The Climate Benefits of Producing Bioethanol from Shrub Willow in New York State

KEY POINTS

1. ESF Researchers used life cycle assessment to determine the Greenhouse Gas (GHG) emissions of using shrub willow grown in New York as a feedstock to produce bioethanol to power flex fuel vehicles.

2. Doing so produces ***negative*** GHG emissions. In other words, more carbon is sequestered (or stored) than is emitted into the atmosphere.

3. On average, for every 1 megajoule of energy contained in the bioethanol, approximately 0.01 kg of CO_2eq (0.80 kg of CO_2 per gallon) was sequestered. While this amount may seem insignificant, it is critically important for addressing climate change. Gasoline emits 0.09 kg CO_2/MJ which increases GHG levels in the atmosphere. Using shrub willow to produce bioethanol would decrease GHG emissions into the atmosphere.

4. In addition to producing bioethanol, growing willow and converting it to bioethanol will create jobs, enhance biodiversity, and improve soil and water quality.

ESF
State University of New York College of
Environmental Science and Forestry

CALCULATING THE GREENHOUSE GAS EMISSIONS OF PRODUCING BIOETHANOL FROM SHRUB WILLOW

- ESF Researchers used life cycle assessment (LCA) to determine the Greenhouse Gas (GHG) emissions from shrub willow [hereinafter referred to as willow] grown in NYS to produce bioethanol for flex fuel vehicles.
- Willow crops, which can be used as a feedstock for bio-based products such as bioethanol, grow rapidly above and below ground and provide 7 harvests during their 23-year life cycle (Figure 1). There are more than 1,200 acres of willow crops in Upstate New York that provided data for this analysis. An additional 460,000 acres in a 5-county area that were identified as suitable for willow production were included in this analysis.
- To convert the willow to bioethanol, researchers used a hot water extraction (HWE) method that has been studied at ESF for more than a decade and tested at pilot-scale.
  - HWE is a process where wood chips are heated in water for a few hours. The resulting solution contains (1) sugars and other valuable chemicals and (2) wood chips that can be used to generate energy (as was modeled in this situation) or used to make other products such as water-resistant pellets.
  - Importantly, HWE requires no harsh chemicals to create the sugars need for fermentation to make bioethanol.
- Researchers used LCA to understand the GHG impacts associated with this process.
  - The LCA determined all of the GHGs emitted and stored in this entire process, from growing the willow in a nursery, to harvesting it seven times, and then converting it to bioethanol.

Figure 1. These four-year old willow in northern NY were harvested after the photo was taken and regrew to this height 3 years later (when they were harvested again).

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KEY DISCOVERIES AND POTENTIAL IMPACTS

Using willow grown in NY to produce bioethanol to power flex fuel vehicles produced negative GHG emissions.

- In other words, more carbon was sequestered (or stored) in the soil than was emitted.
- Specifically, for every 1 megajoule of energy contained in the bioethanol, on average 0.01 kg of CO_2eq was sequestered in the soil [this is written as 0.01 kg CO_2eq MJ^{-1} – note the negative sign indicates sequestration]. In other words, on average every gallon of bioethanol produced using willow will store 0.80 kg of CO_2 in the soil.
- While sequestering -0.01 kg of CO_2eq may seem insignificant, it is critically important in terms of climate change. Gasoline emits 0.09 kg CO_2/MJ, which increases GHG levels in the atmosphere. Using willow decreases GHG emissions.
- Using willow grown in NY to produce bioethanol for flex fuel vehicles on average reduces GHGs by 110% compared to gasoline.

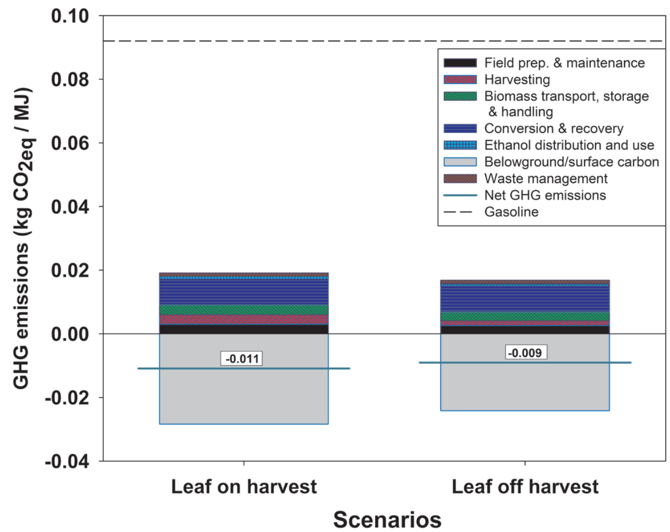

Figure 2. Life cycle GHG emissions using willow grown in NY to produce bioethanol to power flex fuel vehicles. (1) Rectangles below the zero x-axis indicate processes sequestering GHGs; Rectangles above zero x-axis indicate processes emitting GHGs into the atmosphere. (2) The negative values indicated by the green line depict net GHG emissions based on LCA. (3) The life cycle GHG emissions of gasoline is depicted by the dashed line.

- Although these results are based on analysis of NY-based willow, similar results are likely for willow grown in other northeastern and midwestern states and processed in an HWE-based facility located a reasonable distance from those crops (i.e., 25 miles).

The sequestration (or storage) of carbon in willow stumps, coarse roots, and in the soil were the main factors that enabled the willow to bioethanol (via HWE) process to sequester more carbon than was emitted.

Results varied depending on whether willow was harvested in summer (-0.011 kg CO_2eqMJ^{-1}) or winter (-0.009kgCO_2eqMJ^{-1}) (Fig. 2). These differences are attributed in part to (1) summer harvests having higher rates of fuel consumption, (2) higher rates of decomposition of willow chips stored in the summer, and (3) more carbon sequestered in the roots are attributed to each MJ ethanol produced from summer harvested biomass.

In addition to producing bioethanol that reduces GHG levels in the atmosphere, growing willow and converting it to bioethanol will create jobs, enhance biodiversity, and improve soil and water quality.

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