Fuel-Cycle Energy and Emissions Analysis with the GREET Model

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Overview of GREET Model Development

Timeline

- Start – 1995
- Finish – continuous
- % complete – not applicable

Budget

- Total project funding
  - ✓ DOE share: ~$5 million from various EERE offices since 1995
- Funding received from VT Fuel Utilization
  - ✓ FY08: $500k
  - ✓ FY09: $400k

Barriers Addressed

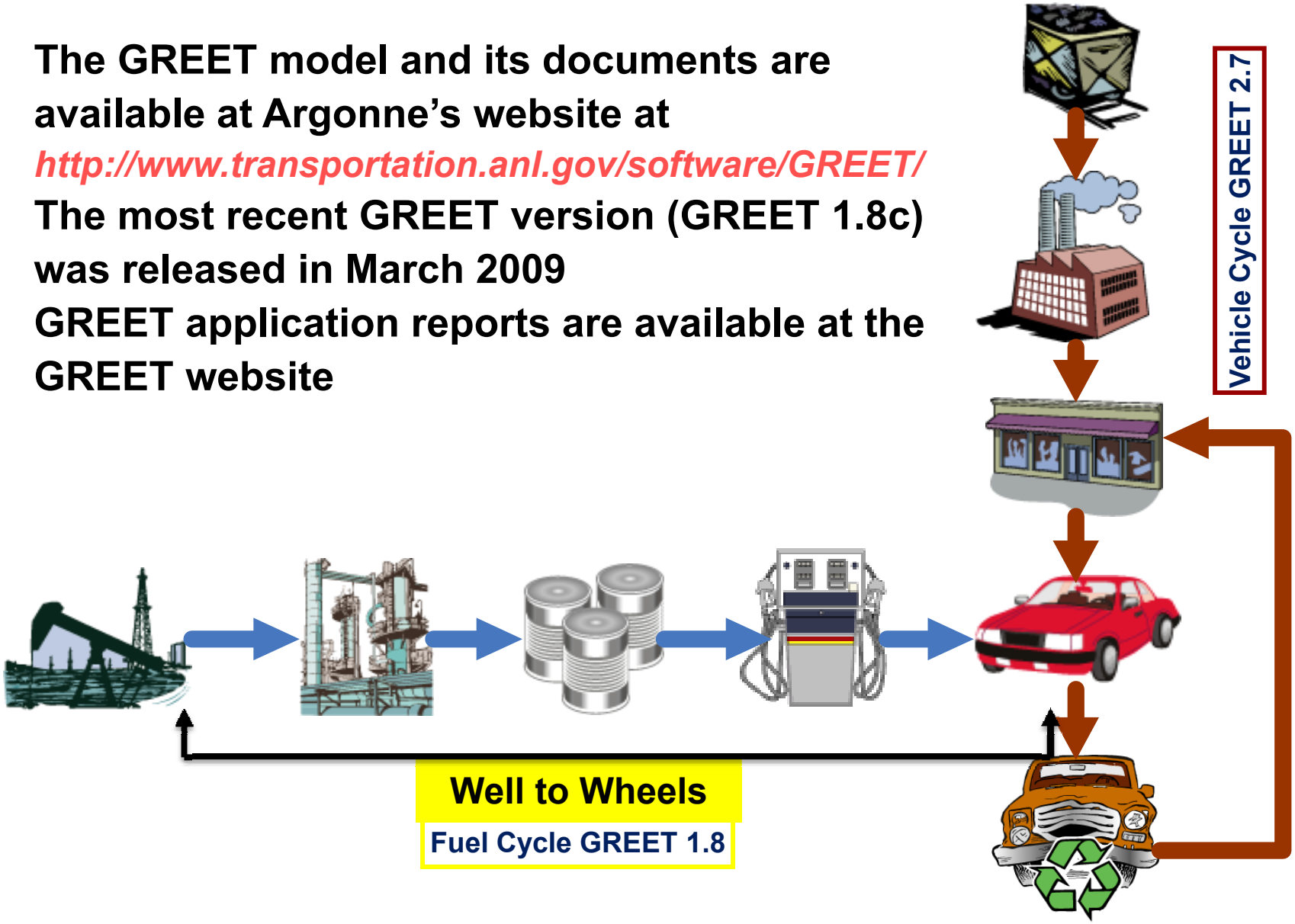
- Develop a comprehensive tool to examine full energy and emission effects of vehicle/fuel systems
- Conduct thorough WTW analyses with the developed tool

Partners

- Other national labs
- The auto industry
- The energy industry
- Other government agencies
- Research institutions and universities

The GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model

- The GREET model and its documents are available at Argonne's website at *http://www.transportation.anl.gov/software/GREET/*
- The most recent GREET version (GREET 1.8c) was released in March 2009
- GREET application reports are available at the GREET website



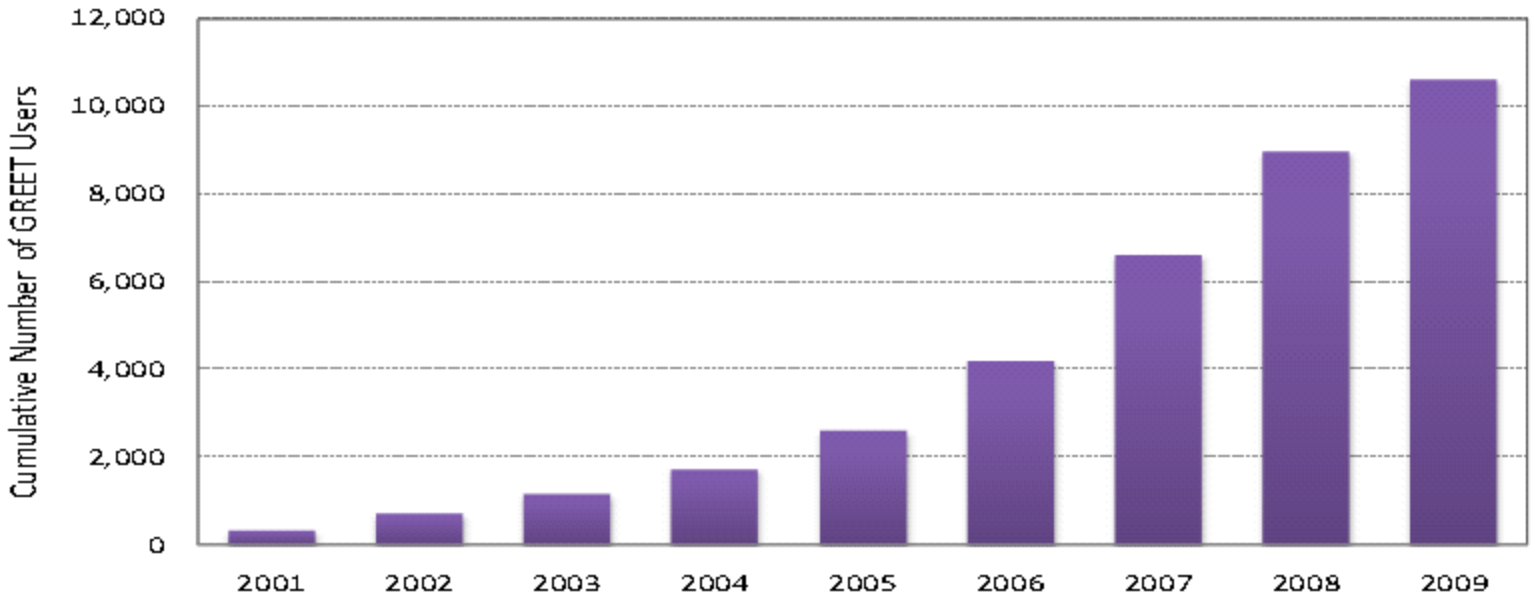
Objectives

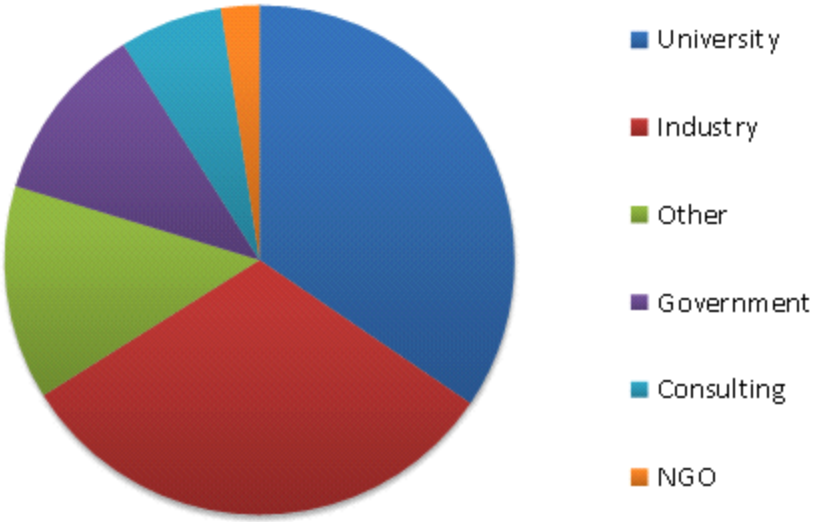
- Develop the GREET model as a consistent, transparent LCA tool so that DOE and stakeholders can evaluate energy and GHG emission effects of advanced vehicle technologies and new transportation fuels
- Conduct thorough well-to-wheels (WTW) analyses of vehicle/fuel systems of interest to DOE and the nation
- Engage in discussions and exchanges with the auto industry, the energy industry, and government agencies to provide objective WTW results for technology R&D and policy development
- Interact with research institutions and universities to advance WTW analytic methodologies

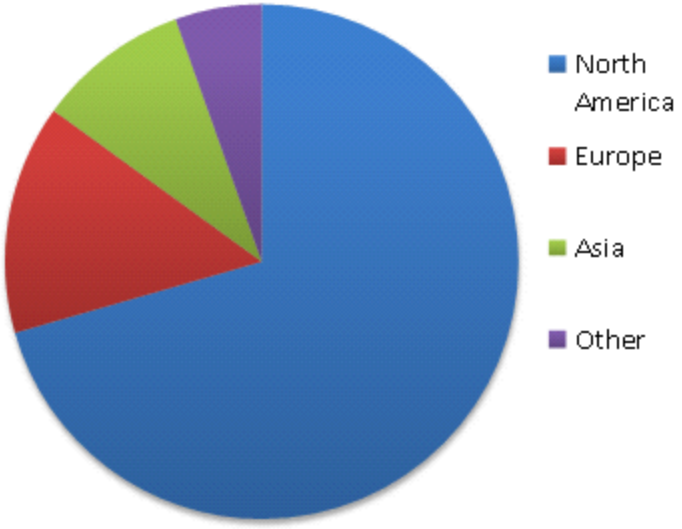
GREET Development Milestones

- The first GREET version was released in 1996
- The most recent GREET version – GREET1.8c – was released in March 2009
- Major WTW studies were completed in the past 13 years:
  - ✓ Alternative-fuel vehicles in 1990s
  - ✓ NG-based fuel production pathways in late 1990s
  - ✓ Hydrogen pathways in early 2000s
  - ✓ Biofuels since the middle of 1990s
  - ✓ XTLs since 2005

GREET Users and Their Distribution



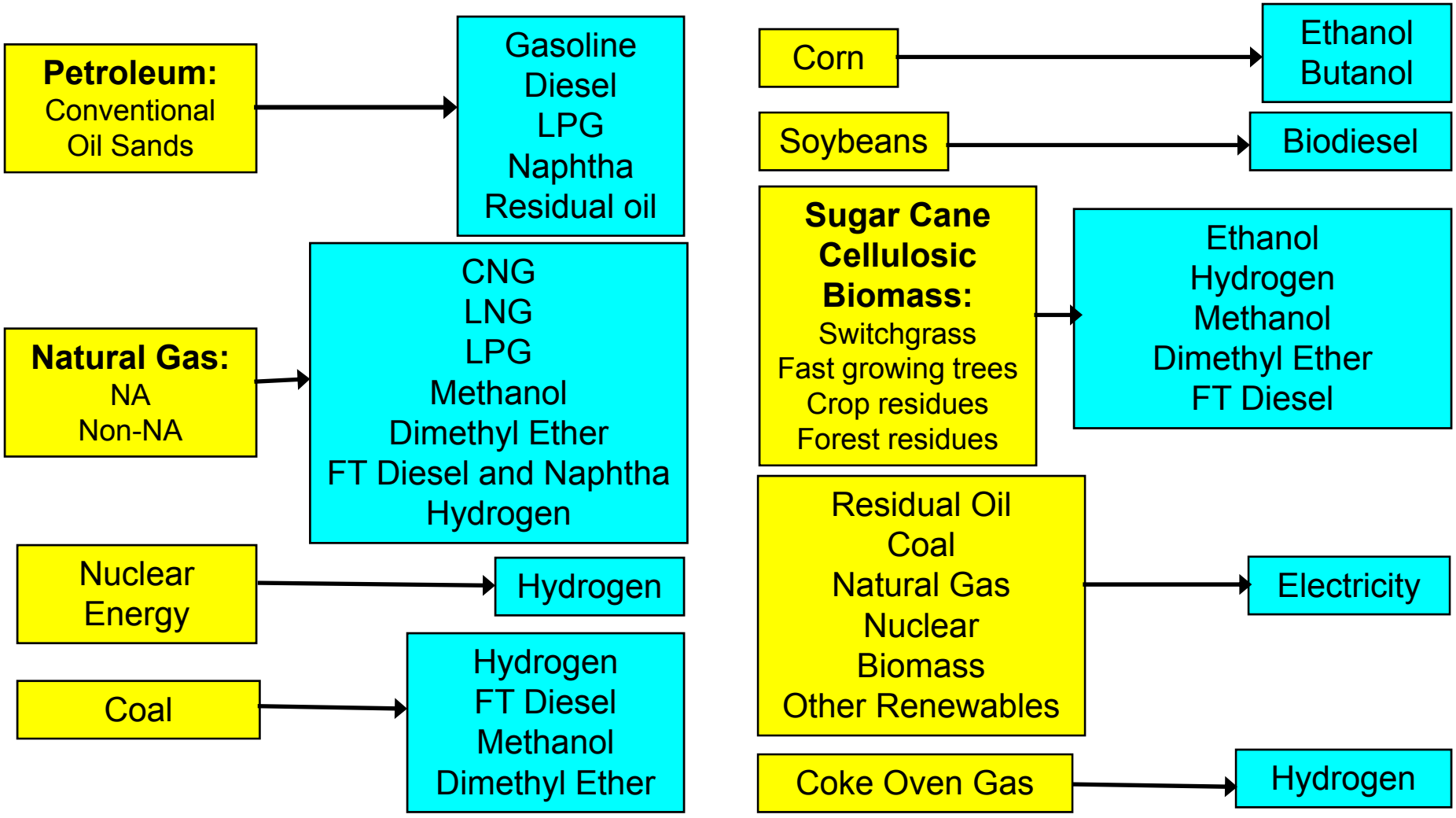




Approach

- Develop the GREET model as a user-friendly LCA model to serve researchers and policy makers for LCA needs
- Obtain and develop reliable input data for the GREET model
- Well-to-pump data sources
  - ✓ Open literature
  - ✓ Engineering analysis (such as ASPEN simulations for mass and energy balance)
  - ✓ Stakeholder inputs (e.g., collaboration with the energy industry)
- Pump-to-wheels data sources
  - ✓ Fuel economy
    - ➢ Open literature
    - ➢ Vehicle simulations with models such as Argonne's PSAT model
  - ✓ Vehicle operation emissions
    - ➢ Open literature
    - ➢ Emission testing results
    - ➢ EPA MOBILE model
    - ➢ CARB EMFAC model

GREET Includes More Than 100 Fuel Production Pathways from Various Energy Feedstocks

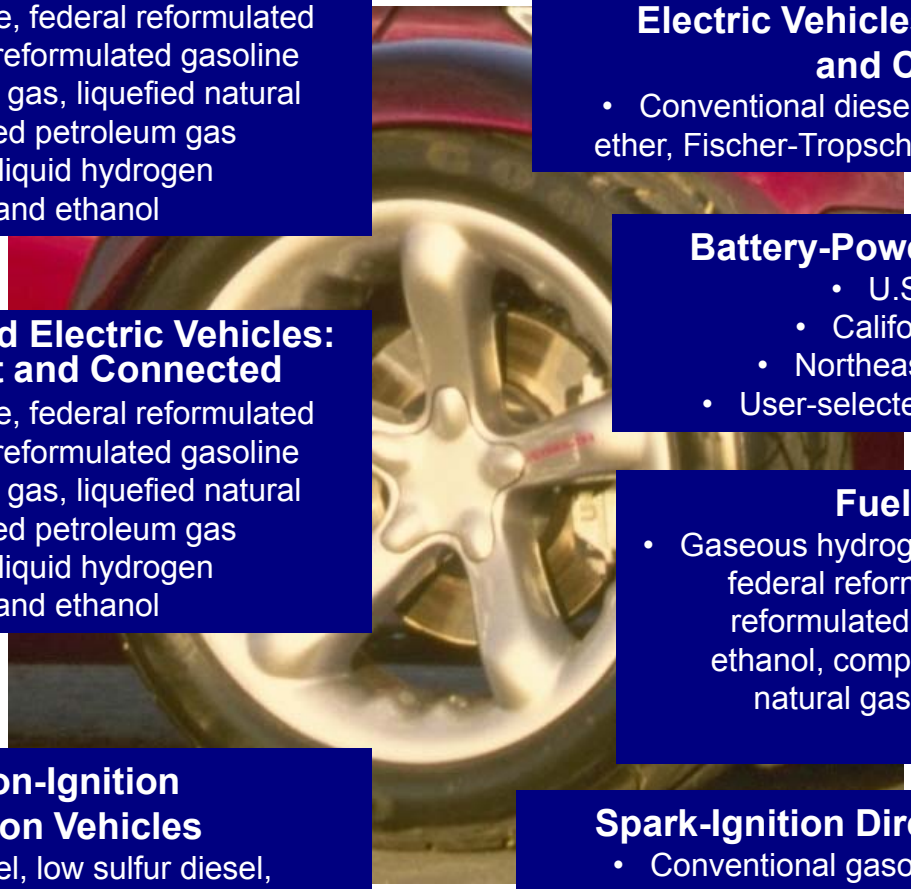


GREET Includes More Than 75 Vehicle/Fuel Systems

Conventional Spark-Ignition Vehicles
- Conventional gasoline, federal reformulated gasoline, California reformulated gasoline
- Compressed natural gas, liquefied natural gas, and liquefied petroleum gas
- Gaseous and liquid hydrogen
- Methanol and ethanol

Spark-Ignition Hybrid Electric Vehicles: Grid-Independent and Connected
- Conventional gasoline, federal reformulated gasoline, California reformulated gasoline
- Compressed natural gas, liquefied natural gas, and liquefied petroleum gas
- Gaseous and liquid hydrogen
- Methanol and ethanol

Compression-Ignition Direct-Injection Vehicles
- Conventional diesel, low sulfur diesel, dimethyl ether, Fischer-Tropsch diesel, E-diesel, and biodiesel



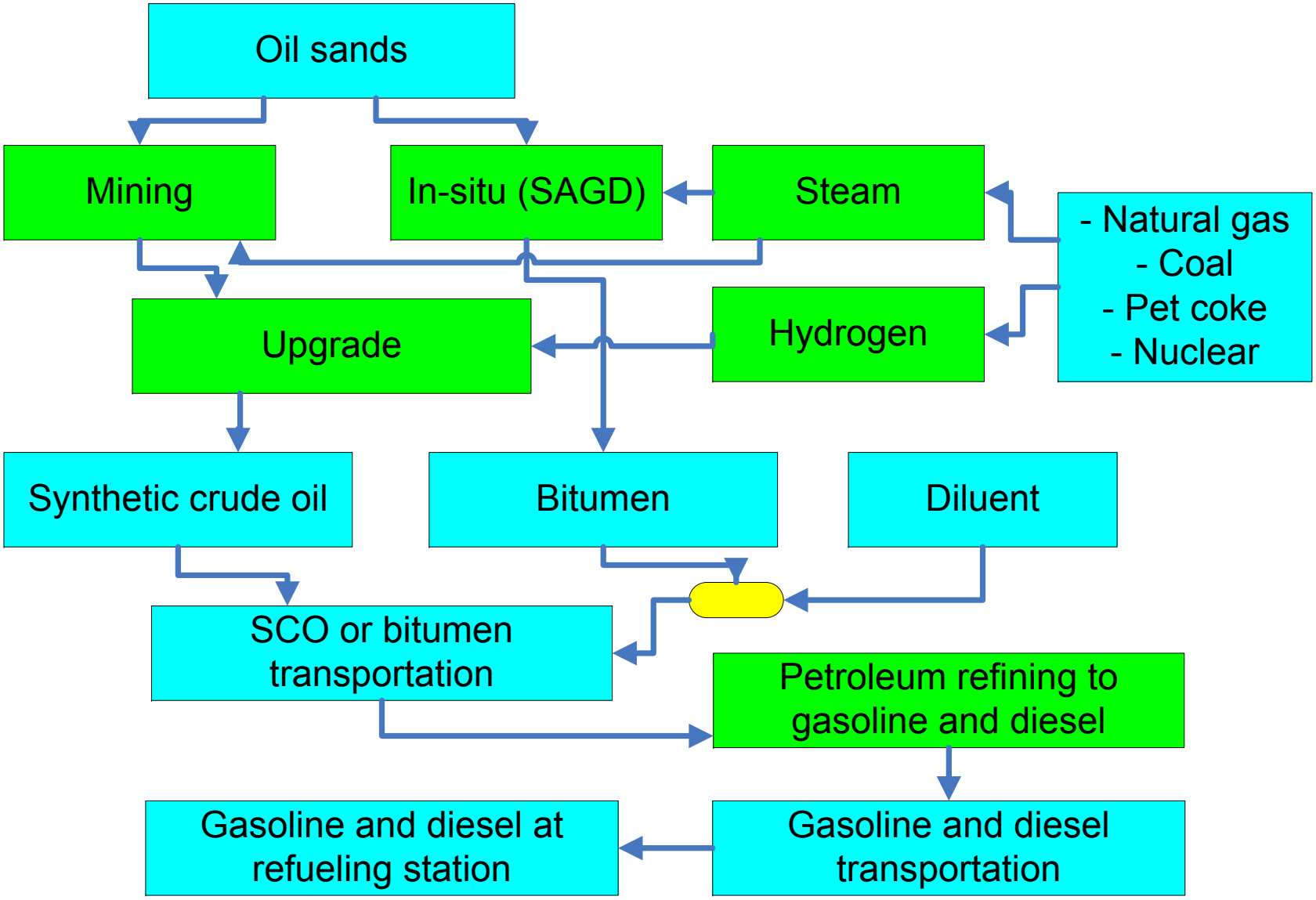
Compression-Ignition Direct-Injection Hybrid Electric Vehicles: Grid-Independent and Connected
- Conventional diesel, low sulfur diesel, dimethyl ether, Fischer-Tropsch diesel, E-diesel, and biodiesel

Battery-Powered Electric Vehicles
- U.S. generation mix
- California generation mix
- Northeast U.S. generation mix
- User-selected generation mix

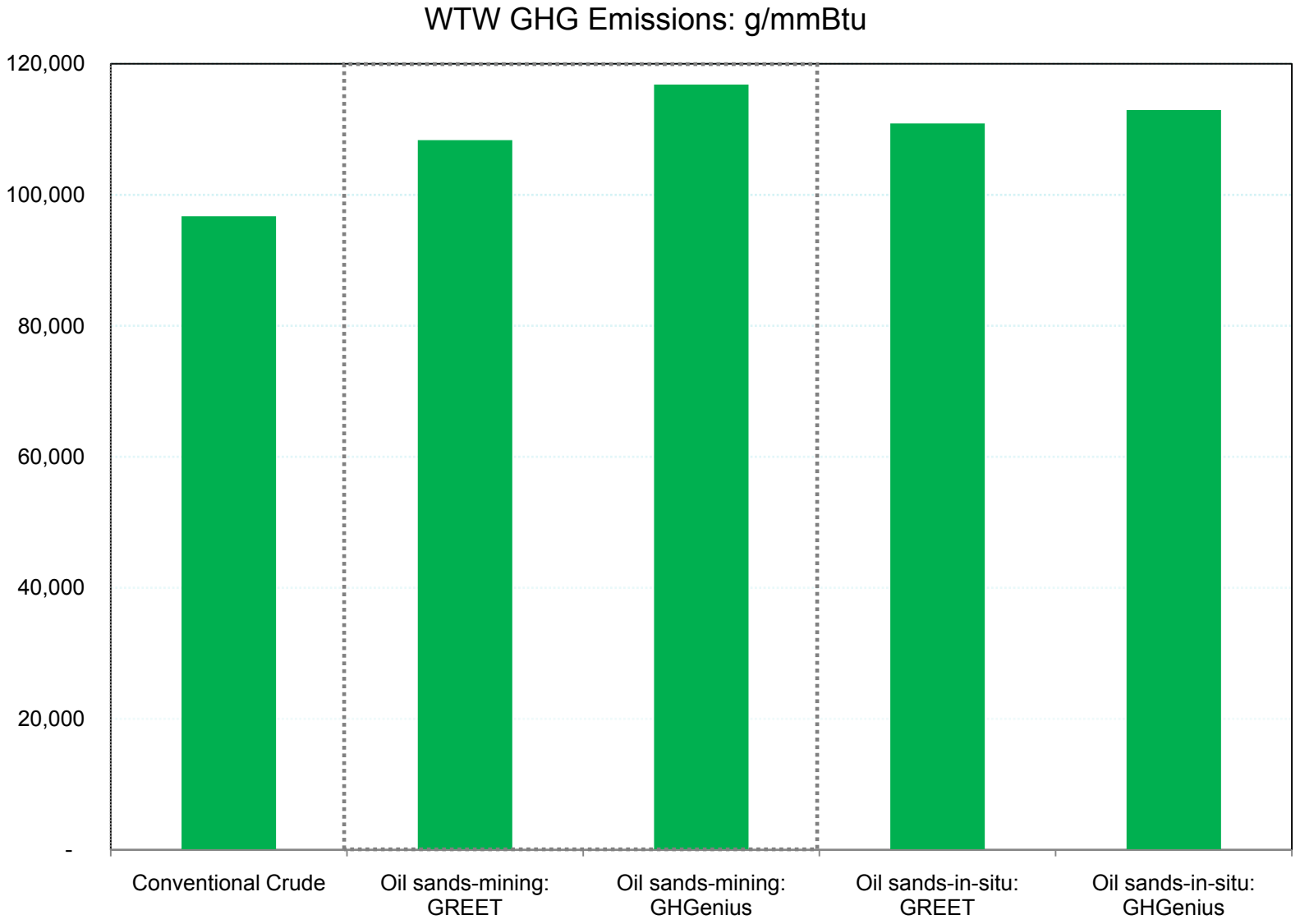
Fuel Cell Vehicles
- Gaseous hydrogen, liquid hydrogen, methanol, federal reformulated gasoline, California reformulated gasoline, low sulfur diesel, ethanol, compressed natural gas, liquefied natural gas, liquefied petroleum gas, and naphtha

Spark-Ignition Direct-Injection Vehicles
- Conventional gasoline, federal reformulated gasoline, and California reformulated gasoline
- Methanol and ethanol

The Pathway of Oil Sands to Gasoline and Diesel Requires a Large Amount of Steam and H_2



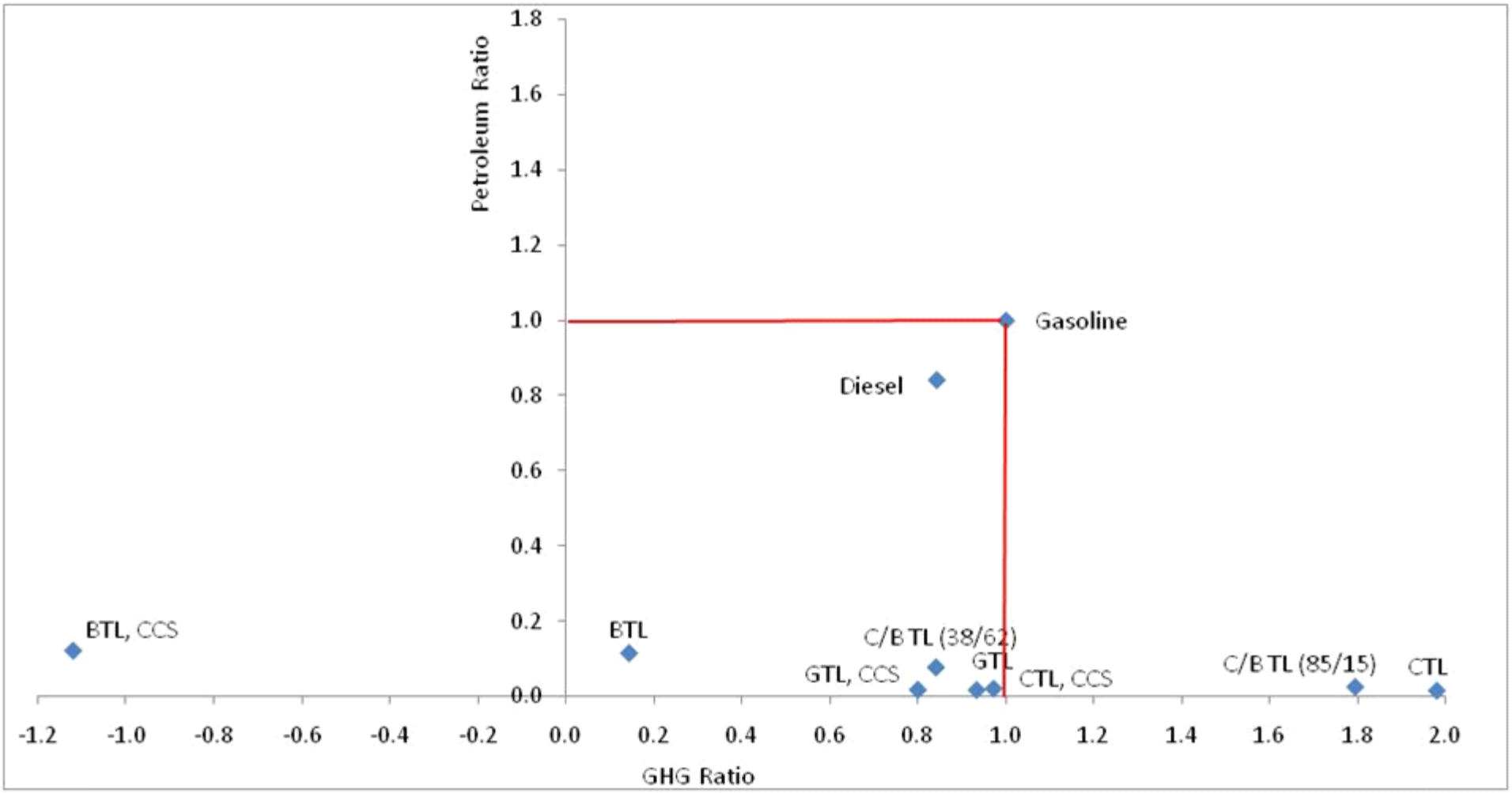
GREET Well-to-Wheels GHG Results for Gasoline from Convention Crude and Oil Sands



Four FT Diesel Production Options Were Evaluated

- Natural gas to liquids (GTL)
- Coal to liquids (CTL)
- Biomass to liquids (BTL)
- Co-firing of coal and biomass to liquids (C/BTL)
  - ✓ 85/15 C/B co-feeding
  - ✓ 38/62 C/B co-feeding: GHG breakeven with petroleum diesel

Trade-Offs Between Petroleum Reductions and GHG Reductions by XTLs



Future Work

- Update GREET with new testing data for XTLs in U.S. diesel cars
- Expand GREET to include new fuel production pathways such as
  - ✓ Landfill gas to CNG and LNG
  - ✓ New biofuel pathways
  - ✓ Other non-petroleum pathways
- Develop GREET with a new programming platform for easier expansion and use
- Conduct WTW analyses to serve DOE and others

Summary

- With EERE support, GREET has become a standard tool for LCAs of vehicle/fuel systems
  - ✓ Examine energy and GHG reduction potentials of advanced vehicle technologies and new transportation fuels
  - ✓ Identify opportunities and challenges of achieving energy and GHG emission reductions by vehicle technologies and fuel production pathways
- Expansion and maintenance of GREET to serve transportation LCA needs will continue