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FUEL CELL SEMINAR
LONG BEACH, CA

GREET® Model for Hydrogen Life Cycle GHG Emissions

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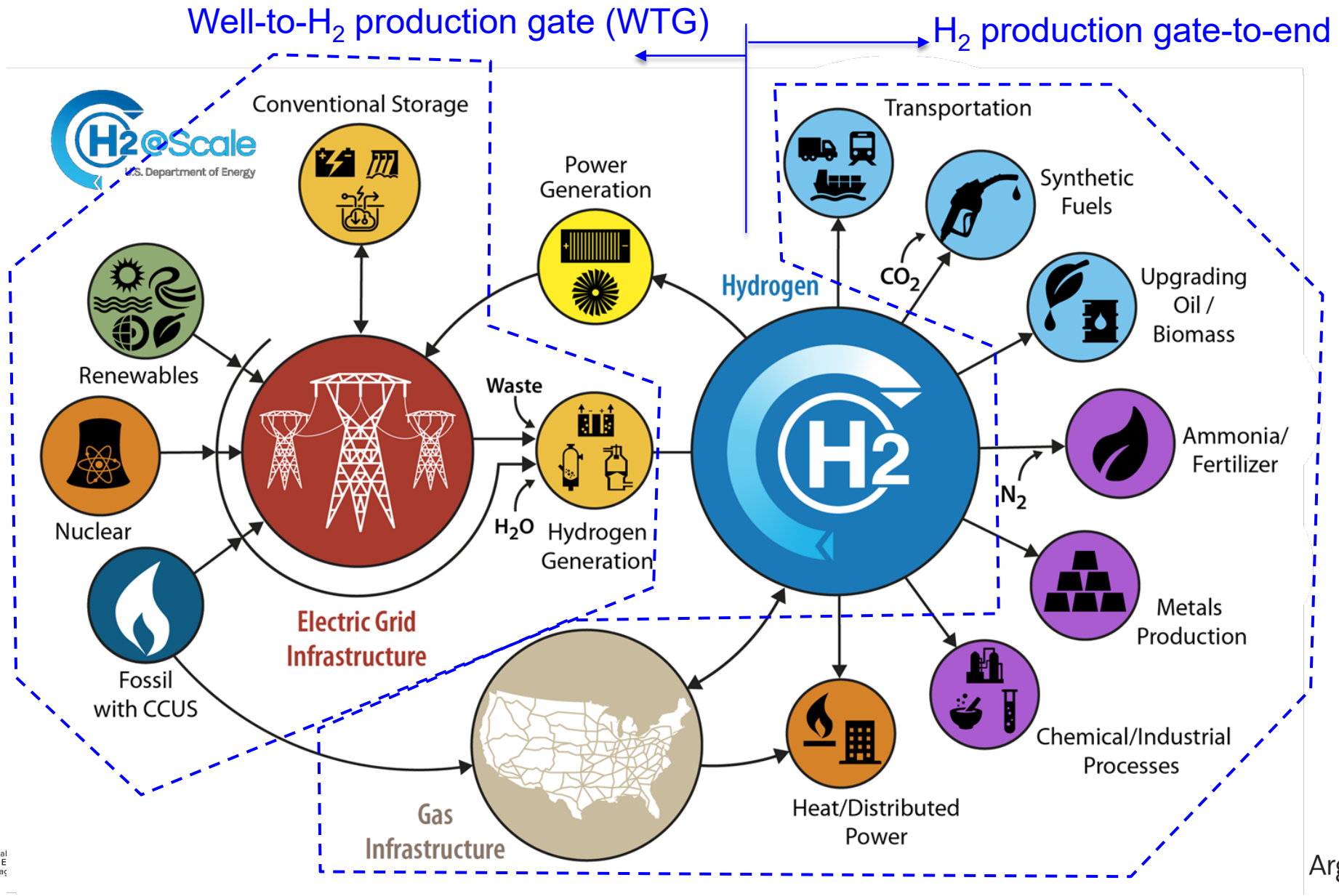
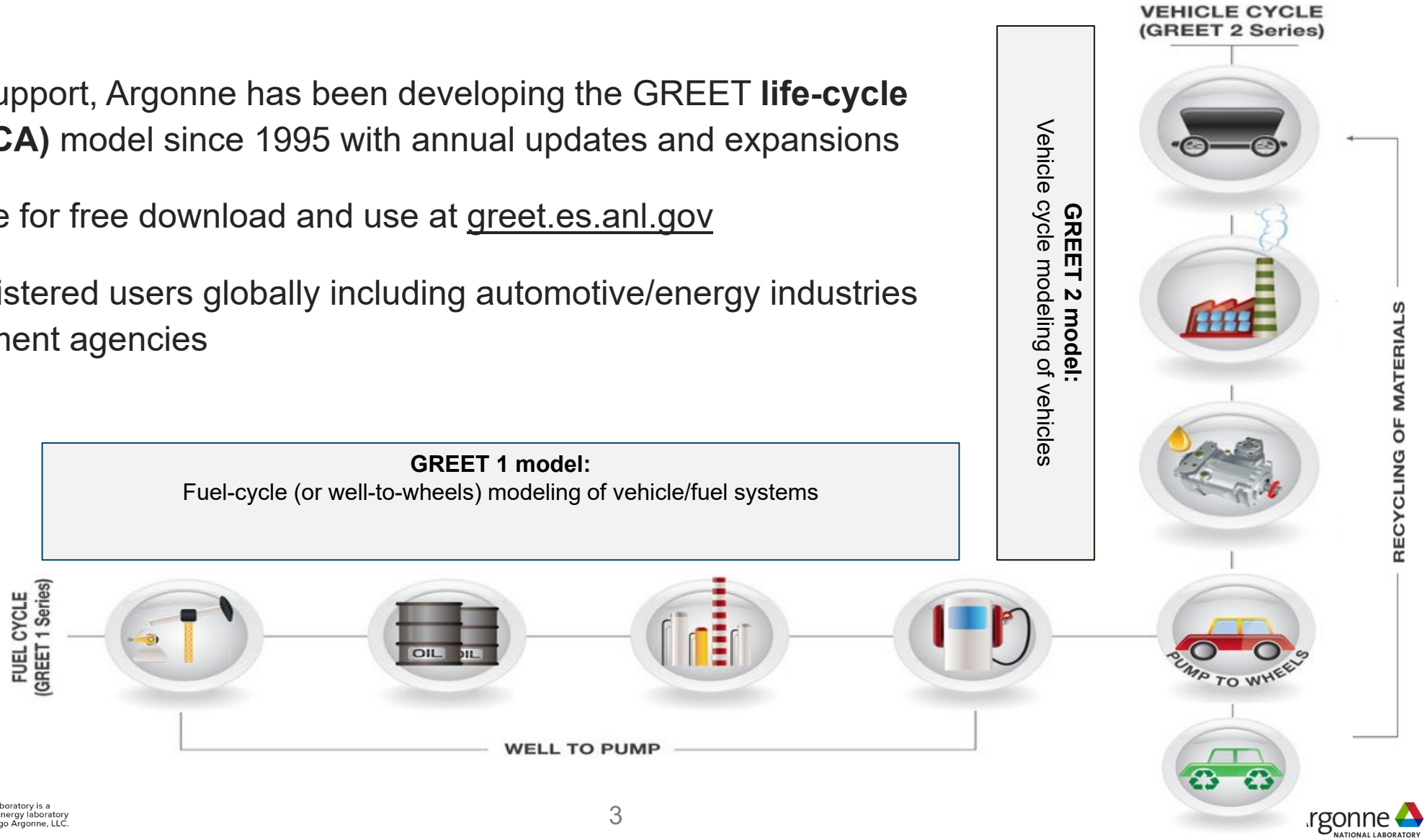
H2@Scale: a DOE initiative for a hydrogen economy



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

- With DOE support, Argonne has been developing the GREET **life-cycle analysis (LCA)** model since 1995 with annual updates and expansions
- It is available for free download and use at greet.es.anl.gov
- >50,000 registered users globally including automotive/energy industries and government agencies



GREET includes a suite of models and tools

- GREET coverage
  - ✓ GREET1: fuel cycle (or WTW) model of vehicle technologies and transportation fuels
  - ✓ GREET2: vehicle manufacturing cycle model of vehicle technologies
- Modeling platform
  - ✓ Excel
  - ✓ .net
- GREET derivatives
  - ✓ ICAO-GREET by ANL, based on GREET1
  - ✓ China-GREET by ANL, with support of Aramco
  - ✓ CA-GREET by CARB, based on GREET1
  - ✓ AFLEET by ANL: alternative-fuel vehicles energy, emissions, and cost estimation
  - ✓ EverBatt by ANL: energy, emissions, and cost modeling of remanufacturing and recycling of EV batteries

GREET applications by agencies

United States Government	Production tax credits and clean hydrogen standard under IRA and BIL
California Environmental Protection Agency Air Resources Board	CA-GREET3.0 built based on and uses data from ANL GREET
DEQ State of Oregon Department of Environmental Quality	Oregon Dept of Environ. Quality Clean Fuel Program
	EPA RFS2 used GREET and other sources for LCA of fuel pathways; GHG regulations
NHTSA	National Highway Traffic Safety Administration (NHTSA) fuel economy regulation
	FAA and ICAO AFTF using GREET to evaluate aviation fuel pathways
USDRIVE	GREET was used for the US DRIVE Fuels Working Group Well-to-Wheels Report
MARAD Maritime Administration	LCA of renewable marine fuel options to meet IMO 2020 sulfur regulations for the DOT MARAD
USDA	US Dept of Agriculture: ARS for carbon intensity of farming practices and management; ERS for food environmental footprints; Office of Chief Economist for bioenergy LCA
Government of Canada	Environment and Climate Change Canada for its Clean Fuel Standard

GREET covers all transportation subsectors

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

The GREET® (Greenhouse gases, Regulated Emissions, and Energy use in Technologies) model with H_2 User Interface

greet.es.anl.gov/greet_hydrogen https://greet.es.anl.gov/greet_hydrogen

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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
  - GREET Aviation Module
  - GREET w/ H_2 User Interface

GREET with H_2 User Interface

Click to save the .xlsm file GREET1_2022_with_H2_user_interface.xlsm to your hard drive.

GREET 2022 with H_2 User Interface

October 12, 2022

The GREET team of Systems Assessment Center at Argonne National Laboratory is pleased to announce the release of GREET with H_2 User Interface.

GREET provides in-depth life-cycle simulations for hydrogen technology pathways and is available as an Excel spreadsheet (GREET Excel) or an application (GREET.Net). Both versions are available for public download at no charge to users. GREET 2022 is released with expansion of the hydrogen technology pathways and updates to process level data. Furthermore, a version of GREET Excel model is released with an additional interactive user interface in a separate dedicated worksheet (H2_User_Inputs) designed for users interested in hydrogen pathways to facilitate simple process data input and various levels of emissions results in the same worksheet. The GREET.Net version is already designed bottom-up with graphical user interface.

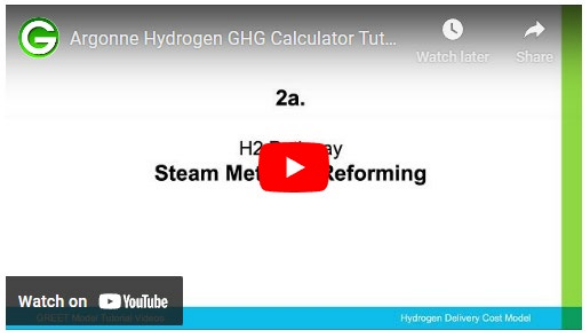
To accompany GREET 2022 release, a report was developed to document and describe the major updates and expansions to the hydrogen technology pathways, and to provides data sources and sample carbon intensity results for each of the hydrogen production pathways.

The model and report can be downloaded through the links provided below.

Download tool and documentation

- GREET 2022 (Excel platform) with H_2 user interface (16.1 MB xlsm)
- GREET 2022 (.Net platform) (link)
- Report and documentation (1.61 MB pdf)

Tutorial Video



https://youtu.be/0NakQjCUSoQ

GREET sustainability metrics include energy use, criteria air pollutants, GHG, and water consumption

Energy use

- Total energy: fossil energy and renewable energy
- Fossil energy: petroleum, natural gas, and coal
- Renewable energy: biomass, nuclear energy, hydro-power, wind power, and solar energy

Resource availability and energy security

Air pollutants

- VOC, CO, NOx, PM_{10}, $PM_{2.5}$, and SOx
- Estimated separately for total and urban (a subset of the total) emissions

Human health and environmental justice

Greenhouse gases

- CO_2, CH_4, N_2O, black carbon, and albedo
- CO_{2e} of the five (with their global warming potentials)

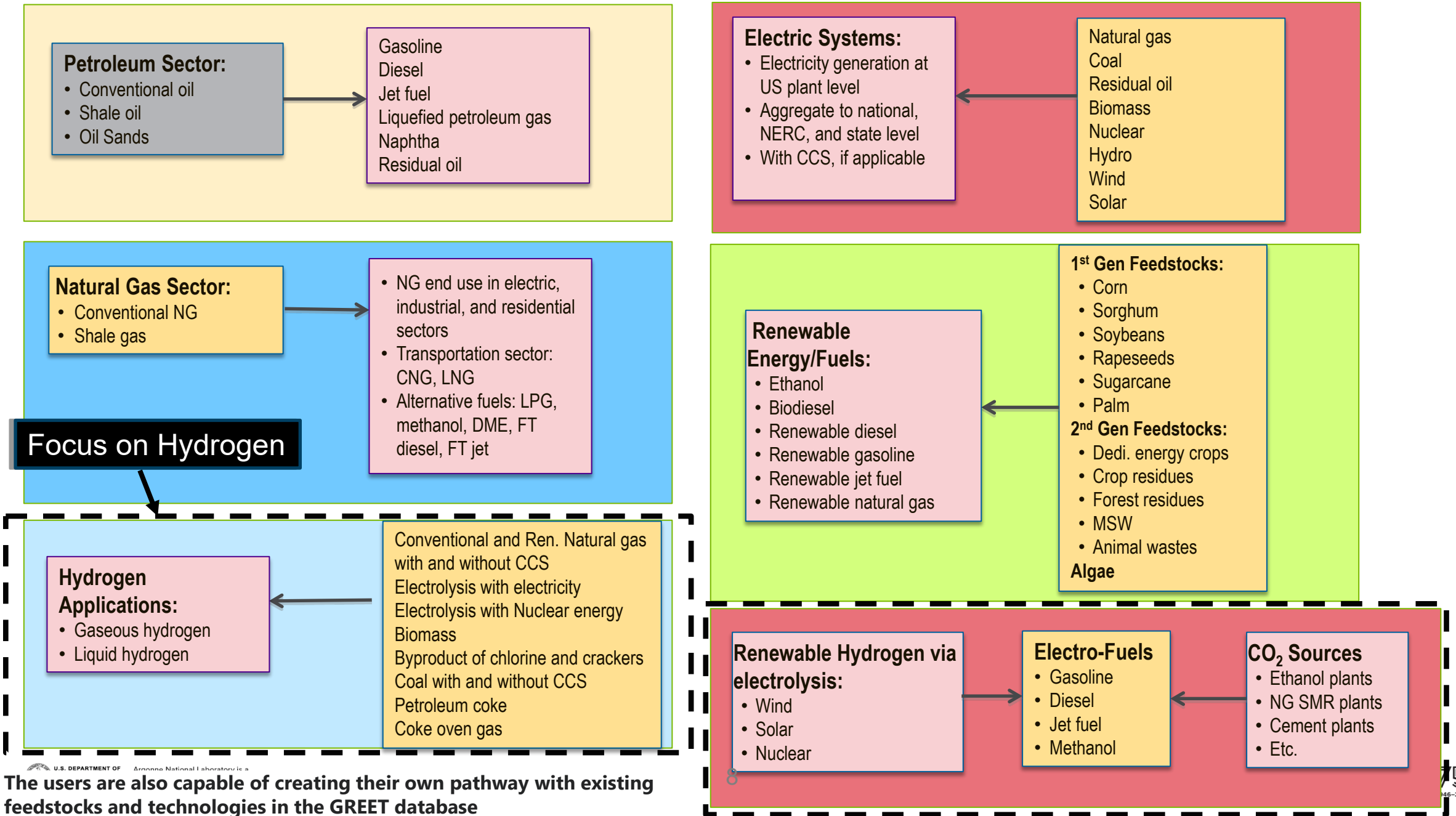
Global warming impacts

Water consumption

- Addressing water supply and demand (energy-water nexus)

Regional/seasonal water stress impacts

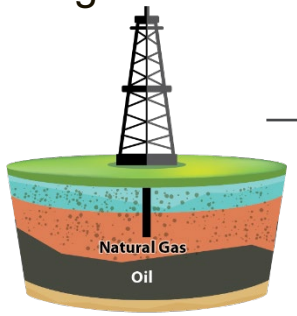
GREET covers many groups of energy systems



The users are also capable of creating their own pathway with existing feedstocks and technologies in the GREET database

Hydrogen production pathway: CH_4 reforming w/ and w/o CCS

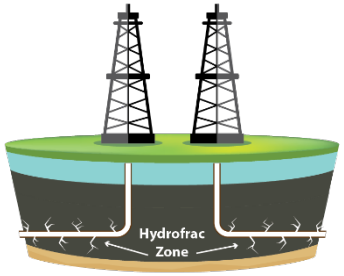
Conventional Gas Drilling & Recovery



NG Processing

NG Compression

Shale Gas Drilling & Recovery



NG Processing

NG Compression

CCS

CO_2 CO_2

combustion reformation

NG Transportation

H_2 + Steam

NG SMR or ATR Plant

Avoided GHG emissions from landfilled MSW

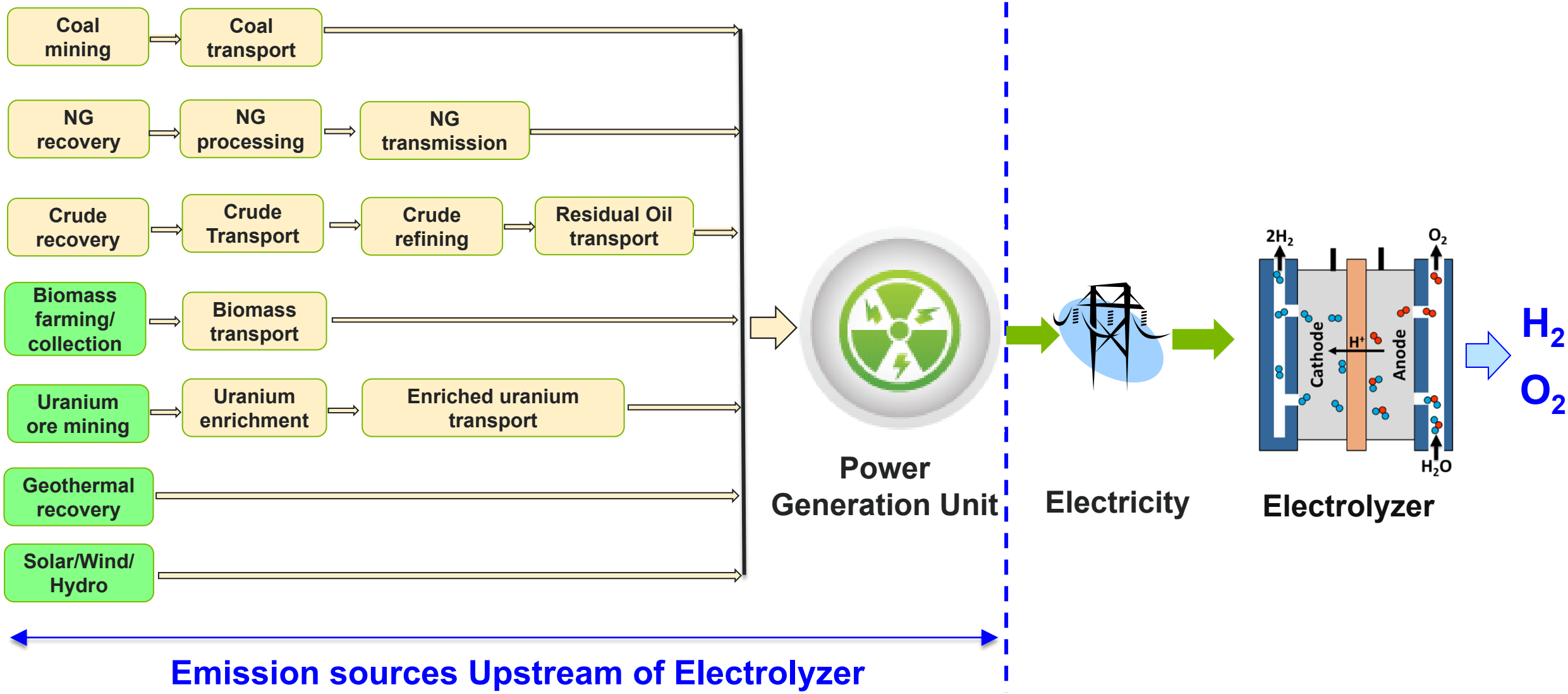
Landfilling

MSW

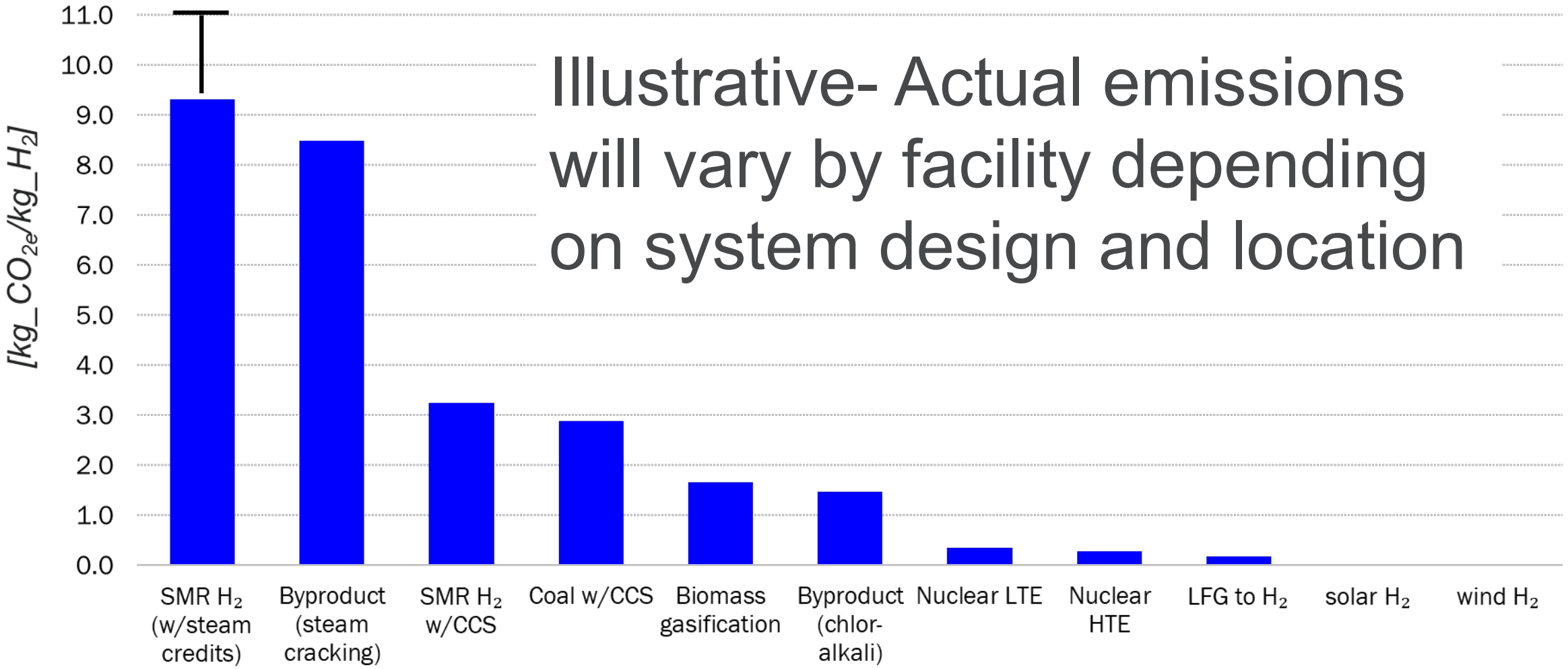
Anerobic Digestion

RNG

Example hydrogen production pathway: water electrolysis

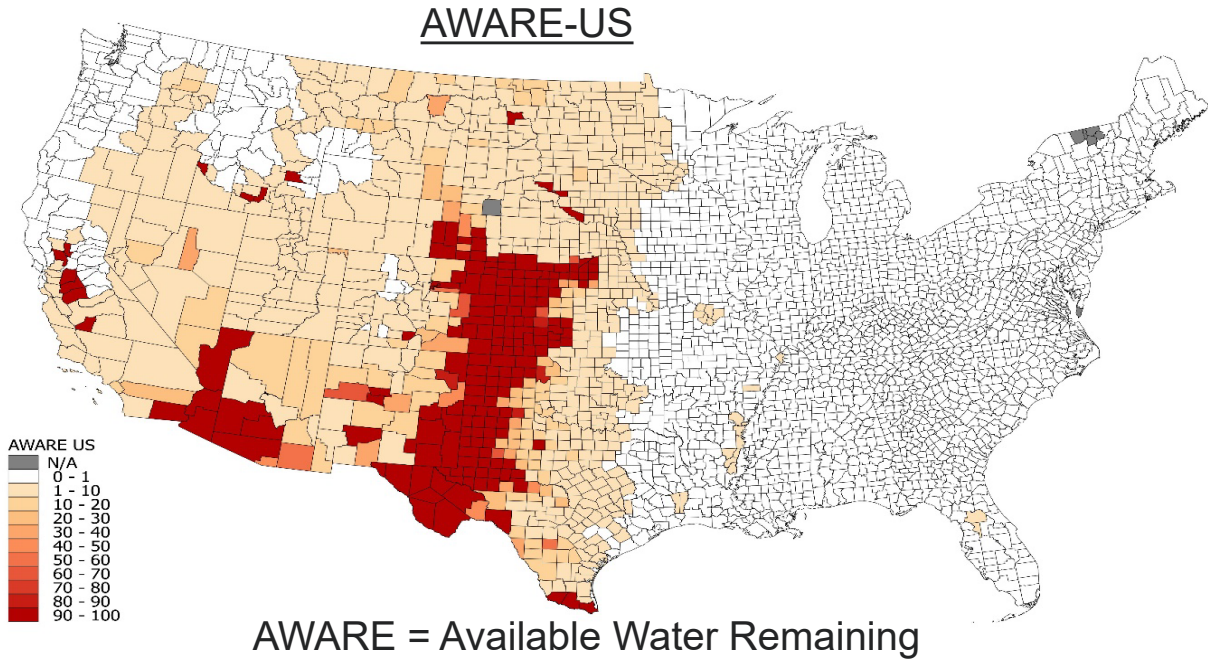


Potential well-to-gate (WTG) GHG emissions of hydrogen production pathways

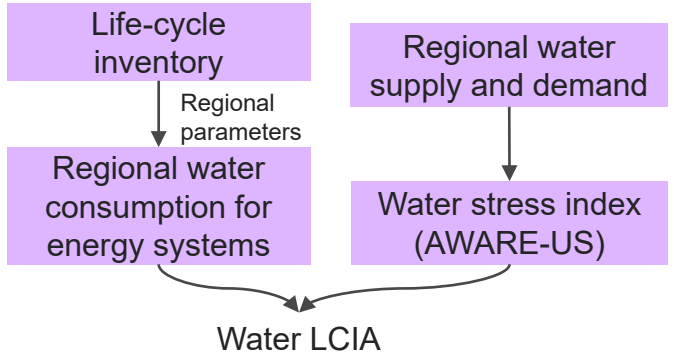


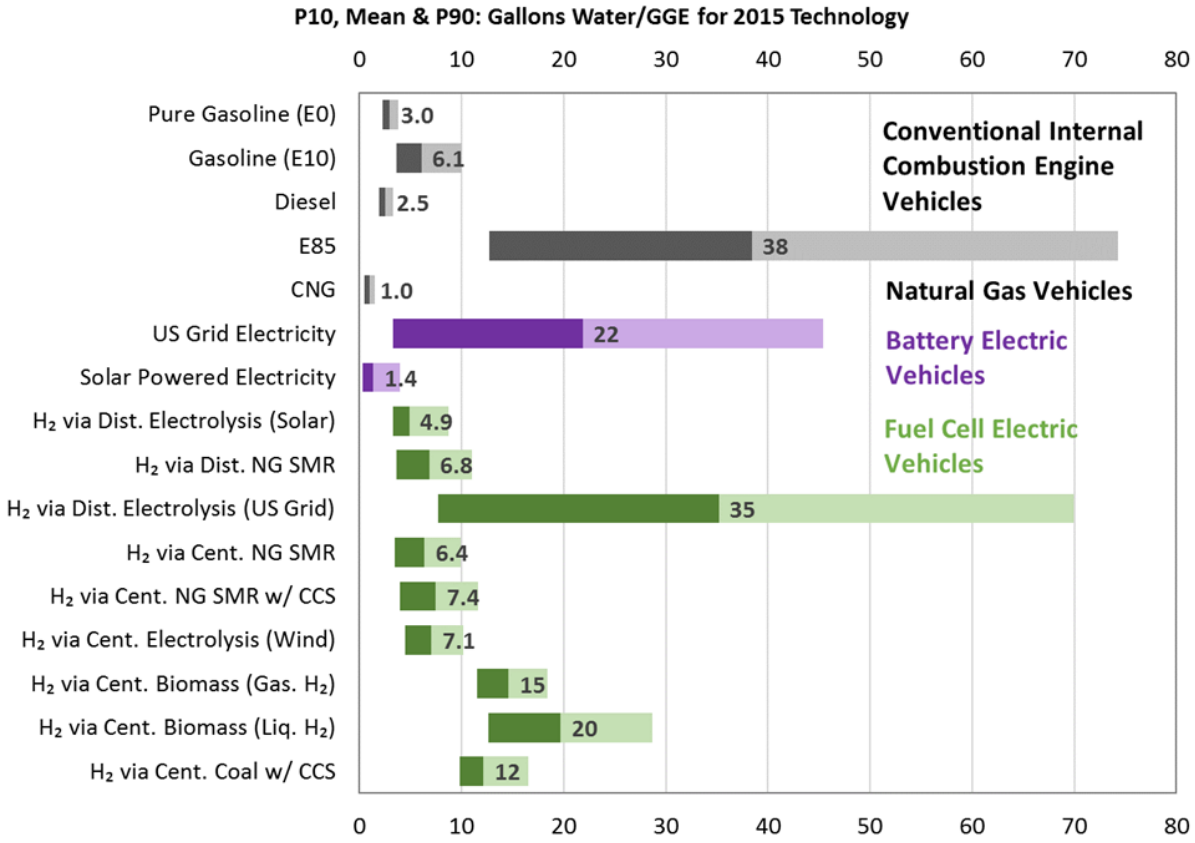
Regional water supply-demand balance is key for large scale H_2 production; Argonne AWARE-US model addresses regional/seasonal water stress impacts

- Brings together water consumption and ambient water availability.
- Considers hydrologic flows and societal water use at county level.
- Applying to a wide range of energy supply chains.



AWARE = Available Water Remaining





https://www.sciencedirect.com/science/article/pii/S0048969718332145?via%3Dihub

Acknowledgment

Hydrogen pathways in GREET® LCA model have been supported by DOE's Office of Energy Efficiency and Renewable Energy's Hydrogen and Fuel Cell Technologies Office (HFTO) for over two decades

Thank You!

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GREET tutorials:

https://youtu.be/BrqRhJ3qRmI

https://youtu.be/0NakQjCUSoQ

Our models and publications are available at:

https://greet.es.anl.gov/publications

https://hdsam.es.anl.gov/