment of geologic storage at the levels suggested by the model. Additionally, policies should be put in place to ensure environmental integrity and to prevent leaks, earthquakes or other preventable negative impacts. Importantly, the model also finds that nearly all CO_2 storage and utilization occurs *intra*-regionally, suggesting that long-distance CO_2 pipelines may not be worth the cost of deployment. Additional analysis should explore this point further.

4. Non-CO_2 greenhouse gas emissions and air pollutants must be addressed. It is becoming increasingly clear that non-CO_2 emissions play a disproportionate role in climate warming. With a few exceptions, carbon management often does not directly reduce non-CO_2 pollution such as methane, sulfur dioxides, nitric oxides, and particulates. This is an important consideration to ensure emission of these gases does not negate carbon management's near- and long-term climate benefit and/or cause adverse health impacts. Alternatively, a proactive strategy to mitigate non-CO_2 pollutants can provide a more efficient pathways to slow the rate of climate warming than focusing on CO_2 alone. Greater analysis, including a more advanced treatment of non-CO_2 emissions, would be valuable to provide a more complete understanding of policy options.

Policy recommendations

The premise of a net-zero scenario assumes the U.S. develops significant policy, regulatory and market drivers to incentivize net-zero energy outcomes. However, the U.S. currently has no enforceable net-zero policy, and existing, enacted policies are insufficient to decarbonize the economy by 2050.

So, what should policymakers do? Many policy opportunities exist, including stimulating innovation in key areas, preparing for effective deployment of emerging solutions, and deploying no-regrets climate solutions. Policies can also address key barriers, which can be economic, environmental, political, and/or social, including the implications for public investment, siting, permitting, equity and justice, pollution, and land-use change.

Based on these insights, EDF recommends that policymakers pursue action in the following areas:

Recommendation #1: Prioritize the advancement of energy efficiency, clean electricity, and electrification. In addition to being no-regrets resources to achieve a stable climate, these options also create market conditions that minimize the need for carbon management and ensure its efficacy. For example, high penetrations of renewable energy are likely to be necessary to accelerate the transition away from fossil fuels, stimulate markets for low-carbon fuels and feedstocks, and reduce the cost of carbon management technologies like DAC.

How?

- Reform, extend, and expand clean energy tax credits to accelerate clean electricity deployment.
- Invest in grid modernization and transmission infrastructure to better accommodate more renewable generation and increased demand from electrification.
- Provide incentives for purchasing electric vehicles and decarbonizing buildings.
- Invest in EV charging networks and domestic manufacturing and supply chains for clean energy technologies.

Recommendation #2: Plan for a future that will potentially require access to carbon management solutions, including long-term infrastructure planning that aligns with net-zero goals.

How?

- Advance support for innovation in key areas (CDR, carbon utilization), including research, development and demonstration.
- Significantly scale-up the planning and investment in the development of solutions required by multiple technological options, such as geological storage in saline formations.
- Enhance policies that ensure the permanence of storage is demonstrated transparently and is performed with environmental integrity.
- Ensure all developments include significant, timely, and inclusive community engagement.
- Carefully consider possible future demand when developing policies and investments for infrastructure build-out (e.g., CO_2 pipelines).

Recommendation #3: Monitor, regulate, and address non-CO_2 pollution. Carbon management is sometimes portrayed as a catch-all tool to mitigate climate warming: unfortunately, it is not. The emissions of short-lived climate pollutants, such as methane, can play a disproportionate role in climate warming, and are not currently considered among carbon management solutions.

How?

- Prioritize the reduction of the emissions of non-CO_2 gases, including through mitigation strategies in non-energy systems (e.g. agriculture, land sources, landfills), and leakage mitigation in energy and industrial systems, including monitoring, verification, and reporting (MRV) and leakage detection and repair (LDAR) systems.