Greenhouse Gas Mitigation Benefits of Expanding U.S. Biofuel Incentives to Promote Bio-Ethylene Production

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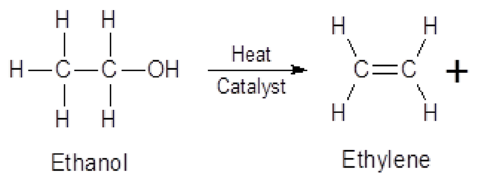
BACKGROUND & MOTIVATION

CHEMICALS

• Bulk chemical production is responsible for ~5% of both U.S. greenhouse gas emissions and primary energy consumption.

• Long term sustainability goals will eventually require a transition to renewable chemical feedstocks. What will be the greenhouse gas (GHG) impacts of such a transition?

• Ethylene is a critical building block in the chemical industry and the world's highest volume organic chemical. It can be made biologically through the dehydration of ethanol:



BIOFUELS

• The U.S. renewable fuel standard (RFS2) requires increasing quantities of biofuel to be brought to market through 2022. Its narrow scope (transportation sector) is a missed opportunity to spur innovation in wider range of uses for biomass.

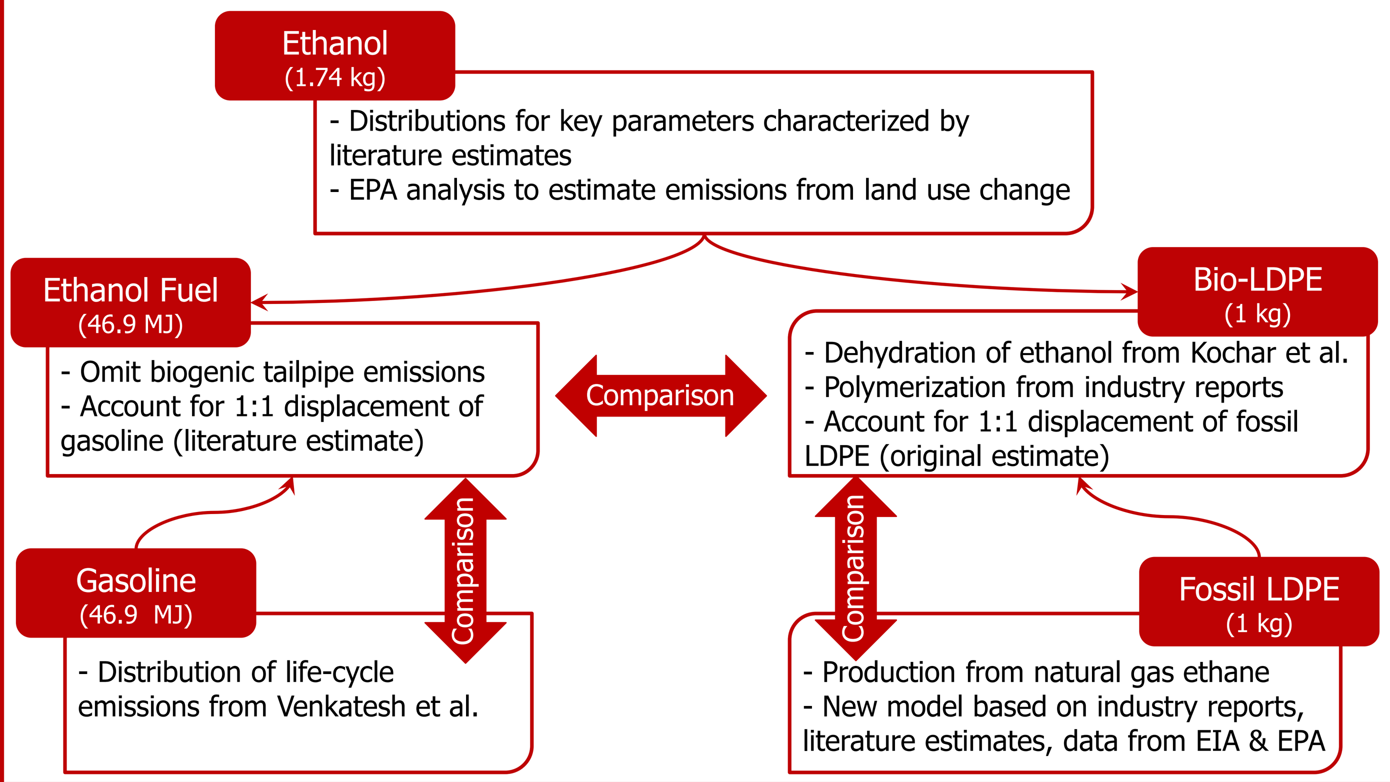
• Due to demand-side market limitations (e.g. the 'blend wall'), target volumes for RFS2 are being scaled back starting in 2014. Additional demand could be created by expanding of the RFS2 mandate to allow credits for chemical use of bio-ethanol.

• **Can RFS2 credits be granted to bio-ethylene without compromising GHG reduction targets? If so, which use of biomass offers greater GHG mitigation benefits?**

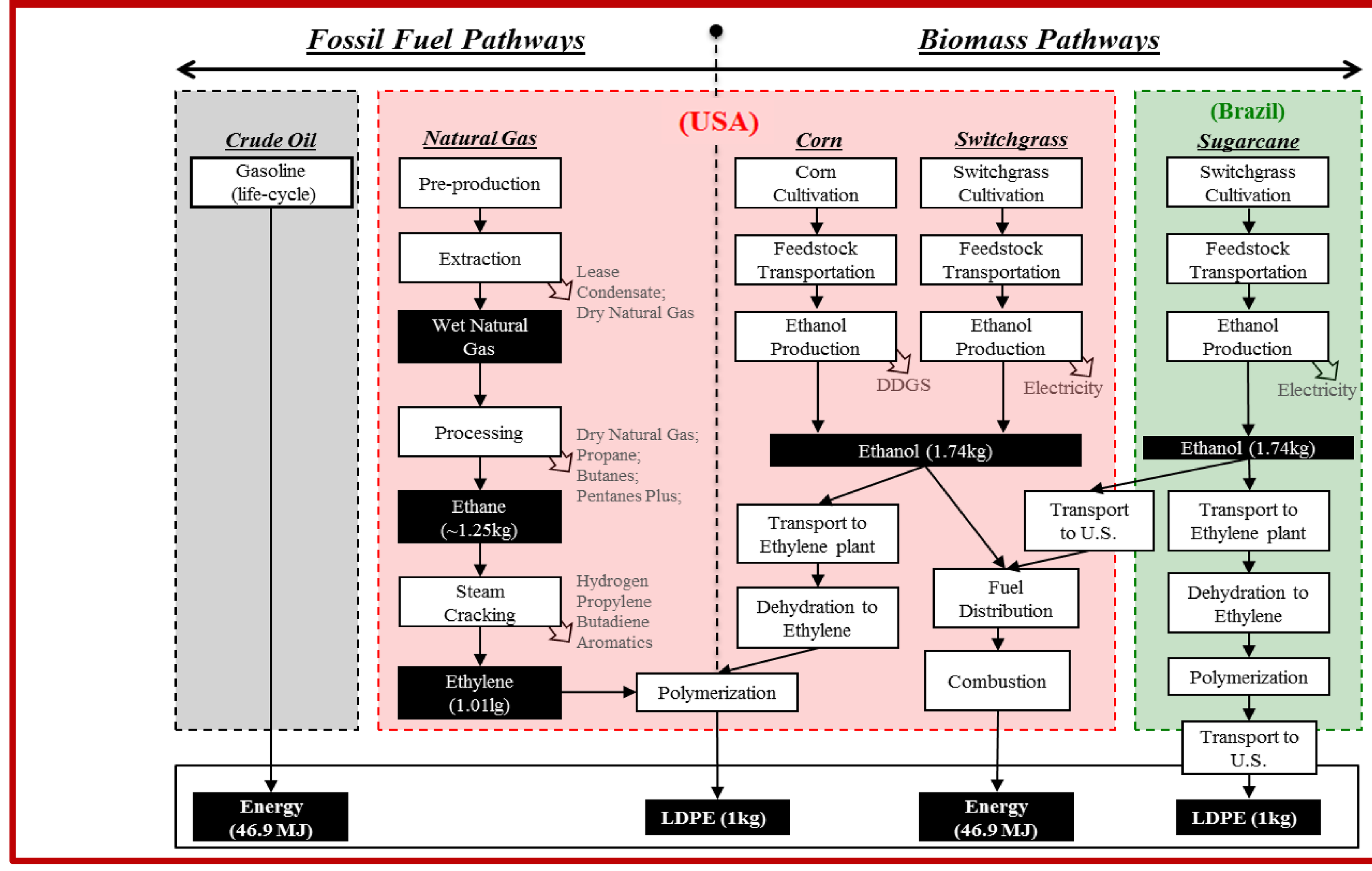
DATA & METHOD

• Low density polyethylene (LDPE) chosen as specific chemical product for study

• **Life-cycle GHG emissions** of fossil-LDPE, bio-LDPE, gasoline and bio-ethanol fuel are quantified and appropriate comparisons are drawn. Uncertainty is characterized by **Monte Carlo simulation.**

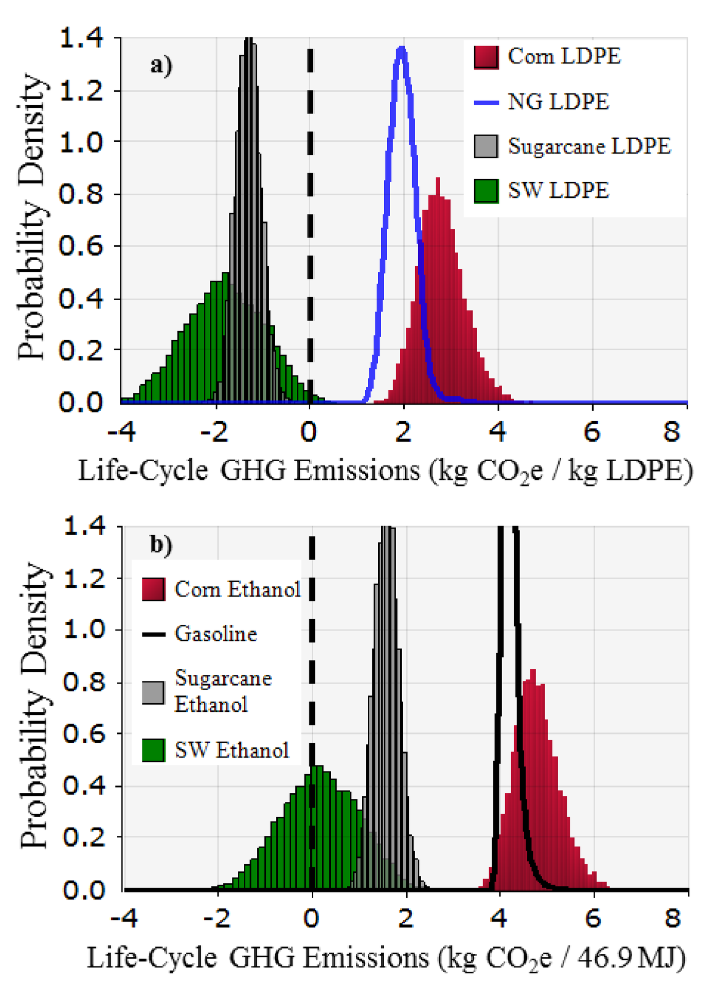


MODEL OVERVIEW



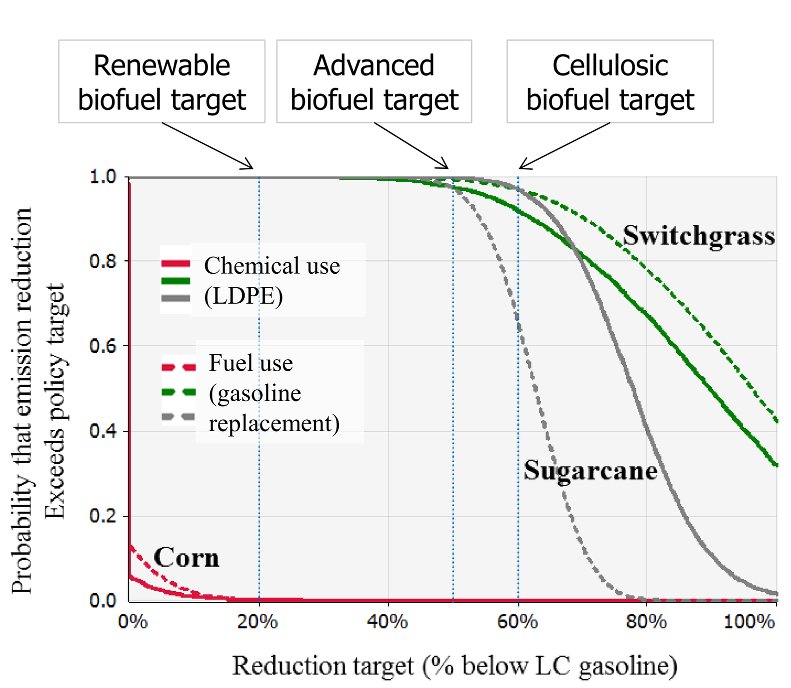
RESULTS

Probability density of emissions from considered pathways: (functional unit scaled to equivalent volumes of ethanol)



Switchgrass and Sugarcane LDPE achieve net CO_2 sequestration

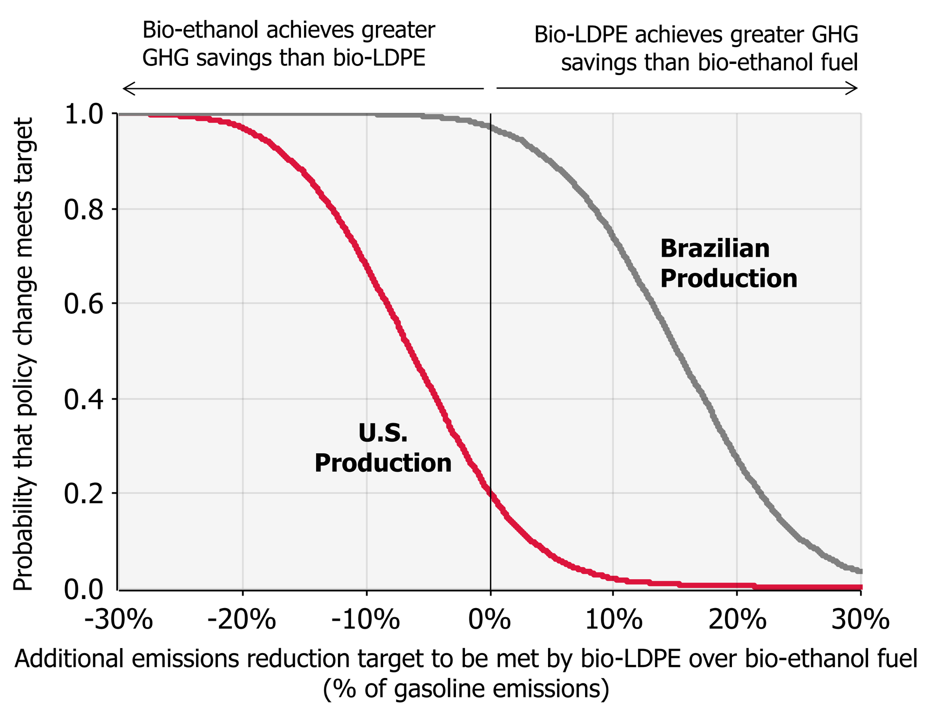
Probability for each bio-based pathway to meet GHG reduction targets in function of target stringency:



$$\frac{\text{Fossil LDPE} - \text{bio-LDPE}}{\text{Gasoline}} \qquad \frac{\text{Gasoline} - \text{bio-ethanol}}{\text{Gasoline}}$$

- **Choice of feedstock is more important than choice of product**
- **Switchgrass and Sugarcane Products can meet RFS2 targets. Corn products can't.**

GHG savings from bio-LDPE relative to bio-ethanol as a percent of gasoline life cycle emissions:



$$\frac{(\text{Fossil LDPE} - \text{bio-LDPE}) - (\text{Gasoline} - \text{bio-ethanol})}{\text{Gasoline}}$$

- **For U.S. Production: bio-ethanol fuel has greater GHG benefits than bio-ethylene**
- **For Brazilian production: bio-ethylene has greater GHG benefits than bio-ethanol fuel**

Table 1. Net greenhouse gas emissions from proposed bio-based pathways.

	Mean net emissions[a] (kg CO_2e / functional unit[b])	Standard Deviation	Lower 90% CI	Upper 90% CI
Corn Ethanol	0.56	0.51	-0.25	1.4
Corn LDPE	0.83	0.57	-0.07	1.8
Sugarcane Ethanol	-2.6	0.32	-3.2	-2.1
Sugarcane LDPE	-3.3	0.41	-3.9	-2.6
Switchgrass Ethanol	-4.0	0.84	-5.4	-2.7
Switchgrass LDPE	-3.8	0.89	-5.3	-2.4

[a] **Includes savings from 1:1 displacement of the relevant fossil fuel product (gasoline or fossil LDPE)**

[b] **The functional unit is scaled so that equivalent volumes of ethanol (1.74 kg) are considered for each pathway. This corresponds to 1kg of bio-LDPE or 46.9 MJ of energy from ethanol fuel.**

Table 2. Implicit carbon price for bio-ethanol and bio-ethylene (90% confidence interval, $/ton CO_2e)

	Corn	Sugarcane	Switchgrass
Bio-ethanol	N/A	(-250) – 0	0-100
Bio-ethylene	N/A	200-450	300-700

CONCLUSIONS

LONG TERM

• Switchgrass and Sugarcane LDPE offer a near-perfect GHG mitigation strategy – plastics production need not be a long term challenge for sustainability.

• Total land use from complete switch to renewable feedstocks and implications for carrying capacity to be explored in future work.

NEAR TERM

• RFS2 was designed with several goals in mind: energy security, rural support, ethanol market development and GHG mitigation. This study focuses primarily on the GHG impact; conclusions should be taken within that context.

• Corn ethanol fuel and corn LDPE both *increase* GHG emissions relative to their fossil counterparts. Incentives for corn products should remain limited or be phased out.

• Sugarcane LDPE reduces GHG emissions by *more* than sugarcane ethanol fuel; inclusion in RFS2 is recommended.

• Switchgrass LDPE can meet RFS2 targets but reduces GHG emissions by *less* than bio-ethanol fuel. RFS2 credits are recommended only in a demand-constrained environment.

• Recent low ethane prices impede the competitiveness of bio-ethylene as a GHG mitigation strategy in the near term.

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