Fuels for Fuel-Cell Vehicles: Energy and Emission Implications

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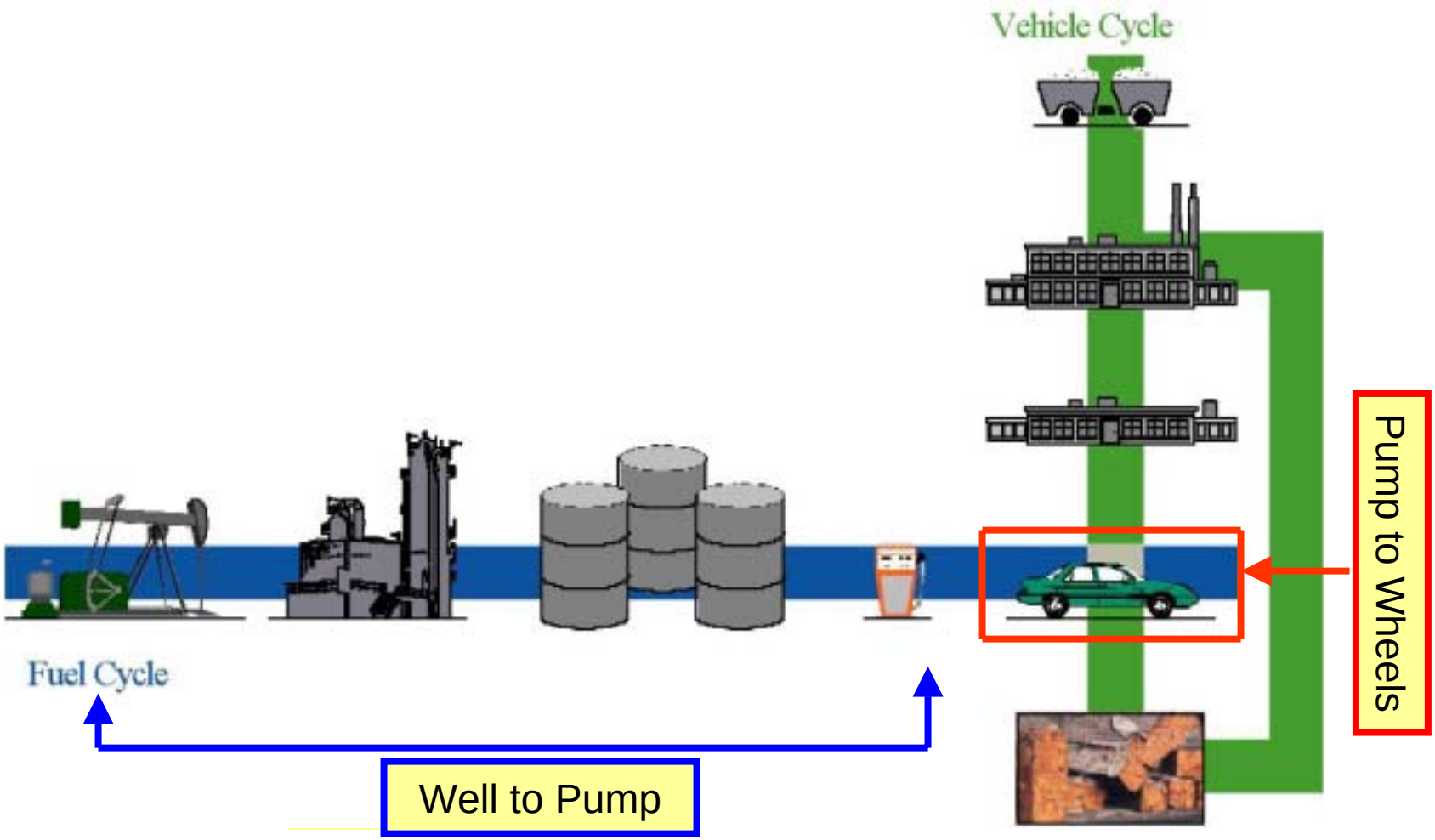
Presentation at the EVAA's Electric Transportation Industry Conference

December 13, 2001

Vehicle and Fuel Cycles: Petroleum-Based Fuels



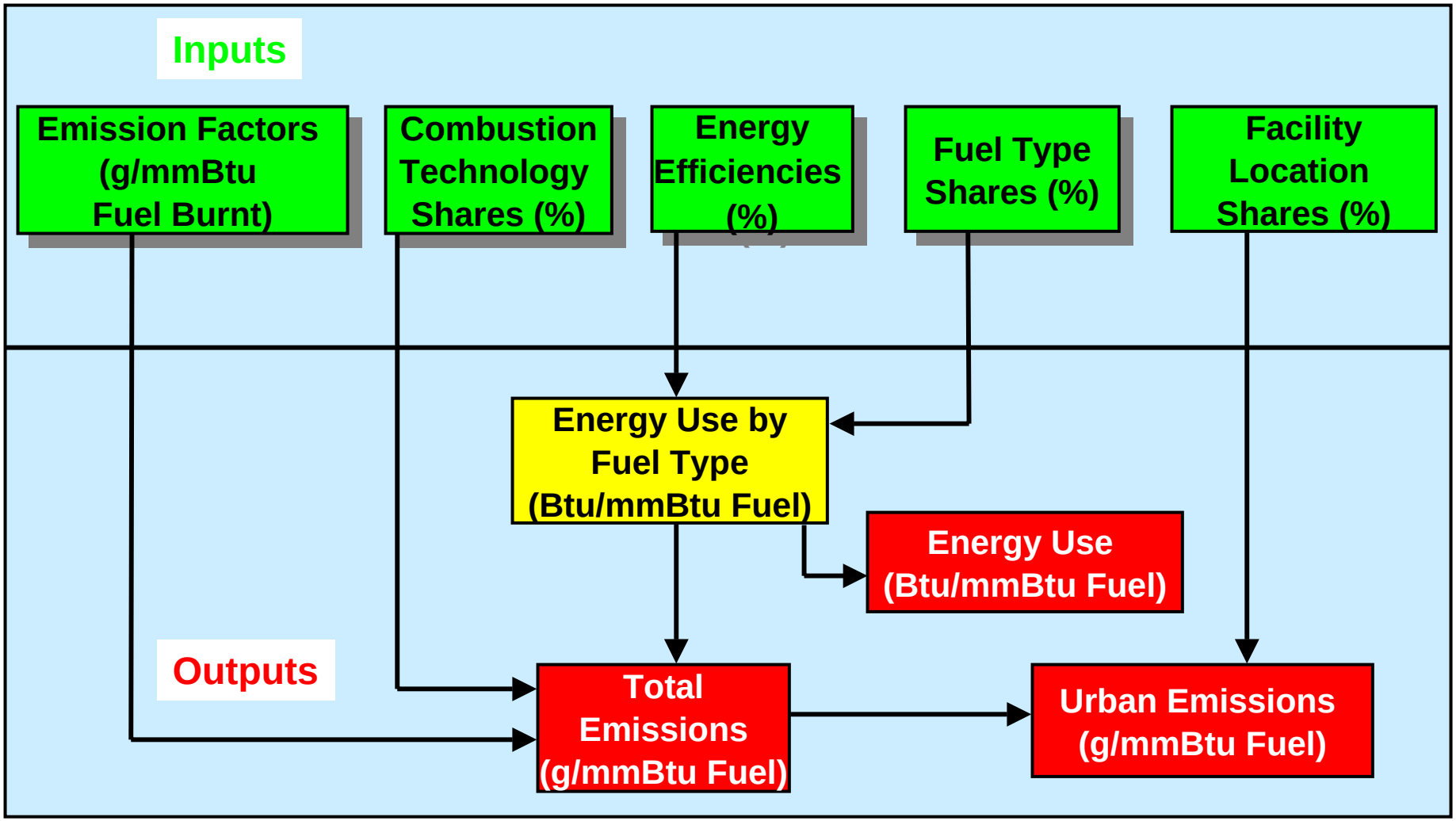
The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model

- A fuel cycle model to estimate per-mile energy use and emissions rates for motor vehicles
- First version was developed in 1996
- The current public version, GREET 1.5a, is on Argonne's Transportation website at http://greet.anl.gov
- The beta version of GREET 1.6 is also posted at this website for download and evaluation

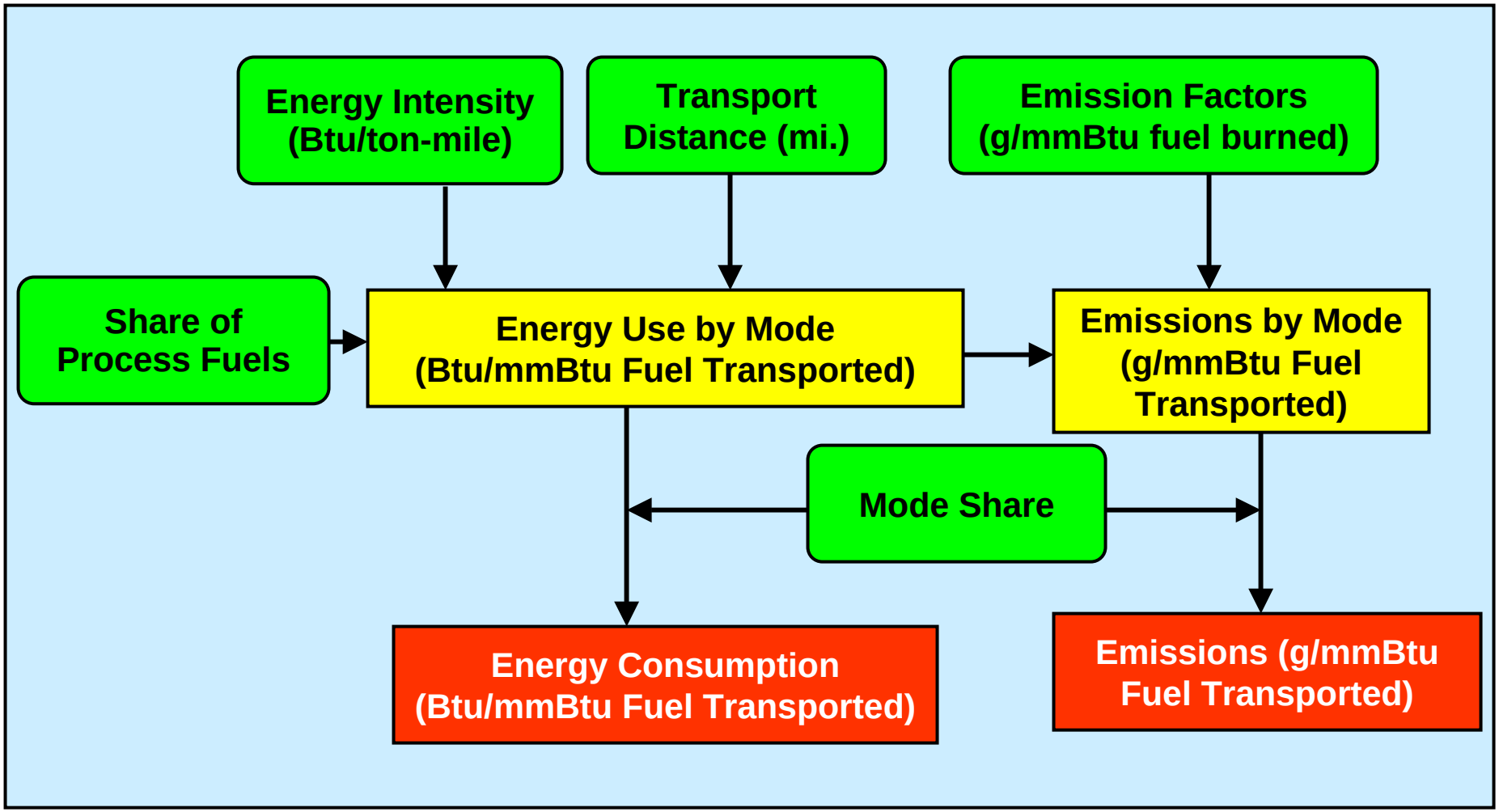
GREET Simulates These Emission and Energy Items

- Emissions of Greenhouse Gases
  - CO2, CH4, and N2O
  - VOC, CO, and NOx as optional GHGs
- Emissions of Five Criteria Pollutants (Total and Urban Separately)
  - VOC, CO, NOx, PM10, and SOx
- Energy Use
  - All energy sources
  - Fossil fuels
  - Petroleum

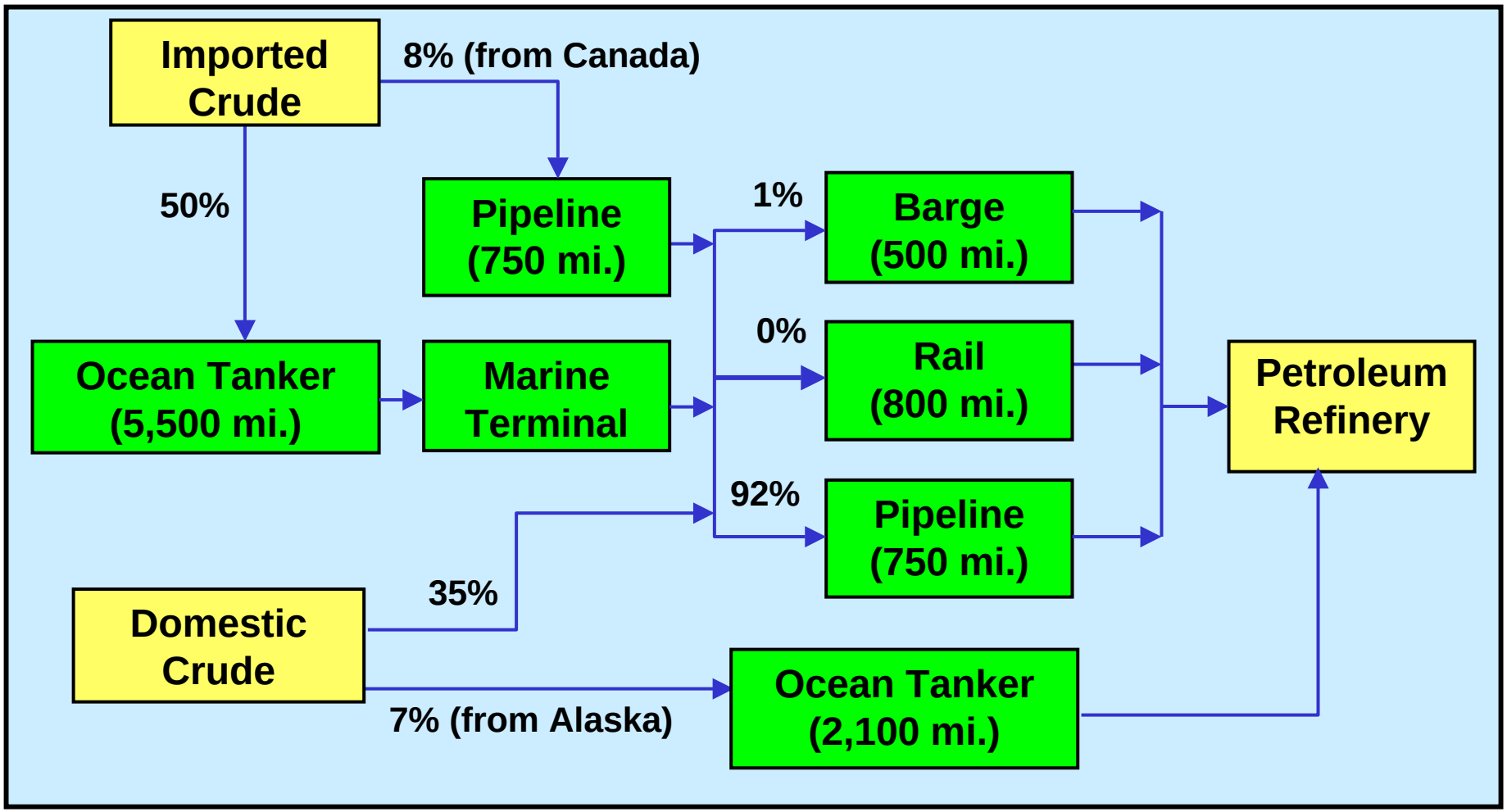
GREET Follows This Calculation Logic for Production of Feedstocks and Fuels



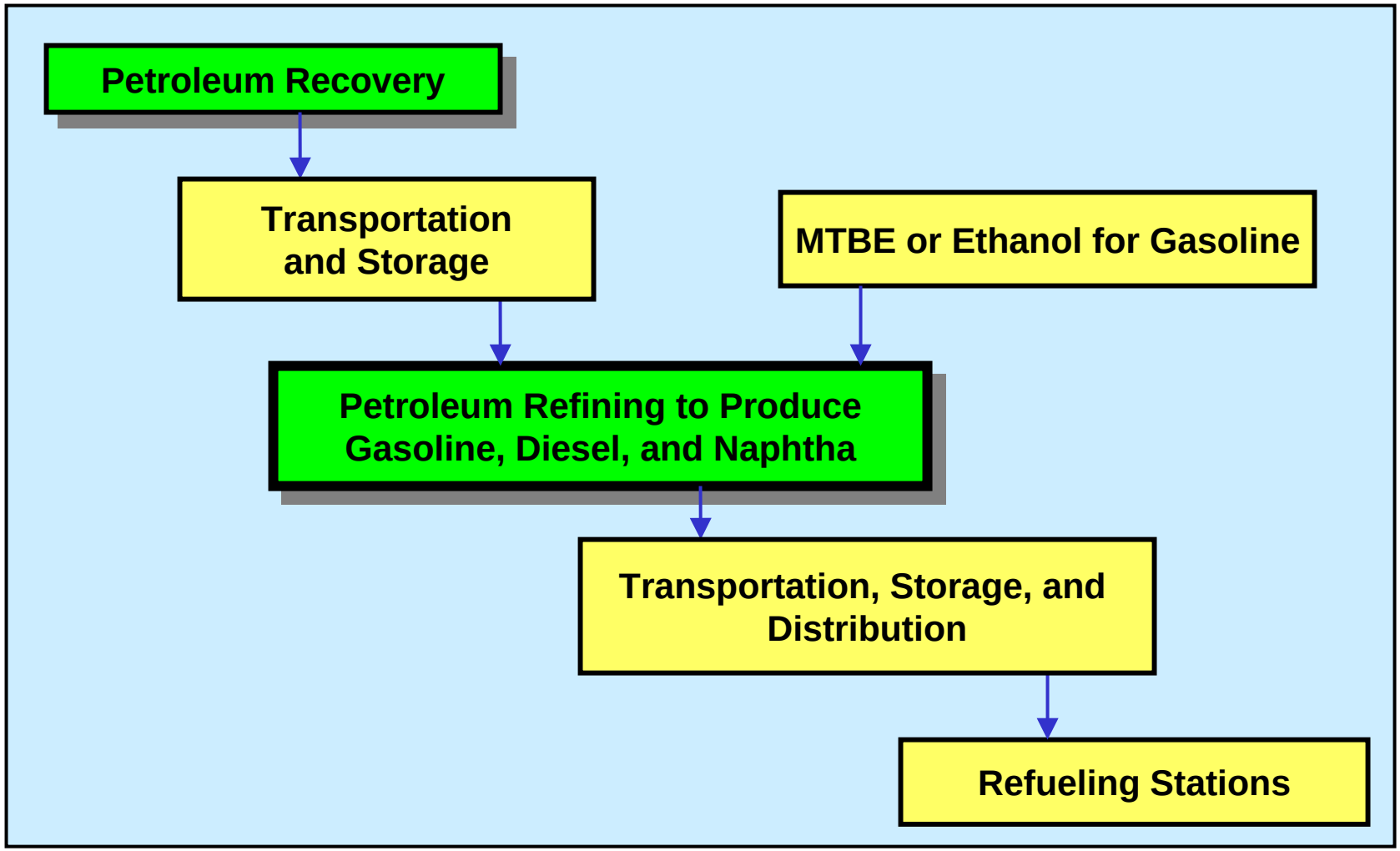
GREET Follows This Calculation Logic for Transportation of Feedstocks and Fuels



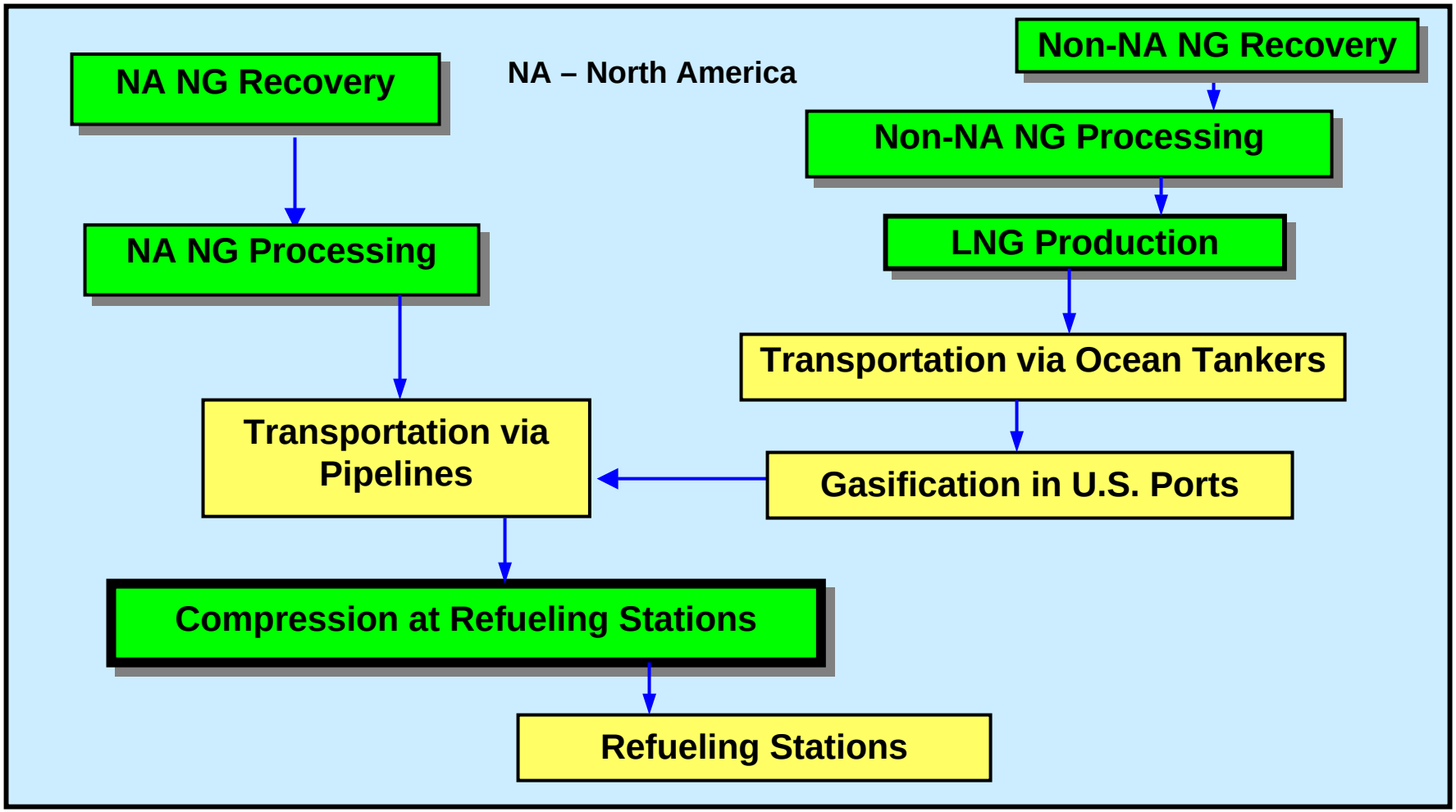
GREET Uses Detailed Transportation Logistics Information



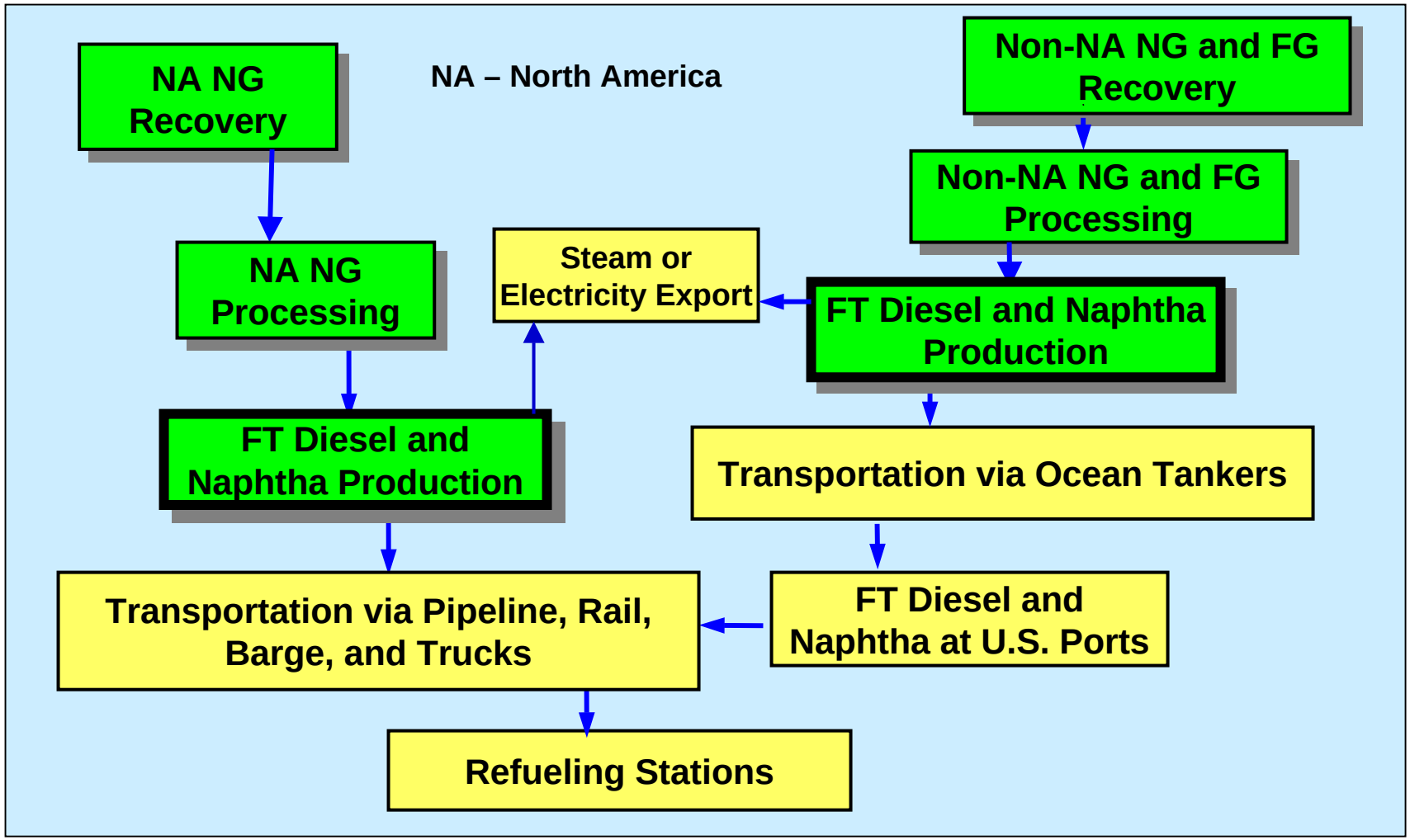
Recovery and Refining Are Key Energy Conversion Steps for Petroleum Fuels



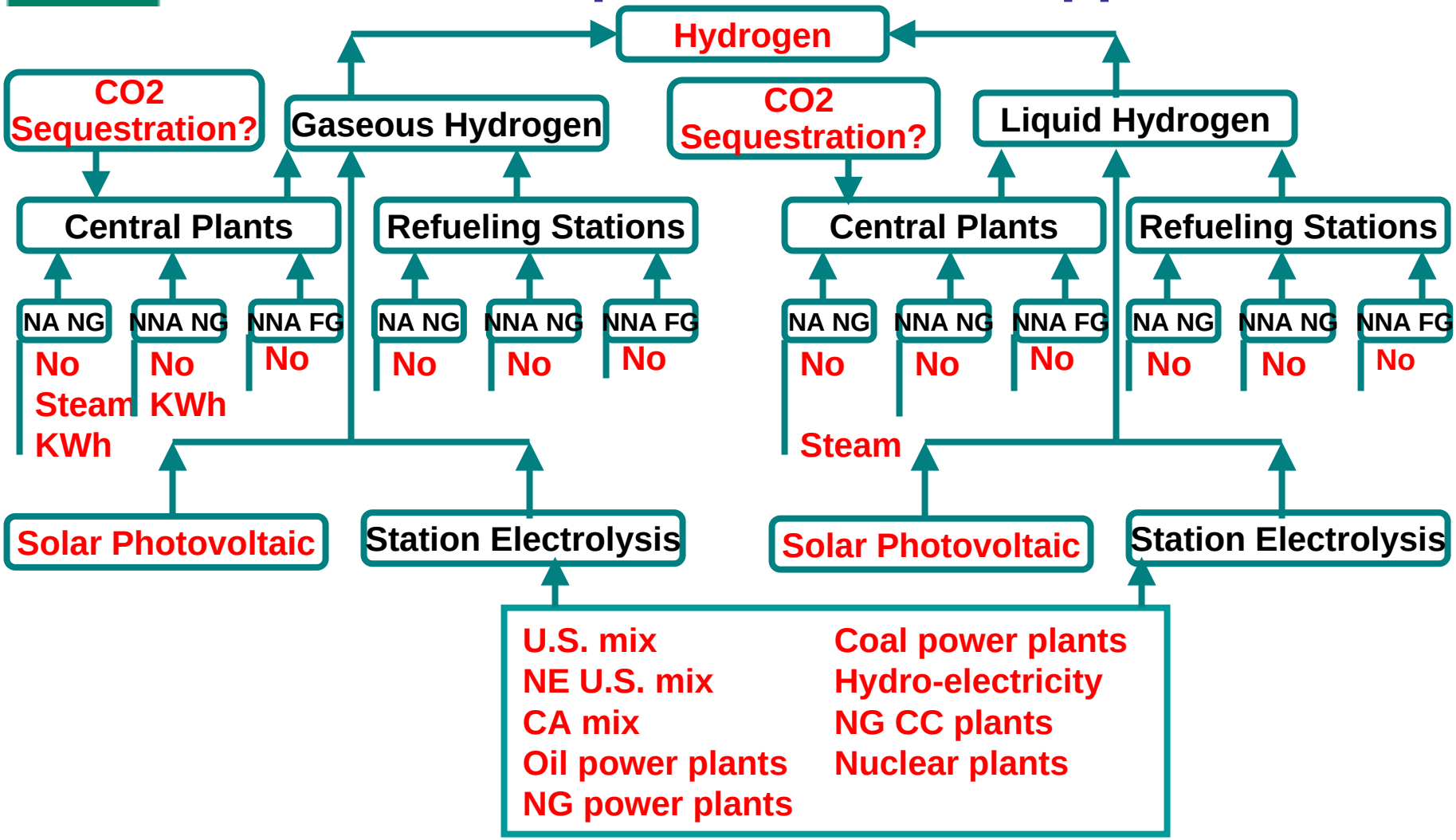
Pathways for Compressed Natural Gas Suffer High Losses at Gas Compression



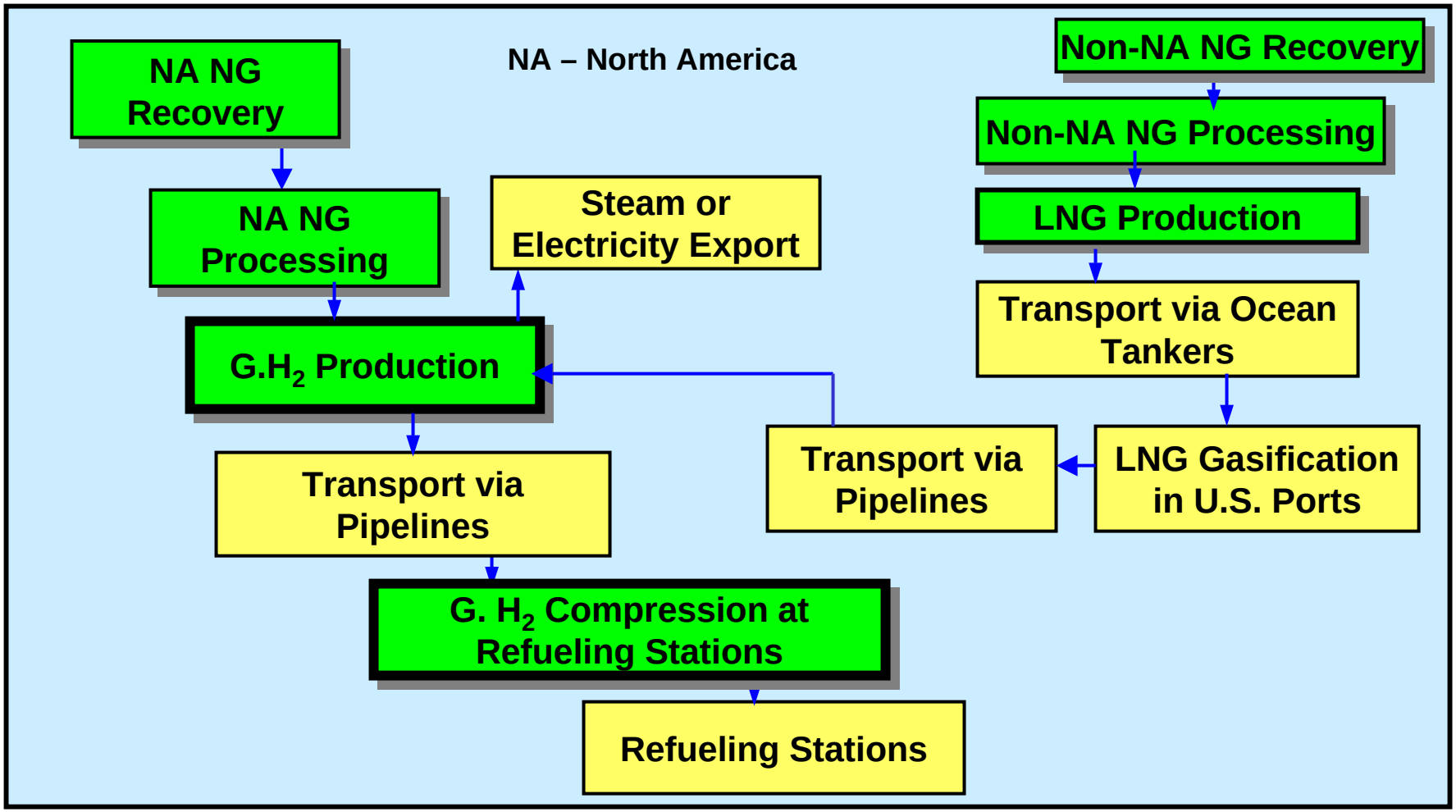
Production of Fischer-Tropsch Diesel and Naphtha Incurs Large Energy Losses



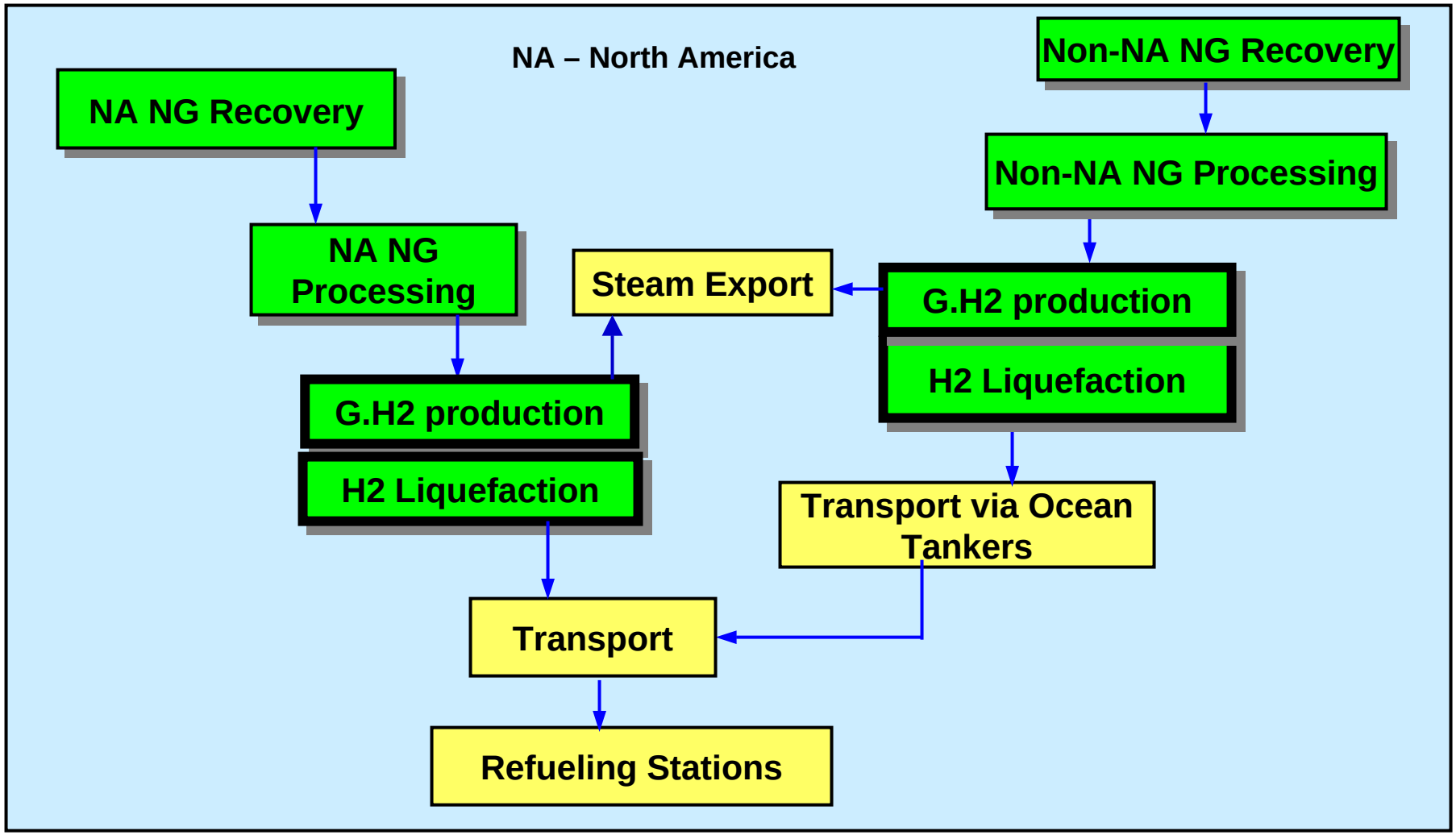
GREET 1.6 Includes 46 Hydrogen Production Options for FCV Applications



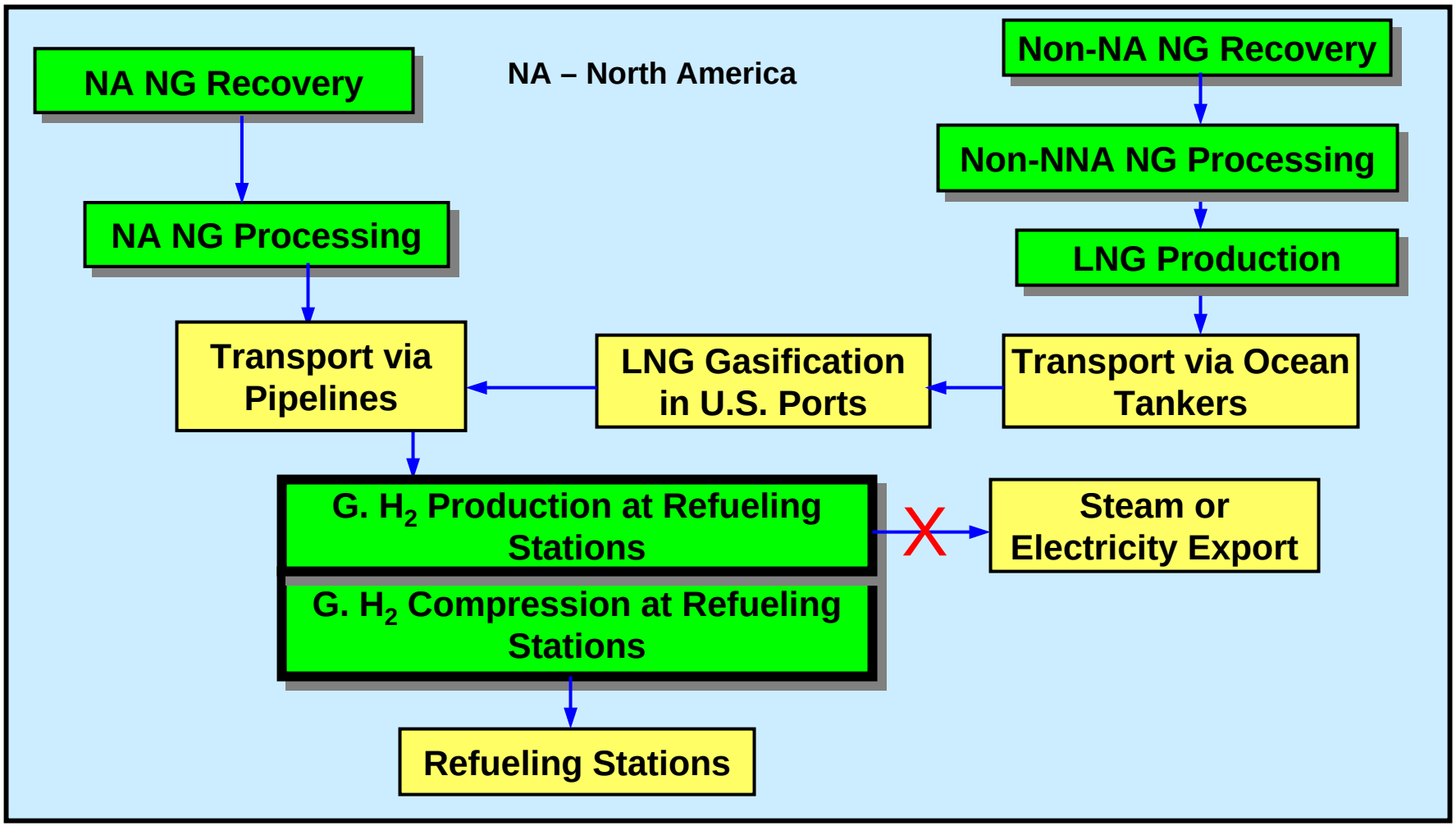
Production and Compression Are Key Steps for Centralized G.H2 Pathways, But ……



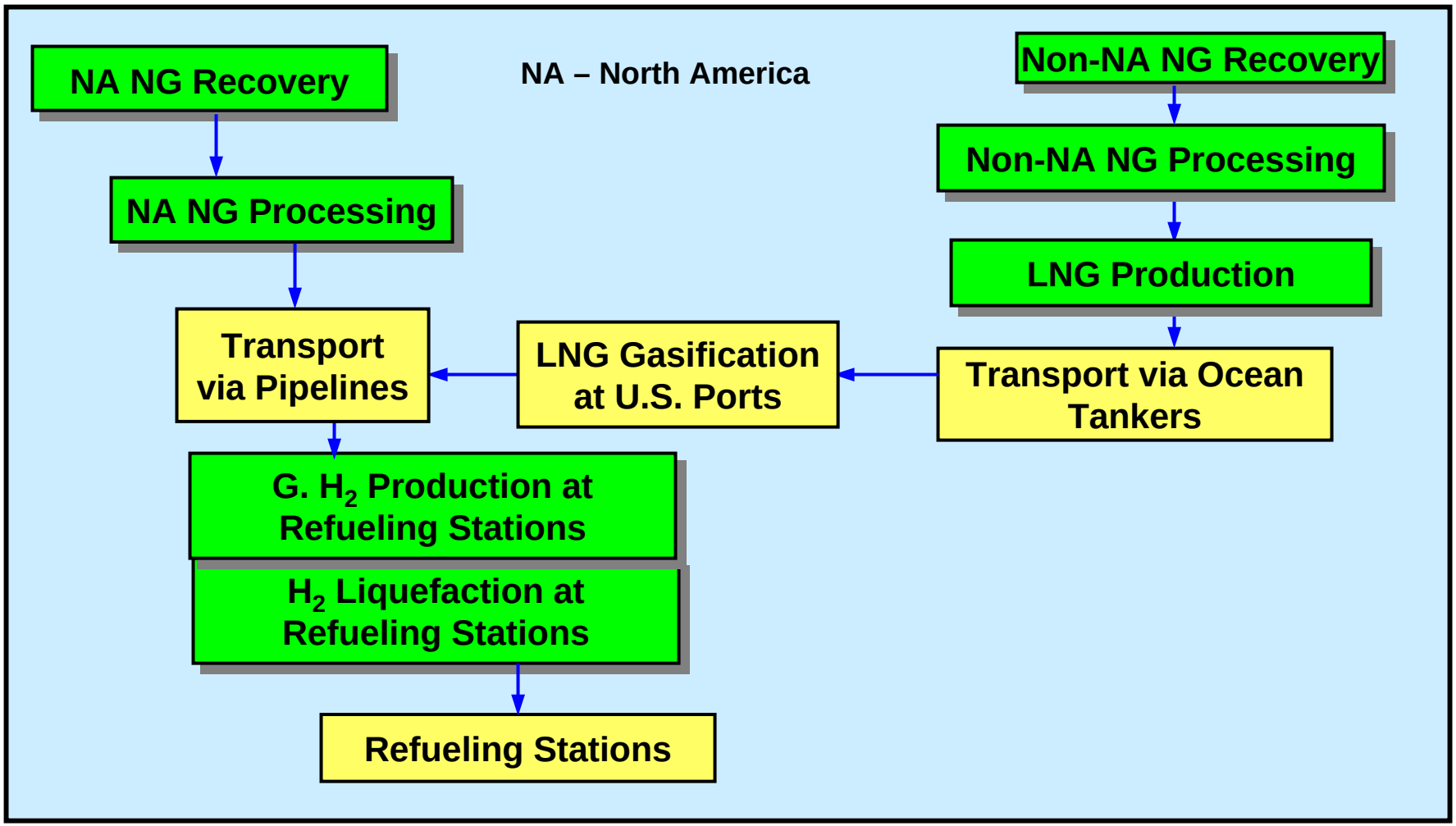
H2 Liquefaction Has Higher Energy Losses Than H2 Compression



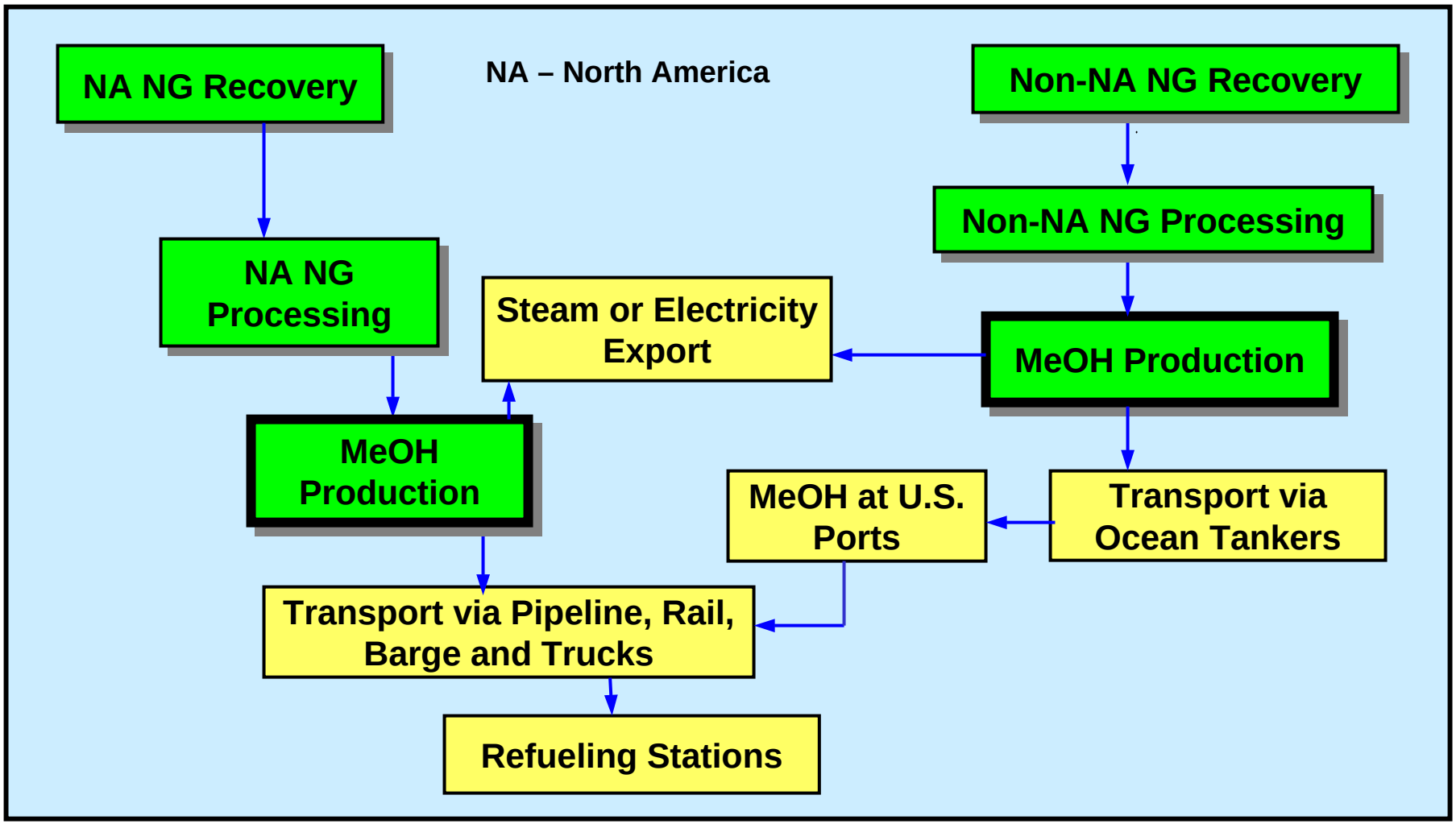
Decentralized H2 Production Lacks Energy Benefits from Selling Co-Products



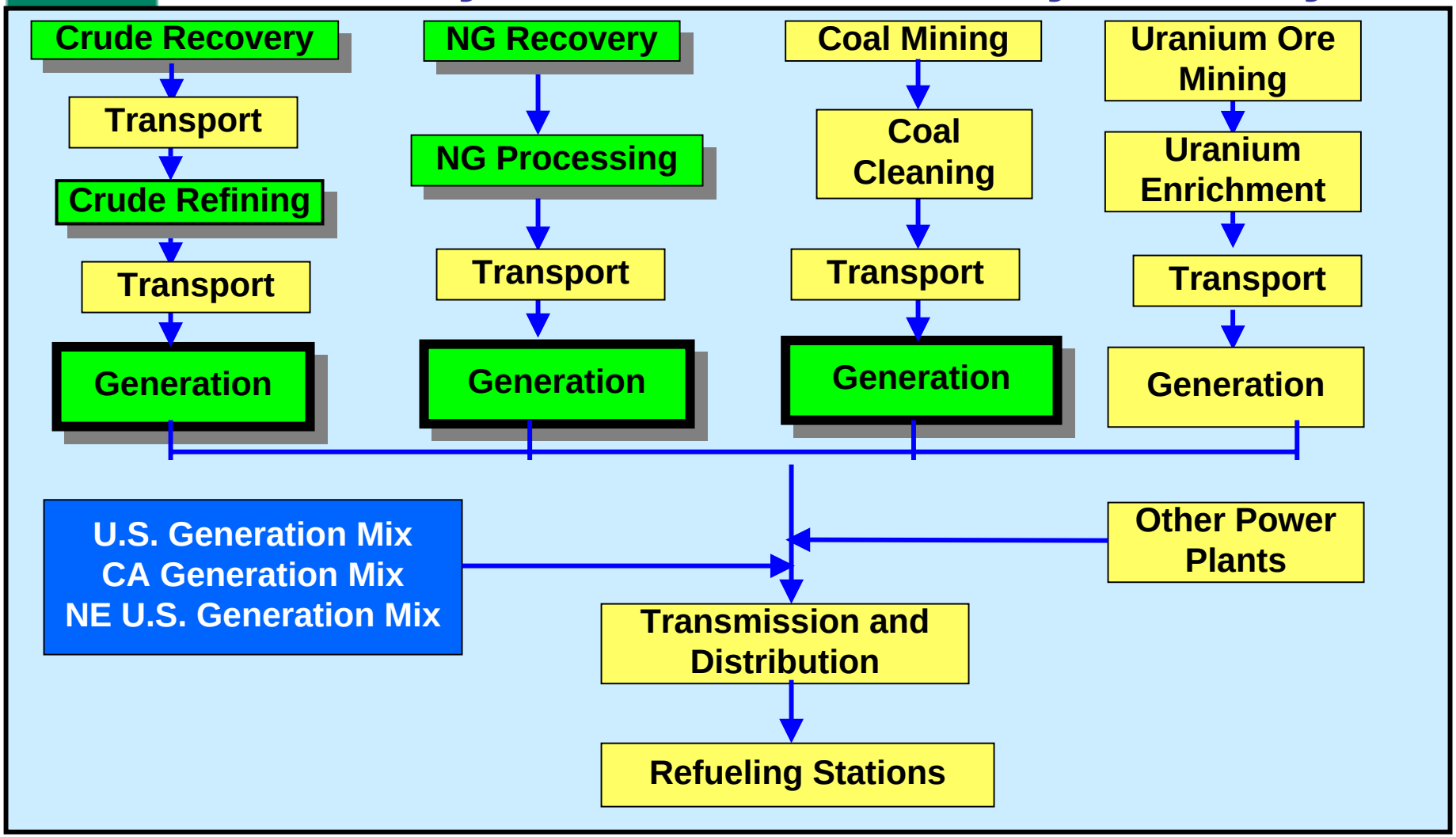
Decentralized Liquid H2 Relies on Small-Scale Facilities with Limited Efficiencies



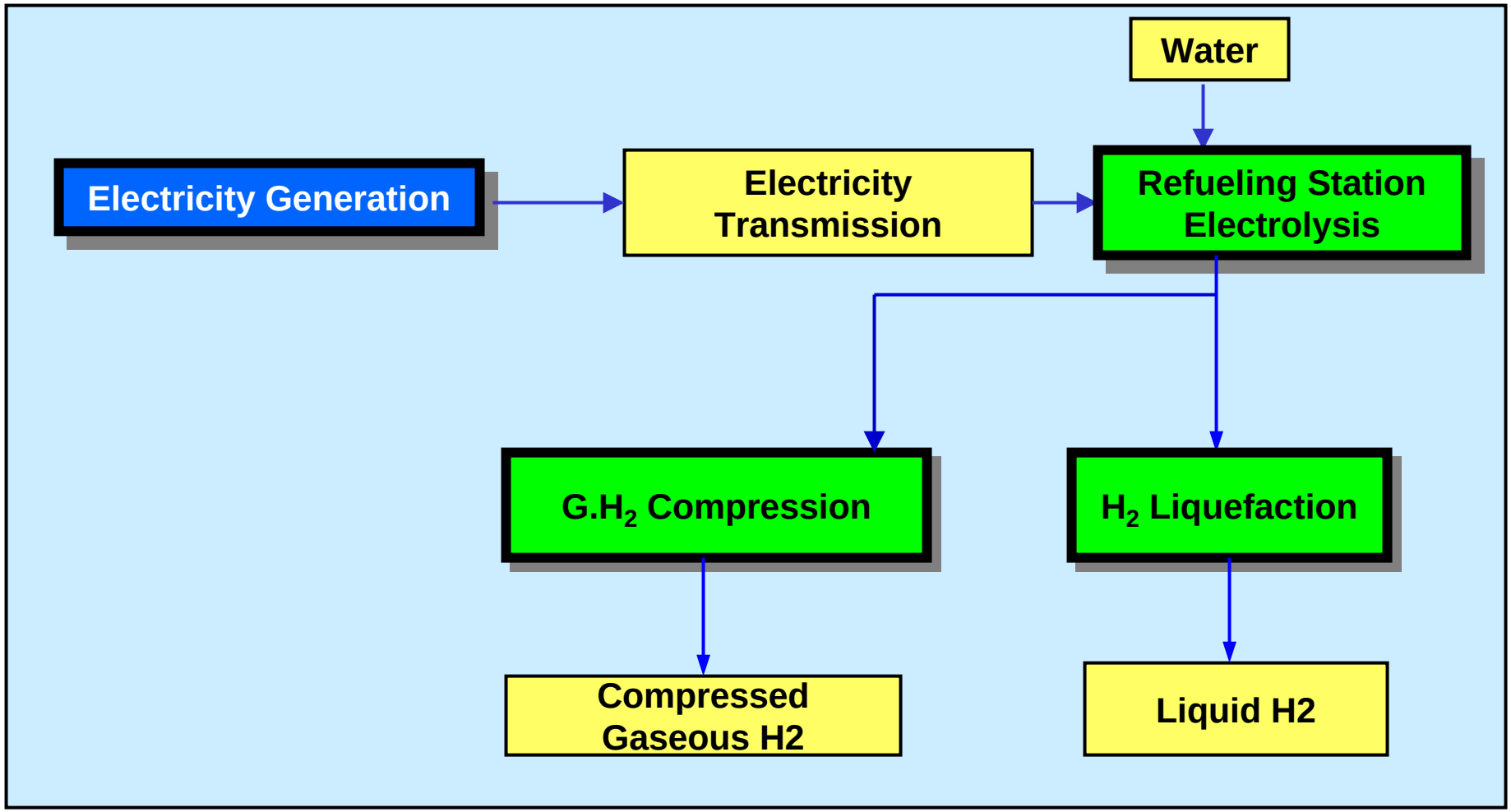
Production Is the Least Efficient Step for Methanol Pathways



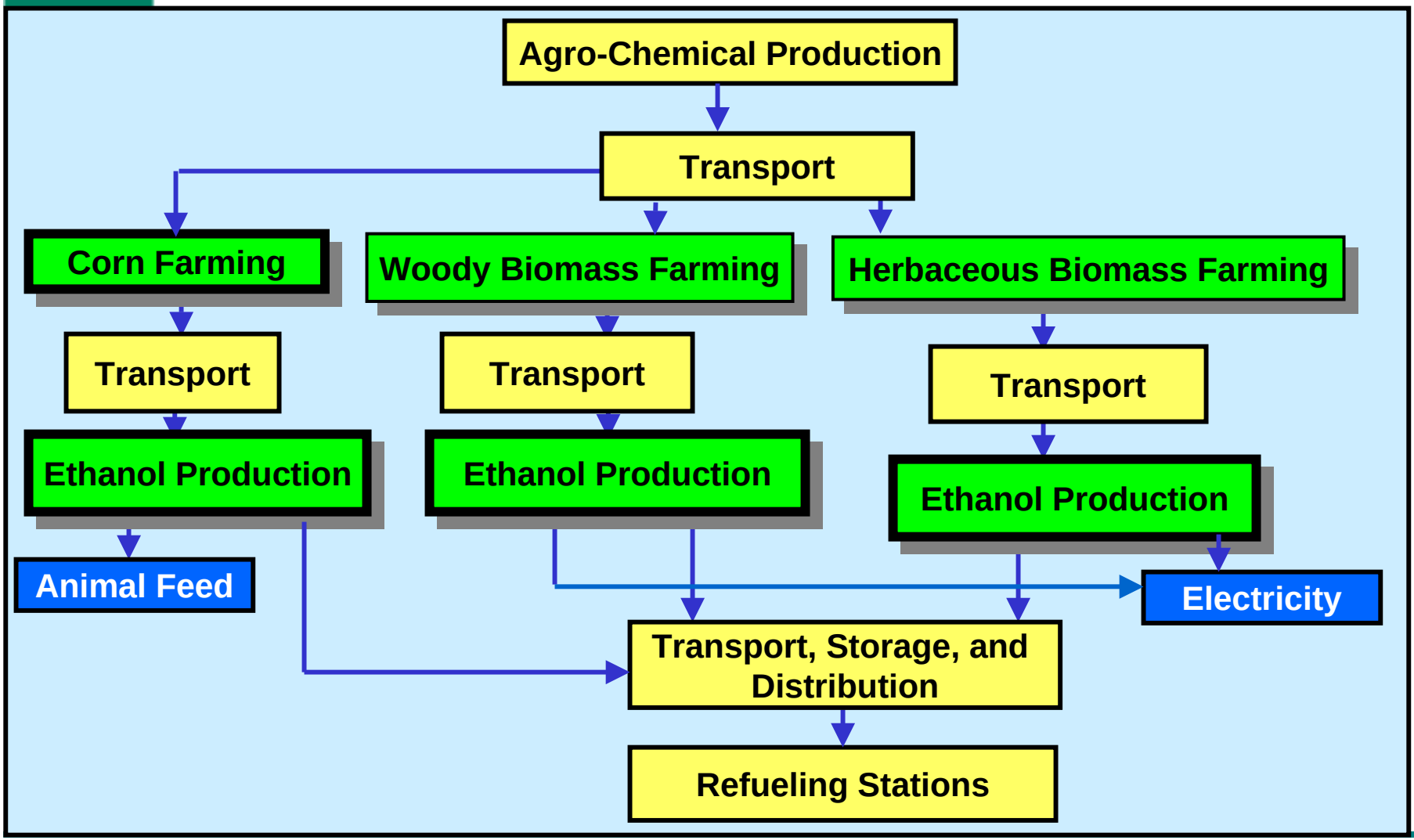
The Generation Step Suffers Large Efficiency Losses in Electricity Pathways



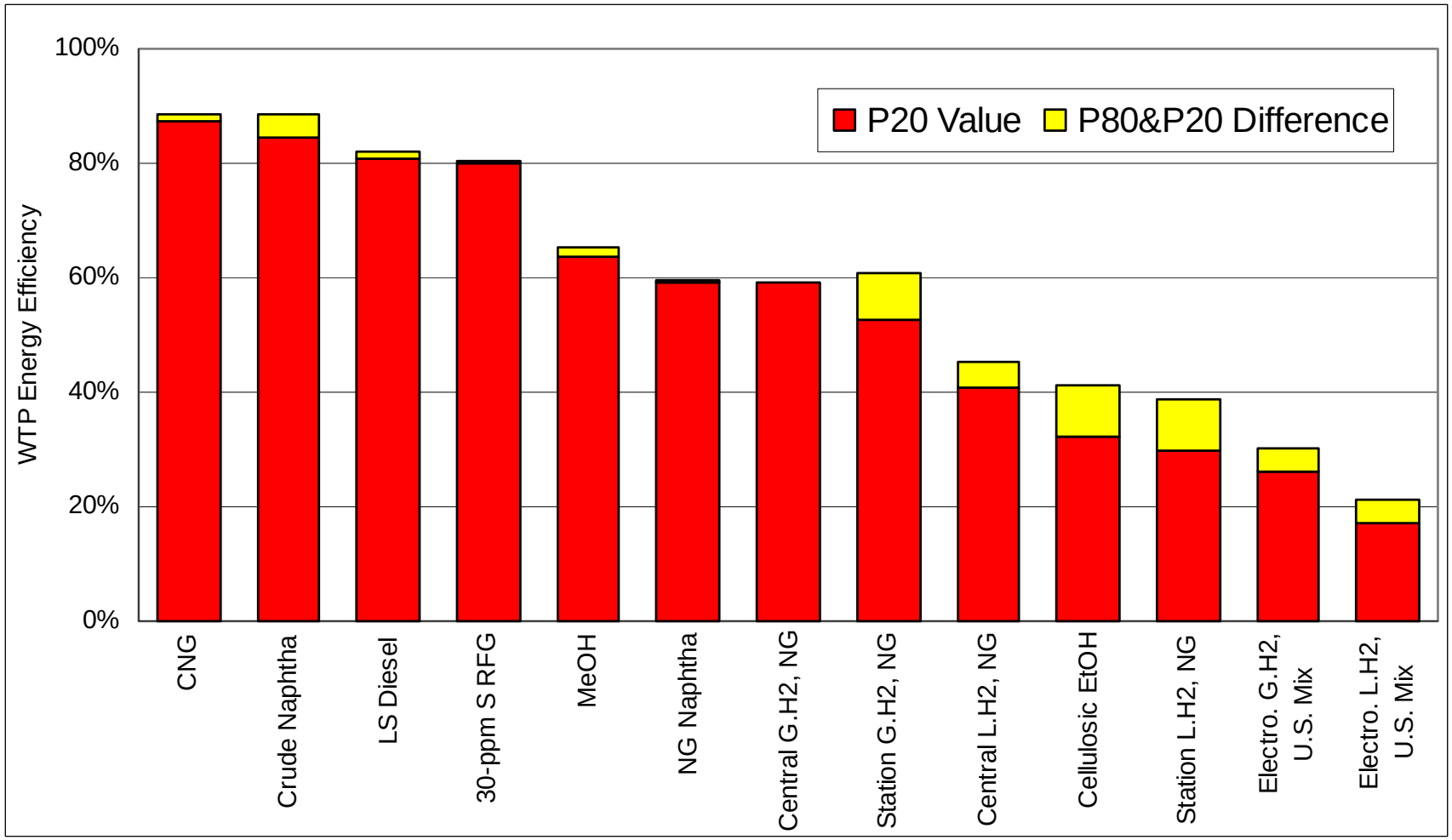
Electrolysis Hydrogen Is Subject to Three Steps with Large Energy Losses



Farming and Production Are Two Major Energy-Using Steps in Ethanol Pathways



Well-to-Pump Energy Efficiencies Vary Greatly Among Fuels



GREET 1.6 Includes 47 Vehicle/Fuel Systems

Conv. SI Vehicles

- FRFG, CARFG
- CNG, LNG, and LPG
- MeOH and EtOH

SIDI Vehicles

- CG, RRFG, and CA RFG
- MeOH, and EtOH

SI HEVs: Grid-Independent and Connected

- FRFG, CARFG, MeOH, EtOH
- CNG, LNG, and LPG

CIDI Vehicles

- LSD, DME, FTD, and biodiesel

CIDI HEVs: Grid-Independent and Connected

- LSD, DME, FTD, and biodiesel

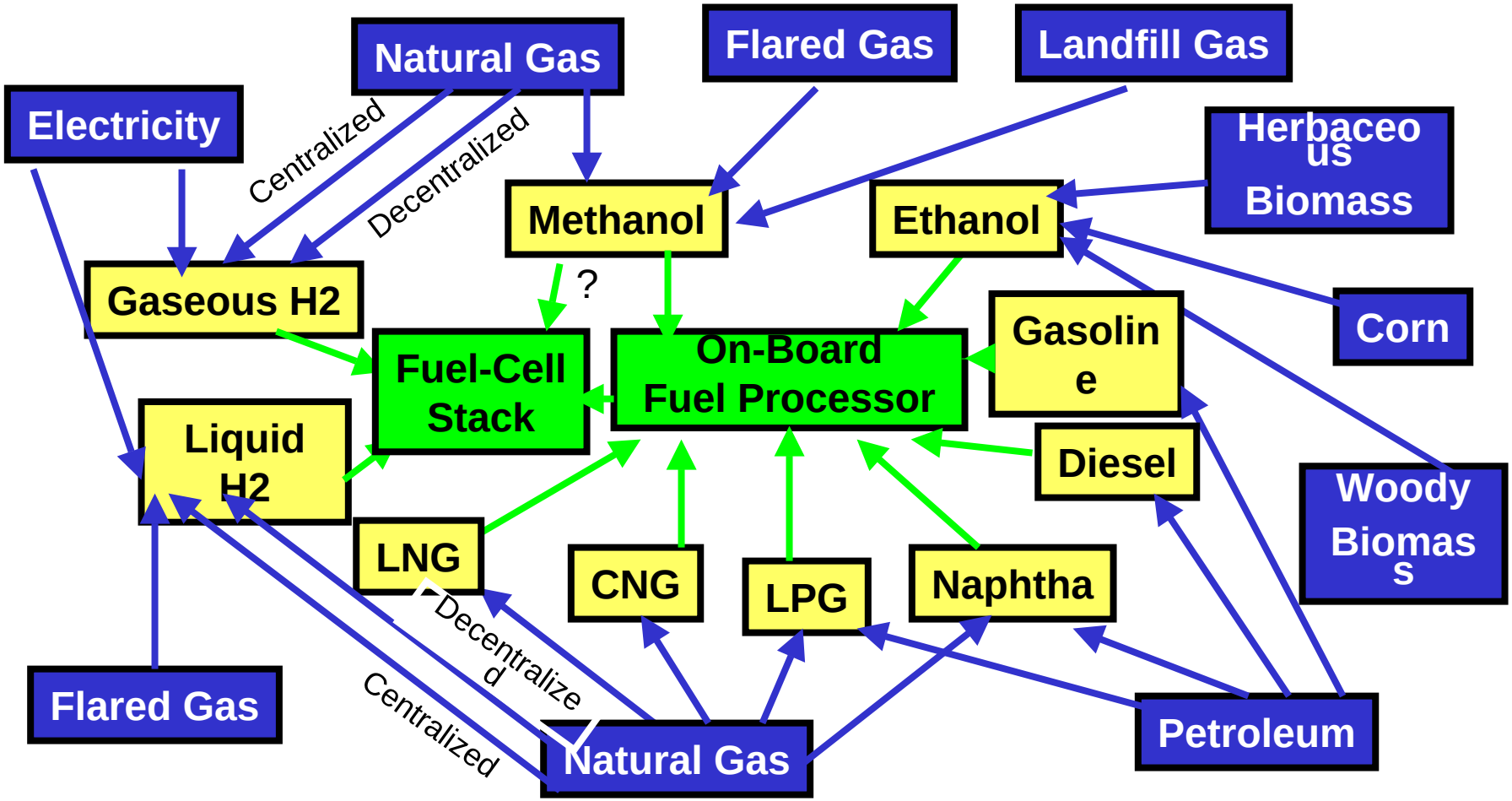
Battery-Powered EVs

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

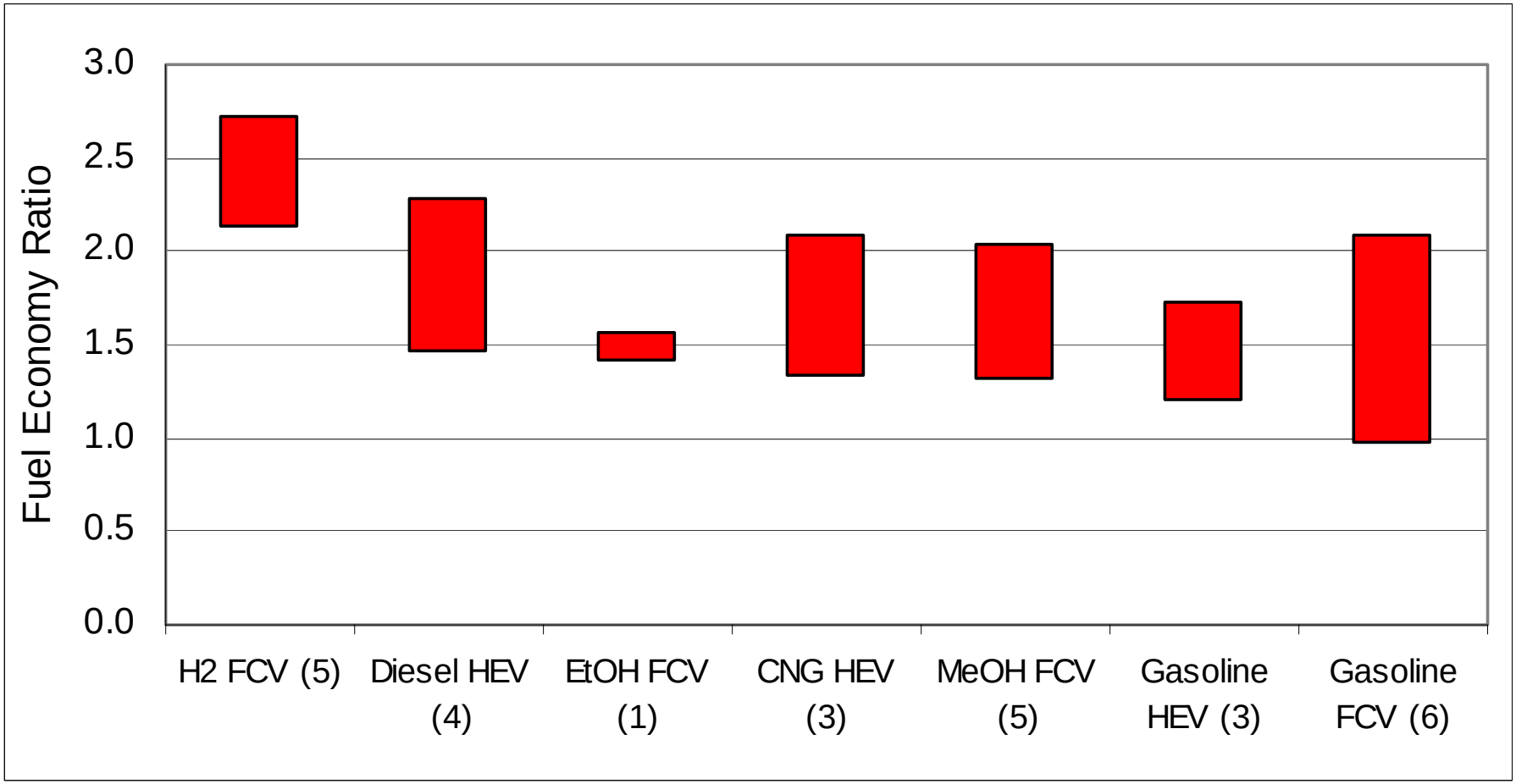
Fuel-Cell Vehicles

- G.H2, L.H2, MeOH, FRFG, CARFG, LSD, EtOH, CNG, LNG, LPG, and naphtha

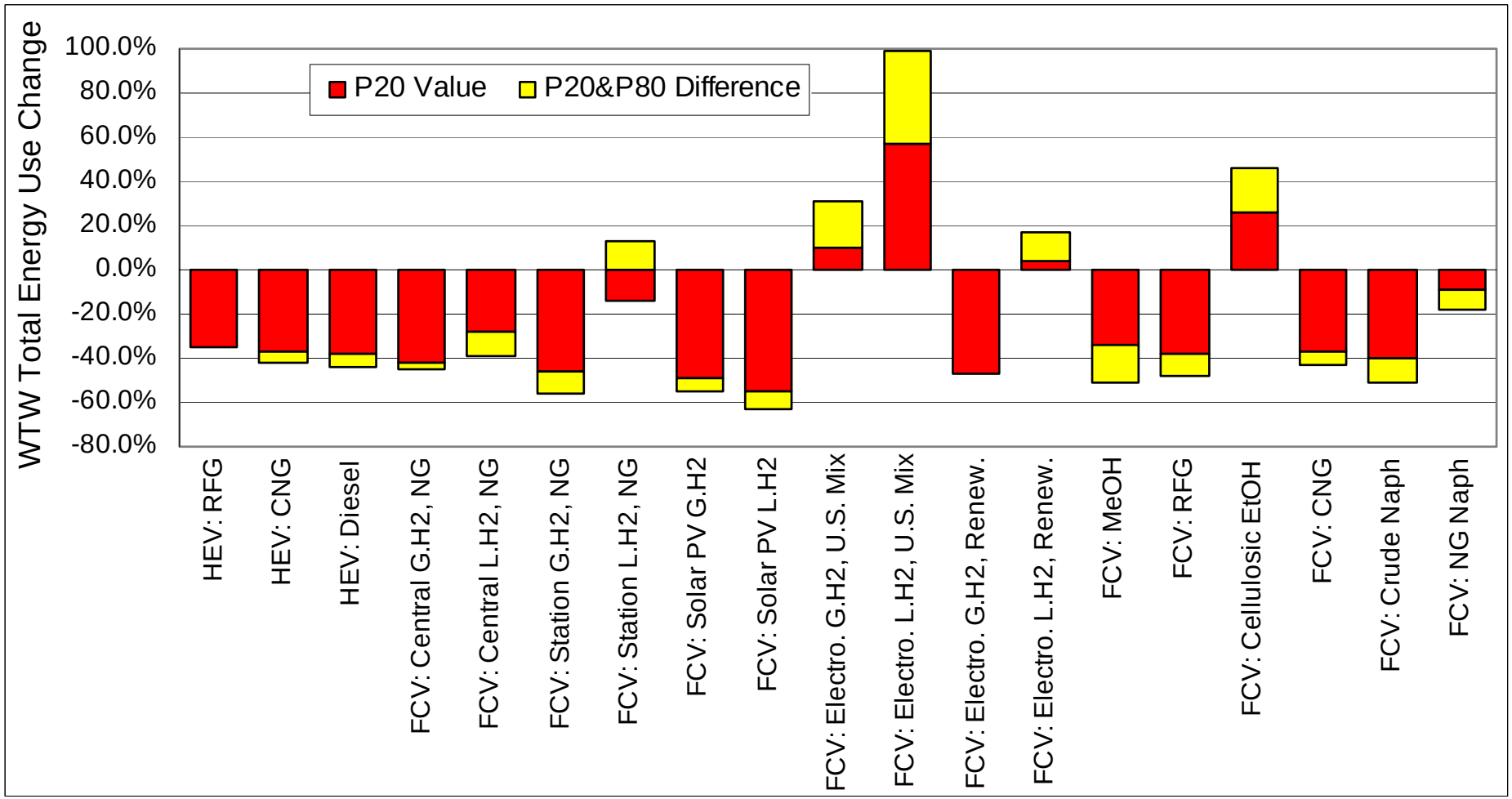
GREET Includes Many Fuels and Fuel Pathways Applicable to Fuel-Cell Vehicles



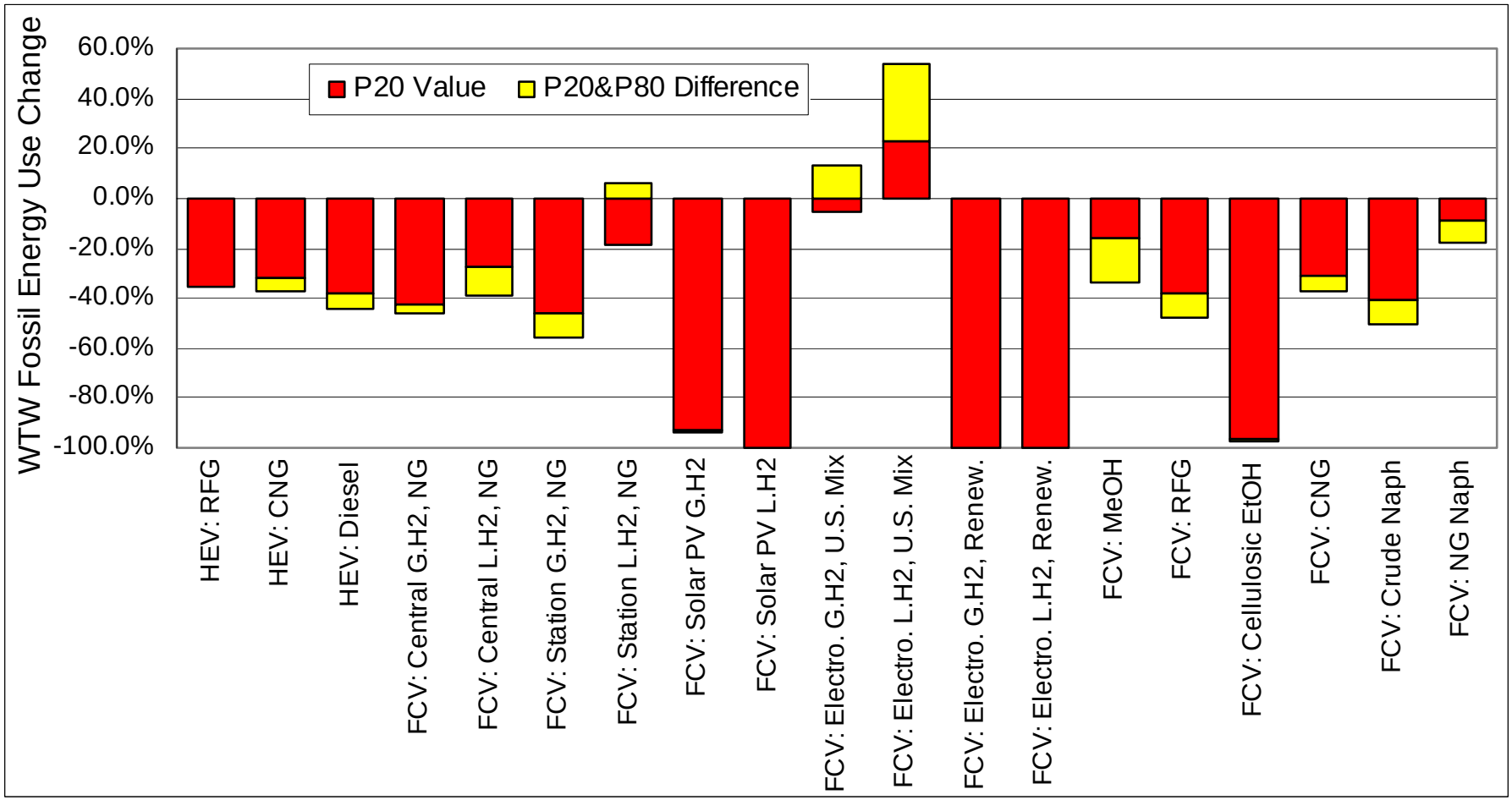
Ranges of Vehicle Fuel Economy Ratios Are Chosen from Available Studies



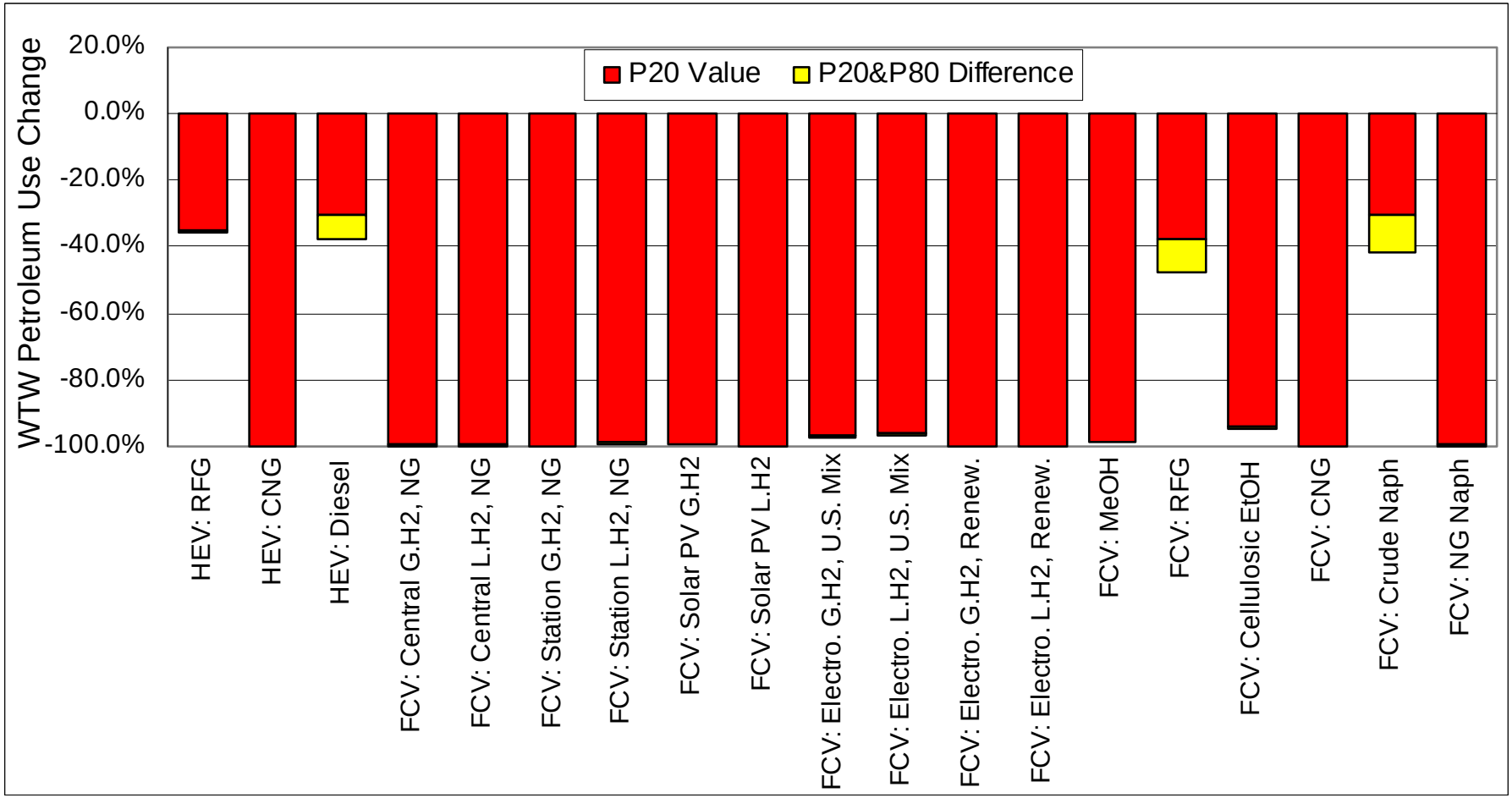
Five FCV Pathways Increase Per-Mile Total Energy Use, But …



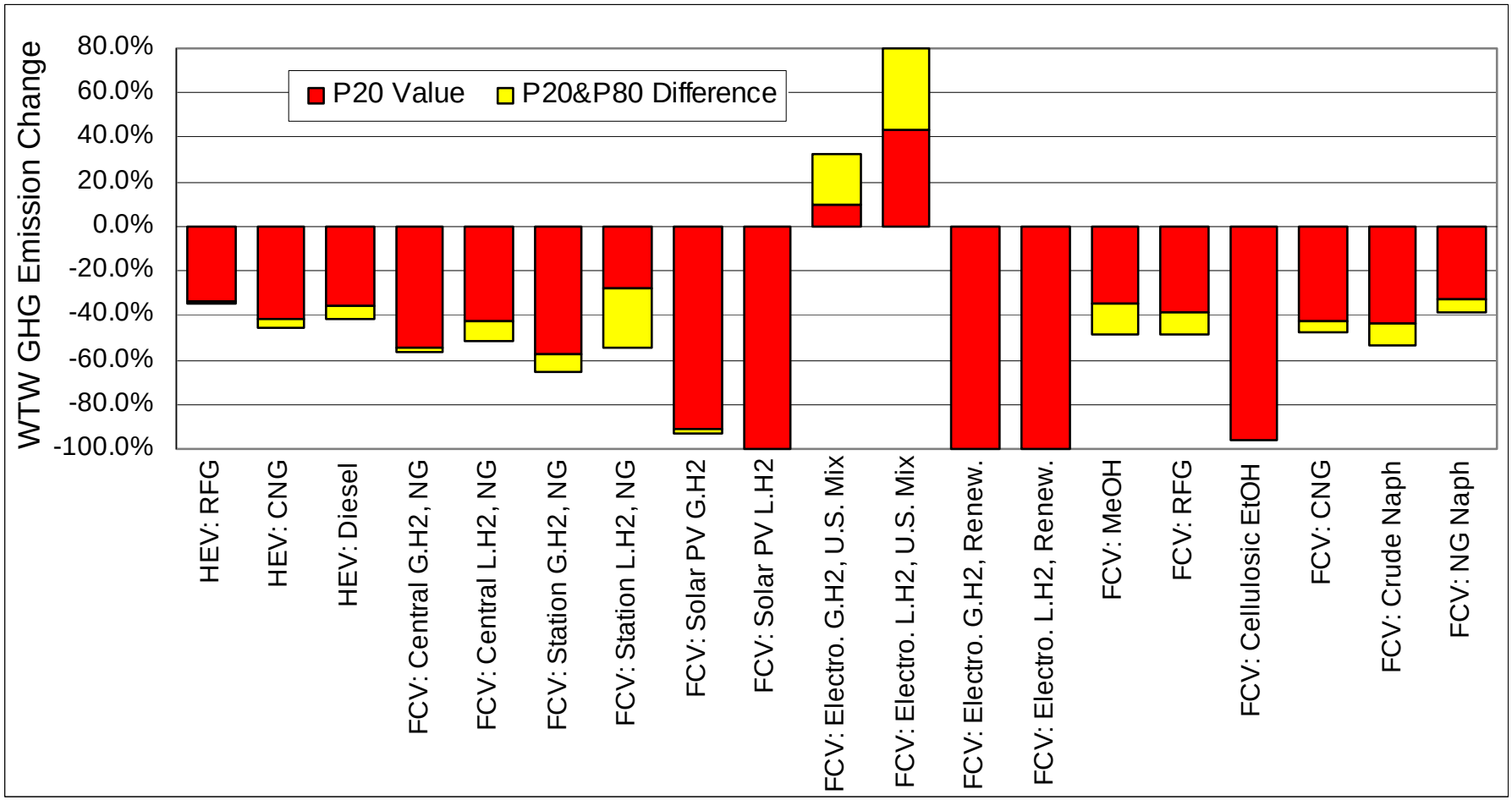
Only Three FCV Pathways Increase Per-Mile Fossil Energy Use



However, Every Non-Crude Pathway Achieves Large Petroleum Reduction



Only the Two U.S. Mix Electrolysis H2 Pathways Increase GHG Emissions



Conclusions

- Energy and emission impacts of fuel-cell vehicle/fuel combinations must be evaluated on a well-to-wheel basis
- Different fuels for fuel-cell vehicle applications can have significantly different energy use, oil use, and GHG emission implications
- All pathways reduce oil use
- Most, but not all, fuel-cell vehicle/fuel combinations achieve significant energy and GHG emission benefits