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Near-term deployment of carbon capture and storage from biorefineries in the United States

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Introduction

Capture and permanent geologic sequestration of biogenic CO_2 emissions play a pivotal role in stringent climate change mitigation. Yet, most near-term assessments of mitigation opportunities assume bioenergy with carbon capture and sequestration (BECCS) is either technologically immature or commercially unavailable. In contrast, biogenic CO_2 capture, utilization, and sequestration from fermentation is already deployed at commercial scale, including several corn ethanol facilities in the United States. These low-cost capture opportunities target pure streams of biogenic CO_2. Capture and sequestration of CO_2 from biorefineries can improve the lifecycle impacts of conventional biofuels and help fulfill the objectives of low-carbon fuel policies.

Here, we study the abatement potential and costs of near-term CO_2 capture and sequestration from existing biorefineries in the U.S. using process engineering, spatial optimization, and lifecycle assessment. We provide detailed spatial characterization of fermentation CO_2 emissions, capture and compression costs, CO_2 transportation networks, and candidate sequestration sites. To identify cost-effective sequestration opportunities, we minimize the total cost of capture, compression, transportation, and sequestration using integer programming.

Methods

Data Sources: U.S. biorefinery location and near-term ethanol production capacity based on data from the Renewable Fuels Association. Saline aquifer storage capacity and location are derived from the National Carbon Sequestration database (NATCARB). We adopt existing pipeline rights-of-way from the National Pipeline Mapping System (NPMS) for CO_2 transmission.

Data Development: We estimate facility-level CO_2 fermentation emissions from data. We estimate capital and operating costs for CO_2 capture and compression based on (1), with updates to fermentation CO_2 parameters from and state-level industrial electricity prices from the Energy Information Administration. We estimate the cost and capacity of CO_2 pipelines constructed from X80 steel, with outer diameters of 3, 4, 6, 8, 10, 14, 18, 22 and 26" based on (2).

Problem statement and scenarios: We minimize the total cost of sequestration or abatement via capture, compression, transportation, and injection using integer programming (3). Decision variables consist of binary CCS construction variables and integer pipeline construction variables. Our model is solved using a branch-and-bound method. In each scenario, we assume a credit price for CO_2 sequestration or lifecycle emissions abatement.

Results

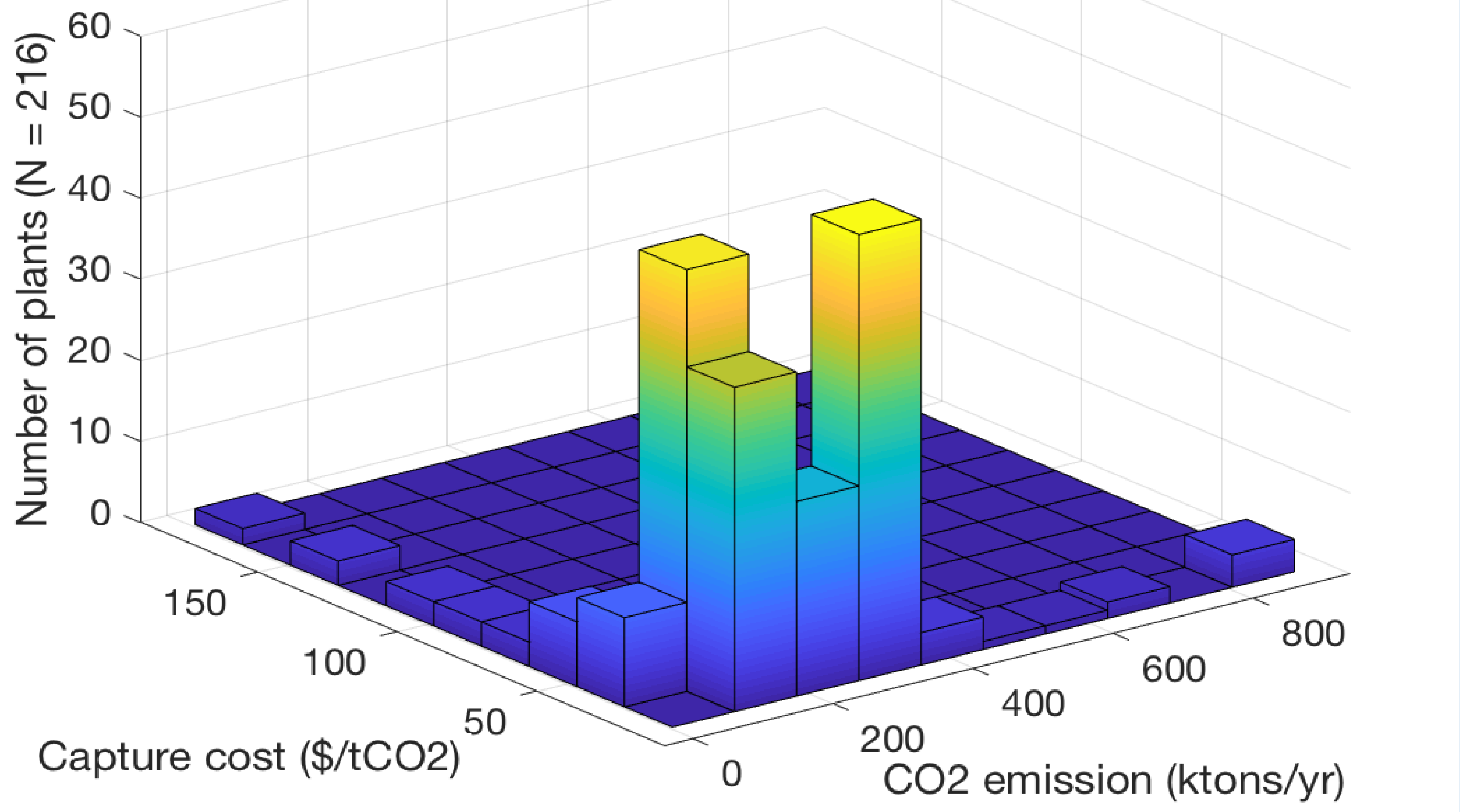

Figure 1. Contour plot of modeled abatement costs and scales for CO_2 capture, dehydration, and compression for biorefineries (N=216). 40% of biorefineries have costs < $25/tCO$_2$, while 90% of biorefineries have costs < $50/tCO$_2$.

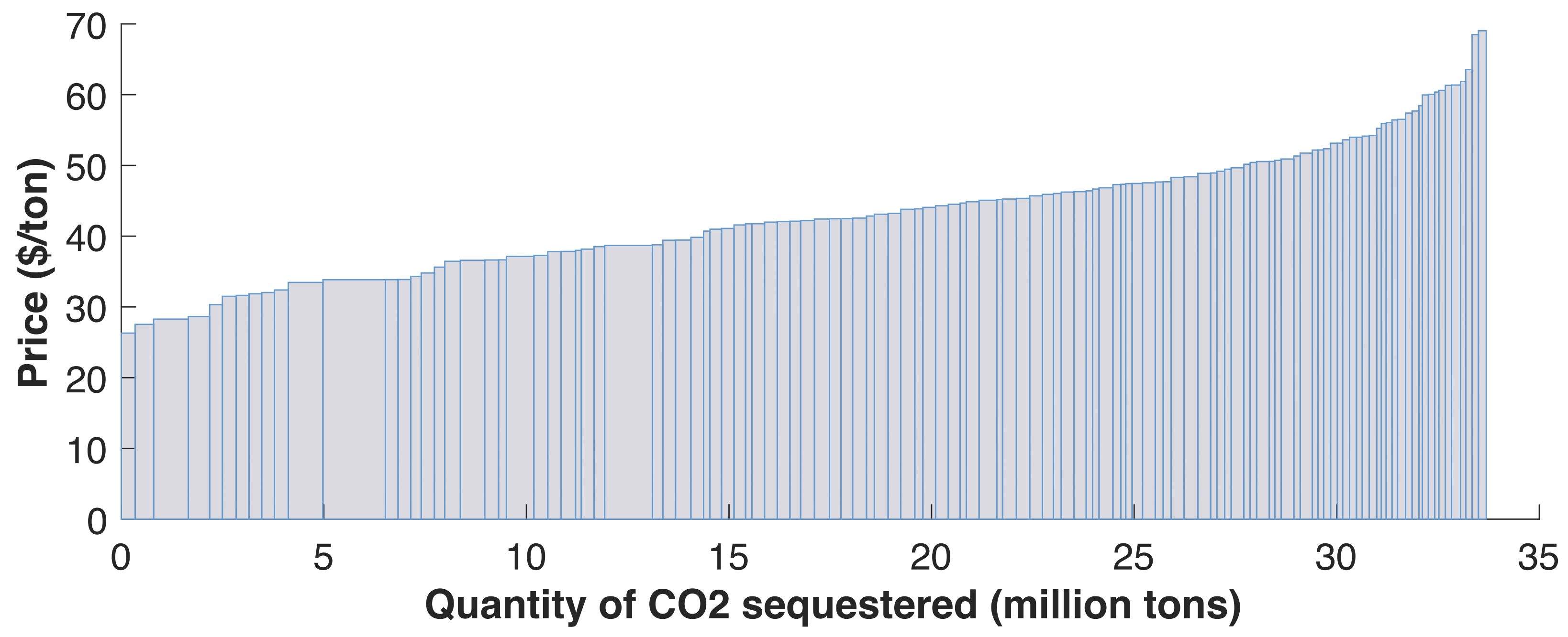

Figure 2. Facility-level capture, transport and sequestration costs for a sequestration credit of $60/tCO$_2$. High-volume sources are low-cost CCS opportunities (N=119).

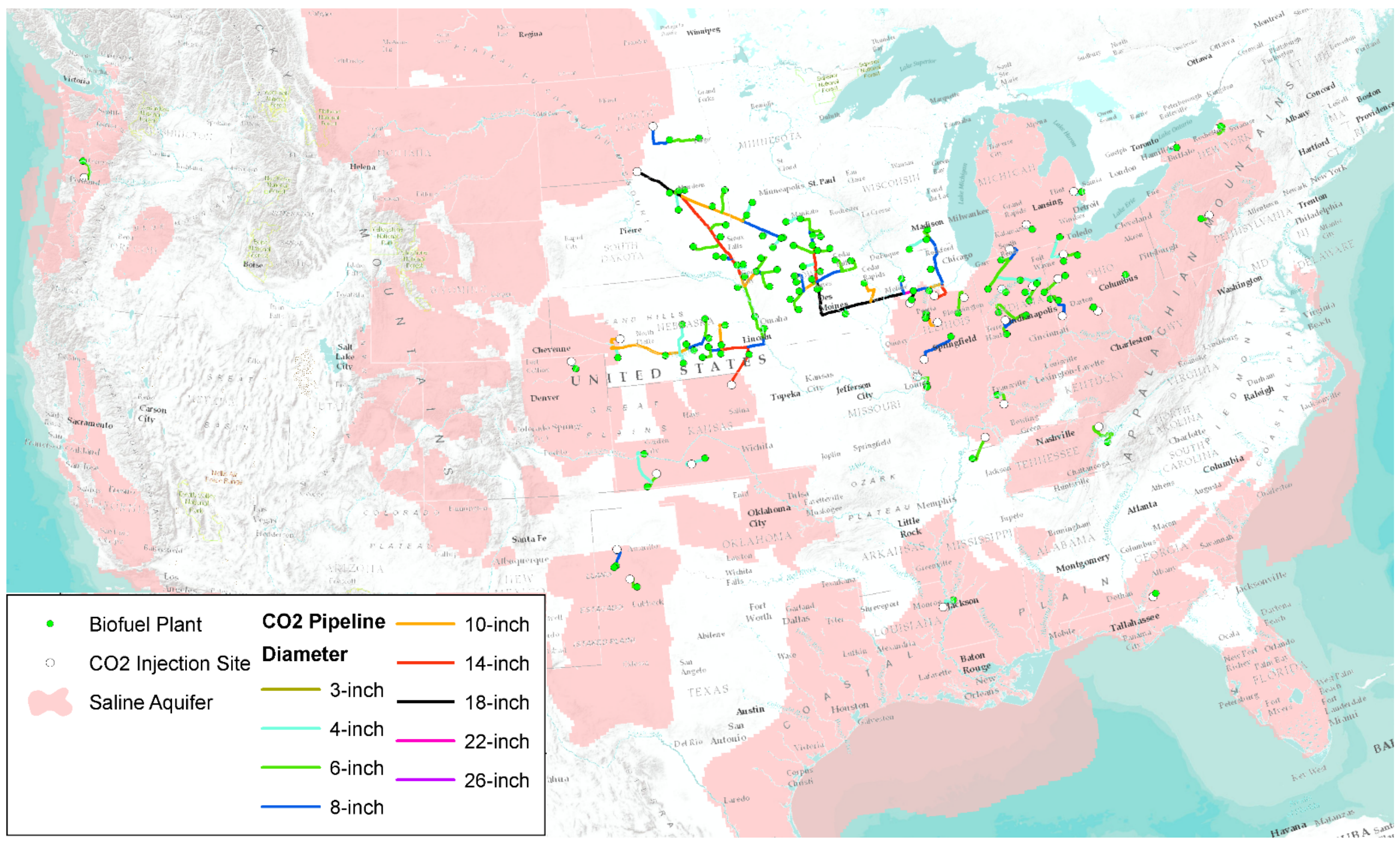

Figure 3. Optimal capture, transportation, and sequestration network for a sequestration credit of $60/tCO$_2$. Overall sequestration is 33.9 MtCO$_2$/yr from 119 biorefineries (a capacity of 11.8 billion gallons per year), with pipeline infrastructure totaling 8500 km. Injection occurs at 35 sites around the U.S.

Policy drivers

- Sequestration tax credits: The Carbon Capture Utilization and Storage Act of 2016 (S.3179) proposes a tax credit of up to $50/tCO$_2$ sequestered in secure geologic storage (Section 45Q) for a 12-year duration. The bill garnered 19 cosponsors.
- Low Carbon Fuel Standards: California's LCFS currently provides an abatement credit, based on lifecycle emissions, of ~$75-125/tCO$_2$, with a price ceiling of $200. The overall market size is roughly 1.5 billion gallons, or 7-8 MtCO$_2$ abated, per year through 2030. California is currently considering quantification and permanence methodologies for CCS from fuels production.
- Renewable Fuel Standards: The U.S. RFS provides limited support for CCS deployment on biofuels, due the structure of the volumetric mandate. EPA is currently considering a CCS methodology as part of its ongoing rulemaking.

Conclusions

- We identify 45 Mt of biogenic CO_2 emitted annually from 216 facilities. 40% of facilities have capture and compression costs < $25/tCO$_2$.
- A sequestration credit of $60/tCO$_2$ can incent 34 MtCO$_2$/yr of sequestration from 119 biorefineries, including 8500 km of pipeline infrastructure in the U.S.
- Recent financial incentives under California's Low Carbon Fuel Standard and proposed in the U.S Senate suggest a substantial near-term opportunity to permanently sequester biogenic CO_2.
- This financial opportunity can catalyze the growth of carbon capture, transport, utilization, and sequestration, improve the lifecycle impacts of conventional biofuels, and help fulfill the mandates of low-carbon fuel policies across the U.S.

Acknowledgements and References

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