Sustainable Transportation Energy with Net Negative Carbon Emissions

**Investigators**
Eric Larson and Robert Williams, Princeton University; Clarence Lehman and David Tilman, University of Minnesota.

**Objective**
This work seeks to identify and analyze promising pathways to net negative carbon emissions for transportation by mid-century. The project will include field studies of potential biomass-energy supplies from degraded lands in the United States and energy systems analyses for alternative bioenergy conversion approaches incorporating results from these studies and associated modeling exercises.

**Background**
The Intergovernmental Panel on Climate Change (IPCC) has highlighted the need for net negative emission technologies (NETs) that remove carbon dioxide from the atmosphere.¹ The IPCC report emphasized that NETs, along with renewables and increases in efficiency, will be required to stabilize atmospheric CO₂ concentrations at levels that are likely to avoid dangerous climate changes. Moreover, to this end, biomass-based NETs must be provided in sustainable ways that avoid or minimize adverse ecological effects and conflicts with food production.²

In earlier work the Princeton researchers have argued that, in principle, 2050 global transportation-fuel demands could be met with zero net greenhouse gas GHG emissions through coordinated use of fossil fuels and biomass supplies that do not compete with food production for cropland via energy systems with geologic carbon capture and storage (CCS). This approach would require less biomass than meeting transportation energy demands with conventional biofuels. That earlier analysis assumed no carbon storage in roots and soils (R/S) associated with biomass production. However, if some level of R/S carbon storage were achieved during biomass production, the global transportation system could in principle become net carbon-negative for one or possibly more of the approaches to bioenergy conversion that are being investigated in this project. This project is investigating the potential for sustainable production of biomass with R/S carbon storage on degraded lands and integrating the findings with analysis of alternative biomass-based energy conversion systems that utilize CCS.

![Diagram of carbon pathways and storage possibilities](image)

**Figure 1:** Carbon pathways (gray arrows) and storage possibilities if biofuels are used for transportation. Storage of carbon in roots and soils would enhance the net negative carbon emissions that can be achieved with biofuel production processes that include capture and geologic storage of CO₂.
Approach

The research team will carry out a comparative assessment of alternative carbon-negative biomass feedstock/conversion systems that might be commercially deployed by mid-century in the U.S. Researchers will consider the current status of technology developments and costs, prospects for cost reduction through experience (learning by doing) and rates of market penetration under alternative market and public policy conditions, taking into account historical experience with market launch of new technologies. Figure 2 summarizes the integrated nature of this multidisciplinary collaboration. The emphasis will be on making liquid fuels, but systems that provide electricity will also be considered. An assessment will be made of the system-wide results of two mechanisms for storing CO₂ once photosynthesis has removed it from the atmosphere: 1) geologic storage of CO₂ captured during feedstock conversion (CCS), including CO₂-enhanced oil recovery as a near-term strategy for commercial introduction of CCS, and 2) storage of carbon in biomass roots and associated soil (R/S).

The fundamental science to be advanced is a new and comprehensive understanding of the ecological dynamics, R/S carbon storage potential, and sustainability of growing perennial grasses on degraded lands that are not well-suited for conventional agriculture. The United States had an estimated 190 million hectares of such land in 2012, according to the U.S. Department of Agriculture.

A key goal is to get a good understanding of the time evolution of the rate of R/S carbon storage, which will vary with the type of soil, the condition of the land, time since establishment, climate, and type of biomass crop. Researchers at Minnesota will conduct studies of biomass production and its impact on land use, water, wildlife, and R/S carbon storage. Those results will be recorded in archival format, disseminated, and used to estimate sustainable biomass yields and R/S carbon-storage rates that will be incorporated into energy systems analyses conducted by researchers at Princeton.

References
