Biofuel Life-cycle Analysis with the GREET Model

Michael Wang

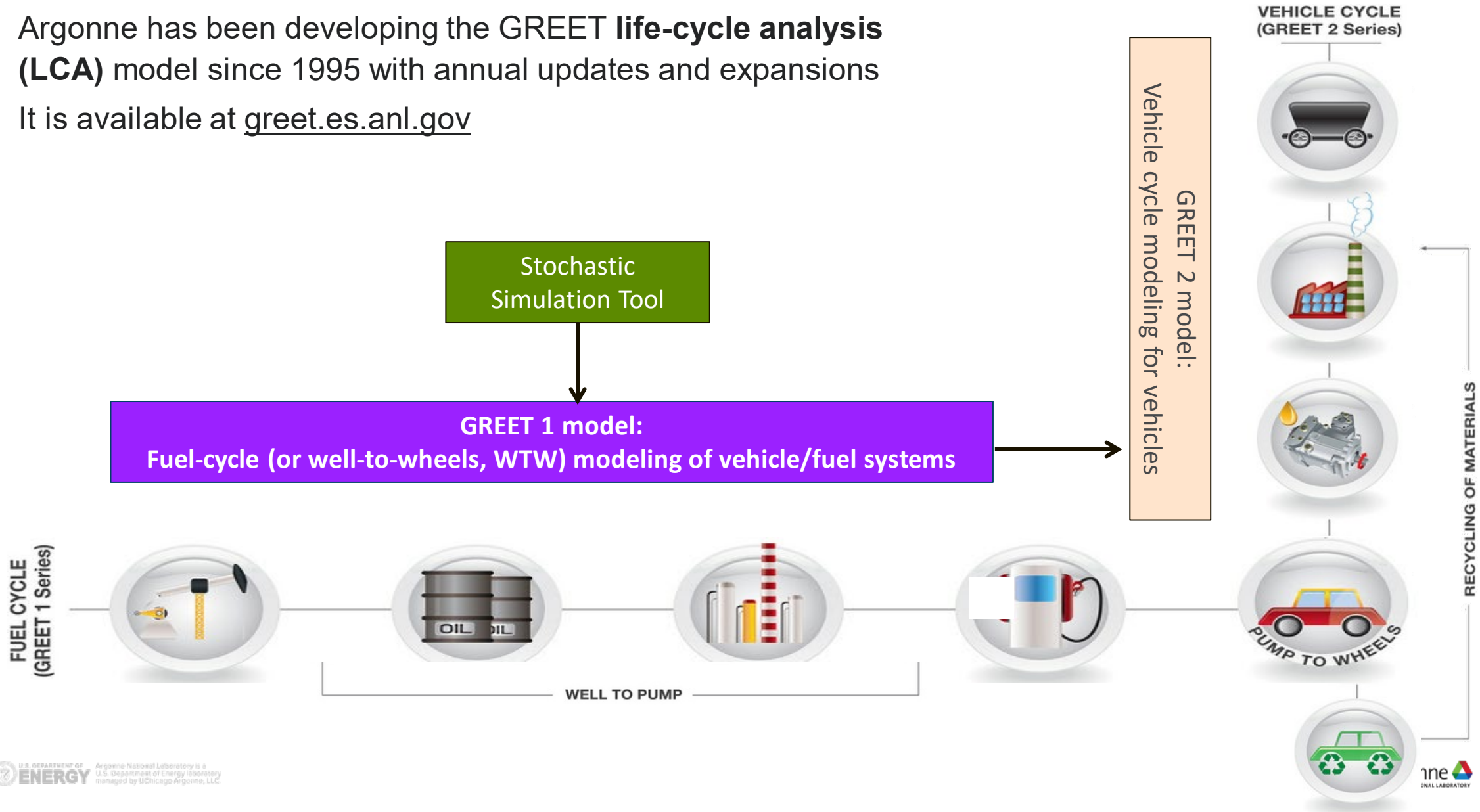
Systems Assessment Center
Energy Systems Division
Argonne National Laboratory

Presentation at the EPA Biofuel Modeling Workshop

March 1, 2022

The GREET (Greenhouse gases, Regulated Emissions, and Energy use in Technologies) model Framework

- Argonne has been developing the GREET **life-cycle analysis (LCA)** model since 1995 with annual updates and expansions
- It is available at greet.es.anl.gov



greet.es.anl.gov

GREET®

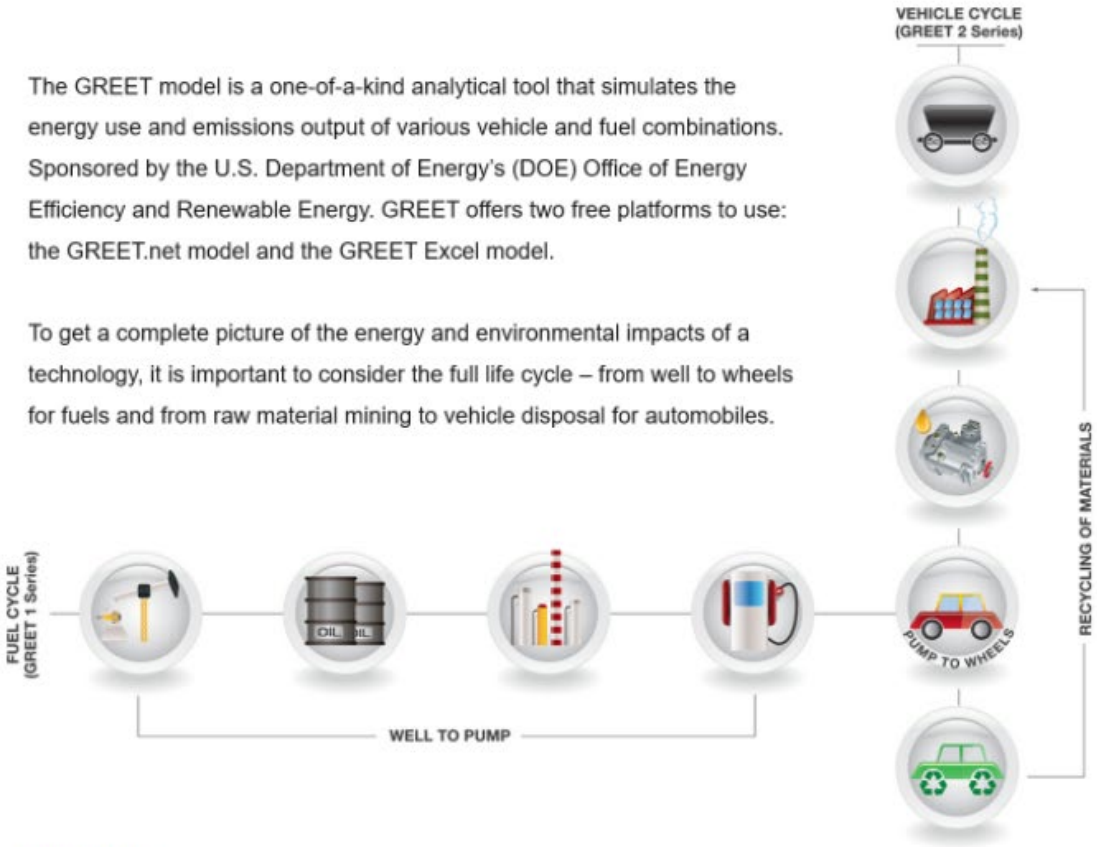
- Publications
- Databases
- GREET Model Platforms
  - GREET .Net
  - GREET Excel
    - Fuel-Cycle Model
    - Vehicle-Cycle Model
- GREET Tools
  - WTW Calculator
  - AFLEET Tool
  - AWARE-US Model
  - FD-CIC Tool
  - Refinery Products VOC
  - GREET Building Module
- Other Related Models
- Workshops
- Copyright Statement
- Contact

GREET® Model

The Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model

The GREET model is a one-of-a-kind analytical tool that simulates the energy use and emissions output of various vehicle and fuel combinations. Sponsored by the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy. GREET offers two free platforms to use: the GREET.net model and the GREET Excel model.

To get a complete picture of the energy and environmental impacts of a technology, it is important to consider the full life cycle – from well to wheels for fuels and from raw material mining to vehicle disposal for automobiles.



GREET News

GREET 2021 Release Oct 11, 2021

The Argonne National Laboratory's Systems Assessment Center is pleased to announce the 2021 release of the suite of GREET Models. Please read Summary of Expansions and Updates in GREET® 2021 (948KB pdf) for more details on updates in this version.

Argonne NATIONAL LABORATORY

ANL/ESD-21/16

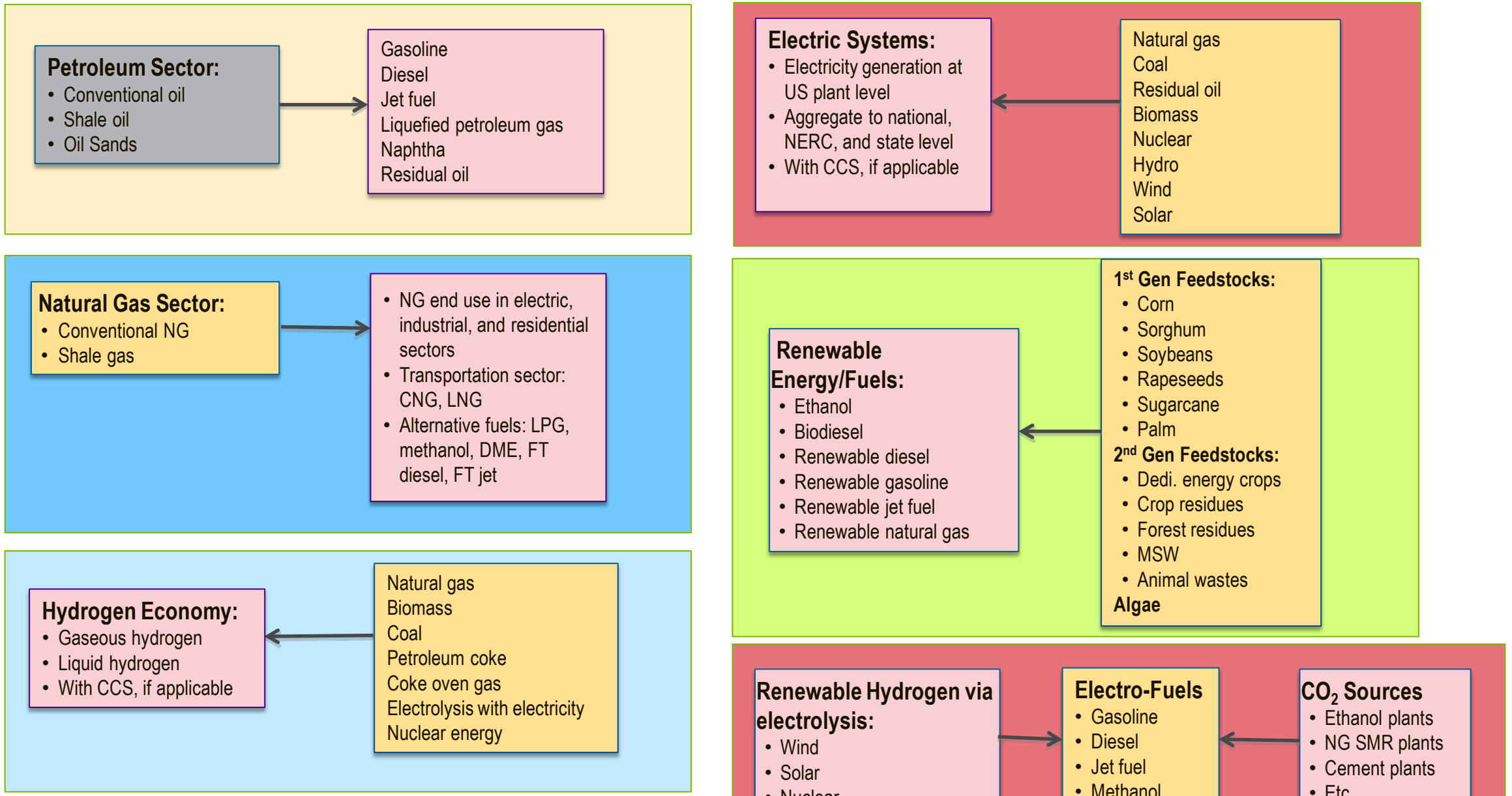
Summary of Expansions and Updates in GREET® 2021

prepared by
Michael Wang, Amgad Elgowainy, Uisung Lee, Adarsh Bafana, Sudhanya Banerjee, Pahola Thathiana Benavides, Pallavi Bobba, Andrew Burnham, Hao Cai, Ulises R Gracida-Alvarez, Troy R. Hawkins, Rakesh Krishnamoorthy Iyer, Jarod C. Kelly, Taemin Kim, Kathryn Kingsbury, Hoyoung Kwon, Yuan Li, Xinyu Liu, Zifeng Lu, Longwen Ou, Nazib Siddique, Pingping Sun, Pradeep Vyawahare, Olumide Winjobi, May Wu, Hui Xu, Eunji Yoo, George G. Zaimes, Guiyan Zang

Systems Assessment Center, Energy Systems Division, Argonne National Laboratory

October 2021

GREET covers many groups of energy systems



Besides energy systems, GREET also includes plastics and products.

GREET LCA modeling framework

- Build LCA modeling capacity
- Build a consistent LCA platform with multiple LCA methods
- Address emerging LCA issues
- Access to primary data sources and conduct detailed analysis
- Document sources of data, modeling and analysis approach, and results/conclusions
- Maintain openness and transparency of LCAs by making GREET and its documentation publicly available
- Primarily process-based LCA approach (the so-called attributional LCA); some features of consequential LCA are incorporated

GREET relies on a variety of data sources

Baseline technologies and systems (background data)

- Energy Information Administration's data and its Annual Energy Outlook projections
- EPA eGrid for electric systems
- US Geology Services for water data

Field operation data (foreground data)

- Oil sands and shale oil operations
- Ethanol plants energy use
- Farming data from USDA

Simulations with models (foreground data)

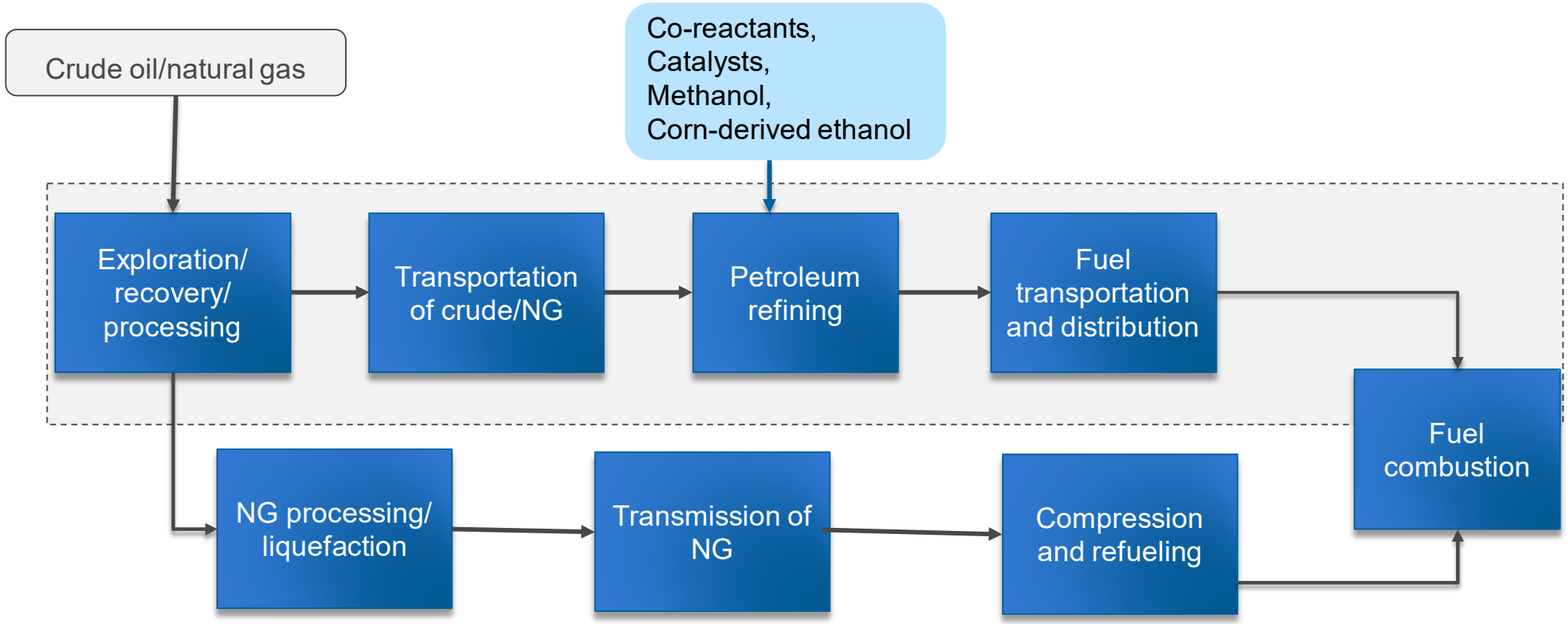
- ASPEN Plus for fuel production
- ANL Autonomie for fuel economy
- EPA MOVES for vehicle emissions, EPA AMPD for stationary emissions
- LP models for petroleum refinery operations
- Electric utility dispatch models for marginal electricity analysis

Collaboration with other organizations

Industry inputs

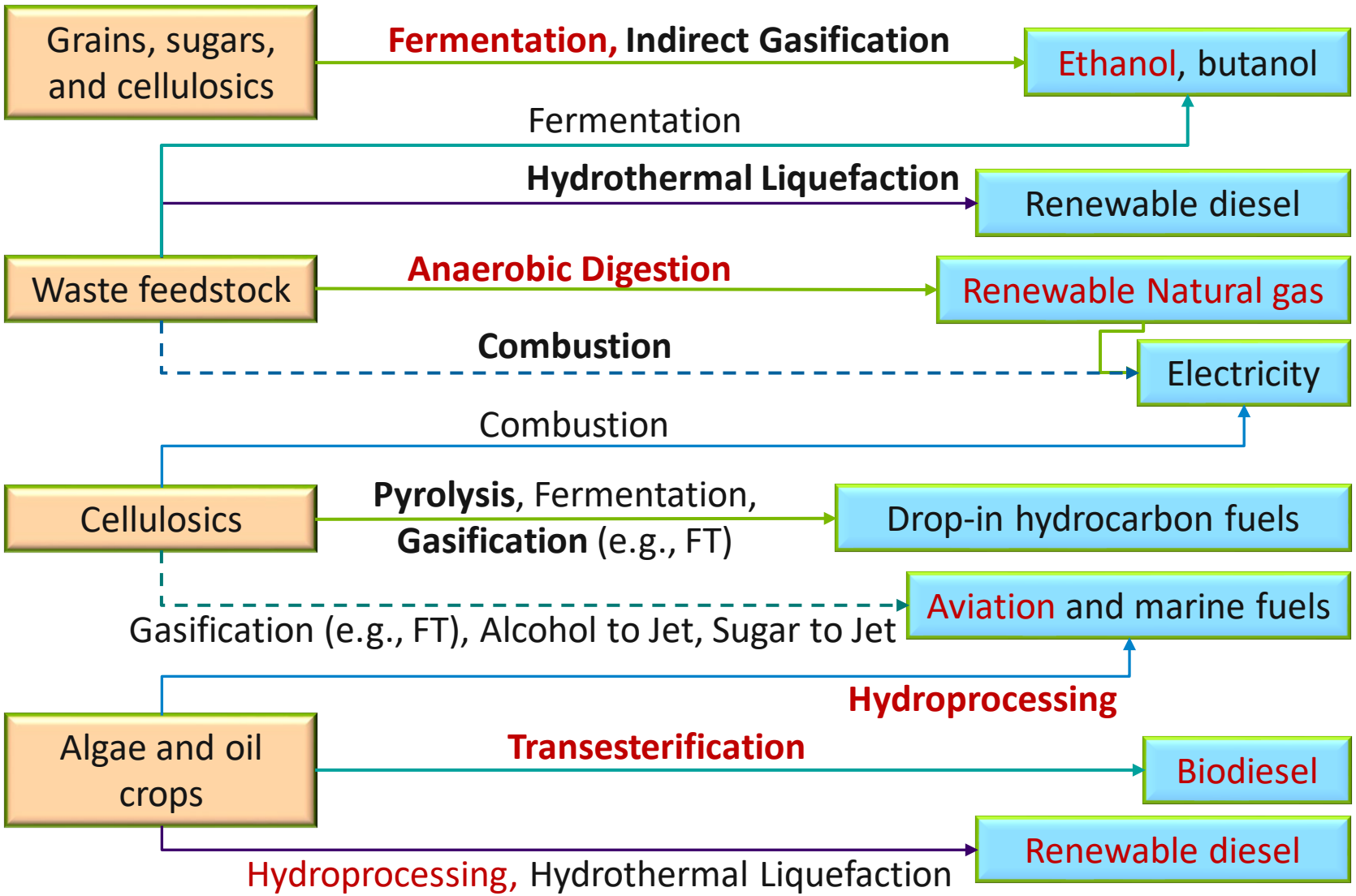
- Fuel producers and technology developers on fuels
- Automakers and system components producers on vehicles

Life cycle of fuels from petroleum and natural gas

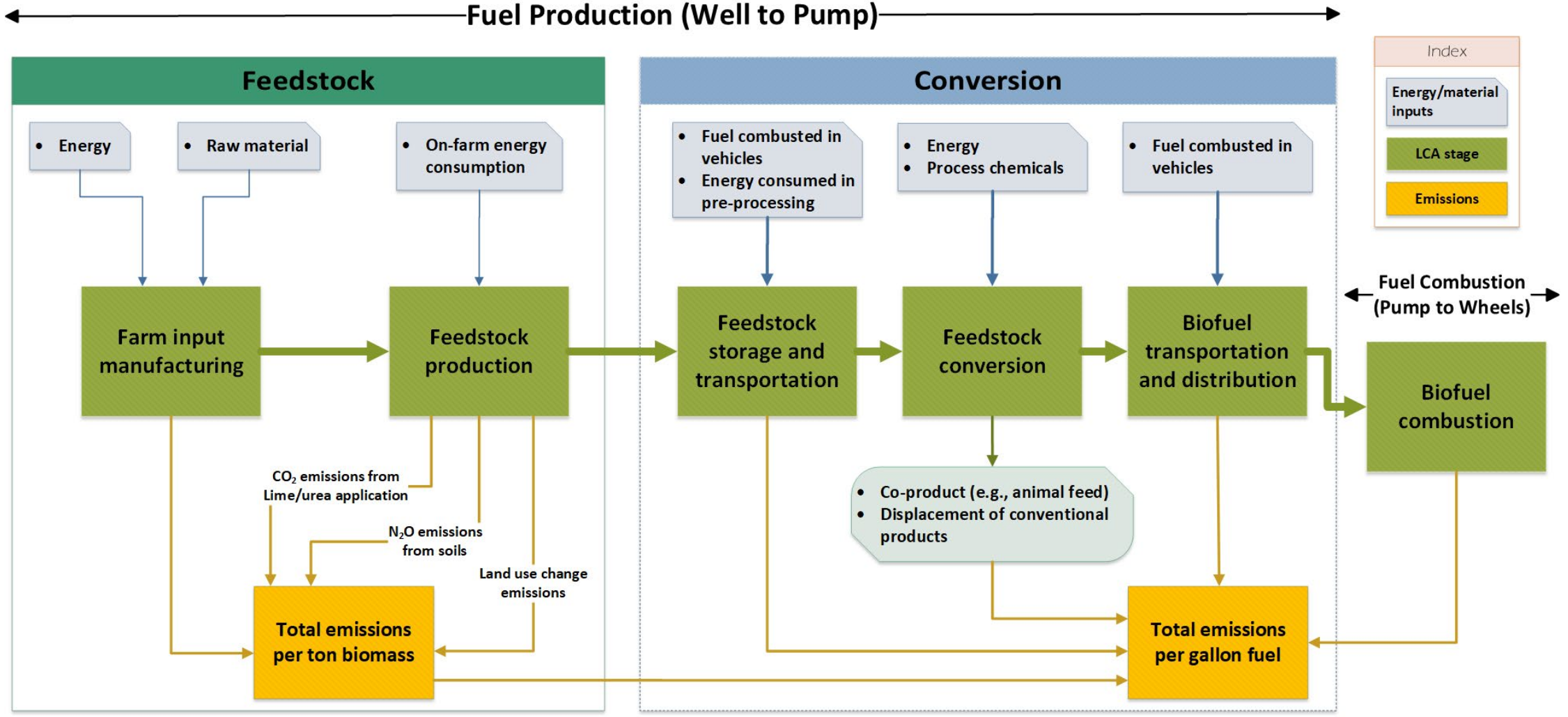


- All direct activities and emissions in the above flowcharts are included
- Land disturbance of oil/NG recovery was assessed and included in GREET (up to 2 g/MJ)
- Methane leakage of the NG supply chain is based on combined bottom-up (EPA GHG Inventory) and top-down (individual studies) approach

A variety of biofuel production pathways are covered in GREET



GREET includes details of both biofuel feedstock and conversion

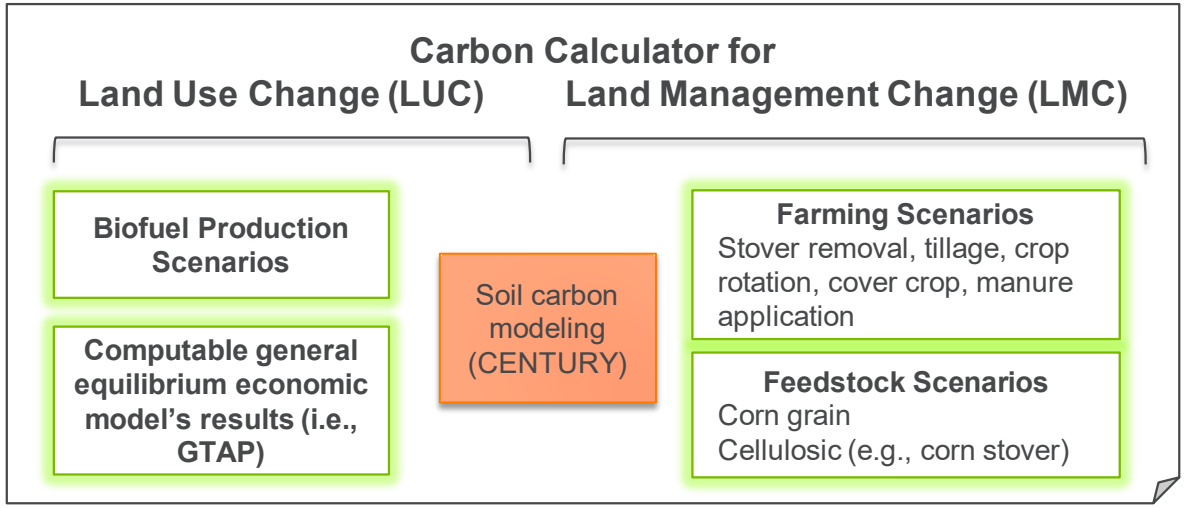


- EU REDII and forthcoming Canadian Clean Fuel Standard allow feedstock certification

- All biofuel regulations in place or under development allow biofuel facility certification

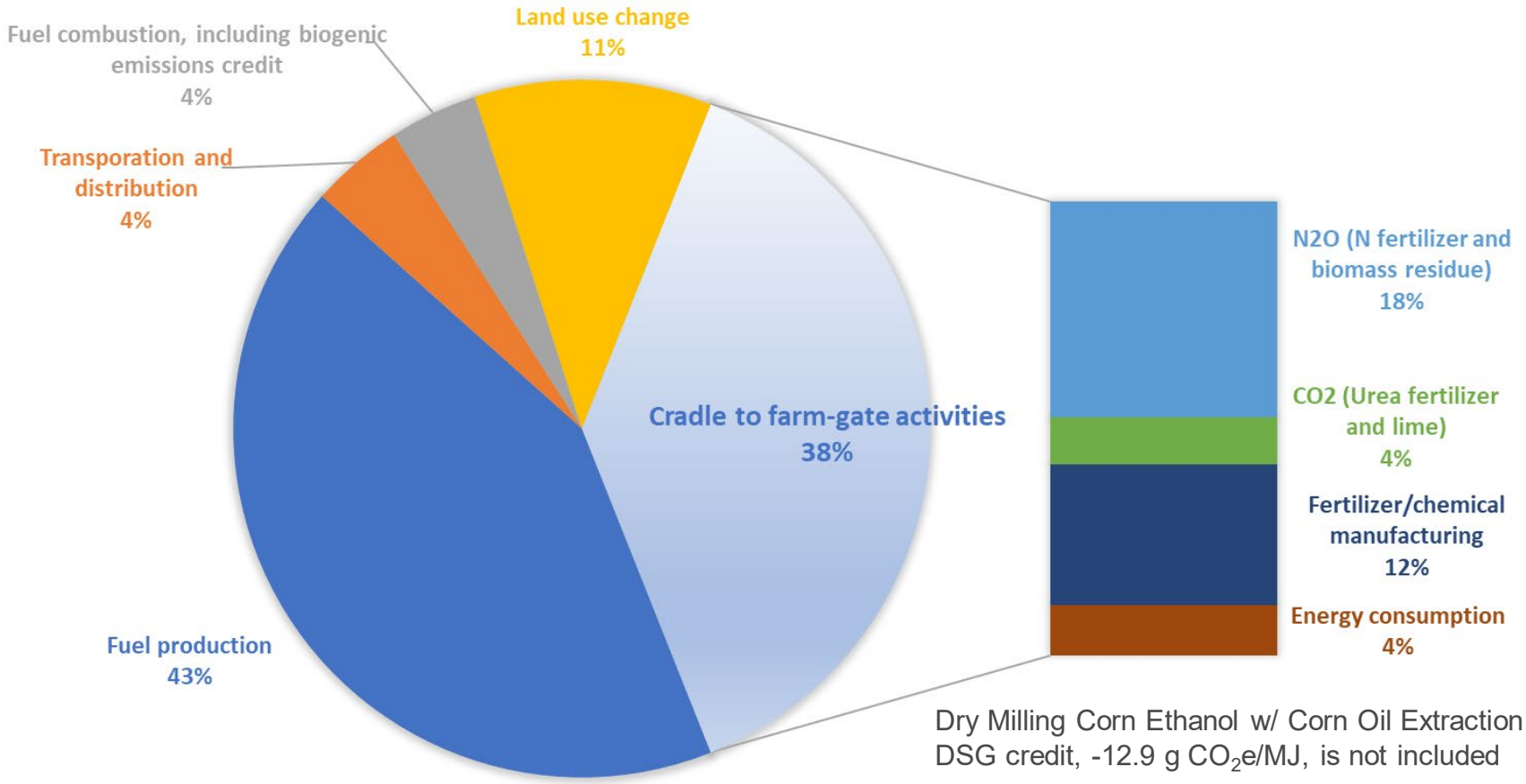
CCLUB Addresses GHG Emissions Related to Soil for Growing Feedstocks

- Land use change (LUC) is defined as the shift in land-use and land-cover that could accompany large-scale feedstock production in cropland to produce biofuels
- GREET biofuel LCA accounts for LUC-induced soil carbon changes



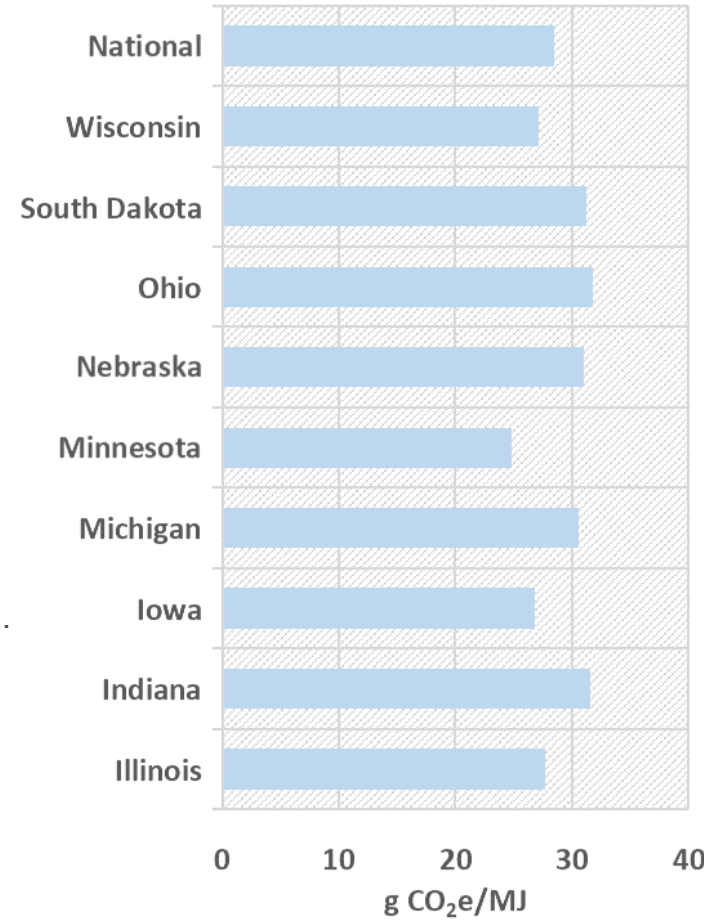
- Land management change (LMC) include diverse farming practices, which would induce soil carbon changes during feedstock production
- GREET biofuel LCA has accounted for the impacts of LMC on soil carbon changes

Feedstock is a significant contributor to corn ethanol LCA GHGs: 38% of corn ethanol CI, in addition to 11% from GREET LUC GHGs



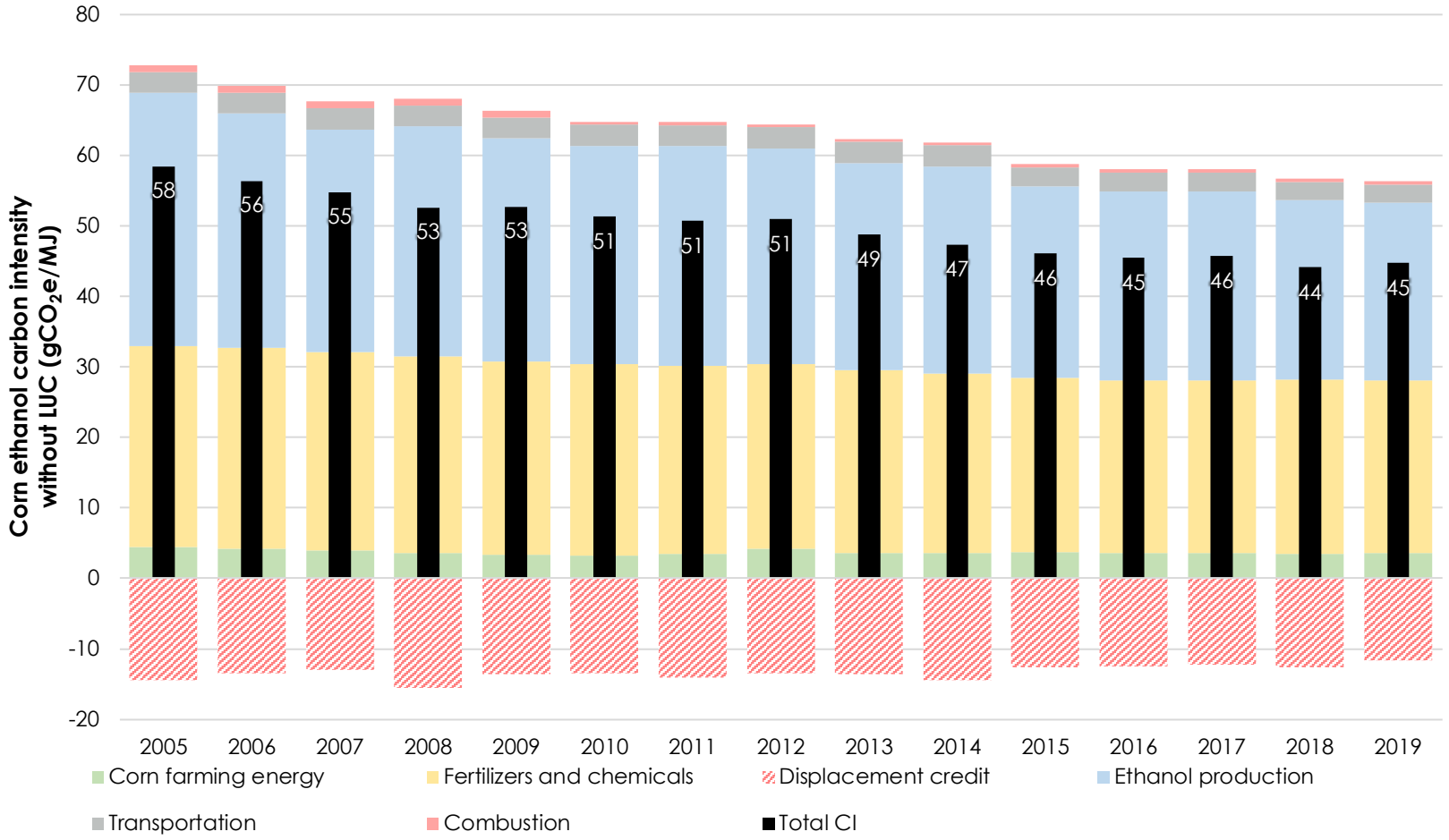
Dry Milling Corn Ethanol w/ Corn Oil Extraction. DSG credit, -12.9 g CO_2e/MJ, is not included

Significant variation exists in feedstock CI among regions



Retrospective carbon intensity of corn ethanol (without LUC)

- Corn ethanol CIs have decreased over the last 15 years (23% or 14gCO_2e/MJ)
- Corn ethanol CI (including LUC) in 2019 shows 44% reduction compared to fossil baseline (93 gCO_2e/MJ)
- Ethanol production-related emissions have decreased 30% (11 gCO_2e/MJ; 36→25)
- Corn farming shows reductions in GHG, 15% (5 gCO_2e/MJ; 33→28)



Observations: Values and Limitations of LCA

- LCA is a major step to holistically evaluate sustainability of a technology
  - From singular stages to the complete supply chain so that shift in environmental burdens from one stage to the other is not missed
  - LCA thinking has helped changes in corporation and consumer behaviors
  - LCA based regulations have helped promotion of sustainable technologies
  - Process level details along a technology's supply chain provide insights of opportunities and challenges of a technology's sustainability
- LCA results are still subject to variations and uncertainties
  - LCA system boundary depends on scope of LCA
  - Attributional and consequential LCA address different questions and have completely different boundaries
  - Co-product methods in LCA can be subjective and affect LCA results significantly
  - Data availability and representation
    - ✓ Temporal variation
    - ✓ Geographic/spatial variation
    - ✓ Data uncertainty (e.g., sources of process energy/chemicals, methane emissions, land use changes from biofuels)
  - Limitations of comparative results from LCA
    - ✓ Current vs. uncertain future
    - ✓ Different technology readiness levels (TRLs) across processes and pathways
    - ✓ Resource and infrastructure availability
    - ✓ Economics, production scalability, and market acceptance/competitiveness

The research effort at Argonne National Laboratory was supported by the Bioenergy Technology Office under the Office of Energy Efficiency and Renewable Energy of the US Department of Energy (DOE) under contract DE-AC02-06CH11357. The views and opinions expressed herein do not necessarily state or reflect those of the US government or any agency thereof. Neither the US government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.