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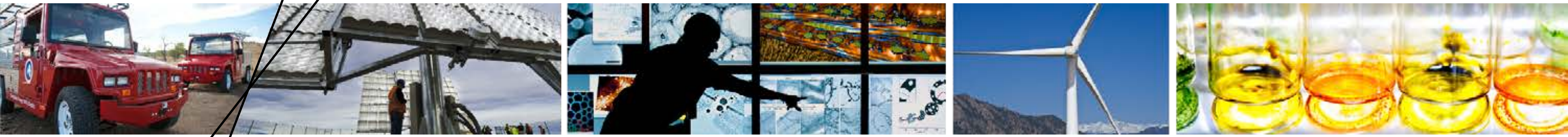
Tools for greenhouse gas (GHG) assessment for biofuels: a comparison



IEA Bioenergy Conference 2015

Helena Chum and Ethan Warner
National Renewable Energy Laboratory (NREL)
Golden, CO 80401, USA

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IEA Bioenergy
Conference 2015
Realising the world's sustainable bioenergy potential
Berlin | Germany | 27 - 29 October 2015

Overview

- **Background**
- **Qualitative summary of model differences**
- **Analysis approach**
- **Comparing GHG emissions – Corn EtOH**
  - GREET and Biograce model
  - GREET model and GHGenius model
- **Summary of insights**

Harmonization of Attributional Life Cycle Assessment (ALCA) GHG Emissions

- Explain why different GHG models give a different outcome at the request from Task 39 (John Neeft, NL member), O'Connor literature

- Request in 5/2014. Approach proposed 11/2014 (Johnson) with Task 38 and 39, reviewed 5/2015 (Goss Eng), US representatives to Task 38 as US in-kind contribution

- **Tools for GHG assessment for biofuels: a comparison**
  - IEA Bioenergy Conference (October 2015)

Corn Ethanol

	BioGrace	RFS2	GREET		GHGenius
			2012_rev2	CA-GREET	
IPCC GWP	2001	1995	2007	2007	2007
Allocation	Energy	Displacement			
	g CO_2eq/MJ (LHV)				
Total	43.4	51.21	55.22	67.56	62.06

- There is **significant variability** between the models studied.
- The **drivers of the variability are real**, with a couple of exceptions they are not model "errors".
- In some cases, the modellers have chosen **different approaches**,
  - **Average vs. marginal**
  - **Allocation**
- There are **real spatial variation** issues.
- There are **real temporal issues**.
- Data quality issues,
  - **Primary vs. secondary data**
  - **Data assumptions.**

No indirect LUC

Background

- **Policy initiatives aimed at increasing the use of bioenergy include sustainability metrics, one of which is GHG emissions**
- **ALCA is the method used to evaluate whether bioenergy meets life cycle GHG reduction criteria**
- **Multiple biofuel LCA tools exist with differing purposes, methods, and data sources, which lead to diverging GHG results**
- **To better understand LCA tools and their results we quantitatively compared three LCA tools by:**
  - Comparing model assumptions (e.g., agricultural inputs)
  - Harmonizing assumptions (where possible) to compare differences in model methods and structure.

LCA Tools Compared

- **BioGrace I Model 4c – EU**
  - Commercial Excel-based LCA model approved for refulatory compliance with EU-RED/FQD
  - Uses public input data from non-public database and model by the EU's JEC Biofuels Program

- **GHGenius Model 4-03c – Canada**
  - Public Excel-based model
  - Evaluates GHG emissions from along the transportation fuel supply chain and from soil
  - Used by Natural Resources Canada for research and policy analysis

- **GREET Model 1-2014 – USA**
  - Public Excel-based model
  - Evaluates GHG emissions from along the transportation fuel supply chain, soil, and global LUC
  - Developed for research purpose, but has become a policy tool and a tool for biofuel producers to demonstrate compliance (e.g., California)

Qualitative Summary of Model Differences

- **The quantitative analysis follows a more general LCA model comparison; relevant insights for this analysis are summarized below:**

	Data Vintage	Upstream Emissions from Materials and Equipment	Soil N_2O and Carbon Change Due to Land Use Change (LUC)	Data Aggregation (and purpose)
BioGrace I	Spreadsheet available. Uses older data (i.e., 2008 and older)	Focuses on large sources of emissions (> 0.1 g CO_2e/MJ)	Uses IPCC Tier 1 for soil N_2O and direct LUC per EU-RED	An input/output model of a pragmatic disaggregation of 2008 JEC model modified to comply with EU-RED and FQD rules
GHGenius	Commercial data is ≥ 2010. Some adv. biofuel data is older	Uses process energy inputs for materials and equipment used	Uses IPCC Tier 2 (and Tier 1 when needed) for soil N_2O and for direct LUC	Uses circular references to allow changes in one energy sector to affect other interacting energy sectors
GREET	Uses mostly recent data (i.e., ≥ 2010). Updates adv. technologies	Models how materials are manufactured and equipment is used	Uses DAYCENT Tier 3 for soil N_2O emissions and the CCLUB model for LUC, based on GTAP model	The GREET model allows greater system integration, through circular references of many energy sectors

CCLUB=Carbon Calculator for Land Use Change from Biofuels Production

IPCC Inventory of GHG and N_2O Emissions

- **An IPCC "tier" represents a level of methodological complexity.**
- **IPCC uses tiers to rate the reliability and methodological complexity of emission factors (EF) and activity data.**
- **Three tier's are described for categorizing both emissions factors and activity data.**
  - Tier 1: IPCC-recommended country-level defaults.
  - Tier 2: More detailed county specific data
  - Tier 3: Detailed modelling and/or measurement approaches
- **Most developing countries use tier 1.**

Analysis Approach

- **Problem:** LCA models differ in purpose, structure, and aggregation of data.
  - Difficult to consistently harmonize model inputs and then to understand other sources of variability between the models
- **Approach:** Harmonize **assumptions** across models to examine differences between models.
- **Assessment Scope:**
  - Modeling year - 2015
  - Geographic area - United States
  - Fuel pathway - Corn EtOH, mature industry
- **Models and default fuel pathways**
  - GREET 2014 – Average U.S., dry mill
  - GHGenius 4.03a – Canadian, natural gas dry mill
  - Biograce-I 4d – European, natural gas combined heat and power (CHP) dry mill

Limits of the Approach

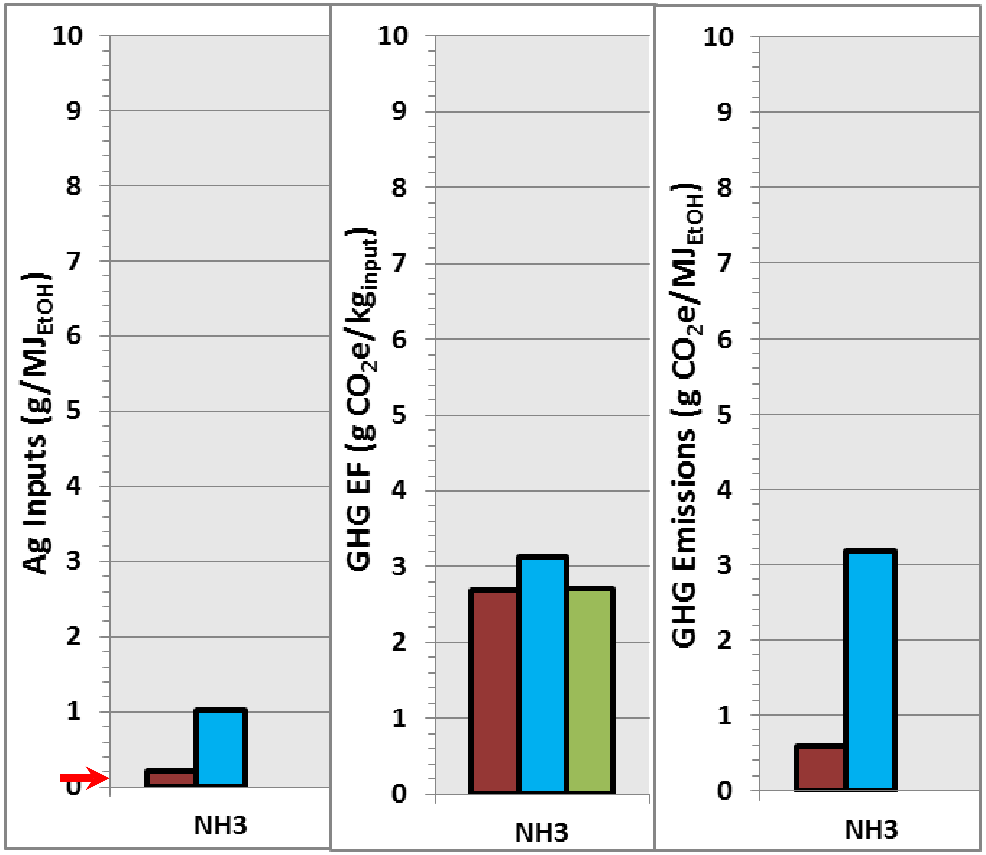
- **Some model structures were completely harmonized with results of GREET modeling:**
  - Estimation of GHG EFs and energy used in producing agricultural inputs and process chemicals
  - Field N_2O emissions
- **Other model structure was examined through scenario analysis**
  - GHG emission credits for co-product
  - Vehicle CO_2 emissions and carbon sequestration by plants
- **Model structure that was not harmonized in final results:**
  - GHG EF of **direct** energy inputs*

*Difficult to harmonize in GREET and to a lesser extent GHGenius as they are internally calculated and interdependent

Example Harmonization of Ammonia

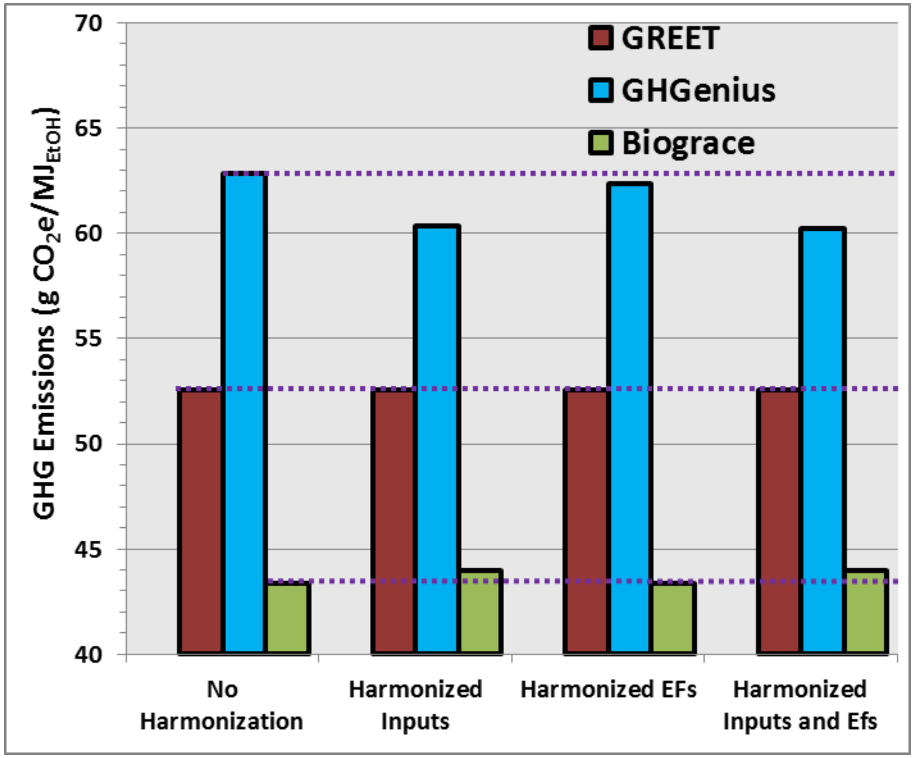
- **Ammonia is a process chemical used in corn EtOH production to control pH and feed yeast.**
- **Process chemical/material activity**
  - No inputs in Biograce: due to **cutoff rule**
  - GREET input is 20% of GHGenius
- **GHG EFs**
  - GREET and Biograce similar
  - Higher GHGenius EF

RED = GREET
BLUE = GHGenius
GREEN = Biograce



Impact of Ammonia Harmonization

- **GREET selected as the most recently published model for harmonization**
  - Not harmonizing towards a scientifically robust estimate.
- **Purple dotted line shows GHG emissions levels with “no harmonization”.**
- **Net impact on GHG emissions:**
  - GHGenius reduced by 4%
  - Biograce increased 1%

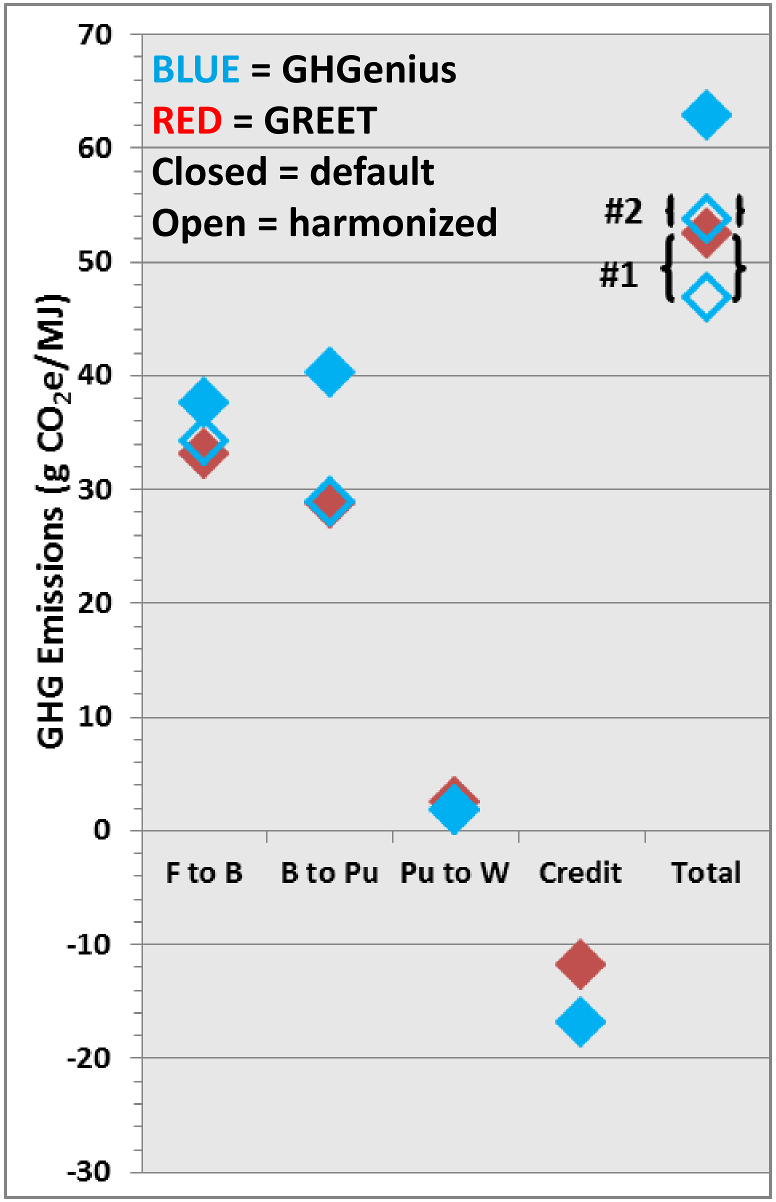


Initial Insights from Harmonization

- **GHG emission inventories for material inputs for corn production (e.g., fertilizer) and corn conversion to EtOH (e.g., enzyme production) were important.**
- **Major contributors to differences were**
  - Differences in assumptions about the mix of process inputs (e.g., no chemical/material inputs for Biograce)
  - Process data vintage
- **Most issues around data vintage are related to the age of the current version of the model and level of technology maturation**
  - Biograce is a static model for 2007/2008 (snapshot)
  - GREET is updated annually, last in October 2015
  - GHGenius last updated in 2013

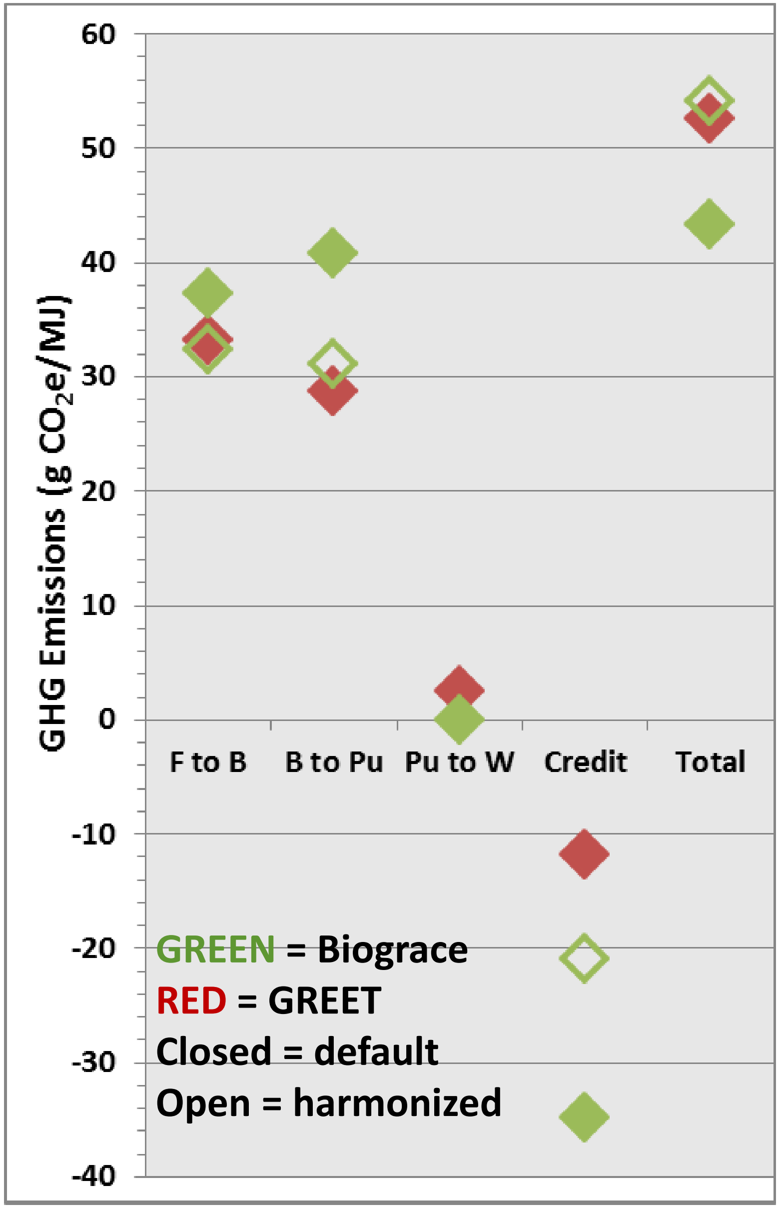
Corn EtOH – GREET and GHGenius

- **Feedstock to Biorefinery Plant (F to B)**
  - Harmonization of N_2O field emissions and fossil energy use
- **Biorefinery Plant to Pump (B to Pu)**
  - Harmonization of fuel yield and process chemical inputs
- **Pump to Wheel (Pu to W)**
  - Similar carbon neutrality, but emissions from vehicles and carbon uptake by biomass differ.
- **Co-product Credit**
  - Both use displacement, but modeling results differ
- **Total**
  - (#1) Remaining difference between models are mostly linked to co-product credits
  - (#2) After co-product harmonization the remaining difference is from fuel transportation related emissions (B to Pu)

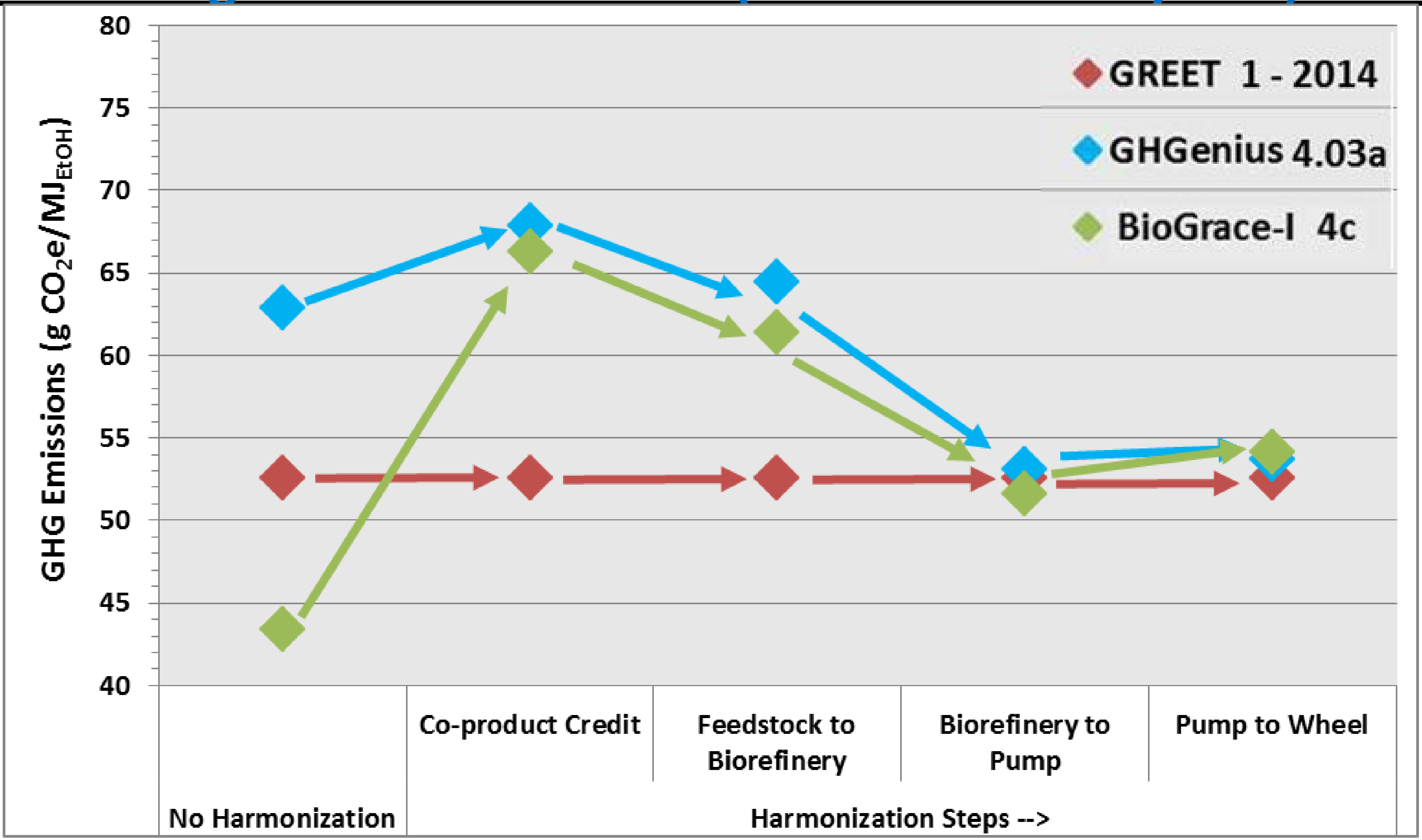


Corn EtOH – GREET and Biograce

- **Feedstock to Biorefinery Plant (F to B)**
  - Harmonization of yield, agricultural inputs, and farming fossil energy use
- **Biorefinery Plant to Pump (B to Pu)**
  - Harmonization of fuel yield, fossil energy inputs (e.g., Biograce's CHP system), and process chemicals
    - Remaining difference linked to natural gas EFs which are higher in Biograce.
- **Pump to Wheel (Pu to W)**
  - Biograce does not model Pu to W
- **Co-product Credit**
  - Biograce uses allocation rather than displacement
- **Total**
  - Harmonized Biograce results differ slightly from default Biograce results, but converge if Pu to W and the co-product credit were harmonized



Changes in life cycle supply chain* GHG emissions through harmonization** (corn ethanol dry mill)



*Feedstock production through biofuel use (no indirect LUC).

**Data quality and method integrity hasn't been assessed in this harmonization process.

Insights - Defining the Biofuel System

- **The most important differences in the LCA model's methods were built-in biofuel systems modelled (default conditions) and the flexibility to model alternative configurations of corn-to-EtOH systems.**
  - GREET model evaluates individual types of corn-to-EtOH plants in major configurations and also provides an average for the United States, commercial data is mostly recent (+2013).
  - Provides an average for a U.S. natural gas dry mill, commercial data is mostly recent (+2010).
  - Biograce is limited to the evaluation of only an EtOH biorefinery powered by a natural gas based CHP.

Insights – Modeling of the Life Cycle

- **Structural differences in how the LCA models incorporate the following are also important:**
  - N_2O field emissions and direct LUC
  - Co-product credits
  - GHG EFs and energy use of material inputs
- **Structural differences in how LCA models include fossil fuel EFs are less important.**
  - Or at least they only contribute in specific instances where direct fossil inputs are high or indirectly through GHG EFs for material inputs.

Further Research Joint with Task 39

- **Examine the impact of individual model changes in detail; CTBE's Virtual Sugarcane Biorefinery LCA**
- **Expand pathways examined**
  - Other commercial biofuels (e.g., sugarcane, wheat, vegetable oils to biodiesel)
  - Waste oil and seed oils to HVO pathway
  - Developing 1st commercial Cellulosic-based fuel pathways
- **Examine other model structural differences in greater detail:**
  - GREET and GHGenius displacement credits
  - N_2O field emissions
  - Land use and carbon sequestration
- **Other member countries will provide in-kind contributions Canada, Germany, The Netherlands**

Acknowledgments

- **Kristen Johnson, Alison Goss Eng – DOE/BETO**
    - http://www.energy.gov/eere/bioenergy/sustainability
    - http://www.energy.gov/eere/bioenergy/biomass-feedstocks
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    - http://task39.org/
- **Annette Cowie, Miguel Brandao – Task 38**
    - http://task38.org/
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- **Don O'Connor – $(S\&T)^2$ Consultants, GHGenius**
- **Michael Wang, ANL, GREET**

Methods – Harmonization Assumptions

- **Where possible we harmonized assumptions in Biograce and GHGenius to be consistent with GREET.**
- **We made consistent:***
  - GWP
  - Yields (i.e., feedstock, fuel, and co-products)
  - Field N_2O and lime CO_2 EF (emission factors)
  - Agricultural inputs (e.g., nitrogen and their GHG EFs)
  - Fuel conversion process chemicals and their GHG EFs
  - Direct fossil energy use in feedstock and fuel production
  - Physical properties (e.g., lower heating value of EtOH)
  - Transportation modes as well as their travel distances and fuel use intensity
  - Biomass losses

*In some cases, absent components of the LCA were added to Biograce (e.g., process chemicals).

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