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U.S. DEPARTMENT OF ENERGY
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Argonne National Laboratory

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Systems Assessment Center

Analyzing the benefits and challenges of technologies to make the U.S. more sustainable, secure, and resilient.

- Assess technologies and programs against sustainability goals
  - Focus on greenhouse gas, criteria pollutants, and resource use.
  - Identifying opportunities for improvement.

- Diverse group of ~65 engineers, economists, analysts, modelers, and planners.

GREET Model

Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies

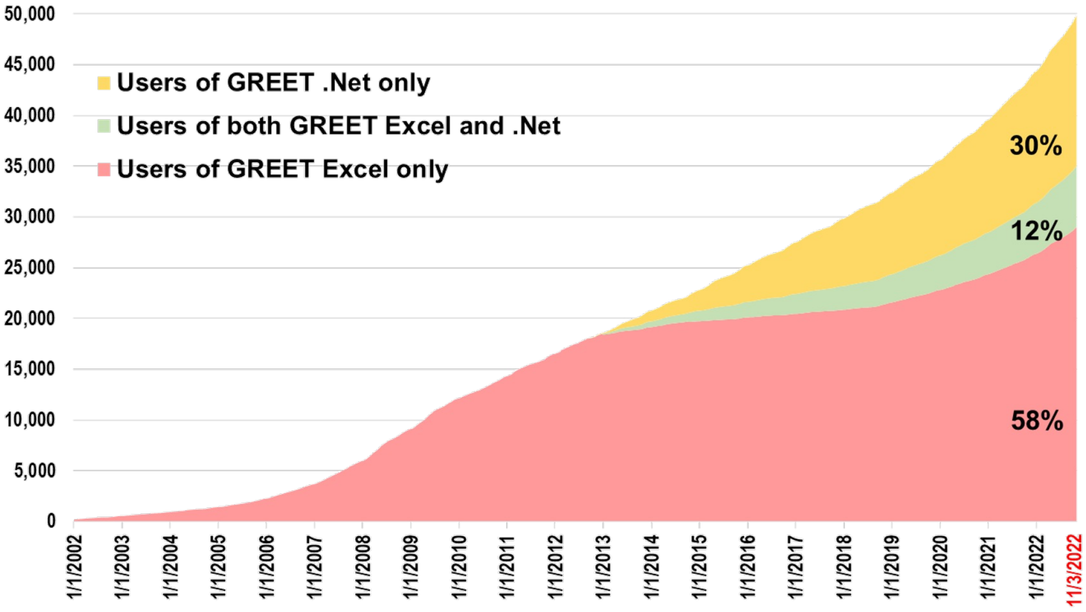
- **Consistent tracking of the life cycle performance of energy and products**
  - Used to inform and guide DOE research

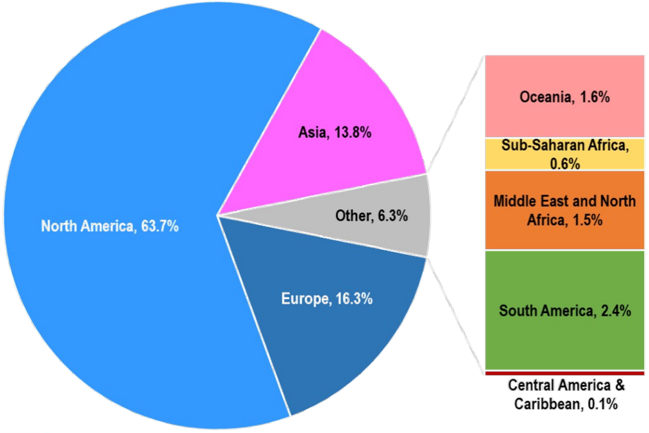
- Argonne has been developing GREET since 1995 with **annual updates and expansions**.

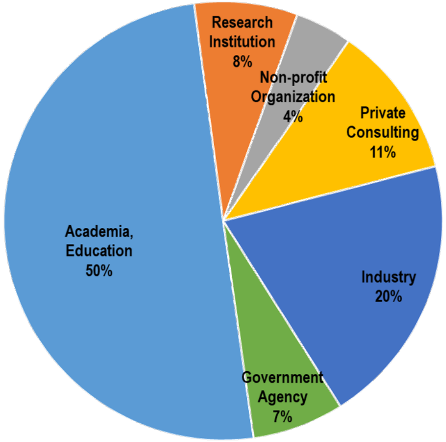
- **Long-term support from U.S. Dept. of Energy**
  - Vehicle Technologies Office (VTO)
  - Hydrogen Fuel-Cell Technology Office (FCTO)
  - Bioenergy Technology Office (BETO)

- **Expanded from transportation-focus to include a wide range of technologies**
  - Fuels, Vehicles, Chemicals, Plastics, Agriculture, Metals, Concrete, Buildings, Batteries, Electricity Infrastructure

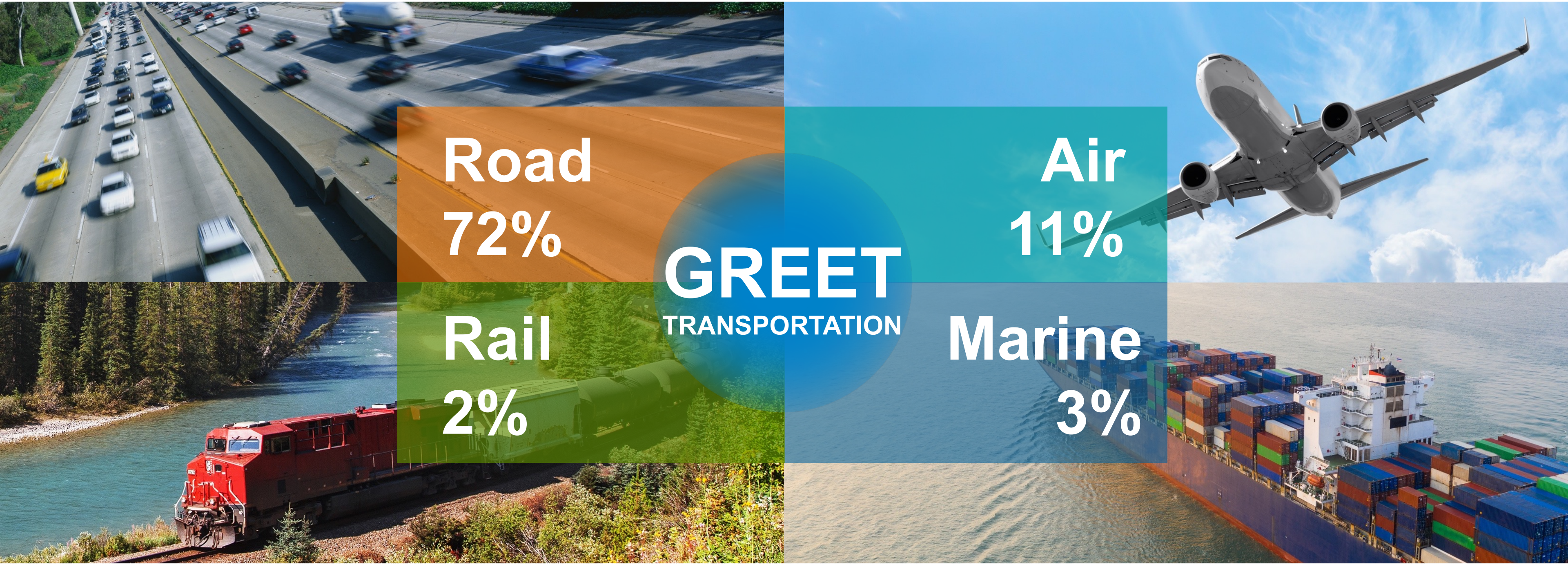
There are ~50,000 registered GREET users globally







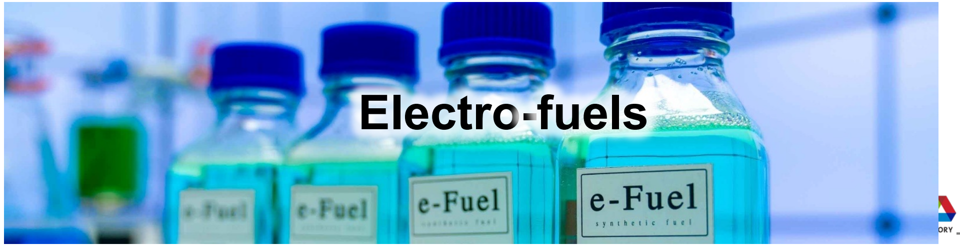
GREET covers all transportation subsectors



Share of US transportation GHG emissions; remaining 12% for US is from pipelines and offroad.

GREET covers many groups of energy systems

Photo credit: Shutterstock.com



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Waste-to-Energy and Waste-to-Product Studies

Landfill Gas

Argonne NATIONAL LABORATORY — ANL/ESD/10-3

Well-to-Wheels Analysis of Landfill Gas-Based Pathways and Their Addition to the GREET Model

Energy Systems Division

Animal Waste

Argonne NATIONAL LABORATORY — ANL/ESD/11-6

Waste-to-Wheel Analysis of Anaerobic-Digestion-Based Renewable Natural Gas Pathways with the GREET Model

Energy Systems Division

Wastewater Sludge

Argonne NATIONAL LABORATORY — ANL/ESD-16/19

Lifecycle Analysis of Renewable Natural Gas and Hydrocarbon Fuels from Wastewater Treatment Plants' Sludge

Energy Systems Division

MSW

Argonne NATIONAL LABORATORY — ANL/ESD-16/20

Well-to-Wheels Analysis of Compressed Natural Gas and Ethanol from Municipal Solid Waste

Energy Systems Division

Journal of Cleaner Production

Evaluation of landfill gas emissions from municipal solid waste landfills for the life-cycle analysis of waste-to-energy pathways

Uisung Lee, Jeongwoo Han, Michael Wang

CHAPTER 8

Life cycle analysis of waste-to-energy pathways

Uisung Lee, Pahola Thathiana Benavides and Michael Wang

Systems Assessment Center, Energy Systems Division, Argonne National Laboratory, Lemont, IL, United States

Waste-to-Energy

Journal of Cleaner Production — Volume 382, 1 January 2023, 135114

Life cycle analysis of gasification and Fischer-Tropsch conversion of municipal solid waste for transportation fuel production

Uisung Lee, Hao Cai, Longwen Ou, Pahola Thathiana Benavides, Yixuan Wang, Michael Wang

https://doi.org/10.1016/j.jclepro.2022.135114

Highlights

- Evaluated carbon intensities of liquid fuels produced from municipal solid

Fuel

Life-cycle analysis of fuels from post-use non-recycled plastics

Pahola Thathiana Benavides, Pingping Sun, Jeongwoo Han, Jennifer B. Dunn, Michael Wang

Journal of Cleaner Production — Volume 311, 15 August 2021, 127653

Life cycle analysis of renewable natural gas and lactic acid production from waste feedstocks

Uisung Lee, Arpit Bhatt, Troy Robert Hawkins, Ling Tao, Pahola Thathiana Benavides, Michael Wang

https://doi.org/10.1016/j.jclepro.2021.127653

Abstract

Producing fuels and chemicals from waste is considered economically favorable, due to low feedstock cost, and environmentally favorable, due to avoided emissions from conventional waste management practices. In this study, we evaluate the life cycle greenhouse gas (GHG) emission reduction benefits of renewable natural gas (RNG) and lactic acid (LA) production from four types of wet waste feedstocks (wastewater sludge, food waste, swine manure, and fats, oil, and grease [FOG]) via anaerobic digestion (AD) and LA fermentation, respectively. RNG can be used as an alternative to fossil natural gas, while LA from waste feedstocks can displace conventional LA production pathways

Waste-to-products

Journal of Cleaner Production — Available online 3 September 2020, 124010

Life Cycle Greenhouse Gas Emissions and Energy Use of Polylactic Acid, Bio-Derived Polyethylene, and Fossil-Derived Polyethylene

Pahola Thathiana Benavides, Uisung Lee, Omid Zare-Mehrjerdi

https://doi.org/10.1016/j.jclepro.2020.124010

Highlights

- Bioderived PE can offer lower GHG emissions and FEC than the fossil-based counterparts.

Waste gas-to-liquid fuels (CO_2 utilization)

Modeling and Analysis — Biofpr

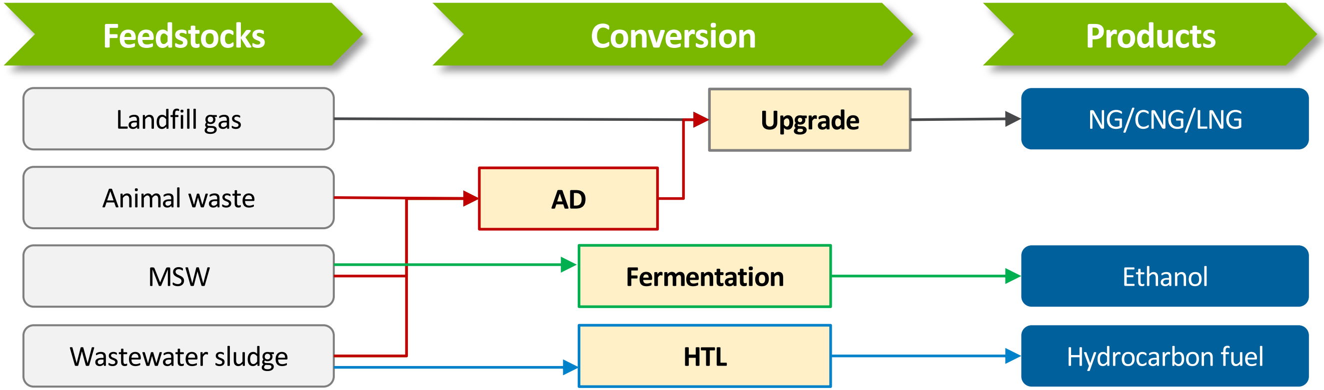
Using waste CO_2 from corn ethanol biorefineries for additional ethanol production: life-cycle analysis

Uisung Lee, Troy R Hawkins, Eunji Yoo, Michael Wang, Zhe Huang, Ling Tao

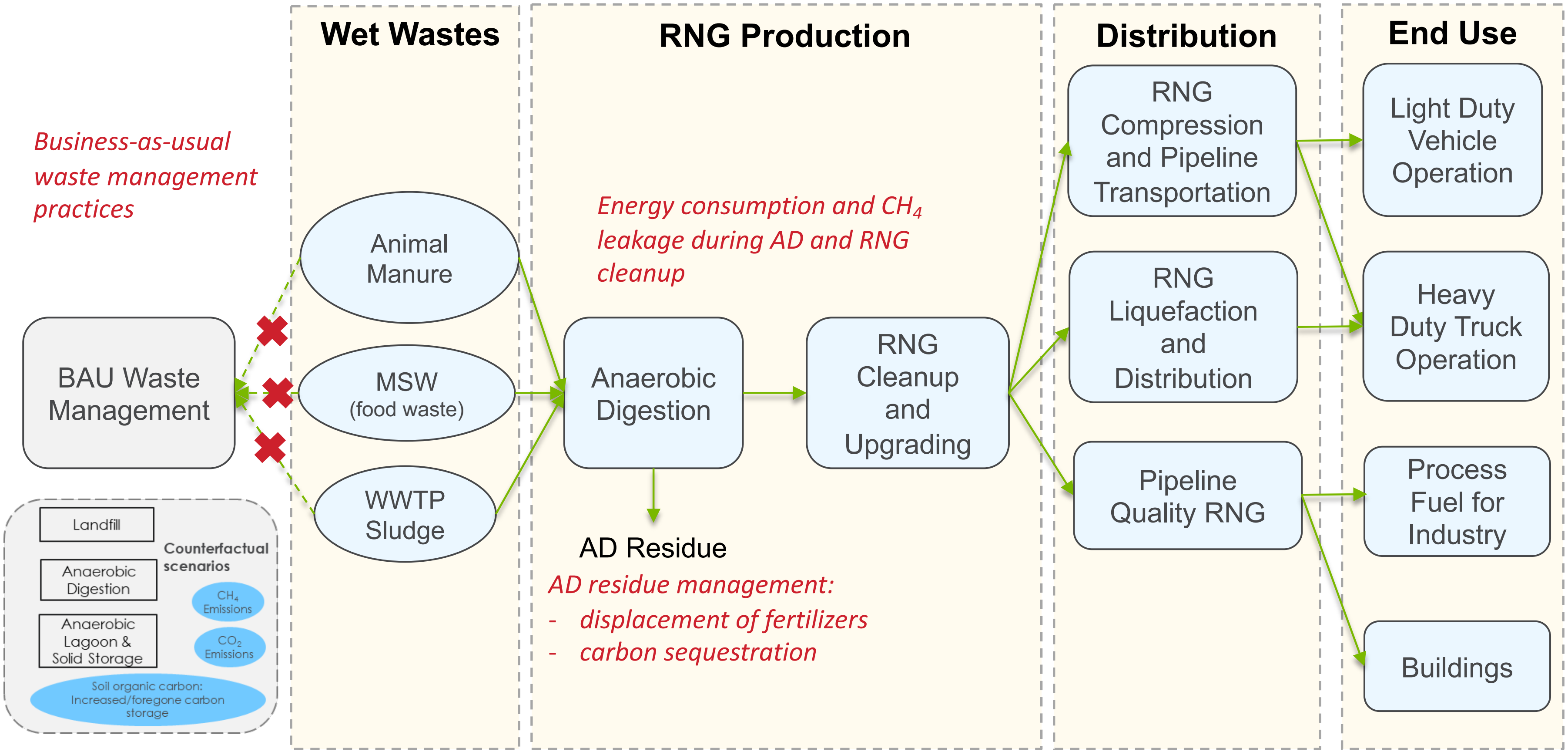
LCA of WTE Pathways that May Provide Significant WTW GHG Reductions

- LCA of waste-to-energy (WTE) pathways evaluate emissions associated with business-as-usual (BAU) waste management and account for avoided emissions.

Pathways in GREET

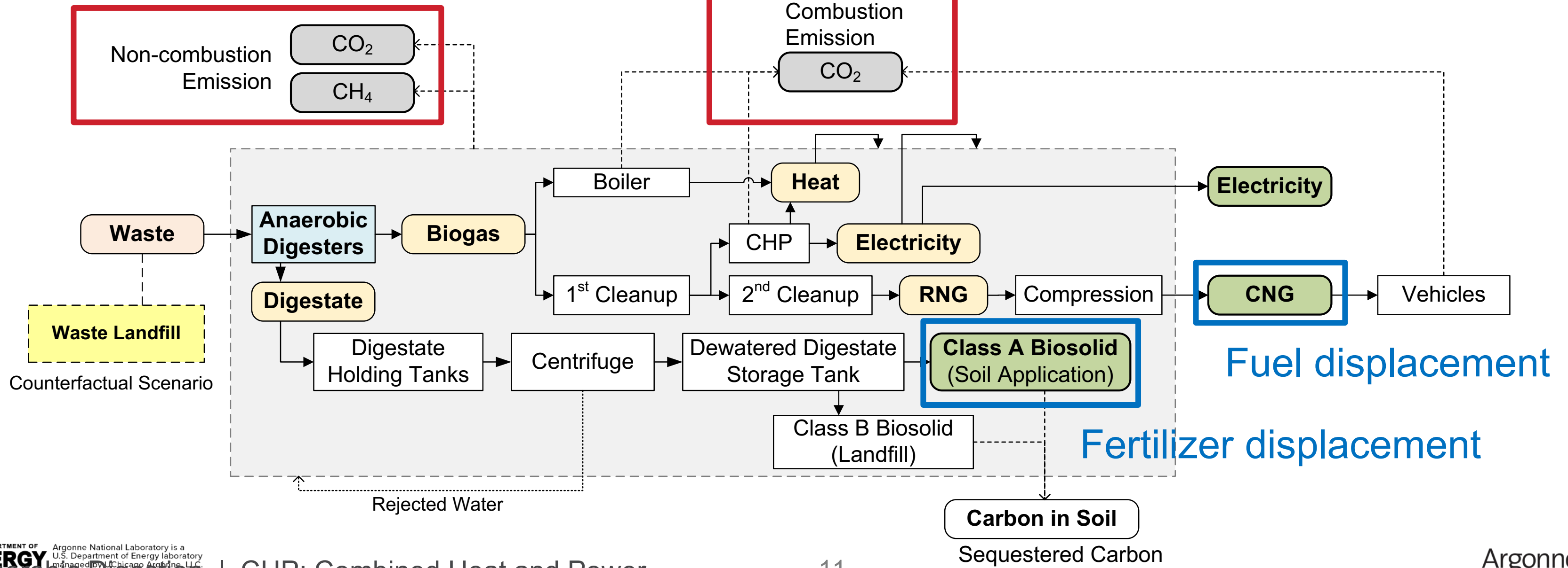


GREET Renewable Natural Gas (RNG) Module



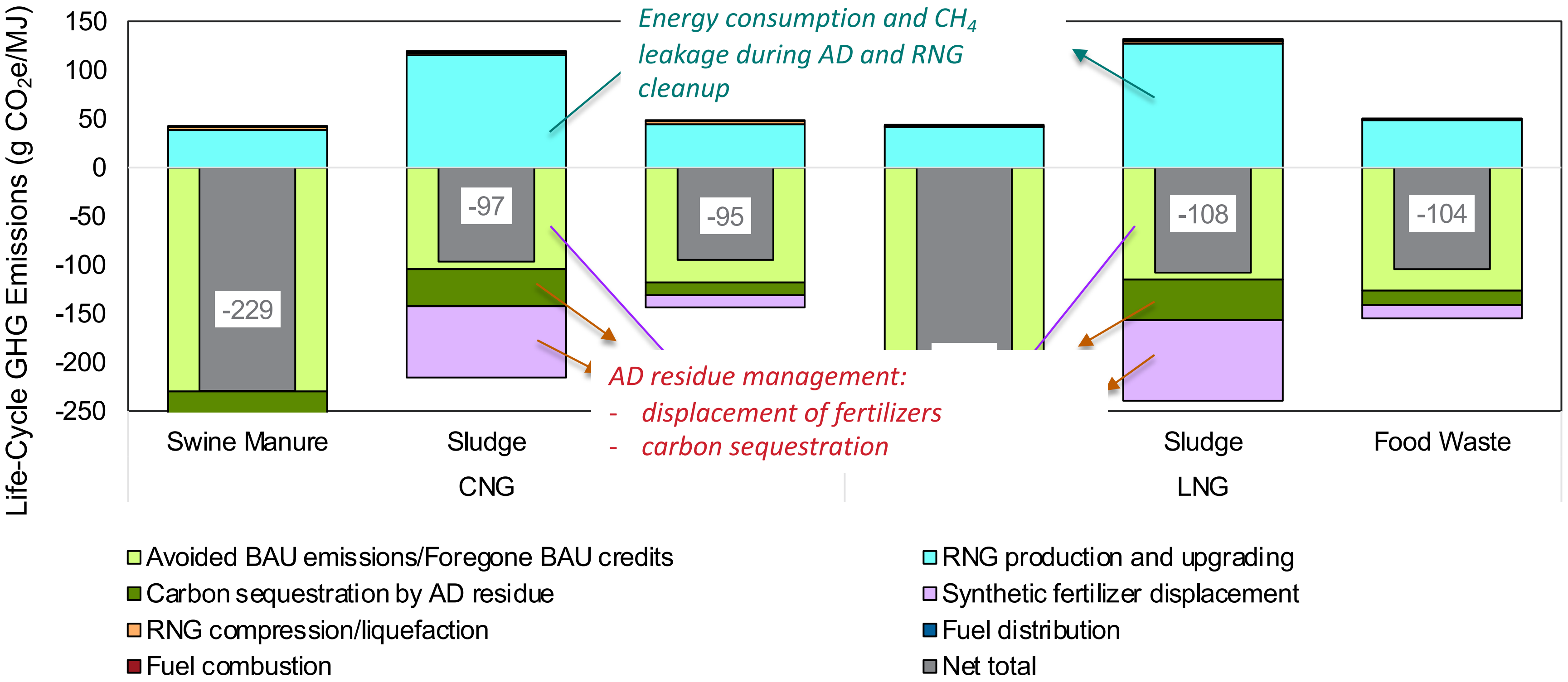
Alternative fuel production scenario: Renewable natural gas from food waste via AD

- ~~Heat and power generated from biogas combustion are used to meet the onsite demands~~
  - Grid electricity/pipeline NG are used to satisfy energy demand for biogas upgrading
- The biogas is upgraded and compressed to RNG
- Fuel and fertilizer displacement are important sources of energy and emissions credits



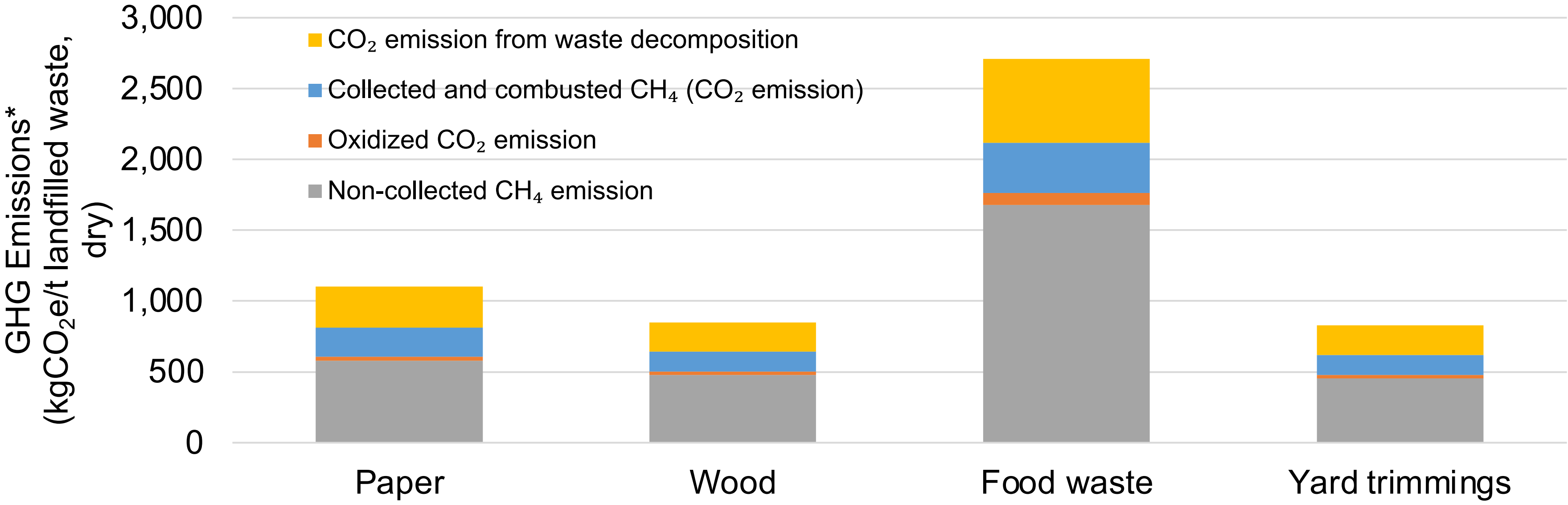
RNG is a very attractive option for decarbonizing heavy-duty transportation, which is hard to electrify and decarbonize.

Avoided GHG emissions and displacement credits can be significant.



Landfill specific parameters should be used to estimate avoided LFG emissions

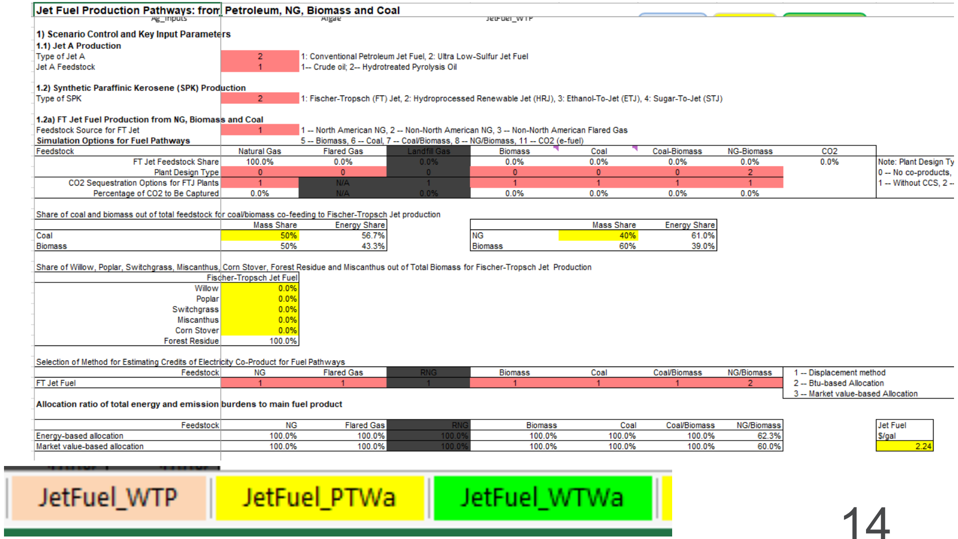
- Due to significant variations in landfill conditions and operations, setting an appropriate BAU which diverts waste from is critically important.



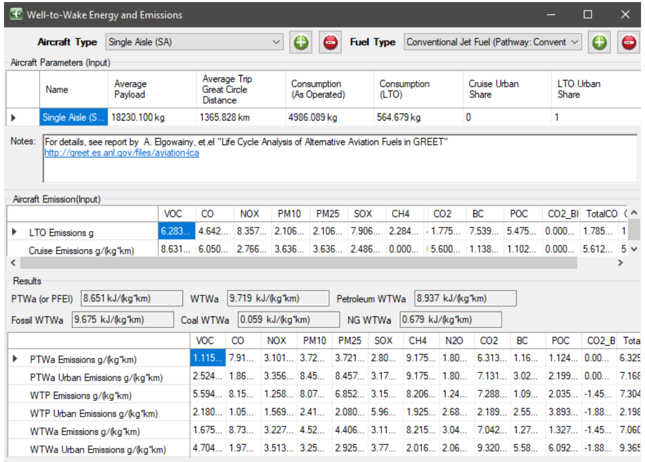
GREET Aviation Module

- Can evaluate SAF pathways with various feedstock/conversion combinations
- Present process-level emission results to identify emission hotspots
- Combustion emissions by aircraft types are available
- Can be expanded for new pathways leveraging existing structure and datasets

GREET Excel Aviation Module



GREET.net Aviation Module



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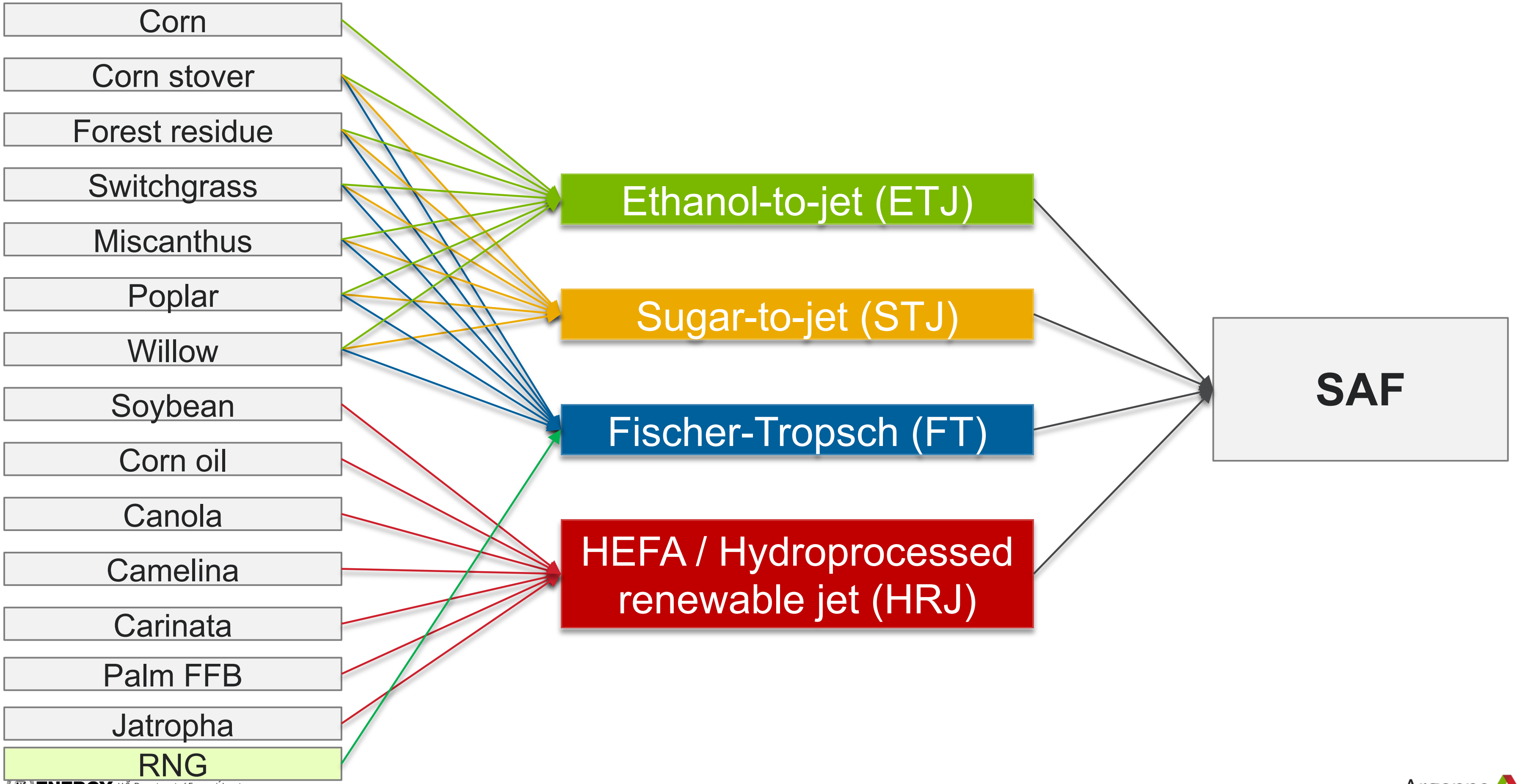
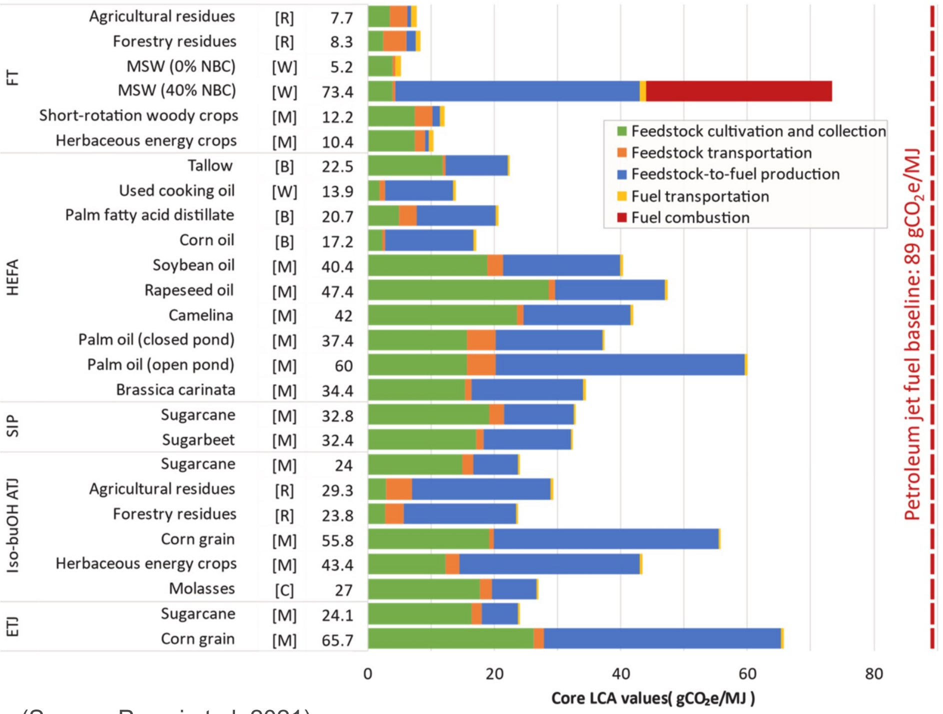
Available Sustainable Aviation Fuel Pathways in GREET

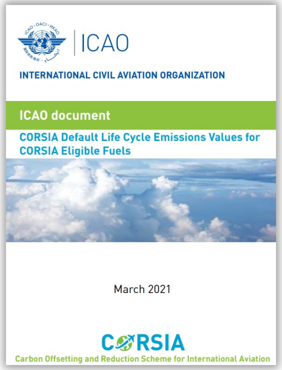


GREET Provides the Carbon Intensities for Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)



(Source: Prussi et al. 2021)

- Argonne has been a member of ICAO's Fuels Task Group (FTG) since inception
- **Argonne's GREET** was used to calculate the core LCA values of SAFs for CORSIA
- Default LCA values available in CORSIA documents



FT: Fischer-Tropsch | HEFA: hydroprocessed esters and fatty acids
SIP: Synthesized iso-paraffins | Iso-BuOH: Iso-butanol
ATJ: Alcohol-to-jet | ETJ: Ethanol-to-jet | NBC: non-biomass carbon

GREET LCA Informs Policy and Regulation

- **California-GREET** is an adaptation of Argonne's GREET model
- **Oregon Clean Fuels Program** also uses an adaptation of Argonne's GREET model
- Specified in **Inflation Reduction Act** related to the **Clean Fuel Production Credit** and the **Clean Hydrogen Credit**
- **U.S. EPA** uses GREET with other sources for **Renewable Fuels Standard** pathway evaluations
- **National Highway Traffic Safety Administration** for fuel economy regulation
- **Federal Aviation Administration** and **International Civil Aviation Organization** using GREET to evaluate aviation fuel pathways
- **U.S. Maritime Administration - renewable marine fuel options for IMO 2020 sulfur limits**
- **U.S. Dept. of Agriculture bioenergy LCA** and carbon intensity of farming practices
- **Canadian Clean Fuel Standard** for Environment and Climate Change Canada fuel pathways

Acknowledgements

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