

Symposium on the Gulf Coast Hydrogen Ecosystem: Opportunities and Solutions

April 17, 2024



Greenhouse Gas Footprints with LCA Approach

Michael Wang, PhD

Director, Systems Assessment Center
Energy Systems and Infrastructure Analysis Division
Argonne National Laboratory

The GREET effort at Argonne National Laboratory is supported by the Office of Energy Efficiency and Renewable Energy, the Office of Fossil Energy and Carbon Management, the Office of Clean Energy Demonstrations, the Office of Nuclear Energy, and ARPA-E 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.

LCA Background

- ❑ LCA is a major step to holistically evaluate sustainability of technologies and policies
 - From singular stages to the complete supply chain; shift in environmental burdens from one stage to another is not missed
 - LCA thinking has helped changes in corporation and consumer behaviors
- ❑ Recent trends of regulatory LCA applications
 - US domestic regulations and programs
 - ✓ EPA Renewable Fuel Standard
 - ✓ State fuels regulations
 - California Low-Carbon Fuel Standard
 - Oregon Clean Fuels Program
 - Washington State Clean Fuel Regulation
 - Regulations in several other states currently under consideration (IL, NM, MN, and VT)
 - ✓ The Inflation Reduction Act incentives for clean hydrogen, sustainable aviation fuels, and clean fuels
 - ✓ California regulation to require reporting of emissions of three scopes by companies
 - International activities
 - ✓ International Civil Aviation Organization's CORSIA program for SAFs
 - ✓ International Marine Organization's discussion of potential low-GHG fuel standard
 - ✓ EU Renewable Fuel Directive
 - ✓ Canadian Clean Fuel Regulations
 - ✓ Brazilian RenovaBio

Life cycle assessment (or analysis) -- LCA

- ❑ ISO 14040 standard
 - Establish guidelines for functional units, system boundary, co-product methods, and data quality evaluation
- ❑ Commercial software/databases
 - SimaPro
 - Gabi
 - Ecoinvent
- ❑ Transportation/energy system LCA models
 - GREET model
 - GHGenius model
 - EC JRC WTW Calculator

Life cycle analysis of technologies vs. enterprise 3-scope emissions

- ❑ Technology LCA: environmental footprints of technologies (e.g., different fuel production technologies)
 - The fuel cycle (the WTW cycle)
 - The vehicle cycle and the facility cycle
 - The C2G cycle

- ❑ Enterprise supply chain environmental footprints (e.g., GHG Protocol by WRI and WBCSD)
 - Scope 1 emissions: company direct emissions
 - Scope 2 emissions: emissions from purchased electricity and steam
 - Scope 3 emissions: other upstream and downstream emissions

Prepared by
Michael Wang, Amgad Elgowainy, Uisung Lee, Kwang Hoon Baek, Sweta Balchandani,
Pahola Thathiana Benavides, Andrew Burnham, Hao Cai, Peter Chen, Yu Gan, Ulises R.
Gracida-Alvarez, Troy R. Hawkins, Tai-Yuan Huang, Rakesh Krishnamoorthy Iyer, Saurajyoti
Kar, Jarod C. Kelly, Taemin Kim, Christopher P. Kolodziej, Kyuha Lee, Xinyu Liu, Zifeng Lu,
Farhad H. Masum, Michele Morales, Clarence Ng, Longwen Ou, Tuhin K. Poddar, Krishna
Reddi, Siddharth Shukla, Udayan Singh, Lili Sun, Pingping Sun, Tom Sykora, Pradeep
Vyawahare, Jingyi Zhang

Systems Assessment Center, Energy Systems and Infrastructure Analysis Division, Argonne
National Laboratory

December 2023

R&D GREET®

Publications

Databases

R&D GREET Model Platforms

R&D GREET .Net

R&D GREET Excel

Fuel-Cycle Model

Vehicle-Cycle Model

GREET Tools

WTW Calculator

AFLEET Tool

AWARE-US Model

FD-CIC Tool

Refinery Products VOC

R&D GREET Building
Module

R&D GREET Marine Module

Decarbonization Model

ICAO-GREET Model

R&D GREET Battery Module

Other Related Models

Workshops

Copyright Statement

Contact

This is Argonne National Laboratory's R&D version of GREET.

For versions of GREET used for determining tax credits, please [click here](#).

R&D GREET® Model

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

GREET News

R&D GREET 2023 Release

December 21, 2023

The Argonne National Laboratory's Systems Assessment Center is pleased to announce the 2023 release of the suite of R&D GREET Models. Please read [Summary of Expansions and Updates in R&D GREET® 2023](#) (674KB pdf) for more details on updates in this version.

DISCLAIMER

R&D GREET 2023 is being released, consistent with Argonne National Laboratory's routine annual R&D GREET update process. Consistent with annual updates since 1995, R&D GREET (also historically called "ANL GREET") includes representation of new fuel pathways and updates to underlying assumptions. Pathways represented in the tool include two major categories: A) those that have been rigorously evaluated and have high certainty; and B) those that are preliminary, which could include pathways that have not recently been evaluated; those where there is still a gap in the science or data, and/or those that are currently under internal or external peer review. Argonne's annual releases of R&D GREET are comprehensive in order to inform the life cycle analysis technical community and elicit stakeholder feedback. These annual releases are meant to share the early-stage perspectives in life-cycle analysis, particularly in preliminary form, so as to gather feedback from the academic and technical expert community and determine where additional research, analysis and data are needed. Not all pathways and data in R&D GREET are appropriate for use in circumstances where a high level of quantitative certainty or precision is required. Inclusion of a pathway or module in R&D GREET does not necessarily represent U.S. Government concurrence for any specific use, but instead is intended to gather technical feedback and advance the science of life-cycle analysis.

GREET is referenced in numerous independent state and federal compliance and incentive programs (including solicitations, rulemakings, and tax incentives), but it is important to note that this particular release (R&D GREET 2023) is not the version used by any of these specific programs. Numerous versions of GREET are currently publicly available (including versions that have been formally adopted in rulemakings, referenced in rulemaking documents, and referenced in solicitations), and others are likely to become adopted. But each

R&D GREET includes a suite of models and tools

- R&D GREET coverage
 - ✓ R&D GREET1: fuel cycle (or WTW) model of energy systems
 - ✓ R&D GREET2: vehicle manufacturing cycle and material embodied emissions
- Modeling platform
 - ✓ Excel
 - ✓ .net
- Other GREET derivatives
 - ✓ 45VH2-GREET for IRA based on GREET1
 - ✓ 40BSAF-GREET for IRA based on GREET1 (forthcoming)
 - ✓ ICAO-GREET by ANL for ICAO CORSIA, based on GREET1
 - ✓ CA-GREET by CARB for LCFS, based on GREET1
 - ✓ GREET for 14 global regions by ANL in collaboration with IEA
 - ✓ GREET battery module
 - ✓ GREET marine module
 - ✓ AFLEET by ANL: alternative-fuel vehicles energy, emissions, and cost estimation
 - ✓ EverBatt by ANL: emission and cost modeling of remanufacturing and recycling of EV batteries

Questions?

Michael Wang (mwang@anl.gov)

Visit <https://greet.anl.gov/>