Comparative Life Cycle Analysis of Fossil and Bio-based PET Bottles

Luyi Chen, Rylie E.O. Pelton, and Timothy M. Smith

NorthStar Initiative for Sustainable Enterprise | Institute on the Environment | University of Minnesota

University of Minnesota

Driven to Discover℠

SWST — Society of Wood Science and Technology

Introduction

Both biofuels and bio-plastics are often regarded as sustainable solutions to current environmental problems such as climate change, fossil depletion and fine particulates emissions. However, both have been criticized for being economically costly, competing with other societally beneficial goods such as food, and offering limited environmental benefits compared to their fossil counterparts. Biorefinery, proposed as a sustainable alternative to fossil refinery, provides the possibility of lowering production costs by producing and selling value-added co-products. This study provides a comparative environmental life cycle analysis for patially and fully fossil or bio-based PET bottles. Results showed that with consideration of displacement credits, some fully bio-based PET bottles have overall better environmental performance than any other scenarios. Results were found to be sensitive to data quality and allocation method. The study served as a building block for comprehensive analysis of optimized biorefineries.

System Boundary

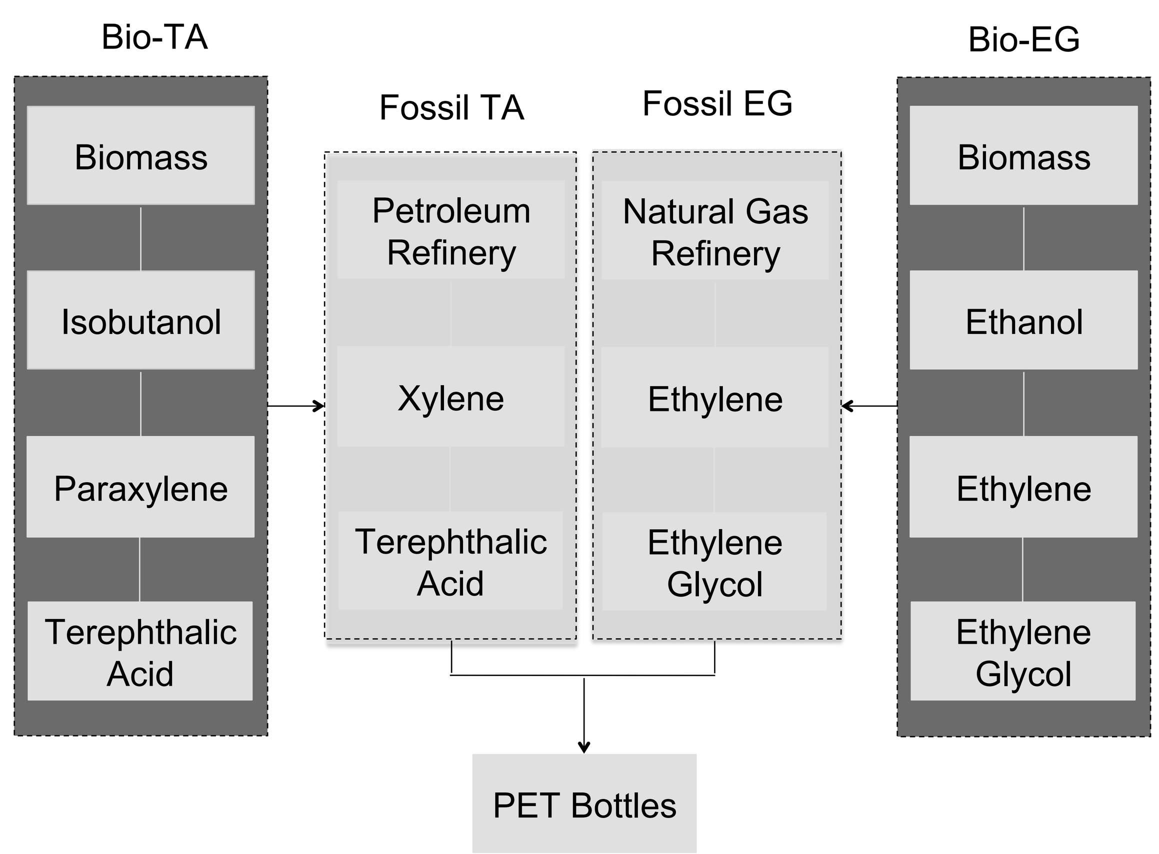


Figure 1. System boundary and life cycles for fossil and bio-PET bottles.

Goals of the Study

- Calculate and compare life cycle Climate Change (GWP), Human Health Particulates and Fossil Resource Depletion of different PET bottle production scenarios.
- Evaluate sensitivity of results on weak points
- Provide preliminary environmental profile for future biorefinery optimization

Methods

- **Attributional** Life Cycle Assessment (LCA)
  - **Cradle-to-Factory Gate** LCA
  - **Functional Unit -** 1 kg PET bottles leaving the factory gate
  - **Scenarios -** Terephthalic Acid made from fossil, forest residues or corn stover vs. Ethylene Glycol made from fossil, corn, switchgrass and wheat straw
- **Avoid allocation** of impacts specified by ISO and US EPA
  - Slash pile burning (avoided by utilizing forest residues)
  - Electricity (avoided by selling excess energy to power company)
  - Co-products (avoided by providing corn grain, soybean meal and urea from corn dry mill)

Results

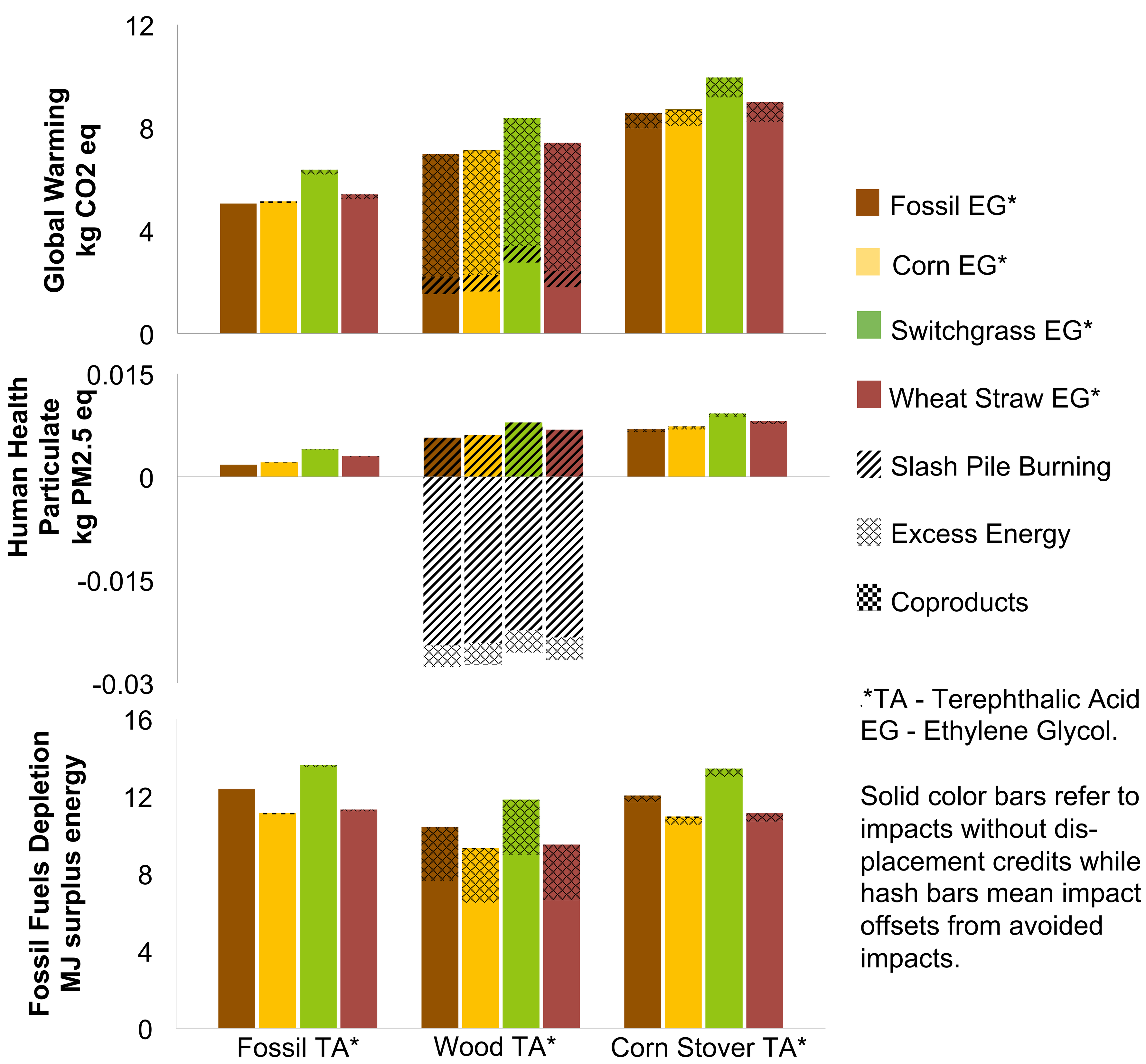
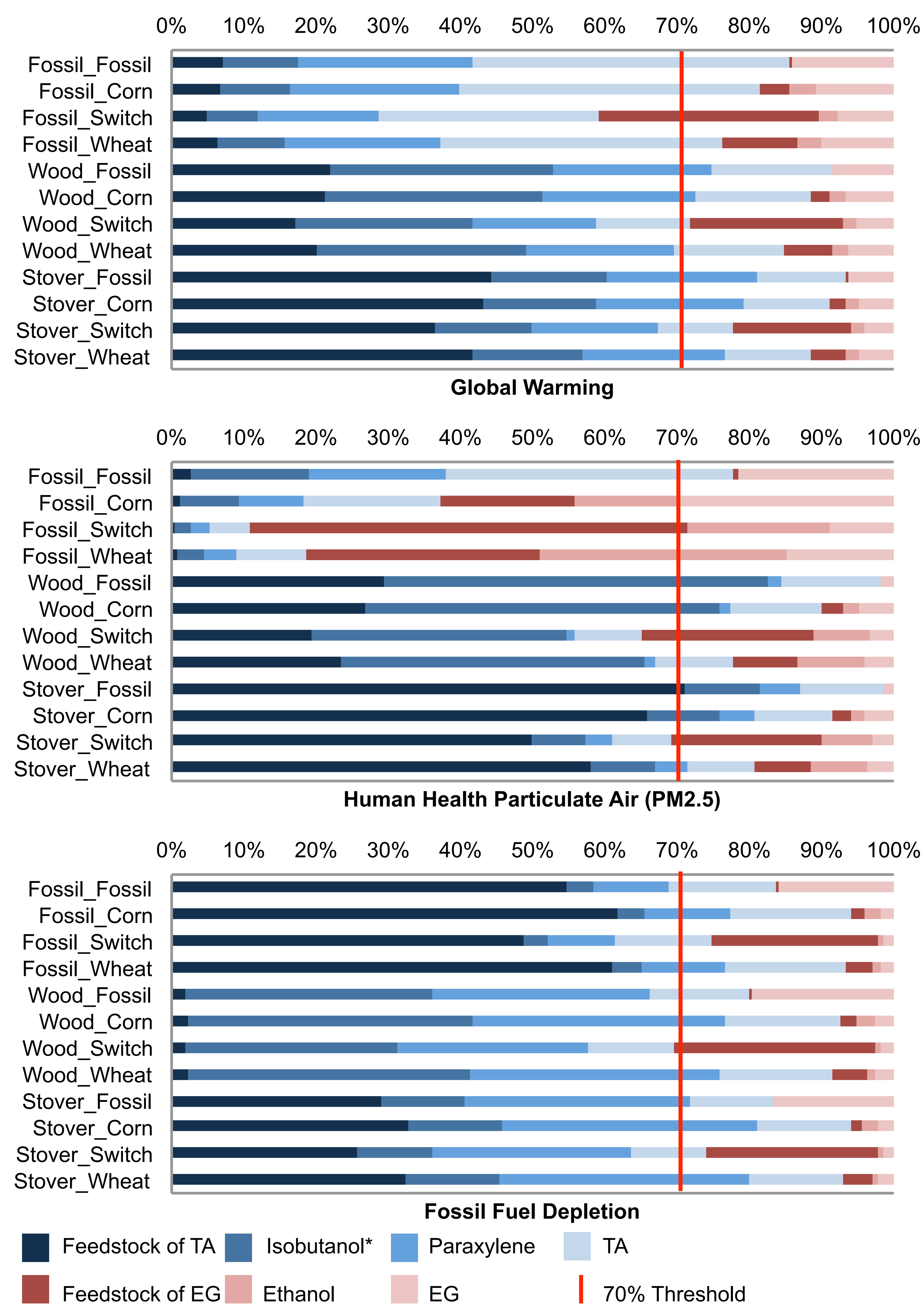


Figure 2. Comparison of GWP, Particulates and Fossil Fuel Depletion of different PET bottle production scenarios



Different scenarios are labeled as 'Feedstock pf TA_Feedstock of EG' at the vertical axis.
*For fossil TA, paraxylene was processed from a series of petroleum refinery co-products so the isobutanol blocks for Fossil TA actually indicated impacts of fossil refinery co-products.

Figure 3. Unit Process Impacts of Different PET bottle production scenarios

Table 1. Sensitivity Analysis of Uncertainty on Paraxylene Production, Slash Pile Burning and Electricity

Weak Point	Paraxylene Process			Slash Pile Burning			Excess Electricity		
% of Estimated Value*	45%	70%	110%	45%	70%	110%	45%	70%	110%
Global Warming Potential**	-43%	-23%	+8%	+23%	+12%	-4%	+171%	+93%	-31%
Human Health Particulate**	-0.33%	-0.18%	+0.06 %	+74%	+41%	-14%	+6%	+3%	-1%
Fossil Fuel Depletion**	-19%	-10%	+3%	NA	NA	NA	+20%	+11%	-4%

*Percentage changes were imposed on estimated value of impacts for a specific process or avoided impacts
**Percentage changes were calculated based on impacts of wood terephthalic acid + fossil ethylene glycol PET bottle scenario.

Conclusions and Future Work

If avoided impacts were considered, woody-biomass based 100% bio-PET bottles had significantly better environmental over other bottles. However, sensitivity analysis indicated that conclusion suffered from uncertainties especially on avoided impacts of excess electricity and slash pile burning as well as inputs on paraxylene conversion process. Unit process results implied that although bio-based PET bottle do not extract fossil resources as raw material, harvesting crop biomass and collecting forest residues biomass processing consume a lot of fossil energy, as well as the biomass conversion process. Future research should focus on: 1) Improving availability and reliability of LCI data; 2) Developing more detailed avoided impacts scenarios; 3) Optimizing biorefinery process; 4) Incorporating economical analysis to deliver a more robust and comprehensive sustainable portfolio of PET bottle biorefinery.

NARA — Northwest Advanced Renewables Alliance

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