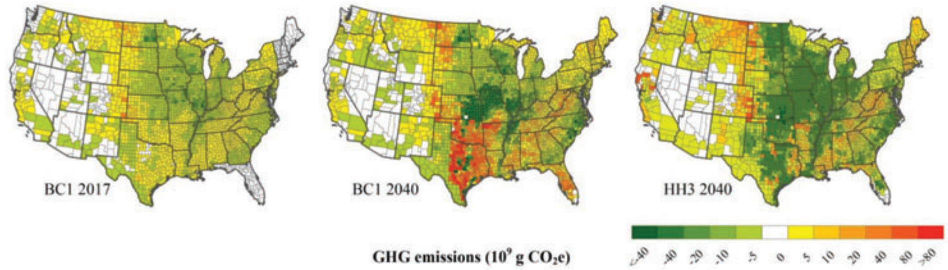
Implications of Greenhouse Gas and Other Air Pollutant Emissions from Producing Agriculture and Forestry Feedstocks



These maps show the soil organic carbon (SOC) gains (in green) and SOC losses (in red) for the three modeled scenarios. County-level SOC changes are highly dependent on crop yield, soil characteristics, and climate.

The *2016 Billion-Ton Report (BT16) Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1* is a pioneering effort to analyze a range of potential environmental effects associated with modeled near-term and long-term biomass production scenarios. Key environmental indicators modeled include soil organic carbon (SOC), greenhouse gas (GHG) emissions, and air pollutant emissions.[1] Results summarized here pertain to the 2017 and 2040 scenarios analyzed in volume 2.[2]

Summary

Results show that most GHG emissions for the near term (2017) are due to conventional crops (e.g., corn and soybeans), while in 2040, most biomass—and therefore most GHG emissions—would be from energy crops (e.g., switchgrass and miscanthus). Generally, conventional crops have the highest GHG intensity (emissions per unit mass) of all feedstocks due to fuel and fertilizer consumption. These intensities are also affected by yield and would be lower in higher-yield scenarios.

Emissions from the production of forestry biomass would be, in general, lower than it would be for other feedstocks because most forestry plots are not fertilized. In cases where they are fertilized, fertilization is only used for site preparation, which doesn't have a large effect on overall results.

Other factors besides yield that influence GHG emissions include advanced feedstock supply and logistics operations—which can be GHG intensive—and SOC changes. The latter factor varies in importance by region, yield, and the type of land management history. Producing energy crops on existing crop land leads to higher levels of carbon sequestration as compared to traditional crop production. In contrast, if energy crops are produced on pastureland, the carbon sequestered may be lower than that of growing pasture. This analysis found that under the two *BT16* 2040 scenarios, changes in SOC could result in a net soil carbon sink nationally, largely due to the land transition to energy crops (particularly miscanthus).

In terms of non-GHG air pollutant emissions,[3] the results indicate that although the air pollutant emissions per dry ton of feedstock produced would vary by county and pollutant, they are generally lower for cellulosic feedstocks than for corn grain. Future air pollutant emissions, if realized and additional (rather than displacing other agriculture or forestry activities), represent increases in emissions that could pose challenges for local compliance with air-quality regulations unless best management practices are adopted to mitigate emissions.

The variability in county-level emissions estimates suggests that certain practices and production locations result in much lower emissions than others. Higher yields, lower tillage requirements, and lower fertilizer and chemical inputs are important factors that contribute to lower air emissions. In addition, using biomass more locally or using more fuel-efficient long-distance transportation methods (e.g., rail or densified biomass) could potentially decrease emissions from truck transport.

Insights and Implications

Future research can explore the sensitivity of assumptions for SOC changes, including the treatment of tillage (the current analysis assumes all corn is produced with conventional till) and the effect of rotation. A second aspect of future research could address the temporal aspects of GHG emissions for forest-derived feedstocks. Additional areas to explore include ways to reduce the GHG intensity of advanced logistics and ways to improve efficiency for biomass preprocessing.

The non-GHG air pollutant emission estimates provided in this study could help inform future air-quality planning, such

[1] The information in this fact sheet is further discussed in *BT16* volume 2 chapters 4 and 9.

[2] Scenarios are specific to *BT16* and are further elaborated in chapter 2.

[3] The air pollutants analyzed are carbon monoxide (CO), particulate matter ($PM_{2.5}$, PM_{10}), oxides of nitrogen (NO_X), oxides of sulfur (SO_X), volatile organic compounds (VOCs), and ammonia (NH_3).

as state implementation plans, which are required to consider new emission sources for future scenarios. They could also be coupled with air-quality screening tools to evaluate potential changes in emissions concentrations or to investigate potential human health impacts. Beyond air quality assessments, this analysis can also help identify constraints or other emission mitigation strategies that could be explored in future modeling.

Background

As estimated in *BT16* volume 1, 800 million dry tons or 1.2 billion dry tons of biomass are potentially available annually by 2040 at $60 per dry ton or less,[4] under base-case (BC1) and high-yield (HH3) scenarios,[5] respectively. Scenarios from 2017 and 2040 were selected to examine potential impacts of a large increase in biomass production with an emphasis on cellulosic biomass in the future, as well as effects of increasing biomass yield. From the forestry assessment, the baseline and high housing—high wood energy scenarios were selected.[6]

The GHG emissions and fossil energy consumption associated with producing the potential biomass supply in the *BT16* scenarios include emissions and energy consumption from biomass production, harvest/collection, transport, and preprocessing activities to the reactor throat. Emissions associated with energy, fertilizers, and agricultural chemicals that are consumed in biomass production are also included. Energy consumption and emissions for biomass logistics are considered only for biomass with delivered costs below $100 per dry ton. The analysis also considers the contribution of changes in SOC to GHG emissions as a result of producing agricultural biomass. Changes in forestry soil carbon are not included because the land area in forestry stayed constant, and no major forestry land management changes were considered. However, a review of potential impacts of using forest biomass as a bioenergy feedstock on soil carbon is discussed.

It is important to note that the analysis for *BT16* stops at the reactor throat and therefore does not analyze the potential GHG benefit of using biomass feedstocks for fuel, power, or chemicals. *BT16* volume 2 chapter 4 describes an analysis completed by Rogers et al. (2016) to estimate potential life-cycle GHG reductions of biobased fuel, power, and chemicals compared to fossil-derived fuel, power, and chemicals.[7]

The non-GHG air pollutant emissions analysis developed county-level emission inventories for seven regulated air pollutants for the three biomass supply scenarios (agriculture combined with forestry). These inventories consider emissions from field preparation through harvest, including chemical application and on-farm (or on-forest) transportation, along with transportation and preprocessing for a selected portion of feedstock to the biorefinery. Upstream air emissions (e.g., emissions associated with fertilizer production) and air emissions avoided by displacing other products or fuels with biomass-derived products or fuels are beyond the scope of this study.

Further details on the approaches taken can be found in *BT16* volume 2 chapters 4 and 9.

4 This price is at farmgate or roadside, marginal cost. In GHG-emissions analyses and air-emissions analyses, supplies delivered to the biorefinery (up to a price of $100 per dry ton at the reactor throat) are included.

5 Base case refers to a 1% annual yield increase. High yield refers to a 3% annual yield increase.

6 The baseline scenario (ML) assumes moderate housing and low wood energy demand. The high housing–high wood energy scenario (HH) assumes a high demand for housing. In the forestry assessment, biomass availability decreases from 2017 to 2040. Furthermore, biomass is lower in the HH 2040 scenario than in the ML 2040 scenario because of the high demand assumed for housing.

7 J. Rogers, B. Stokes, J. Dunn, H. Cai, M. Wu, Z. Haq, and H. Baumes, "An Assessment of the Potential Products and Economic and Environmental Impacts Resulting from a Billion Ton Bioeconomy," *Biofuels, Bioproducts & Biorefining* 11, no. 1 (2017): 110–128, doi:10.1002/bbb.1728.

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