Full Fuel-Cycle Greenhouse Gas Emission Impacts of Transportation Fuels Produced from Natural Gas

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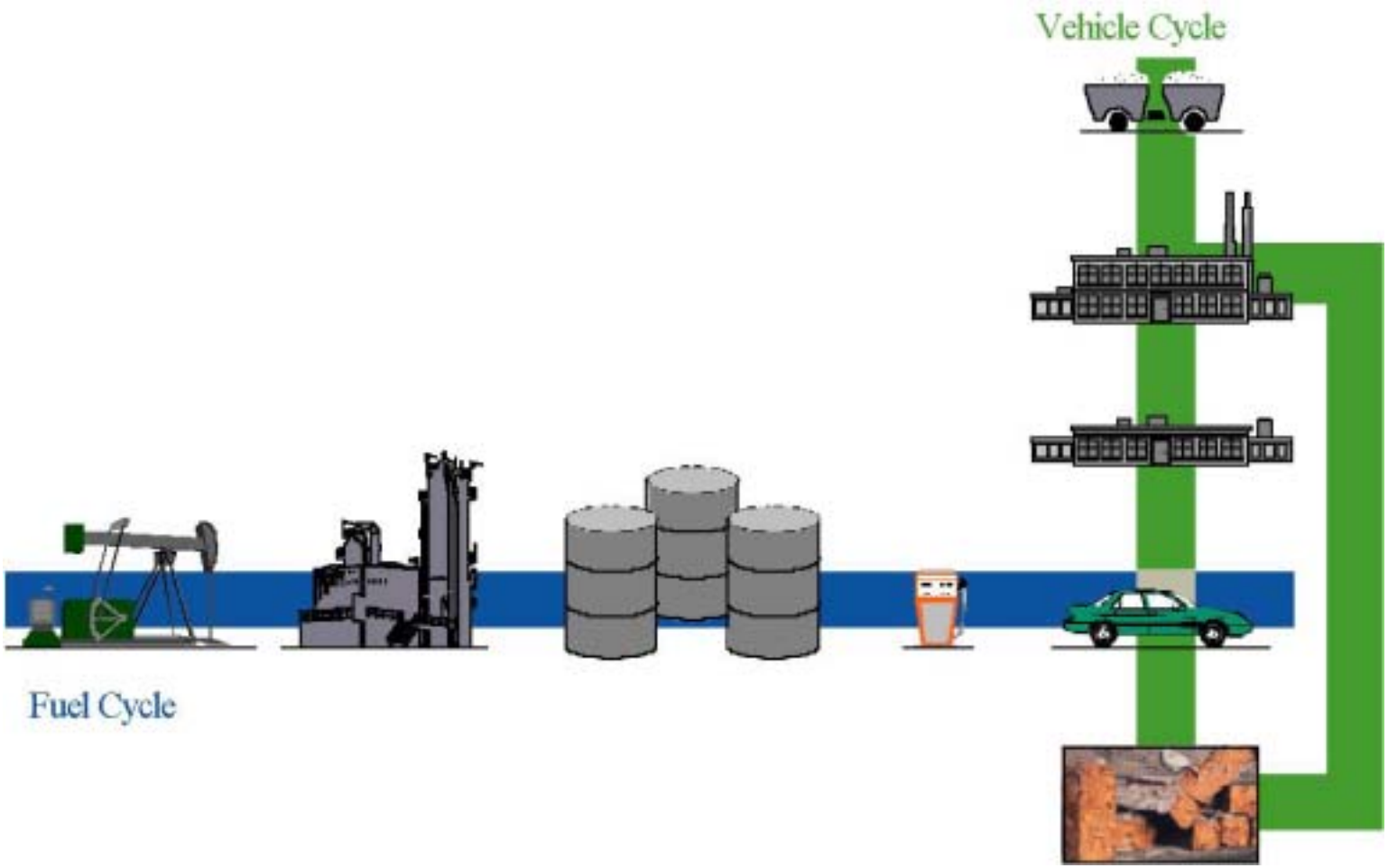
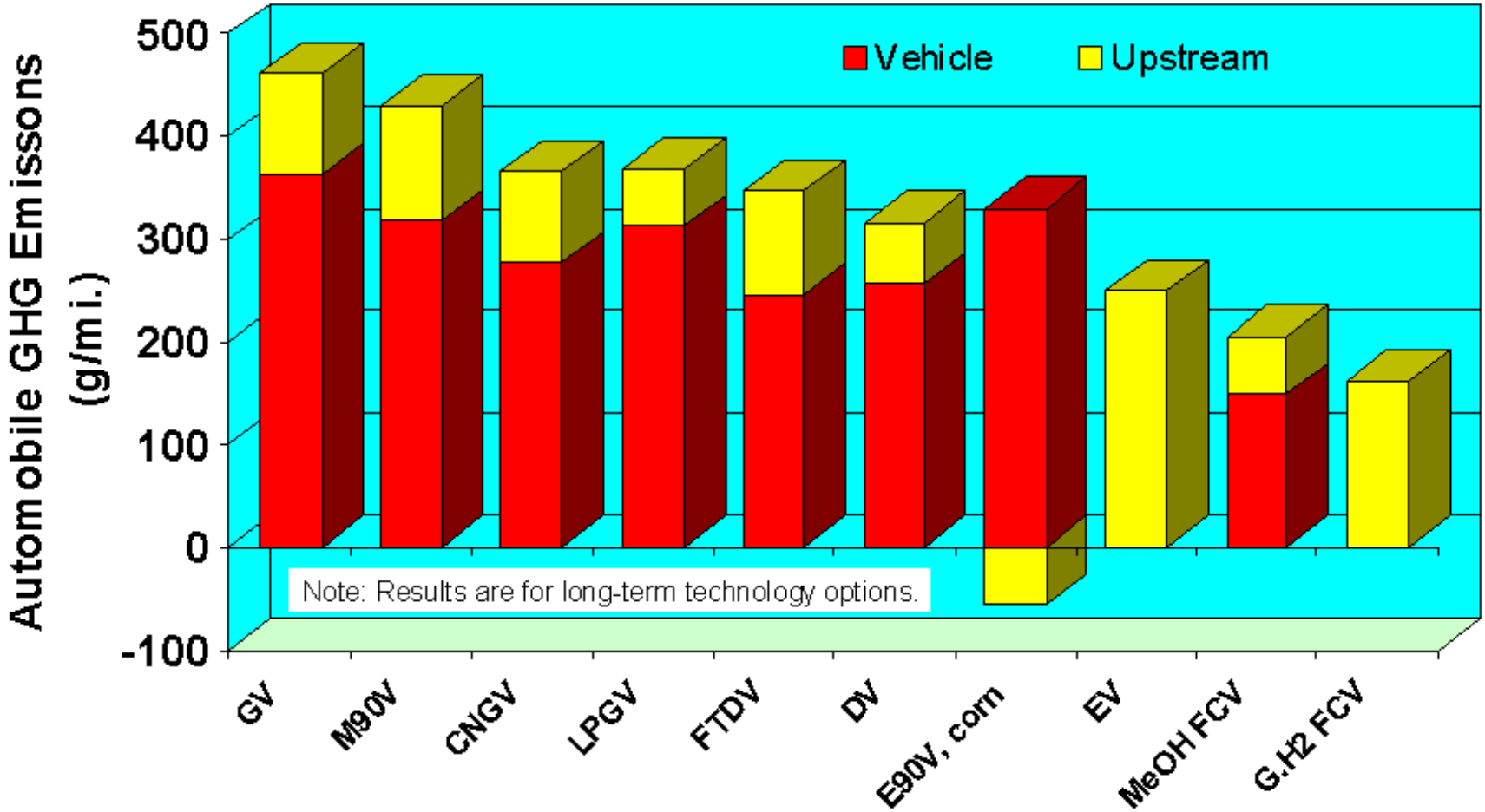
Vehicle and Fuel Cycles: Petroleum-Based Fuels



Upstream Emissions Can Make a Difference When Comparing Vehicle/Fuel Systems



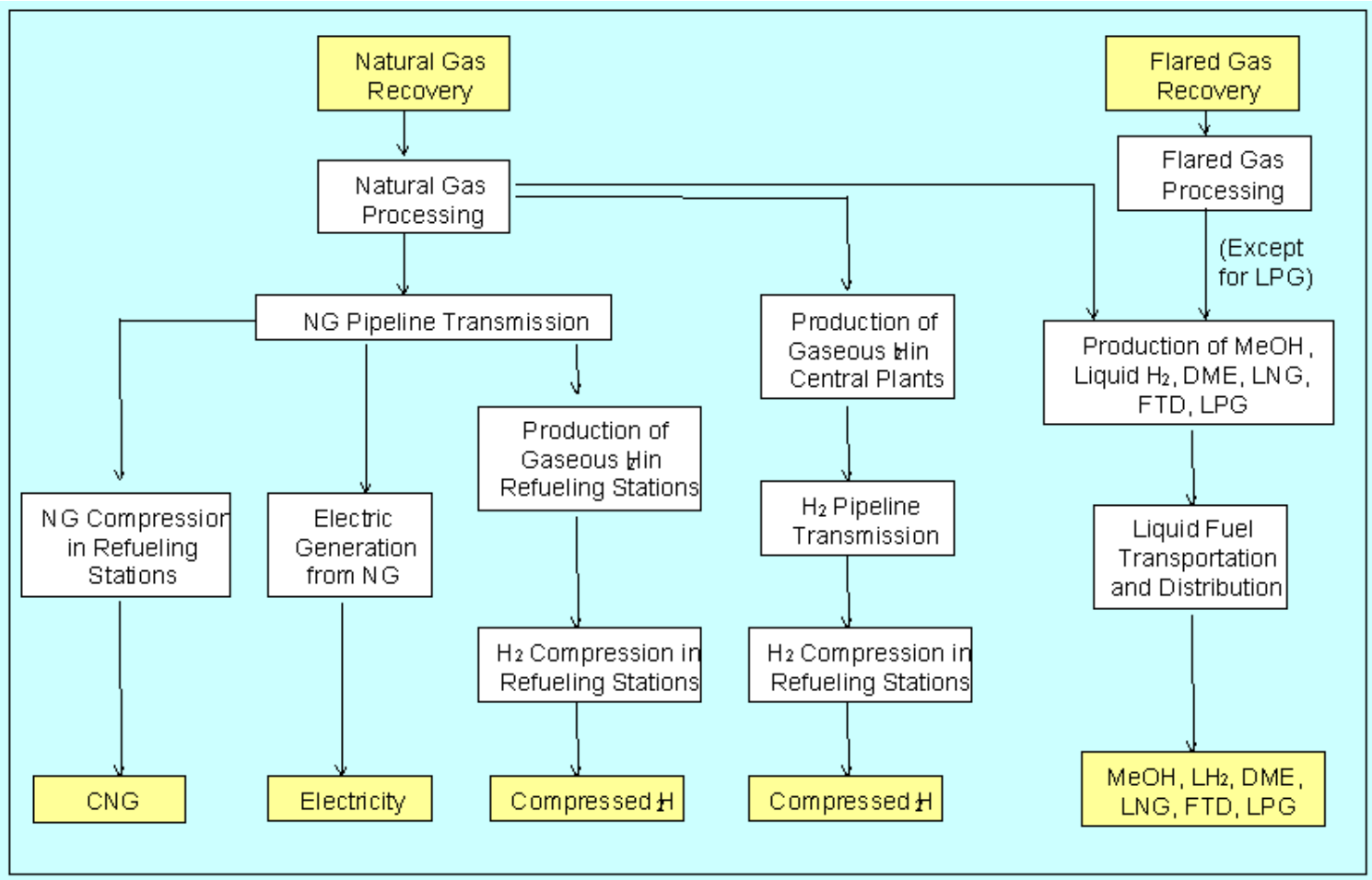
The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model

- **The GREET Model**
  - A total energy cycle model to estimate per-mile energy use and emissions
  - First version was developed in 1996
- **GREET Comprises Three Sub-Models**
  - The 1st is a fuel-cycle model for cars and light-duty trucks (the current version is GREET1.5a)
  - The 2nd is a vehicle-cycle model for cars and light-duty trucks
  - The 3rd is a fuel-cycle model for classes 2b - 8 trucks

GREET Simulates These Emission and Energy Items

- **Emissions of Greenhouse Gases**
  - CO_2, CH_4, and N_2O
  - VOC, CO, and NOx as optional GHGs
- **Emissions of Five Criteria Pollutants (Total and Urban Separately)**
  - VOC, CO, NO_x, PM_{10}, and SO_x
- **Energy Use**
  - All energy sources
  - Fossil fuels
  - Petroleum

This Study Evaluated 15 Natural Gas-Based Fuel Pathways



Key Upstream Issues: Petroleum Fuels

- Gasoline sulfur content will be reduced to ~30 ppm by 2006 from the current level of 200-300 ppm
- Diesel sulfur content will probably be reduced to <50 ppm from the current level of ~300 ppm
- On the other hand, marginal crude has high sulfur content
- Desulfurization in petroleum refineries increases hydrogen consumption considerably, resulting in high energy use and emissions
- MTBE in gasoline will be likely phased out nationwide. It is not clear what oxygenates, if any, will be used

Key Upstream Issues: Natural Gas-Based Fuels

- **Gas Reserve**
  - Worldwide, the size of conventional gas reserve is about as large as that of crude reserve
  - At present, gas consumption is only ~60% of oil consumption
- **CNG**
  - An energy efficient way to use gas in transportation
  - CNG stations could cause high urban NOx emissions
  - CNG vehicle driving range is limited
- **LNG**
  - Allows for cross-ocean transportation
  - Production suffers moderate efficiency loss

Key Upstream Issues: Natural Gas-Based Fuels (cont.)

- **Methanol**
  - Technology is proven and mature
  - Production suffers efficiency loss and high emissions
  - Is being promoted as a fuel-cell fuel
- **Fischer-Tropsch Diesel**
  - A high-quality diesel engine fuel (low sulfur and aromatics)
  - Able to use the existing diesel fuel distribution infrastructure
  - Production technology is still evolving
  - Production suffers large efficiency loss and emissions
- **Dimethyl Ether**
  - Can be stored in liquid form at moderate pressure (like LPG)
  - A good diesel engine fuel
  - Production suffers efficiency loss and high emissions

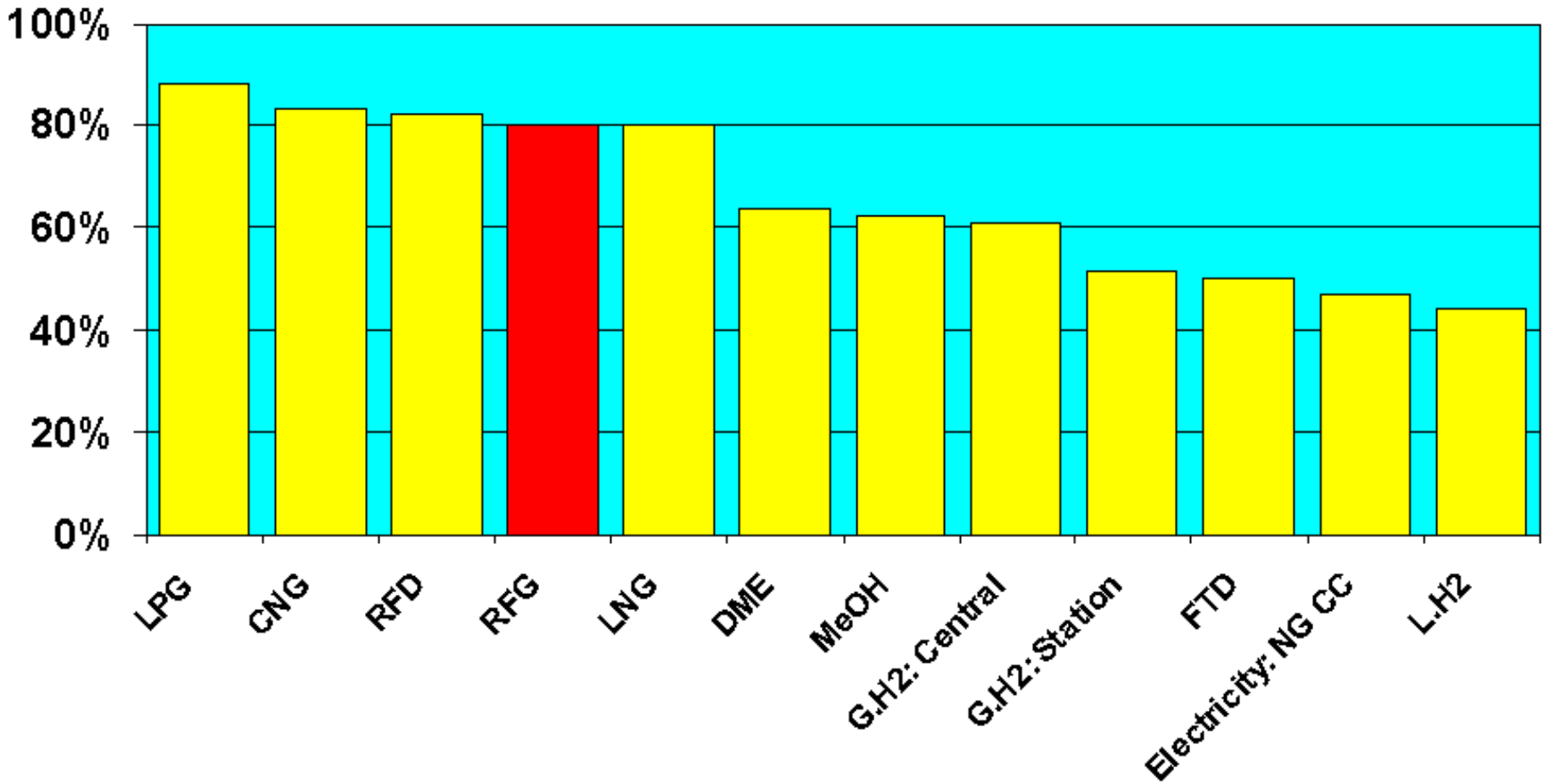
Fuels Produced from Flared Gas Achieve Huge Energy and Emission Benefits

- Worldwide, ~3.8 trillion ft3 of gas (~655 million barrels of oil) is flared each year
- Gas flaring is already restricted in some countries for reducing CO2 emissions
- Production of liquid fuels from flared gas makes it possible to transport the fuels to user sites
- GREET1.5a simulates production of methanol, dimethyl ether, Fischer-Tropsch diesel, liquefied natural gas, and liquid hydrogen from flared gas
- These pathways achieve huge energy and emission benefits.

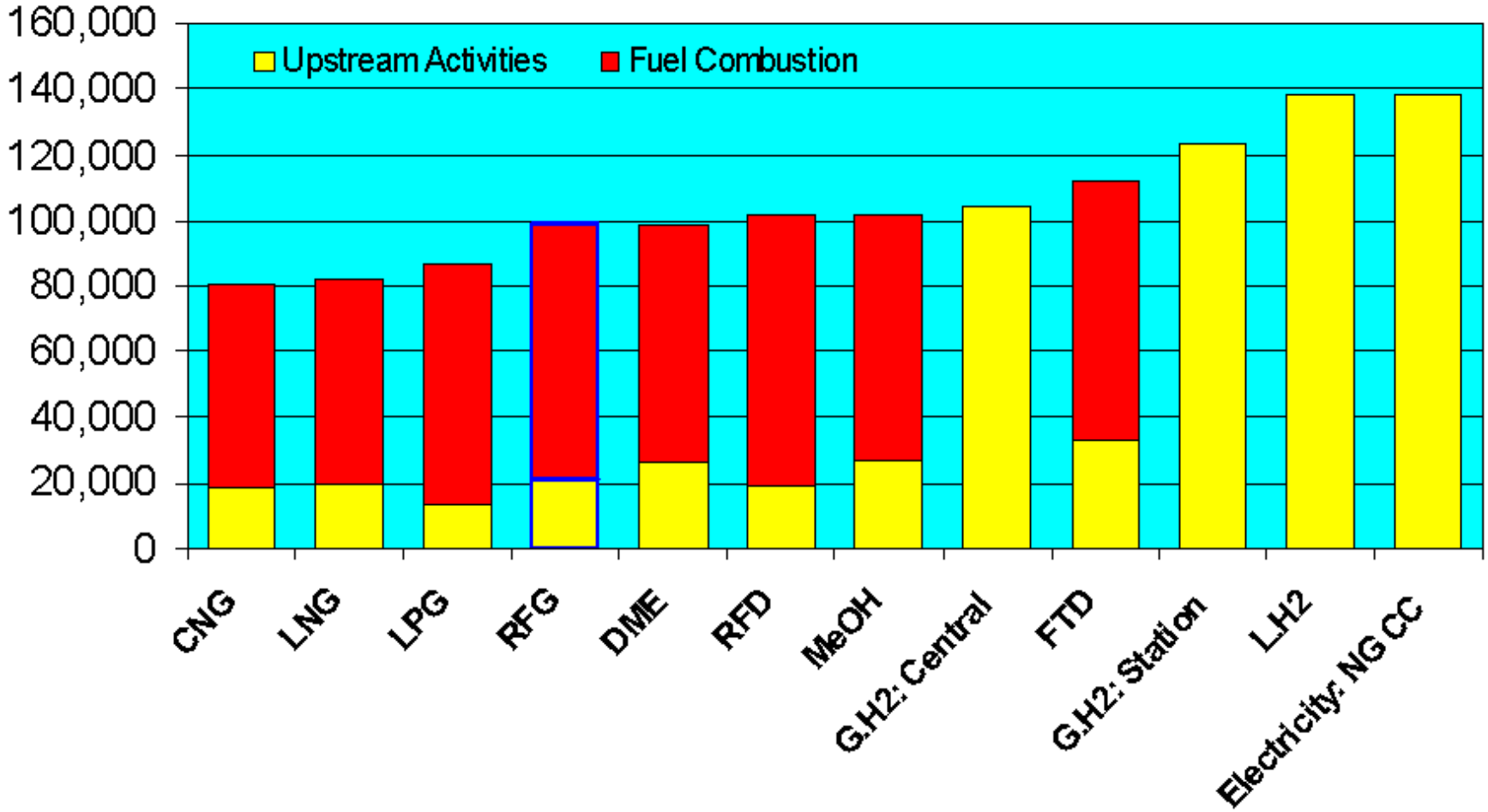
Comparison of Three Pathways of Producing H2 from NG

	NG to G.H_2: large central plants	NG to G.H_2: R. stations	NG to L.H2
Fuel production	Large, efficient	Small, less efficient	Large, but inefficient
H_2 pipelines (expensive)	Yes	No	No
Vehicle driving range	Short	Short	Long
Upstream H_2 storage	Yes (extensive)	Yes (less extensive)	Yes
CO_2 sequestration	Yes	Probably no	Yes

Energy Efficiencies of Upstream Activities (Wells to Tanks)



GHG Emissions of Fuel Production and Combustion: Grams per Million Btu of Fuel



GREET1.5a Includes 45 Long-Term Vehicle/Fuel Systems (available ~2010)

Conv. SI Vehicles

- RFG
- CNG, LNG, LPG: dedicated
- MeOH, EtOH: dedicated

SIDI Vehicles

- RFG, MeOH, EtOH

SI HEVs: Grid-Independent and Grid-Connected

- RFG, MeOH, EtOH (SIDI)
- CNG, LNG, LPG (SI)

CIDI Vehicles

- RFD, DME, FTD, biodiesel

CIDI HEVs: Grid-Independent and Grid-Connected

- RFD, DME, FTD, biodiesel

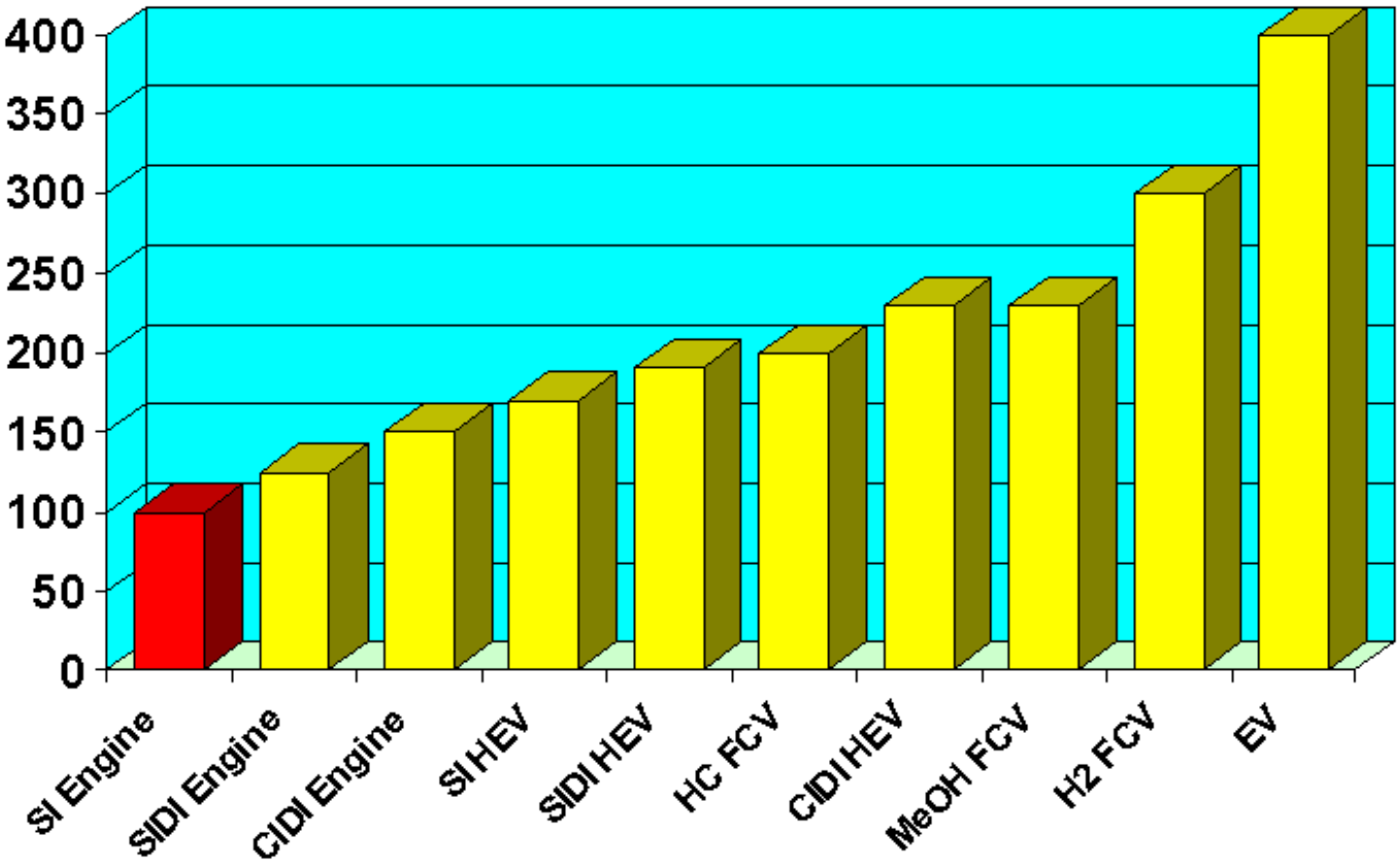
Battery-Powered EVs

- U.S. generation mix
- CA generation mix
- NE U.S. generation mix

Fuel-Cell Vehicles

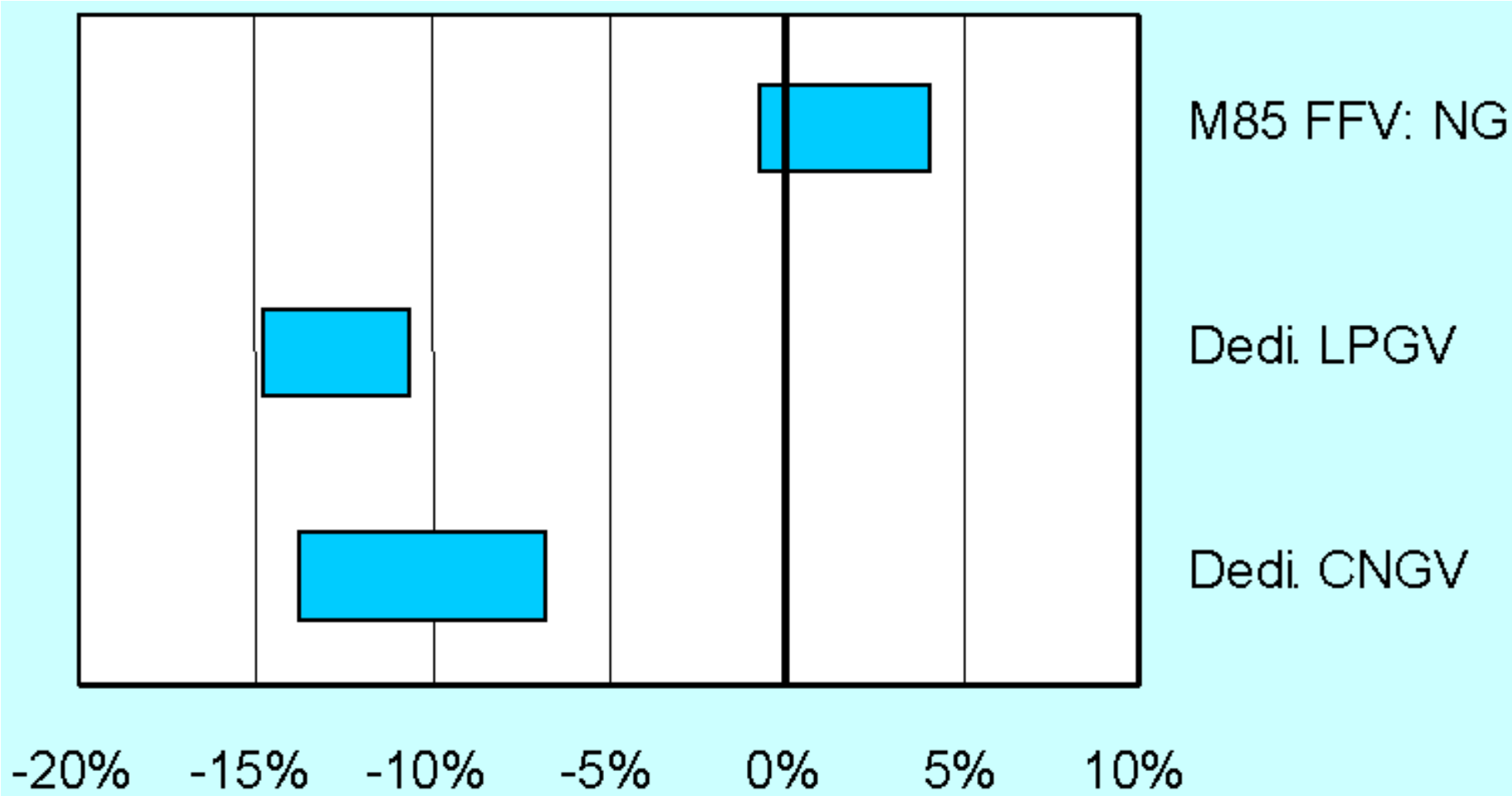
- G.H2, L.H2, MeOH, RFG, RFD, EtOH, CNG, LNG, LPG

Relative Fuel Economy of Vehicle Propulsion Systems (Tanks to Wheels)

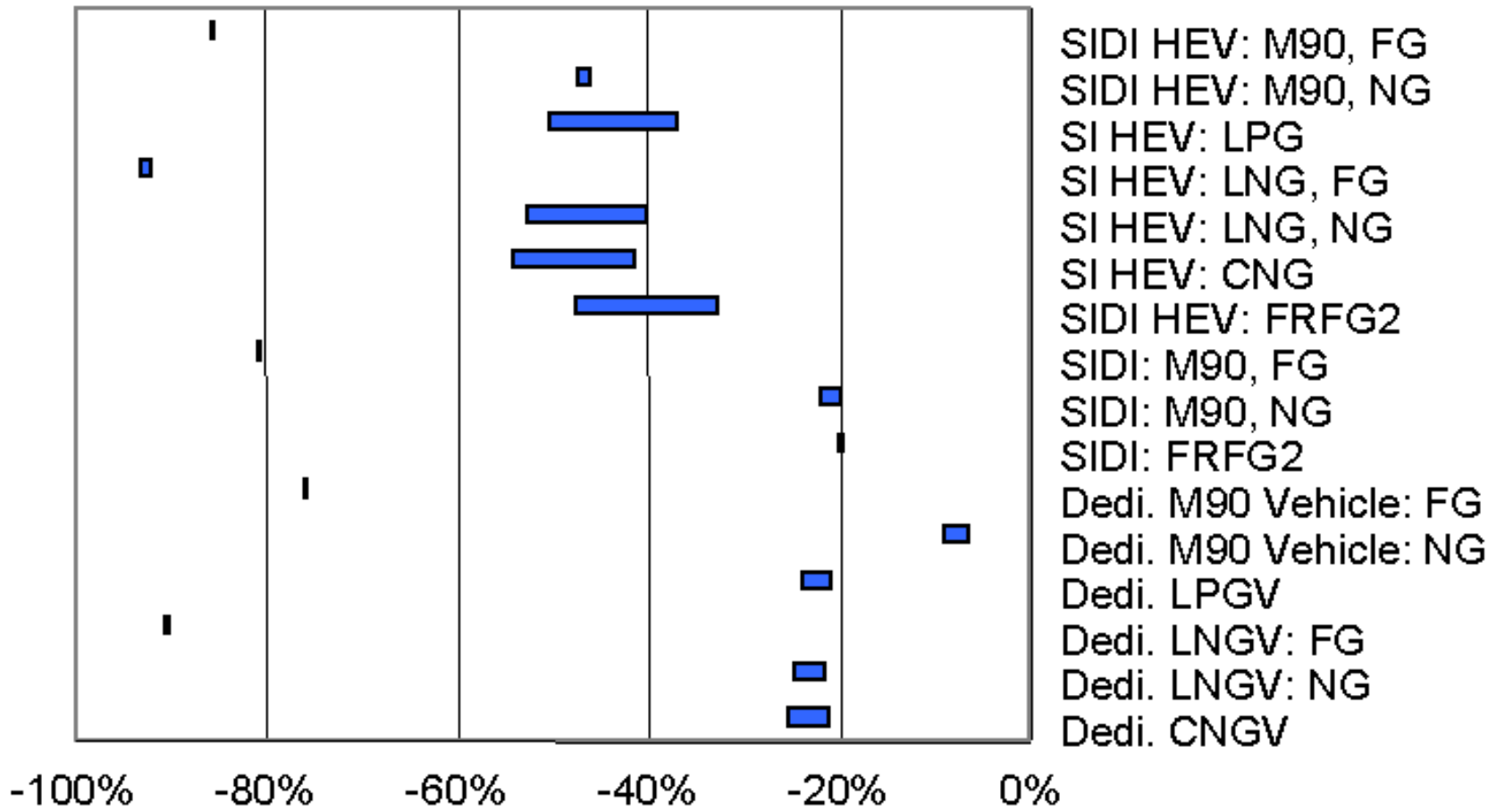


Note: Based on gasoline-equivalent fuel economy and for technologies to be available around 2010.

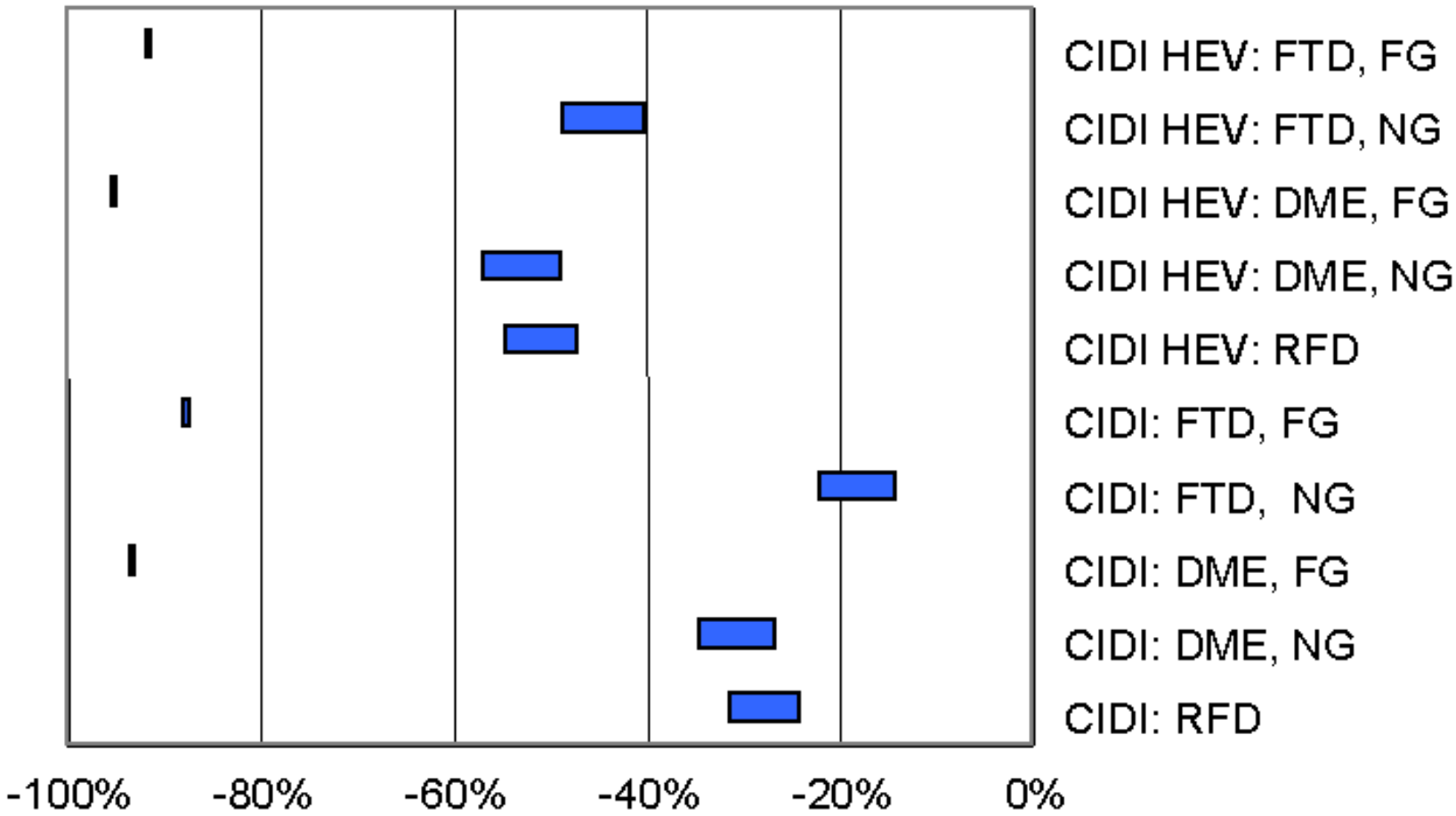
Fuel-Cycle GHG Emission Changes: Near-Term Technologies (Relative to CG GV)



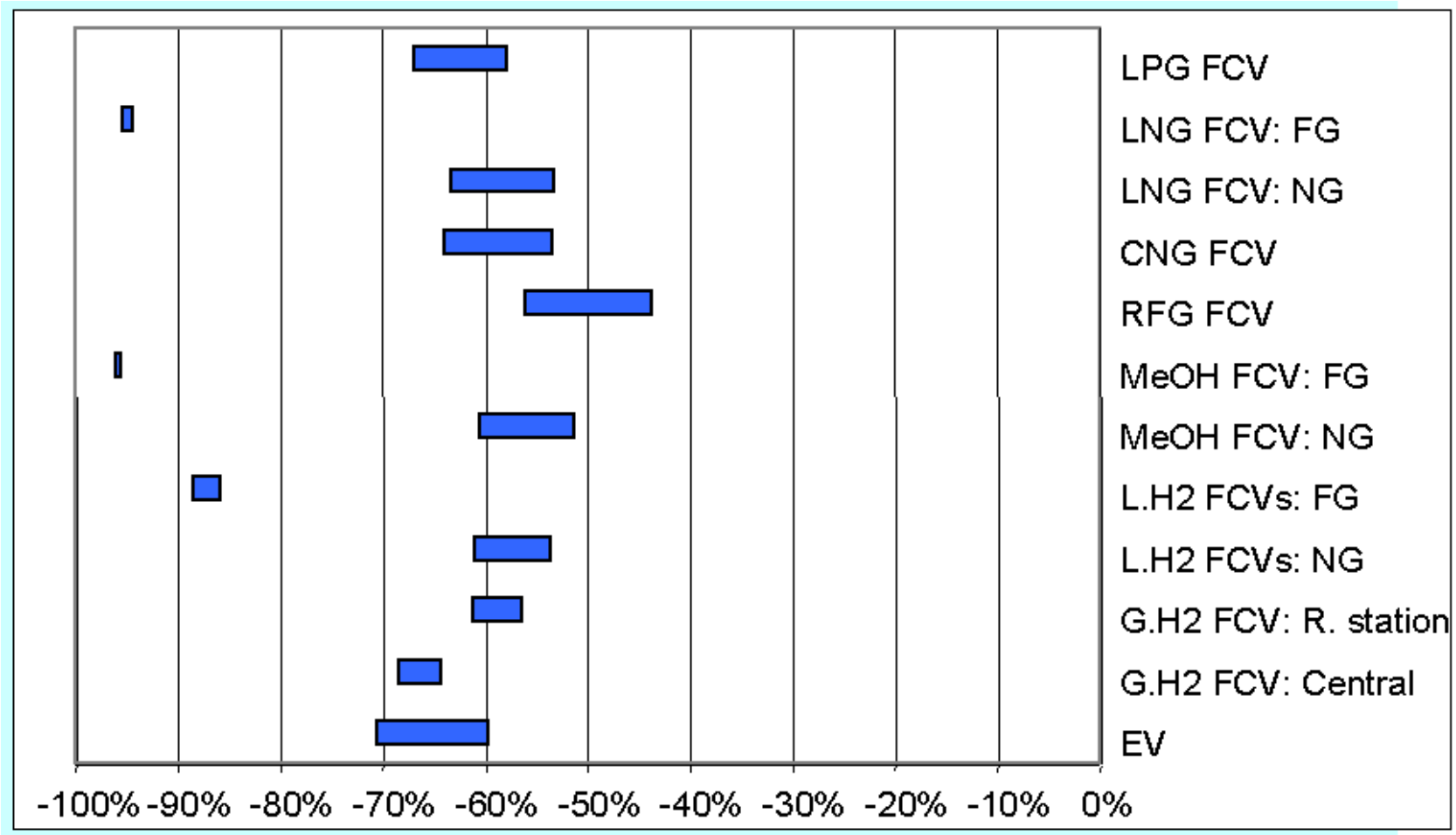
Fuel-Cycle GHG Emission Changes: Long-Term SI and SIDI Technologies (Relative to RFG GV)



Fuel-Cycle GHG Emission Changes: Long-Term CIDI Technologies (Relative to RFG GV)



Fuel-Cycle GHG Emission Changes: Long-Term EVs and FCVs (Relative to RFG GV)



Summary: GHG Emission Impacts

- Near-term technologies offer limited GHG emission reduction benefits, but they can bring reductions now
- Long-term, advanced technologies offer great GHG emission reduction benefits. However, some of them face market hurdles, and others are in the R&D stage
- Use of transportation fuels produced from waste sources such flared gas results in huge GHG emission reduction benefits

GREET model and documents are available at: www.transportation.anl.gov/ttrdc/greet/

TTRDC - Argonne Transportation - GREET Model - Microsoft Internet Explorer provided by MSN

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The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model

For a given transportation fuel/technology combination, GREET 1.5 separately calculates:

1. fuel-cycle consumption of
   - total energy (all energy sources),
   - fossil fuels (petroleum, natural gas, and coal), and
   - petroleum;
2. fuel-cycle emissions of greenhouse gases — primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O); and
3. fuel-cycle emissions of five criteria pollutants – volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter with a diameter measuring 10 micrometers or less (PM_{10}), and sulfur oxides (SO_x).

The model is designed to readily allow researchers to input their own assumptions and generate fuel-cycle energy and emission results for specific fuel/technology combinations.

Download GREET Model

NOTE: Please read the following copyright/license terms and memo before downloading the GREET model. These documents contain essential information about using the model.

- Copyright and License Terms and Conditions
- GREET 1.5a: Changes from GREET1.5 [160kb pdf - added 2/22/00]