LCA, Environmental and Sustainability Aspects of Emerging Biomass Conversion Technologies

Sabrina Spatari, Drexel University

There has been much interest in developing domestic alternatives to petroleum-based transportation fuels in recent years due to volatile petroleum prices, geo-political challenges, the carbon intensity of fossil energy supply, and the economic benefits of expanding domestic energy markets. Biofuels are a promising option for transportation because of their ease of blending with fossil fuels in the interim, their compatibility with the existing fuel infrastructure, and that there are few alternatives to liquid storage of energy for long haul transportation. In view of these advantages and to address global climate change, energy security, and other sustainability goals, countries around the world including the U.S., Canada, Germany, and the UK have developed policies to incentivize biofuels into the market. North American policy instruments include the federal Renewable Fuel Standard (RFS2) and state-level policies such as California's Low Carbon Fuel Standard (LCFS). Pursuit of biofuel policy precipitated from the promise of the scalability of biomass resources and the low carbon intensity of the biofuels themselves[1]. However, controversy and challenge arose due to the fact that the current commercial investment options rely on feedstocks (e.g., corn) that compete with food and have potentially negative land and water-related environmental impacts; and that there are significant technological and economic barriers to scaling the more sustainable biomass feedstock options, as well as thermodynamic tradeoffs for all "farm/forest-to-wheel" pathways. Such challenges may be overcome by R&D investment in lignocellulose (biomass) conversion to infrastructure compatible fuels and chemicals via thermochemical and biochemical platforms; and biomass feedstock development focused on marginal lands and residue management (e.g., the sustainable removal of agricultural and forest residues from their native ecosystems).

At present biological and thermochemical technologies are under development at laboratory, pilot scale, and in some cases at a demonstration stage to investigate the technological needs of scaling biofuels. Ethanol, higher alcohols, and fully infrastructure compatible fuels (with 0% oxygen – physically and chemically similar to current petroleum based fuels) are being developed at different scales, including farm scale (up to 200 dry metric tons/day) and industrial scale (2000 dry metric tons/day and higher) to utilize diverse lignocellulosic sources. An important part of developing sustainable biofuels is using analytical tools to understand the environmental and economic outcomes of scaling biomass-bioenergy systems across managed ecosystems, including agricultural and forest landscapes. Biomass feedstocks from agricultural ecosystems vary in their "environmental" intensity due to local conditions (climate, soil, slopes, etc.) that directly affect the biogeochemistry of nutrients that maintain those ecosystems. Moreover, biomass and biofuel policy can have unforeseen global consequences to land, water, air, and climate due to changes mediated through agricultural and forest products markets. Life cycle assessment (LCA) and techno-economic analysis are essential methods for evaluating the environmental and economic performance of biofuels emerging through R&D, and are necessary tools for developing and judging the compliance of those biofuels under state and federal policy standards.

Life cycle models are central to the systematic analysis of biomass-to-bioenergy pathways, and the policies for evaluating their sustainable commercial development. This presentation investigates technological, environmental, and energy and resource impacts of a set of emerging lignocellulose-based biofuels from biological and thermochemical technologies at different scales using statistically based LCA methods. Uncertainties that stem from technological performance in the near and medium terms are characterized. This presentation will further highlight how analytical models for understanding the full set of environmental tradeoffs associated with emerging fuel technologies are essential inputs to guiding policy and commercial enterprise decision making for improving the overall sustainability of transportation energy.

---

[1] Pacala, S., Socolow, R., 2004. Stabilization wedges: Solving the climate problem for the next 50 years with current technologies. Science 305, 968-972.