Biofuel Life-Cycle Analysis: Possible for Standardization?

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2014 RCN Conference on Pan American Biofuels & Bioenergy Sustainability
July 22-25, 2014
Recife, Brazil

US Transportation Sector in 2013

Energy Consumption
Total Energy: 28 Trillion MJ (28% of Total US)
Petroleum: 27 Trillion MJ (72% of Total US)

CO_2 Emissions
1.8 Billion Tonnes
(34% of Total US)

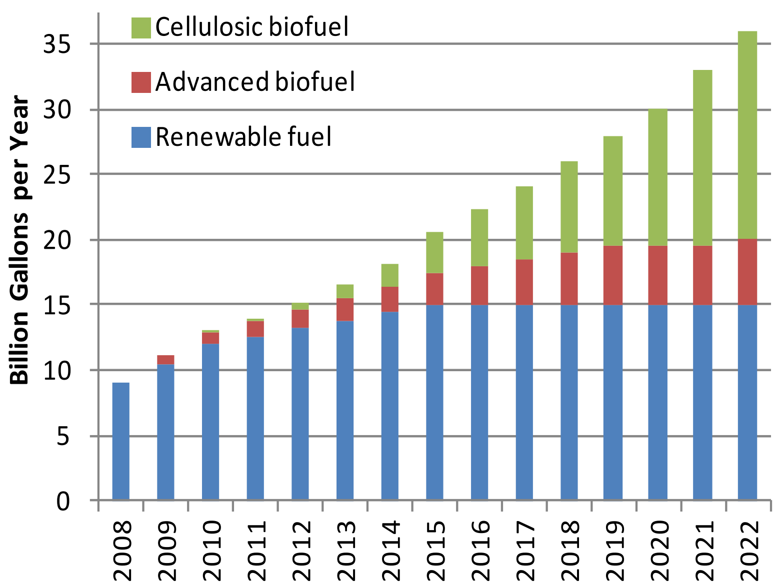
Crude Source
Domestic: 43%
Import: 57%

Source: U.S. Energy Information Administration. Annual Energy Outlook 2014 Early Release (http://www.eia.gov/forecasts/aeo/)

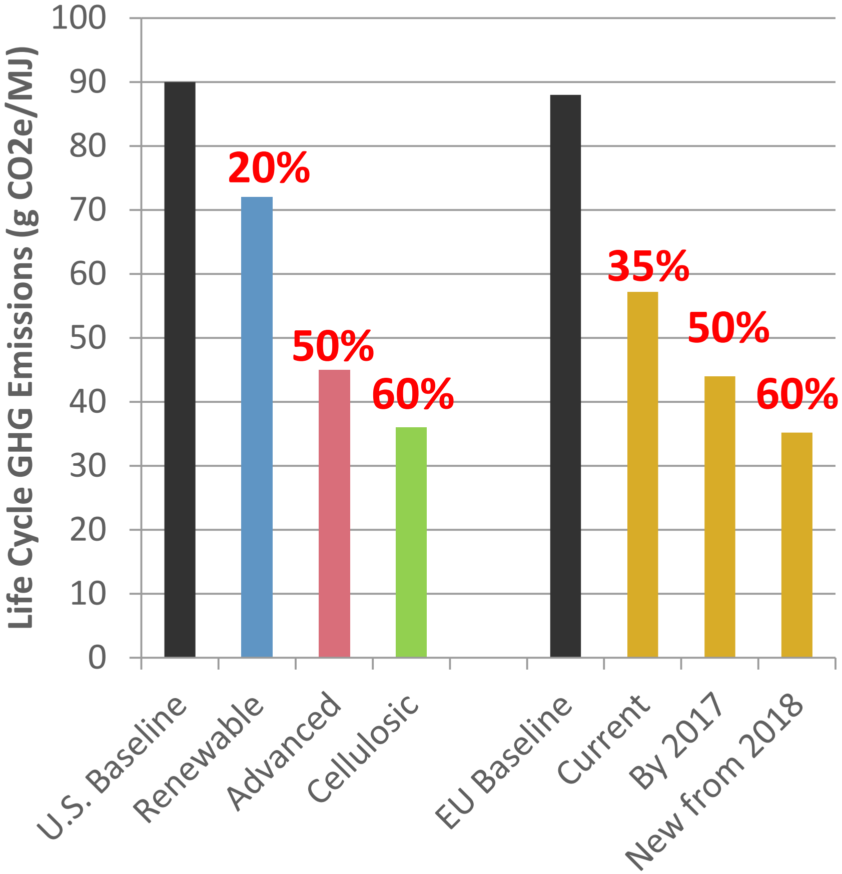
- To reduce the transportation energy consumption, Corporate Average Fuel Economy (CAFE) standard was implemented.
- However, more dramatic reductions in crude import and GHG emissions require the development of **alternative fuels**, such as natural gas-based fuels, electricity and biofuels

Life cycle Analysis (LCA) is used in US and EU policies targeting expanded use of biofuels

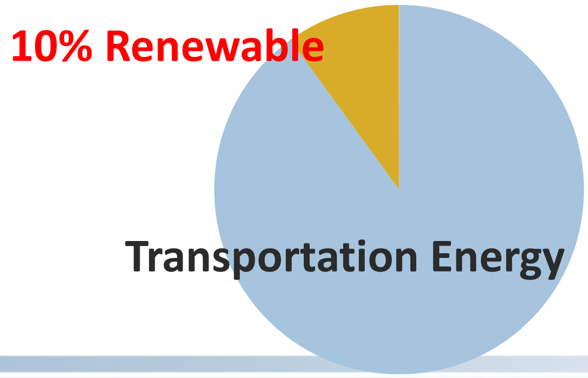
Renewable Fuel Standard (US)



Life Cycle GHG Threshold



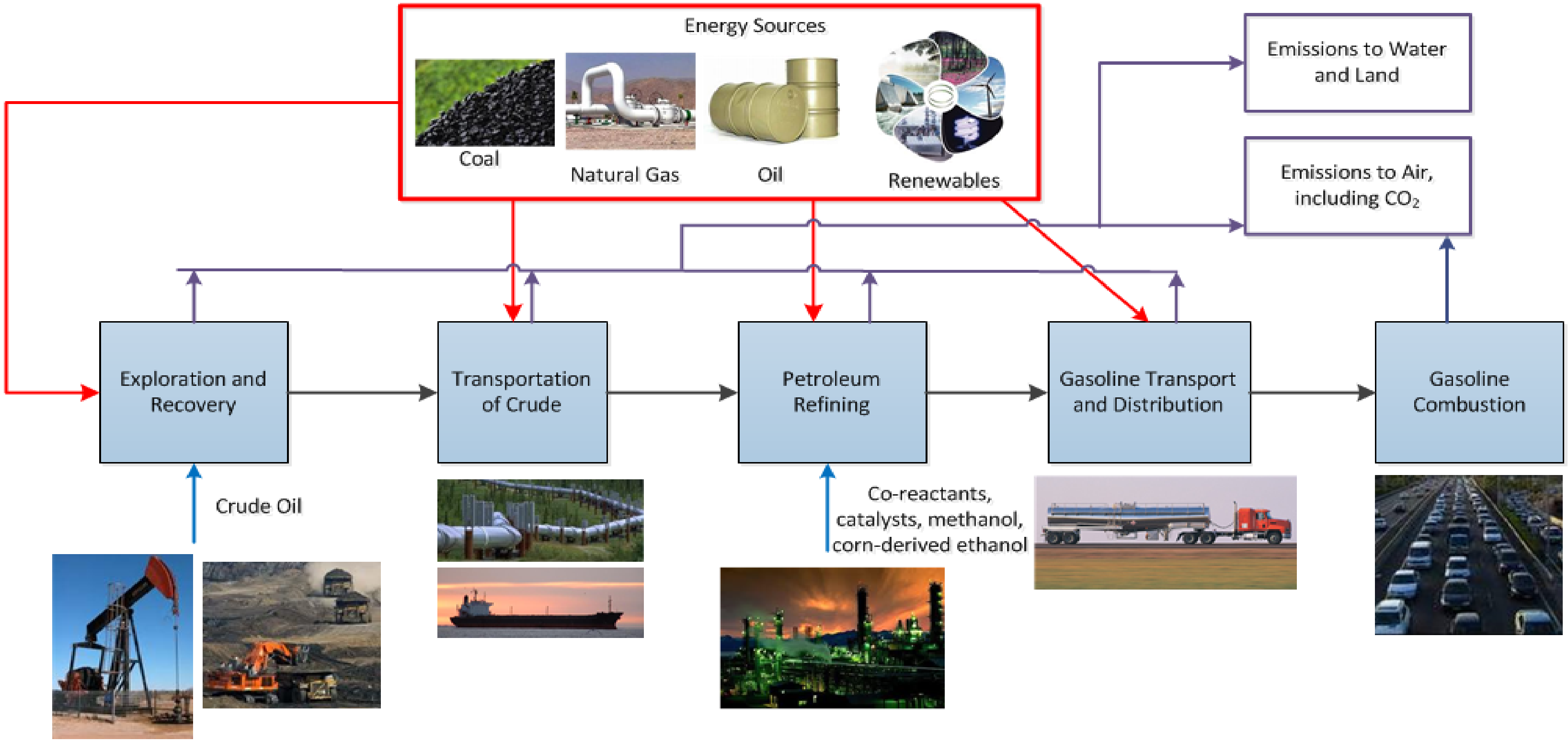
Renewable Energy Directive & Fuel Quality Directive (EU)



Under Low-Carbon Fuel Standard (LCFS) by California Air Resource Board, credit is accounted for the amount of GHG reductions (Performance-based)

Life Cycle Analysis of Transportation Fuels

- Life cycle analysis (LCA): Systematic accounting of the energy use and emissions at every stage of the production, use, disposal and recycle of a product
- Well-To-Wheel (WTW) analysis: Specific to transportation fuels
- WTW analysis takes into account the direct fuel use and its upstream energy use and associated emissions



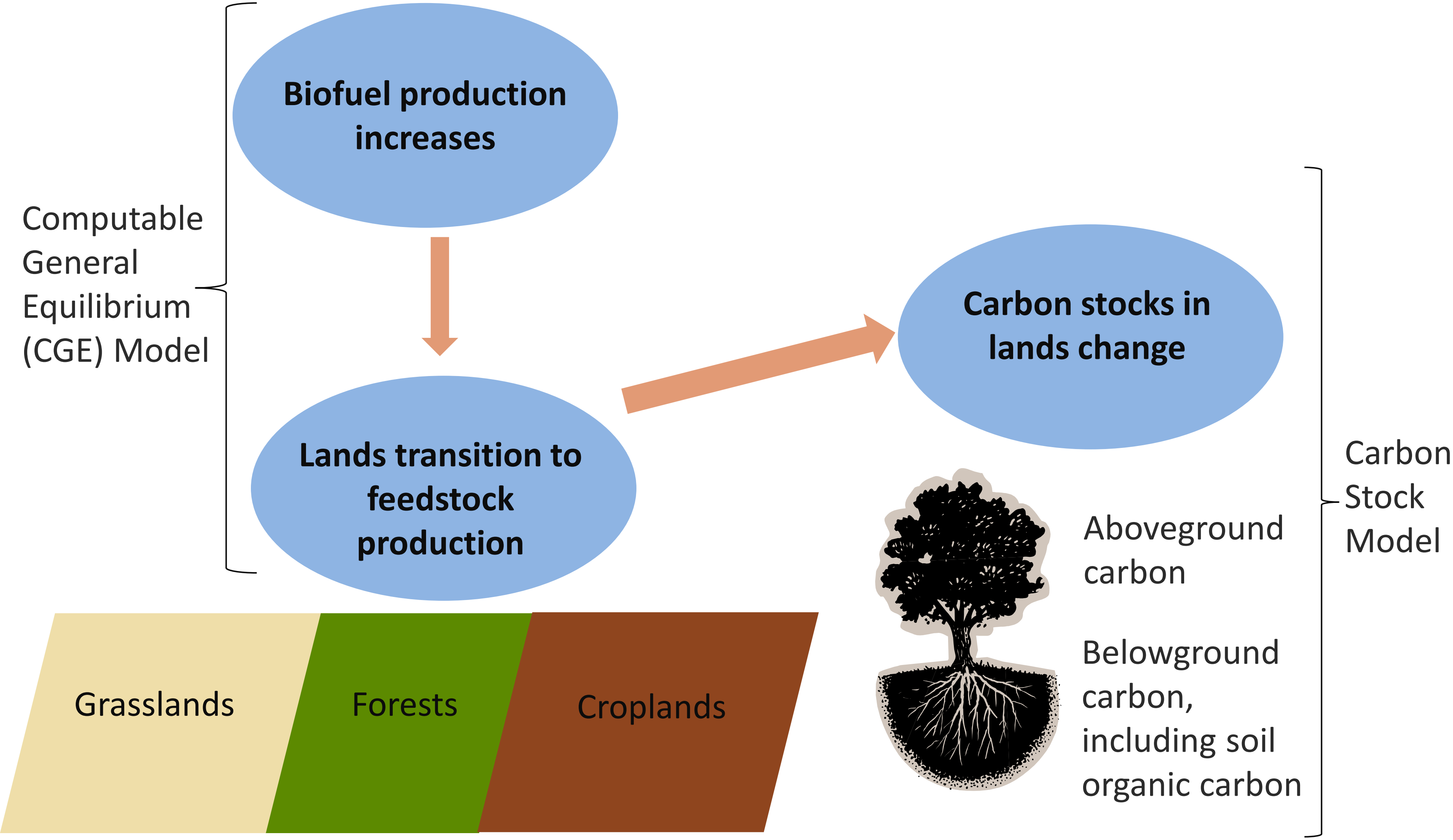
Life Cycle Analysis (LCA) Models Available Worldwide for Transportation Fuel Examination

- The GREET model at Argonne National Laboratory
  - CARB LCFS
  - One of a suite of models of EPA RFS2 (along with DAYCENT, GREET, FASOM & FAPRI-CARD)
- The lifecycle emission model (LEM) at University of California at Davis
- Canadian GHGenius model
- BioGrace database in Europe
  - EU Renewable Energy Directive (RED) and Fuel Quality Directive (FQD)
- Other generic LCA models (e.g. SimaPro and Gabi) that can be applied to examine transportation fuels and vehicle technologies
- Newly emerging consequential LCA methods based on economic interactions within a country and/or in the world

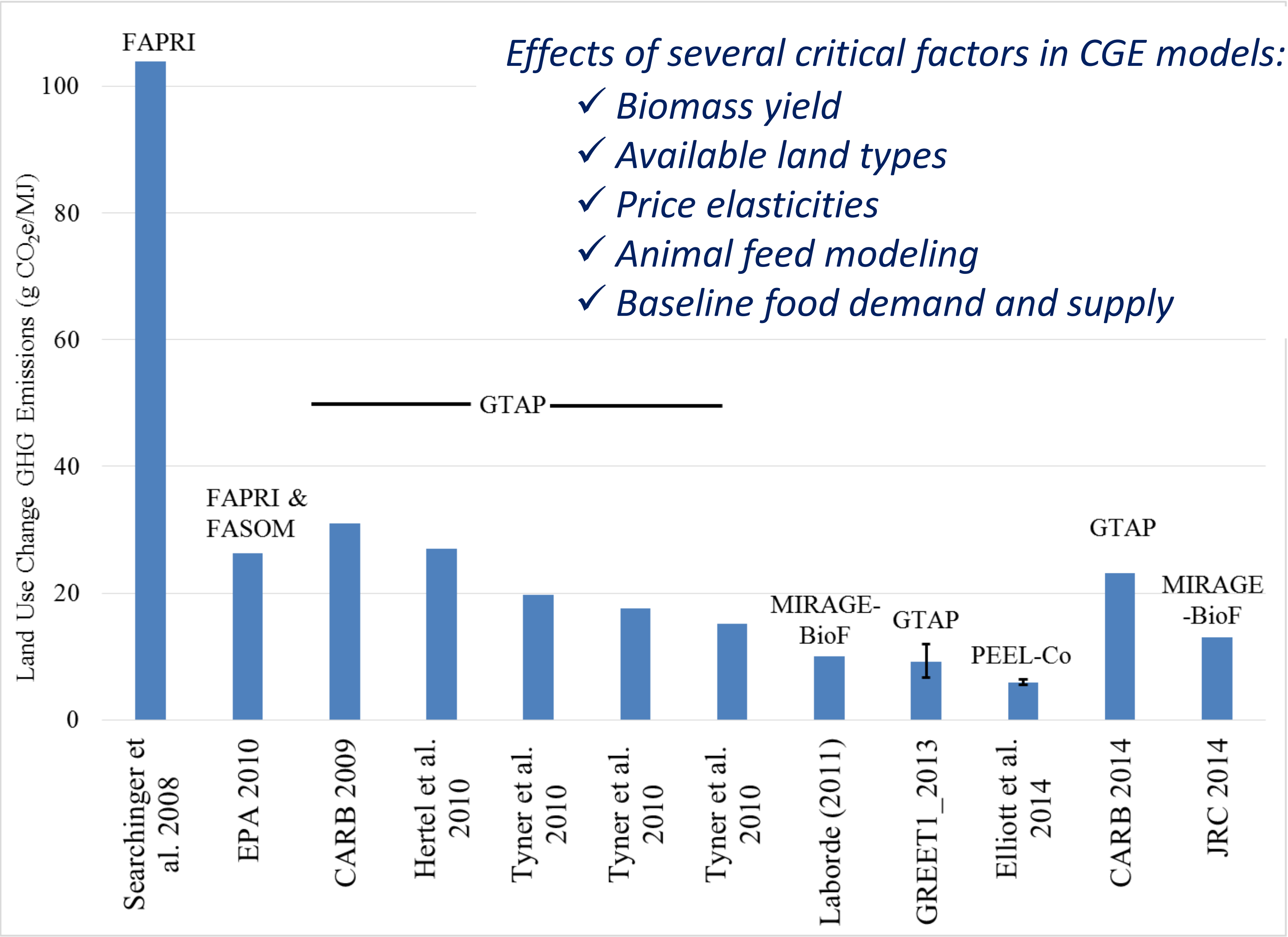
Technical Issues with LCA

- Modeling framework
  - Consequential vs. attributional
- Modeling decisions
  - System boundary definition (including land-use change)
  - Allocation methodology
- Data inputs
  - Regional/geo-spatial assumptions
  - References & databases used
  - Technology development over time
  - Sensitivity of LCA parameters and uncertainty analysis

Land-Use Change Overview



Estimates of LUC GHG emissions for the corn ethanol

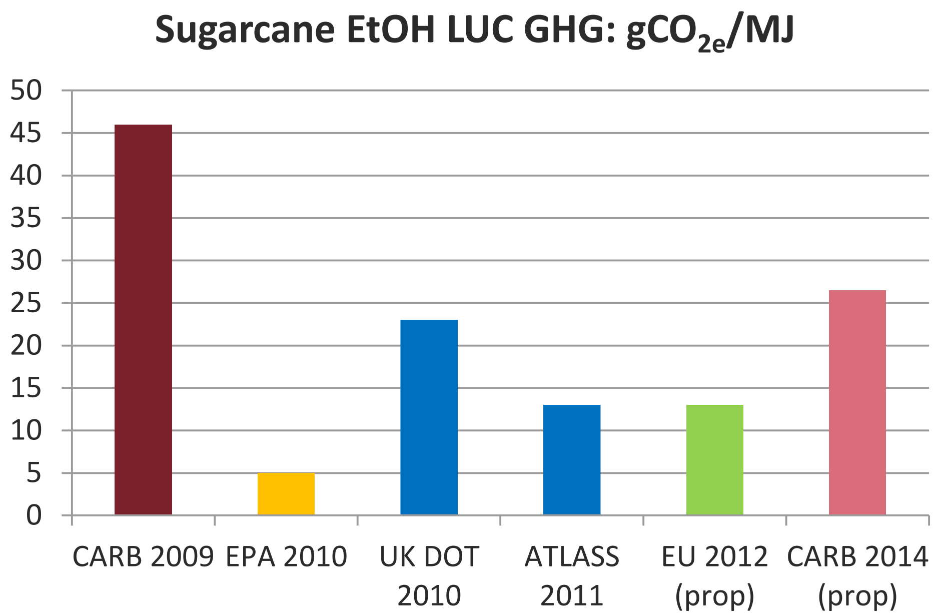


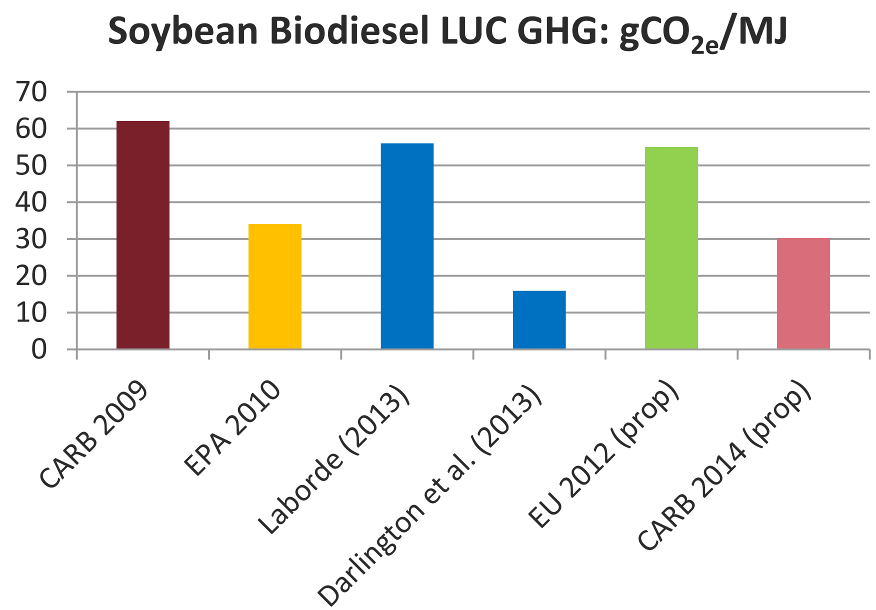
Effects of several critical factors in CGE models:

- ✓ *Biomass yield*
- ✓ *Available land types*
- ✓ *Price elasticities*
- ✓ *Animal feed modeling*
- ✓ *Baseline food demand and supply*

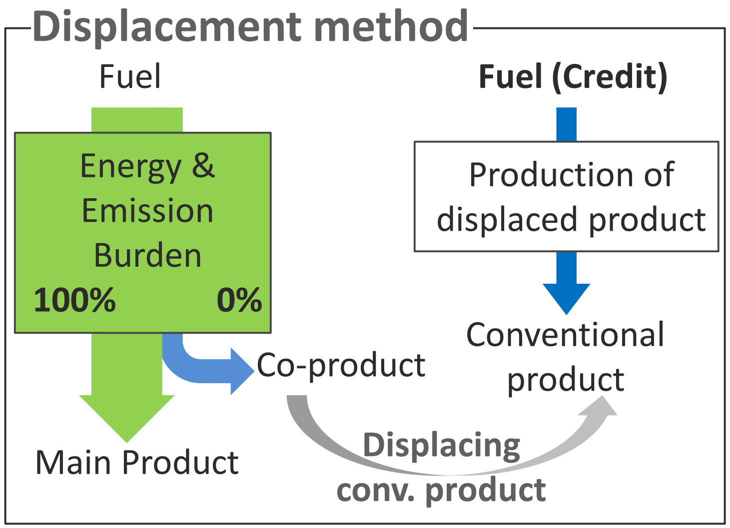
EU's proposed ILUC emissions for cereals and other starch rich crops: 12 gCO_{2e}/MJ

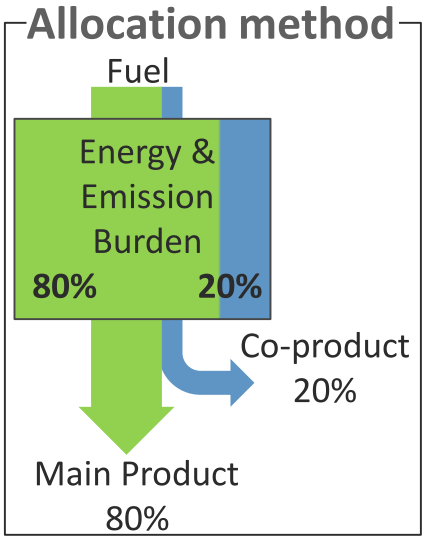
Estimates of LUC GHG emissions for sugarcane ethanol and soybean diesel



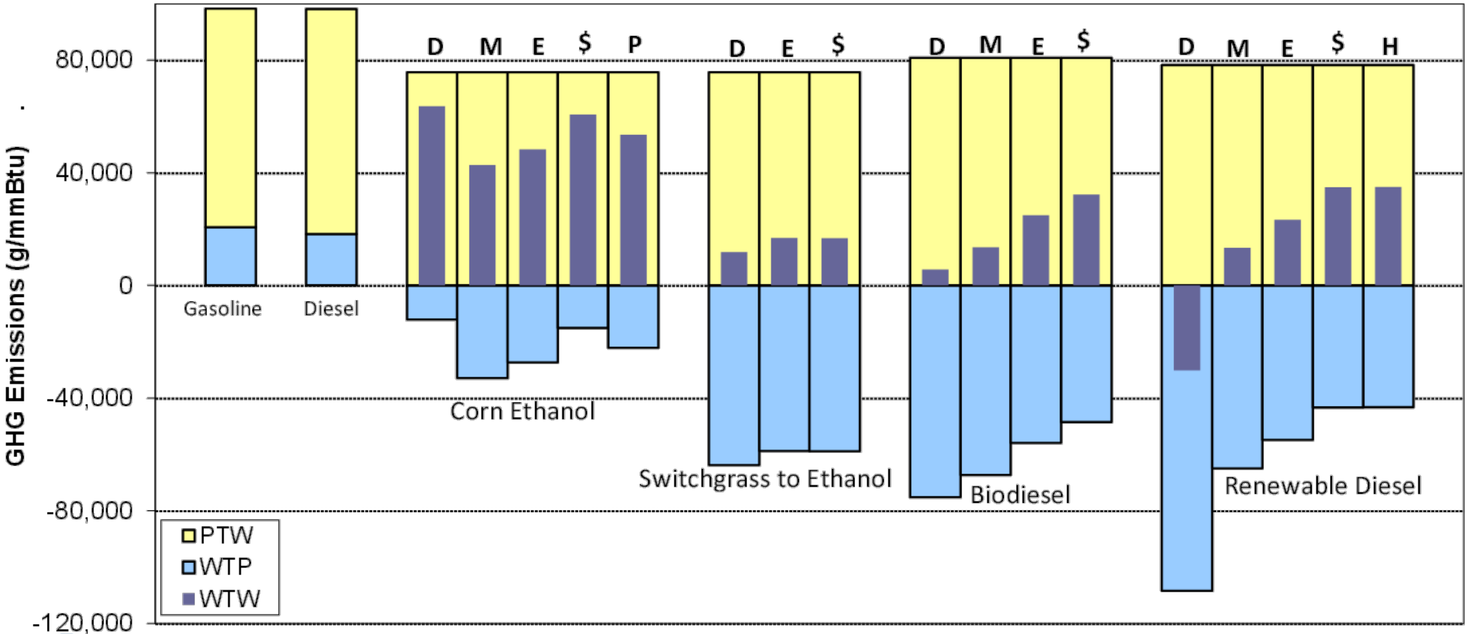


Choice of co-product methods can have significant LCA effects for biofuels



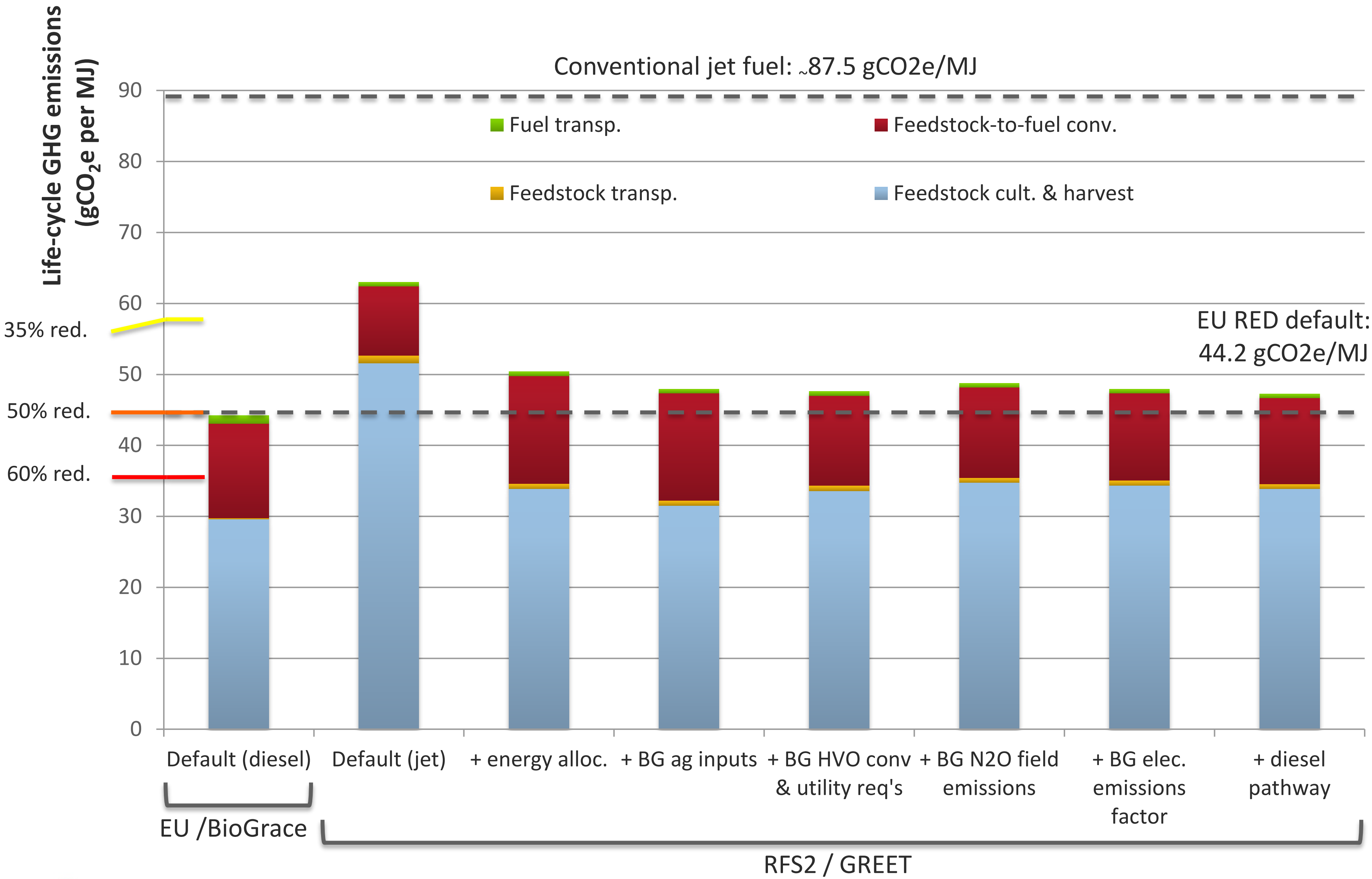


EPA generally uses displacement method while EU uses energy allocation methods



D: Displacement
M: Mass based
E: Energy Based
$: Market Value
P: Process Purpose
H: Hybrid Allocation

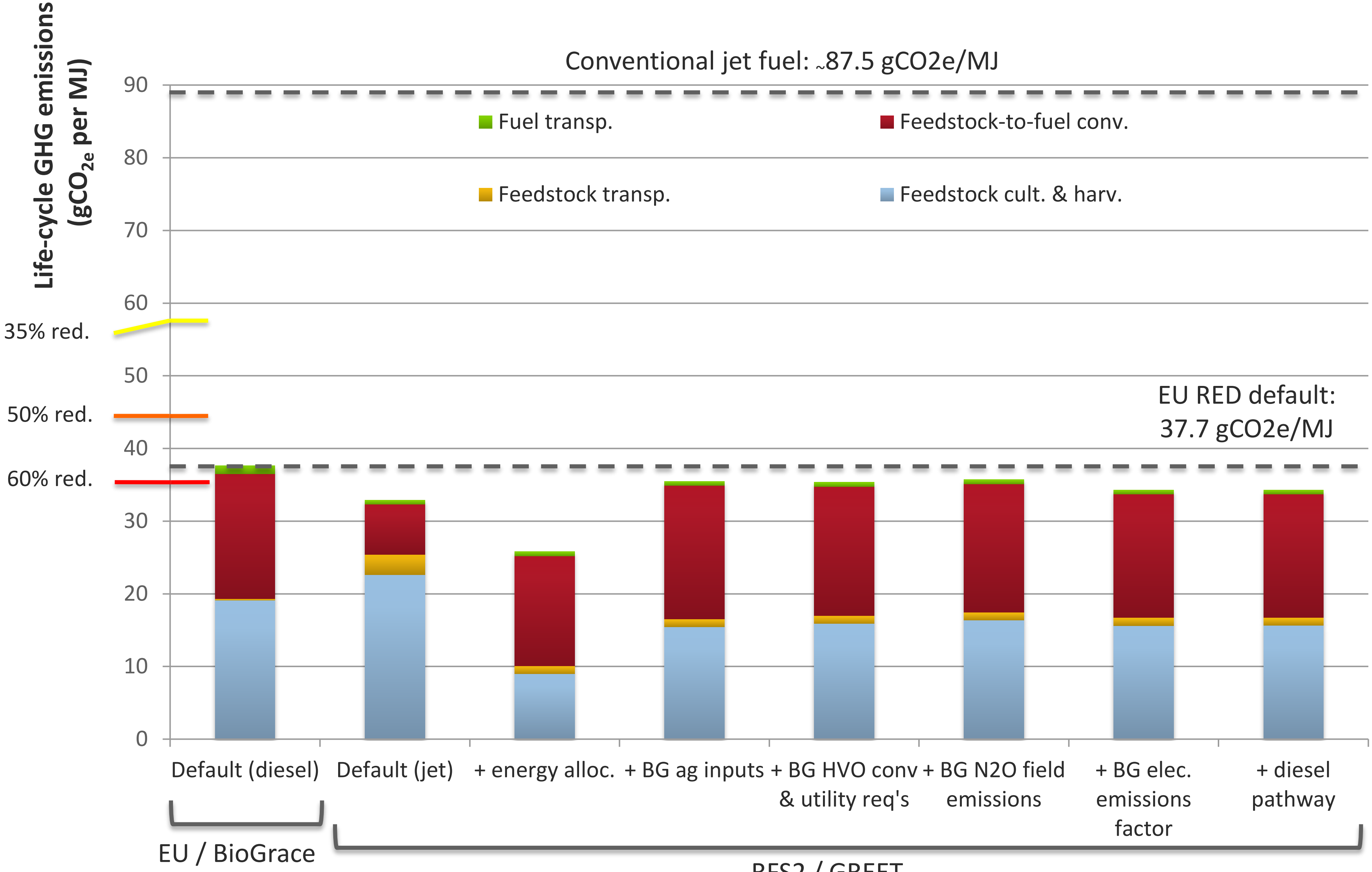
Harmonization of Rapeseed HEFA/HVO Pathway



PRELIMINARY RESULTS – PLEASE DO NOT CITE OR QUOTE

Courtesy of Robert Malina

Harmonization of Soybean HEFA/HVO Pathways



PRELIMINARY RESULTS – PLEASE DO NOT CITE OR QUOTE

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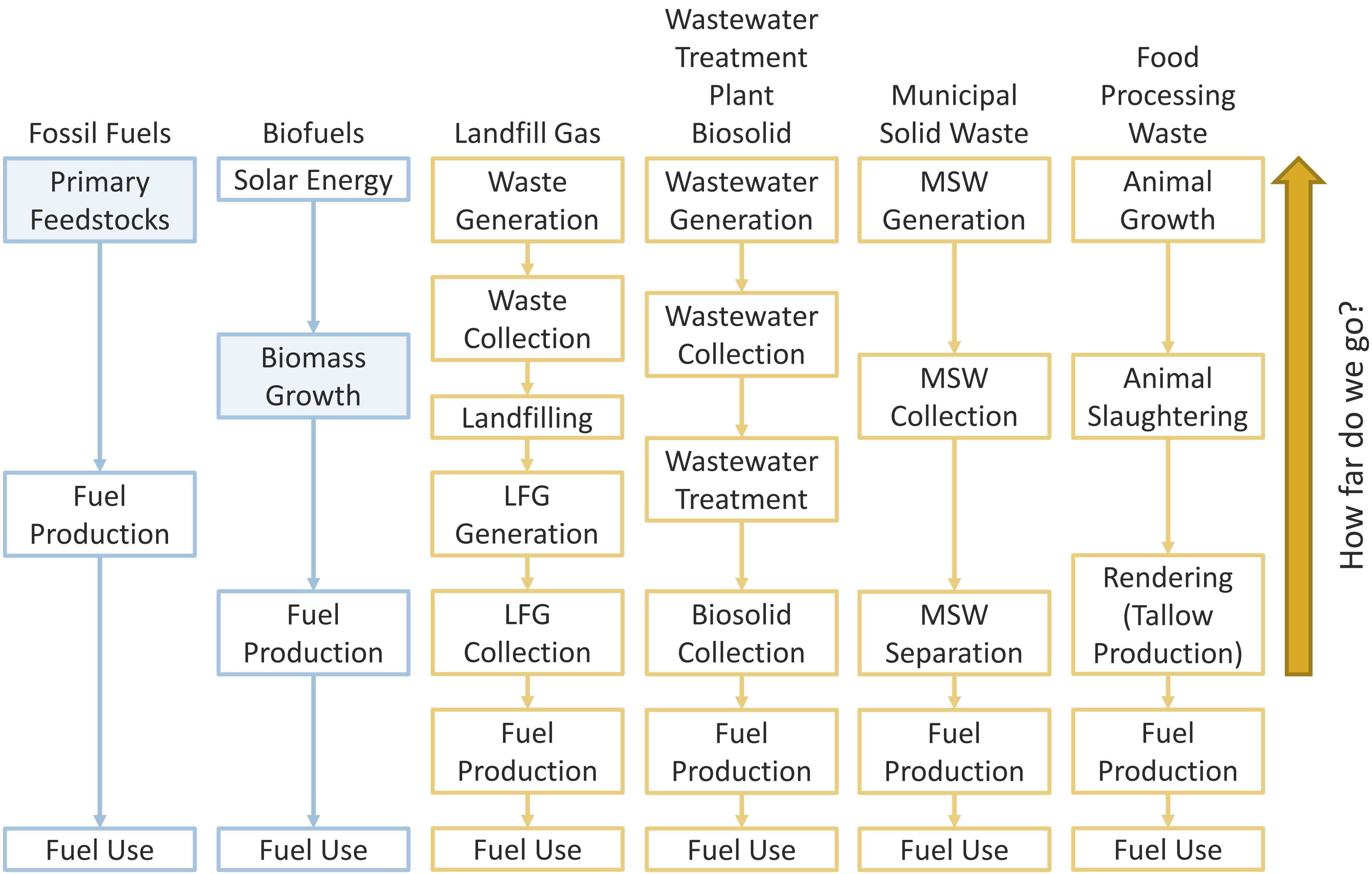
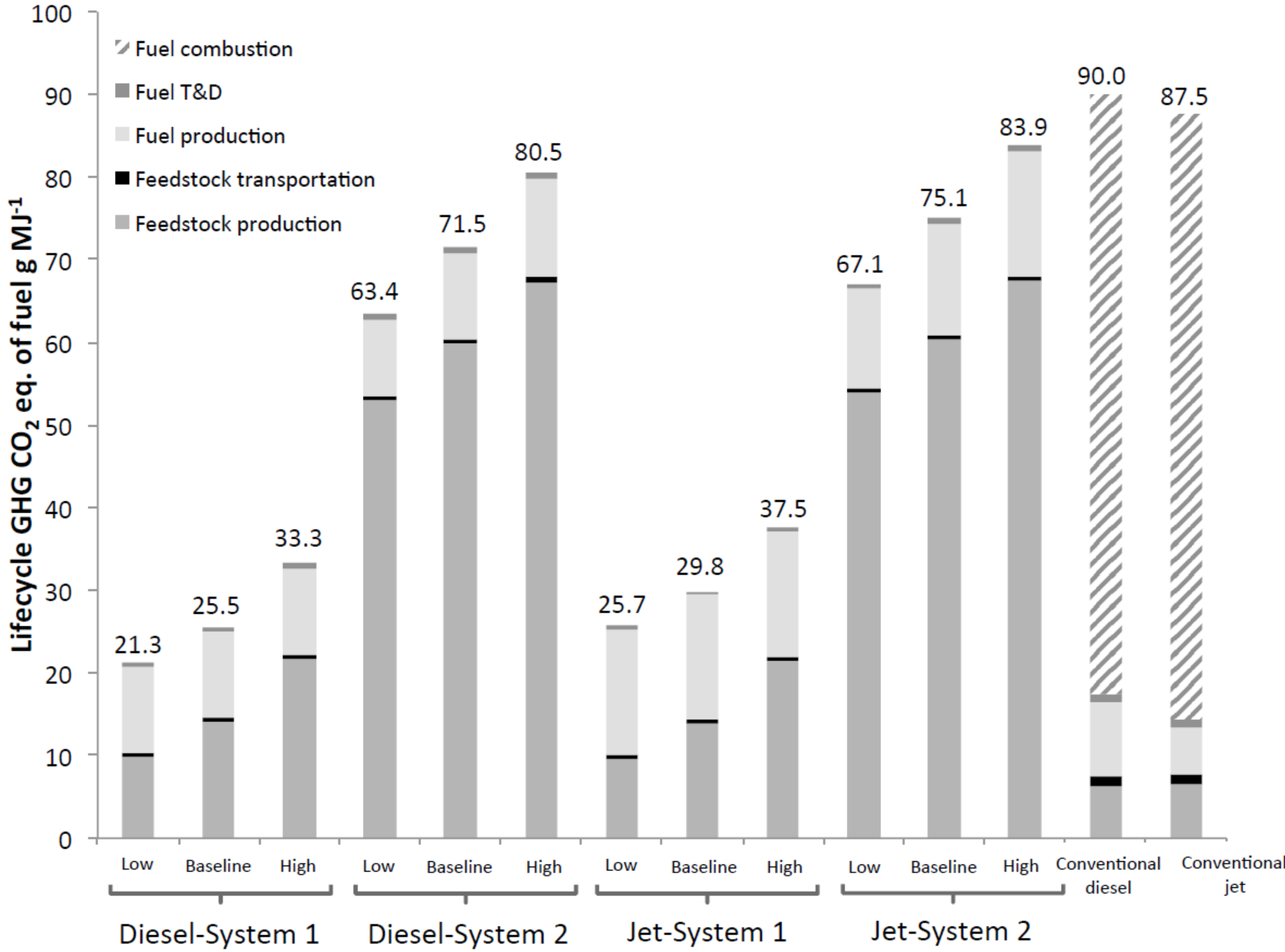
System Boundary Issue for Waste-based Feedstock



System boundary of waste-based feedstocks affects LCA results significantly



Seber et al. 2014

Tallow-based renewable diesel and HEFA

System 1 starts at rendering while System 2 starts at animal growth

Concluding Remarks

- Differences in lifecycle results for pathways assessed due to:
  - Allocation rules (Energy vs. Displacement):
    Δ 7-12 gCO_{2e}/MJ for HEFA pathways
  - System boundaries, including land-use change:
    Up to 55 gCO_{2e}/MJ for oil seed
  - Agricultural inputs
    Δ 2-9 gCO_{2e}/MJ for HEFA pathways
- Not all differences are indicative of a need for harmonization (systematic vs. parametric differences)
- In addition to technical discrepancy in LCA, regulatory framework is also an important factor
  - Baseline fuels' GHG intensity
  - Threshold- vs. performance-based

Questions/Comments

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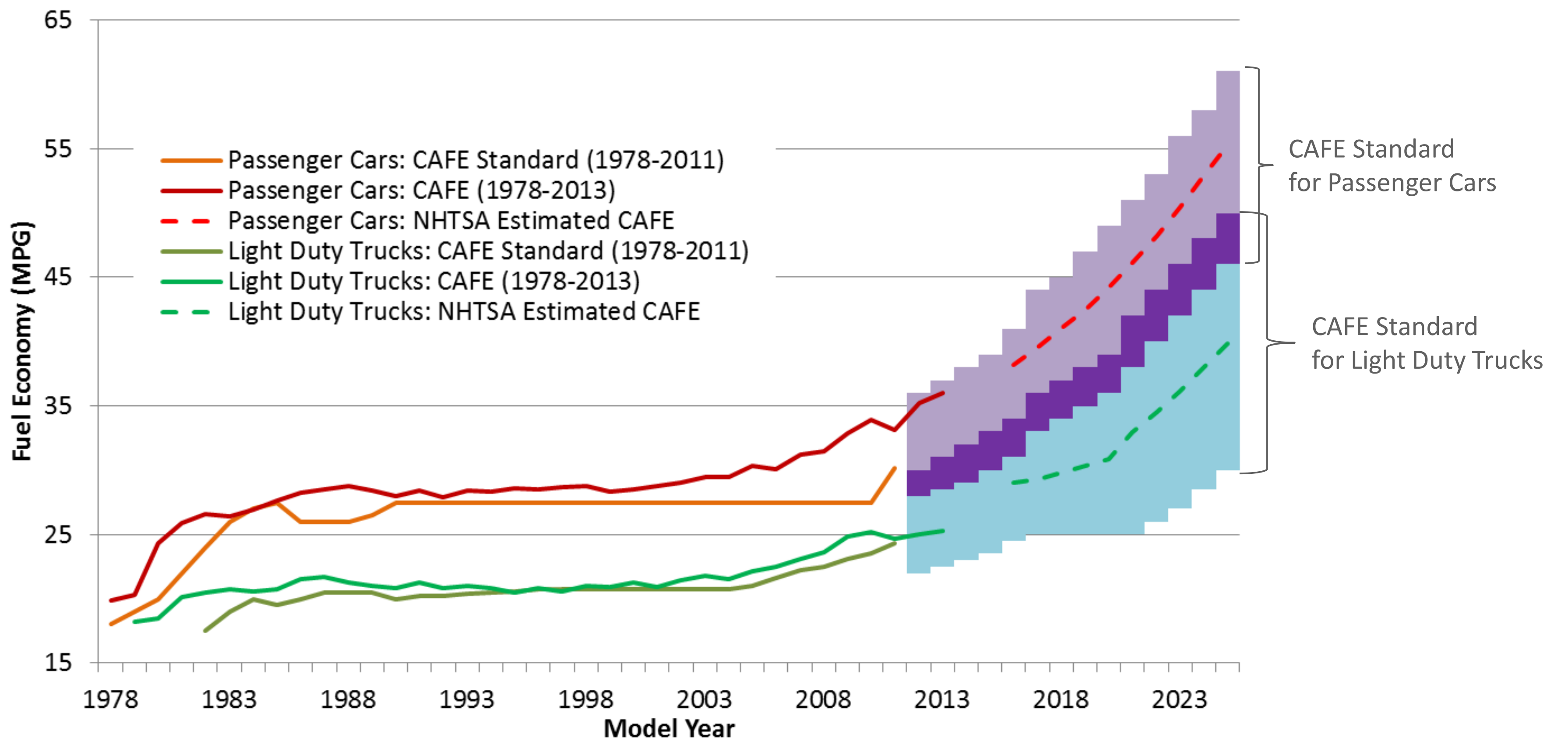
To reduce the transportation energy consumption, Corporate Average Fuel Economy (CAFE) standard was implemented



- Cumulative reduction in fuel consumptions is expected to be 16~31% during 2017-2060
- Cumulative reduction in GHG emissions is expected to be 22~34% during 2017-2100
- However, more dramatic reductions in crude import and GHG emissions require the development of **alternative fuels**, such as natural gas-based fuels, electricity and biofuels

Source: U.S. National Highway Traffic Safety Administration (NHTSA). CAFE – Fuel Economy (http://www.nhtsa.gov/fuel-economy)