ARGONNE NATIONAL LABORATORY

TRANSPORTATION TECHNOLOGY R&D CENTER

Fuel Choices for Fuel-Cell Vehicles: Well-to-Wheels Energy and Emission Impacts

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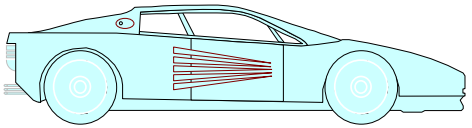
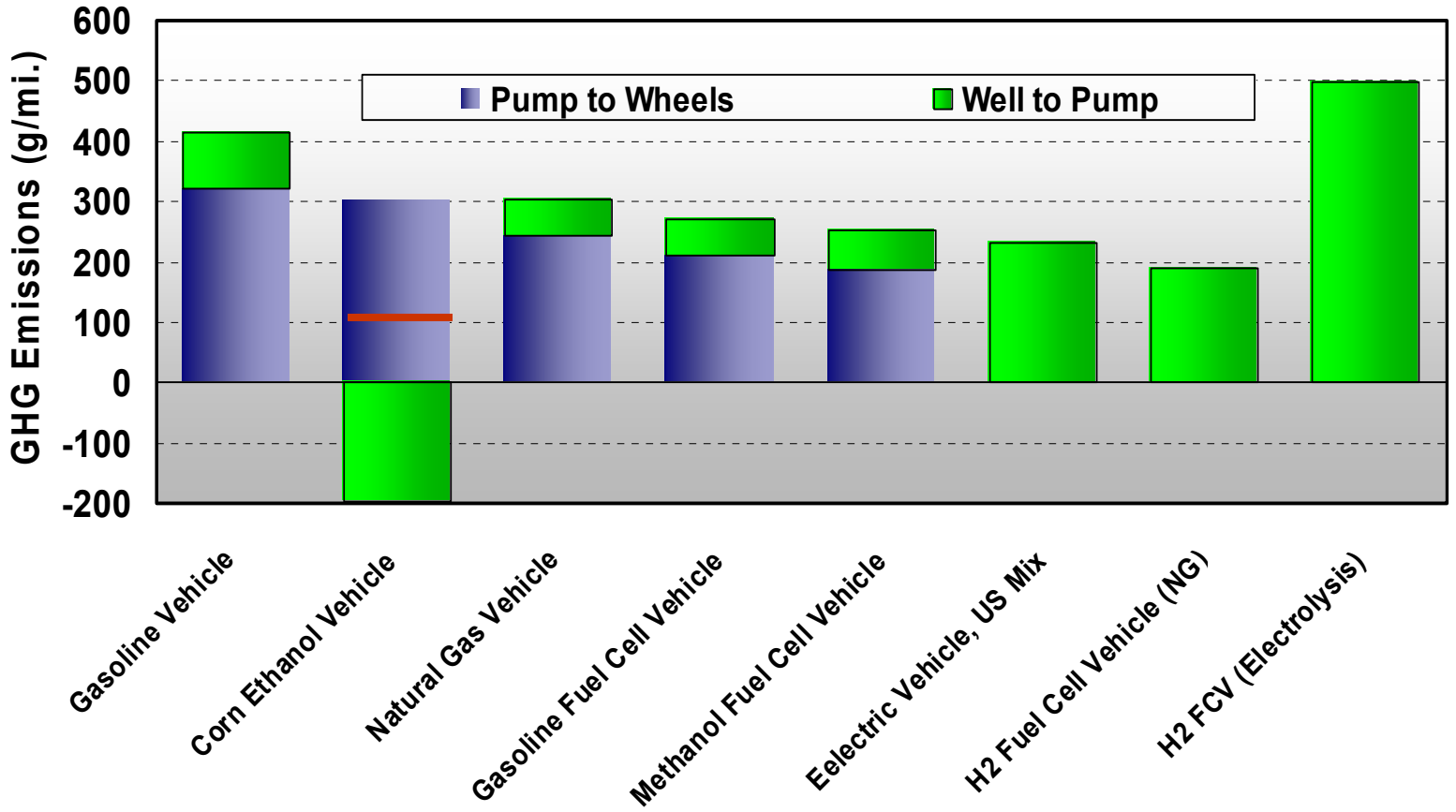


2002 Fuel Cell Seminar
Palm Springs, California
Nov. 18-21, 2002

WTW Analysis Is a Complete Energy/Emissions Comparison

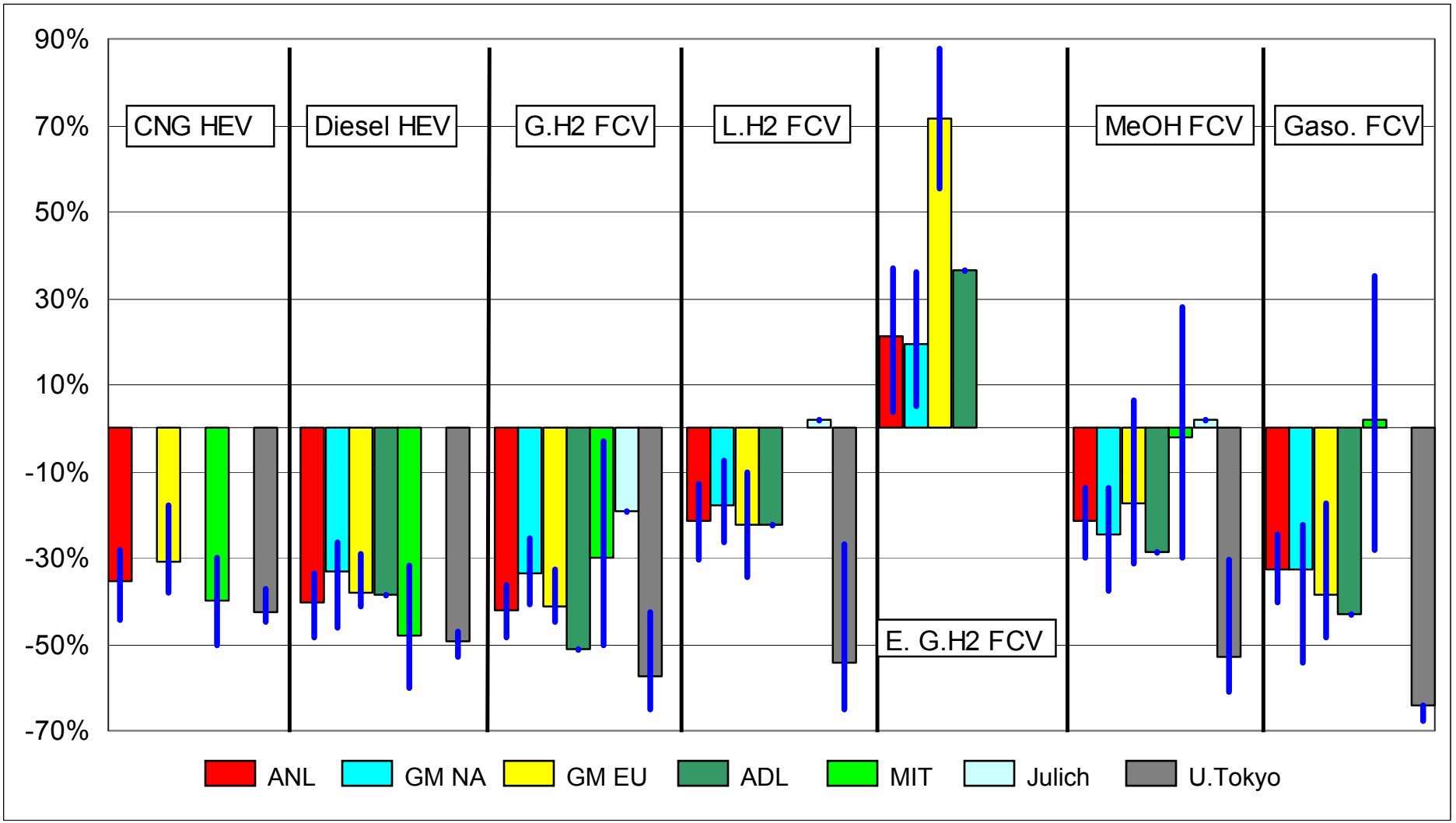
As an example, greenhouse gases are illustrated here



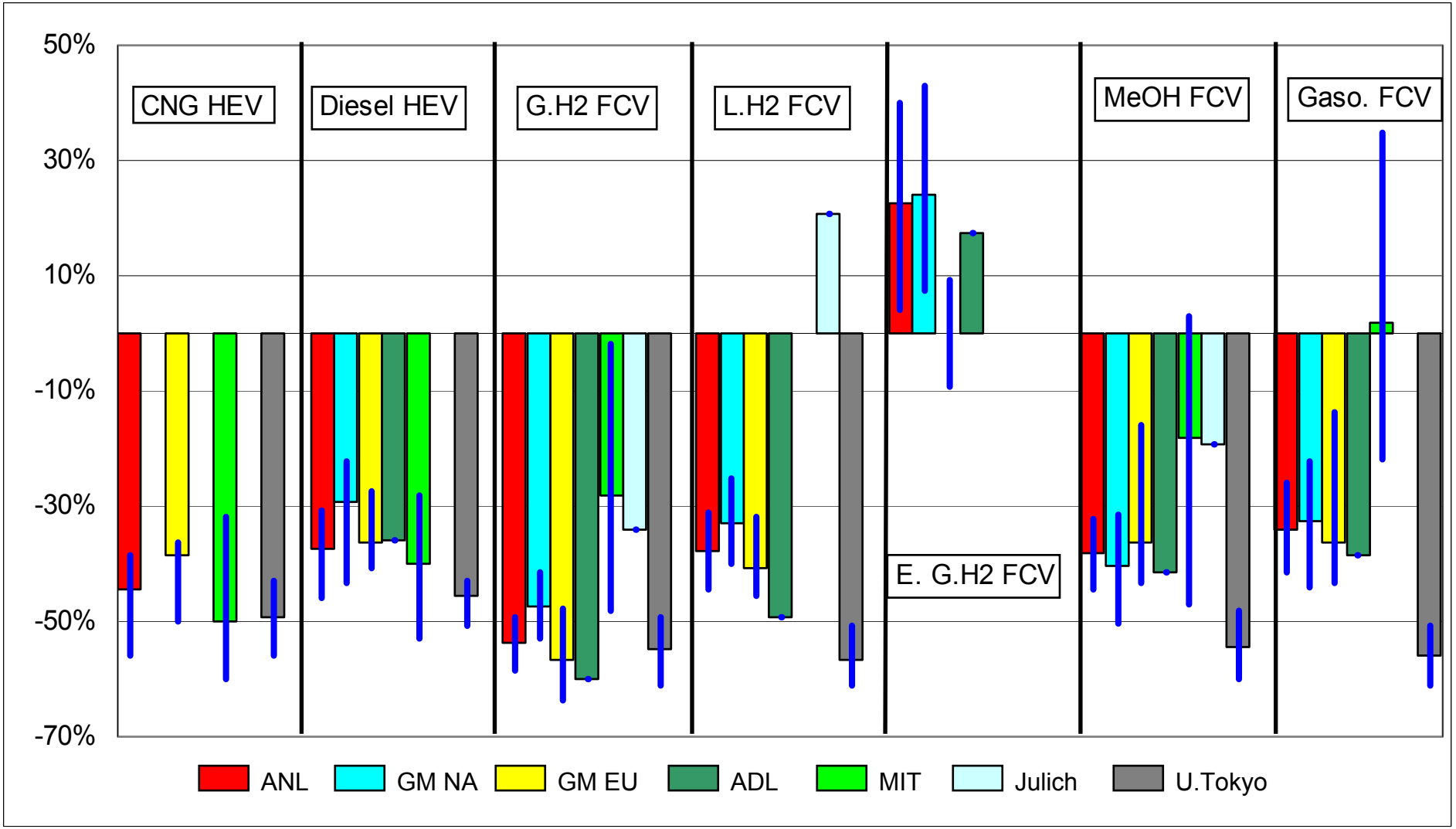
Recent Completed WTW Studies

- Argonne National Laboratory (ANL) U.S. Study, 2002
- GM European (GM EU) study, 2002
- A.D. Little (ADL) U.S. study, 2002
- German Julich Research Center German Study, 2001
- GM North American study, 2001
- University of Tokyo Japanese, 2001
- MIT U.S. study, 2000

WTW Energy Use Changes from Seven Completed Studies



WTW GHG Emissions Changes from Seven Completed Studies



The GREET (*G*reenhouse gases, *R*egulated *E*missions, and *E*nergy use in *T*ransportation) Model

- **GREET includes emissions of greenhouse gases**
  - CO_2, CH_4, and N_2O
  - VOC, CO, and NO_x as optional GHGs
- **GREET estimates emissions of five criteria pollutants**
  - Total and urban separately
  - VOC, CO, NO_x, PM_{10}, and SO_x
- **GREET separates energy use into**
  - All energy sources
  - Fossil fuels (petroleum, natural gas, and coal)
  - Petroleum
- **The GREET model and Its documents are available at http://greet.anl.gov; there are 640 registered GREET users**

Details of This Presentation Is in the Paper Published in Journal of Power Sources

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Fuel choices for fuel-cell vehicles: well-to-wheels energy and emission impacts

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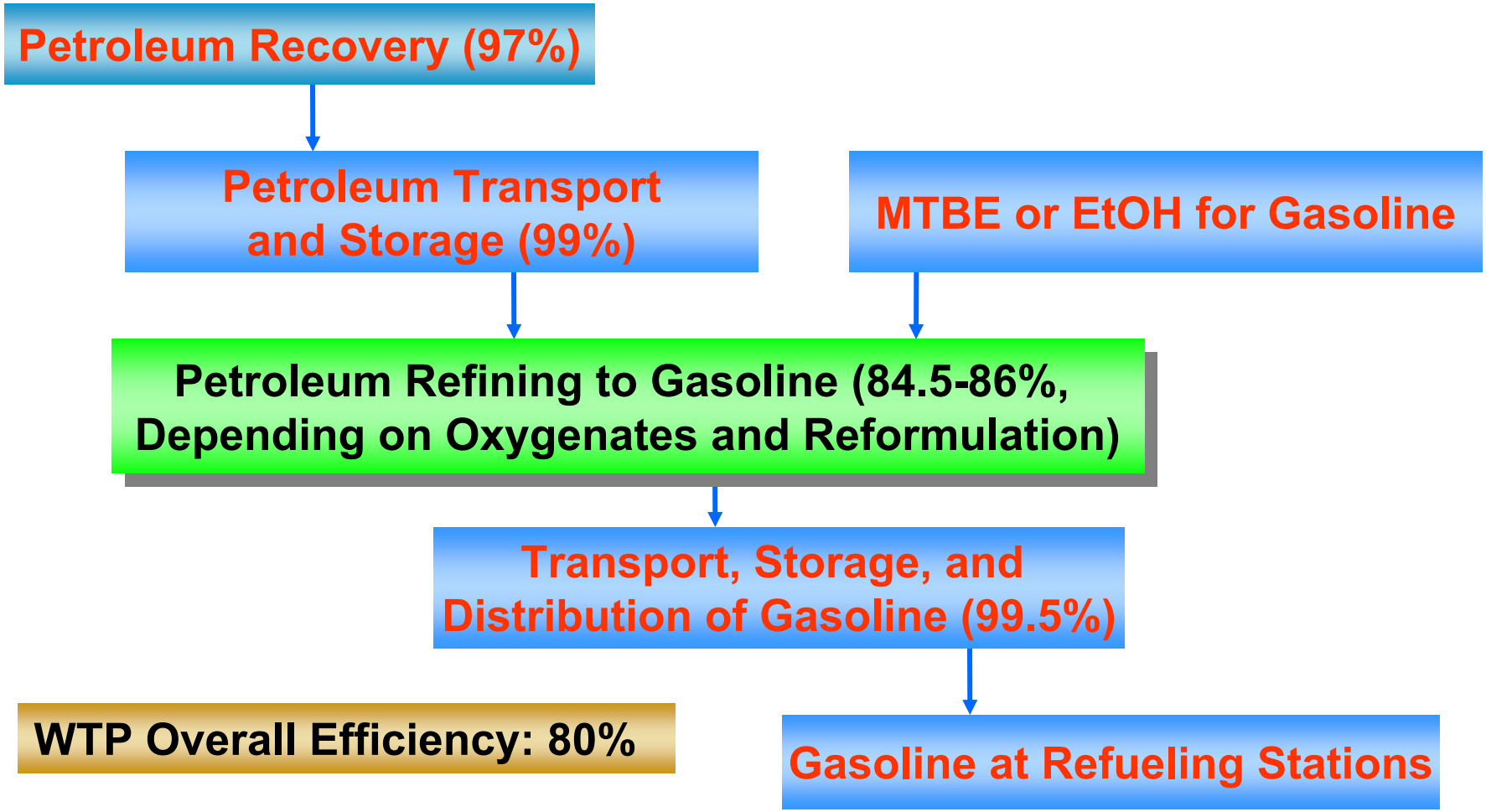
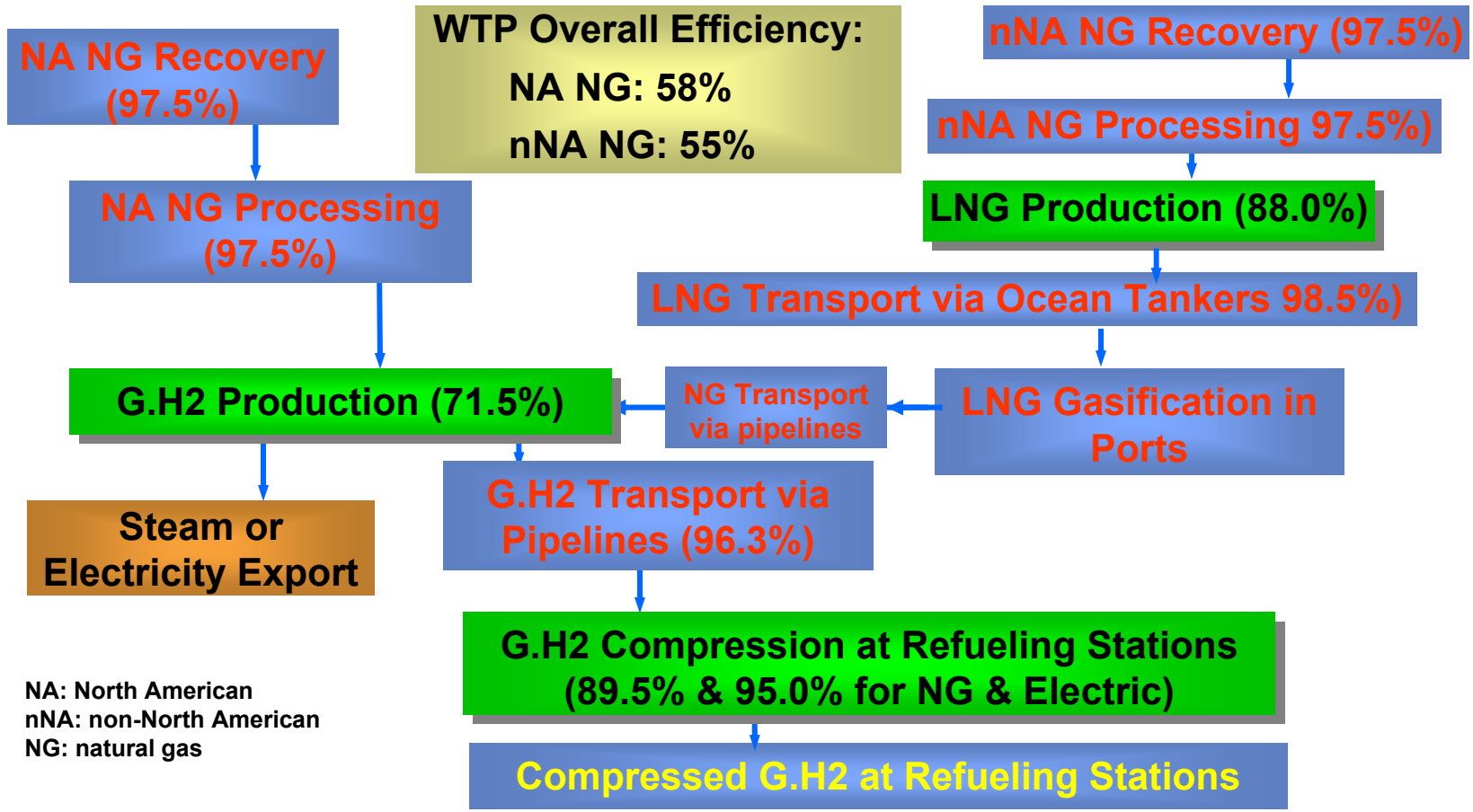
Argonne Evaluated These Fuel Production Pathways in This Study

Feedstock	*Fuel*
Petroleum	30-ppm gasoline; 10-ppm gasoline; 15-ppm diesel; naphtha
Natural gas	Central G.H2; station G.H2; central L.H2; station L.H2; methanol; compressed NG
U.S. electricity	G.H2; L.H2 (station production)
Renewable electricity	G.H2; L.H2 (station production)
Solar energy	G.H2; L.H2 (central production)
Cellulosic biomass	Ethanol

Petroleum Refining Is the Key Energy Conversion Step for Gasoline

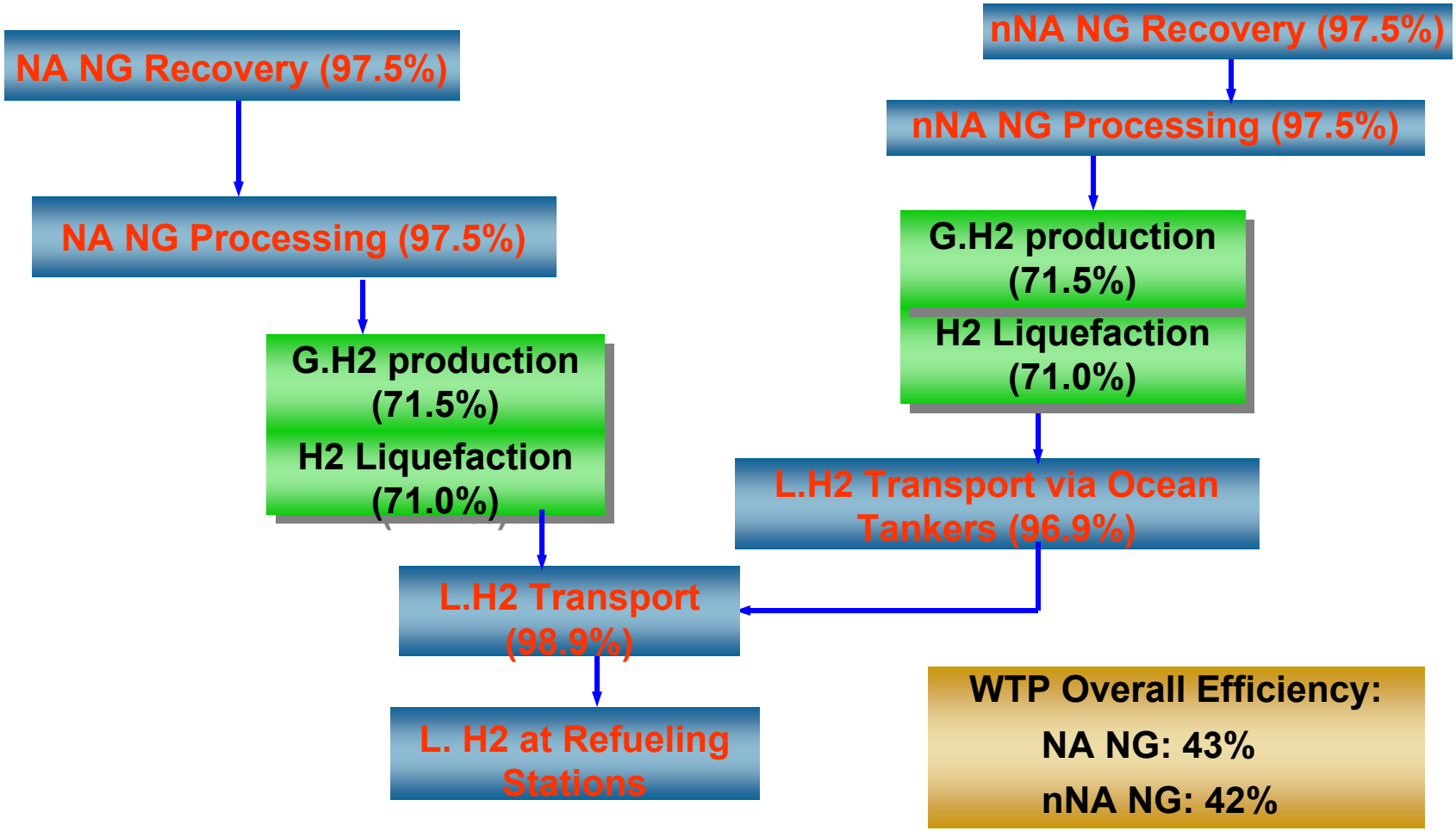


Production and Compression Are Key Steps for Centralized G.H_2 Pathways

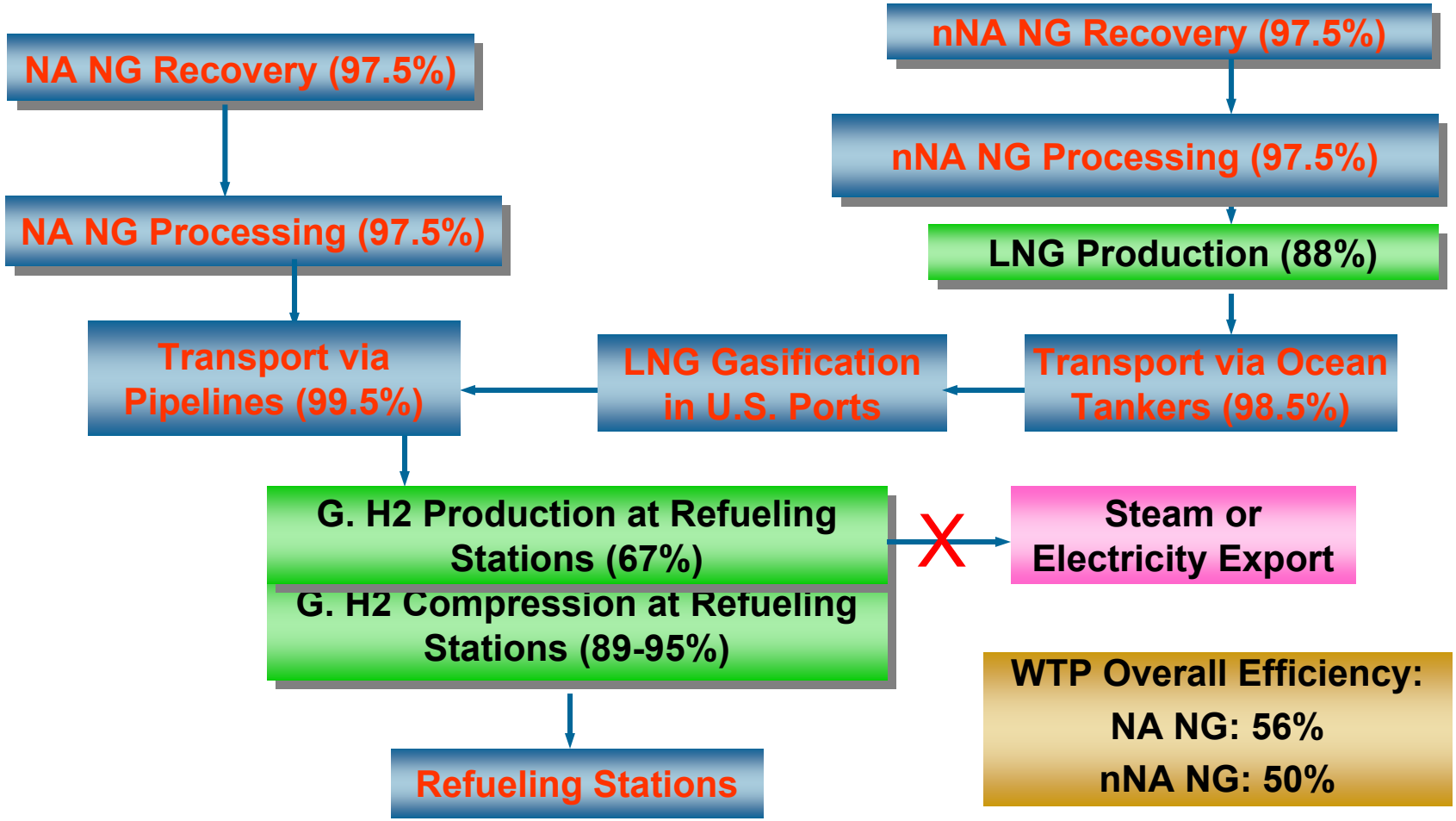


NA: North American
nNA: non-North American
NG: natural gas

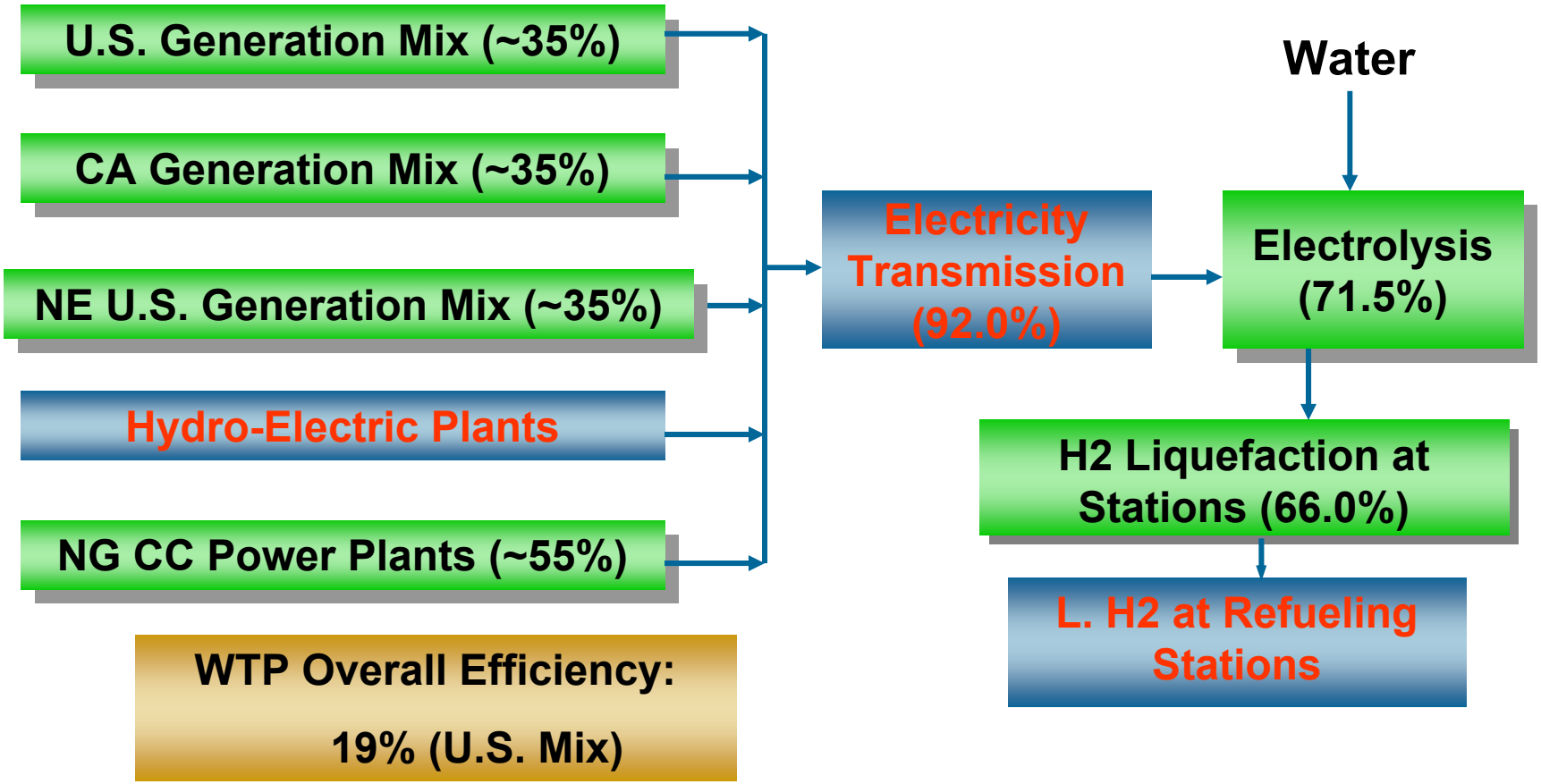
H_2 Liquefaction Has Higher Energy Losses Than H_2 Compression



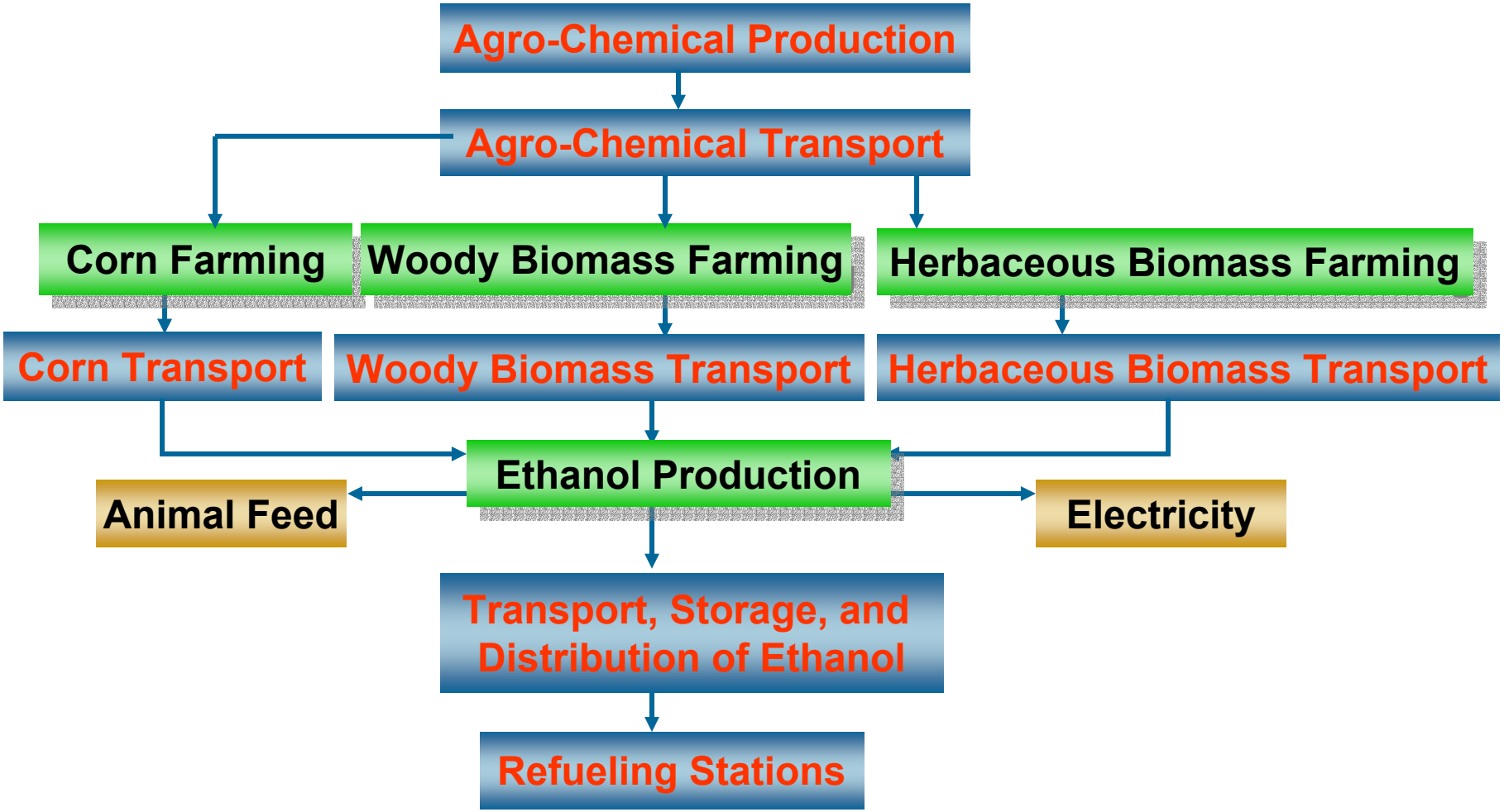
Station H_2 Production Lacks Energy Benefits from Co-Products



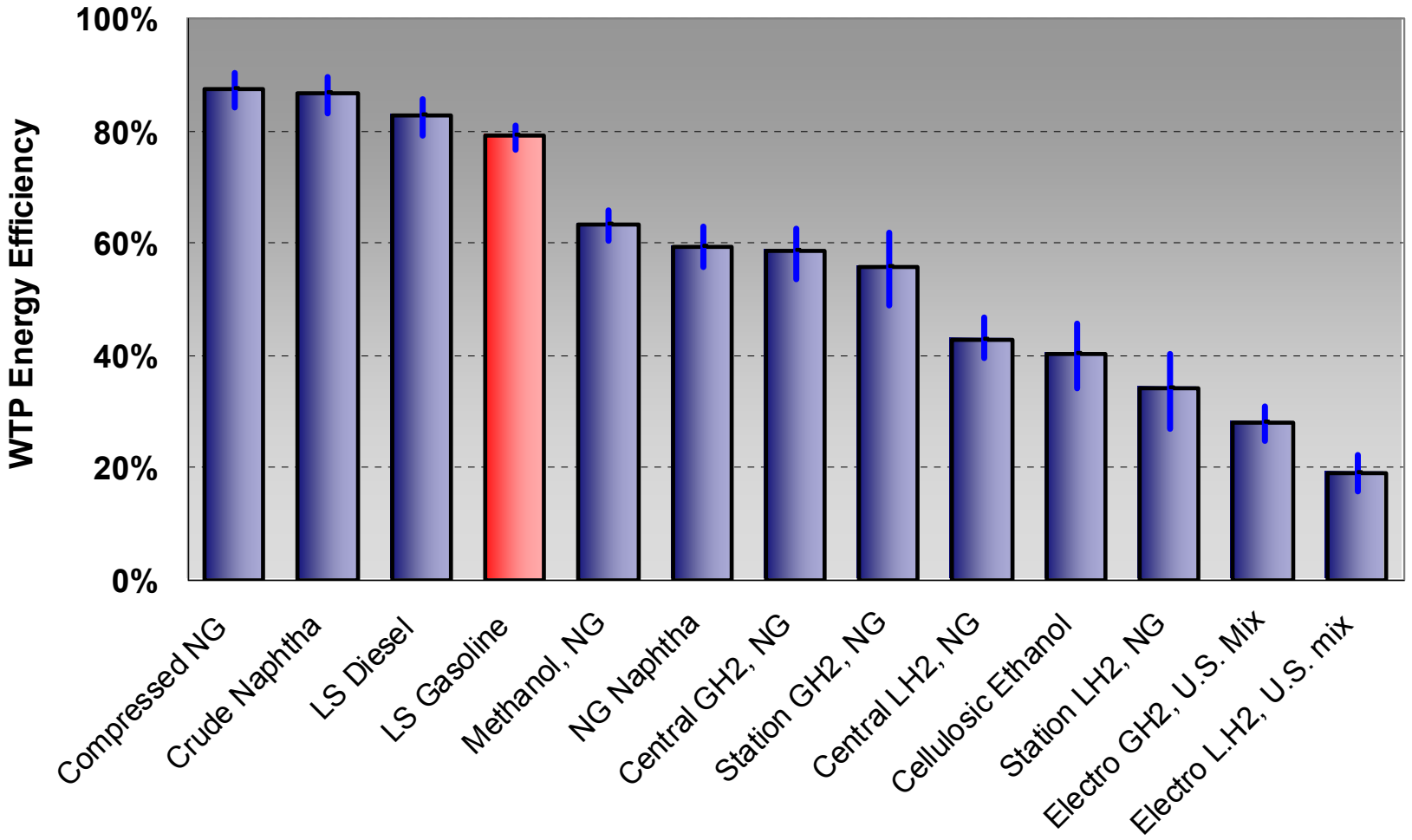
Electrolysis Liquid Hydrogen Is Subject to Three Steps with Large Energy Losses



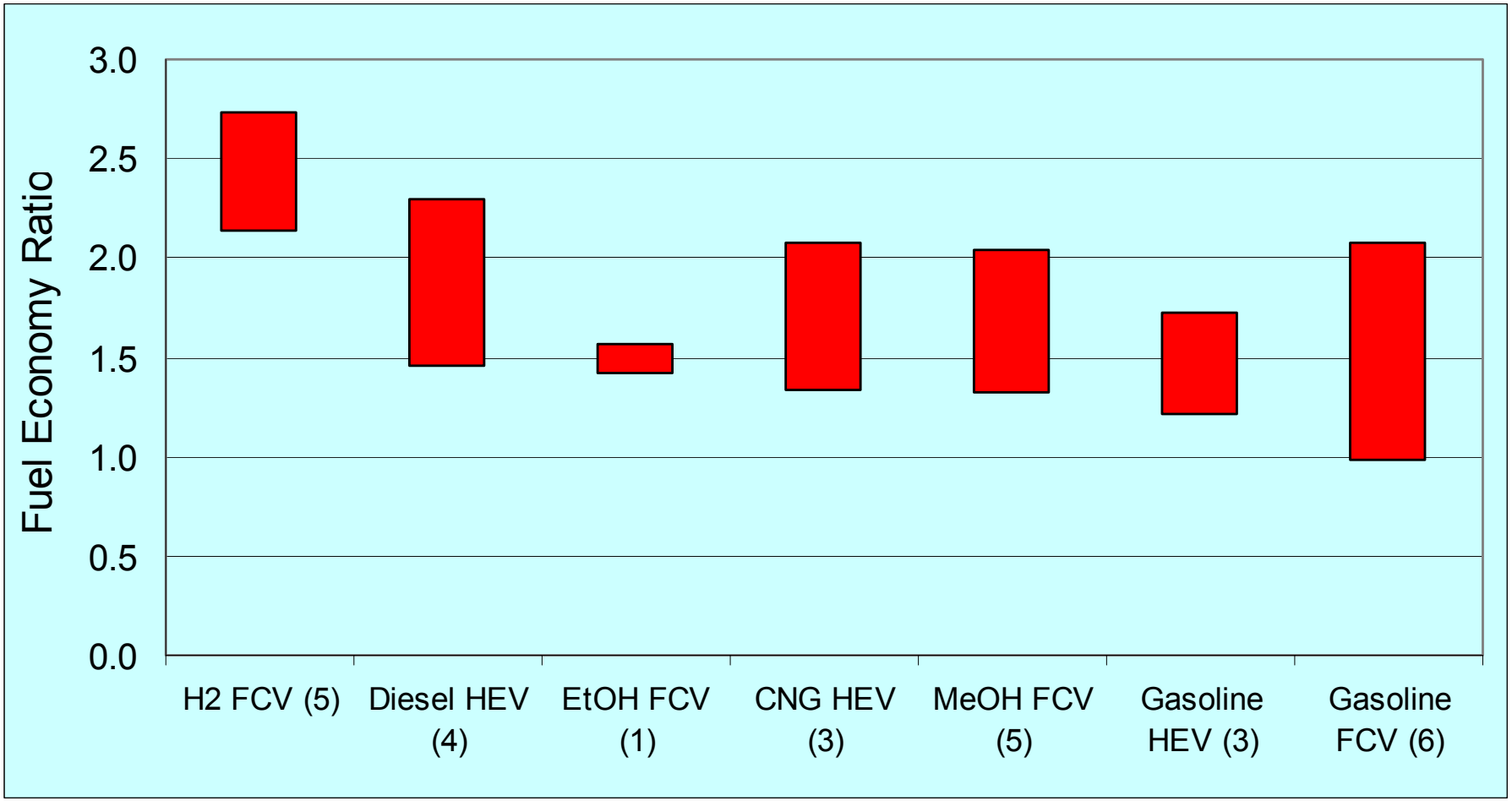
Ethanol Pathways Include activities from Fertilizer to Ethanol at Stations



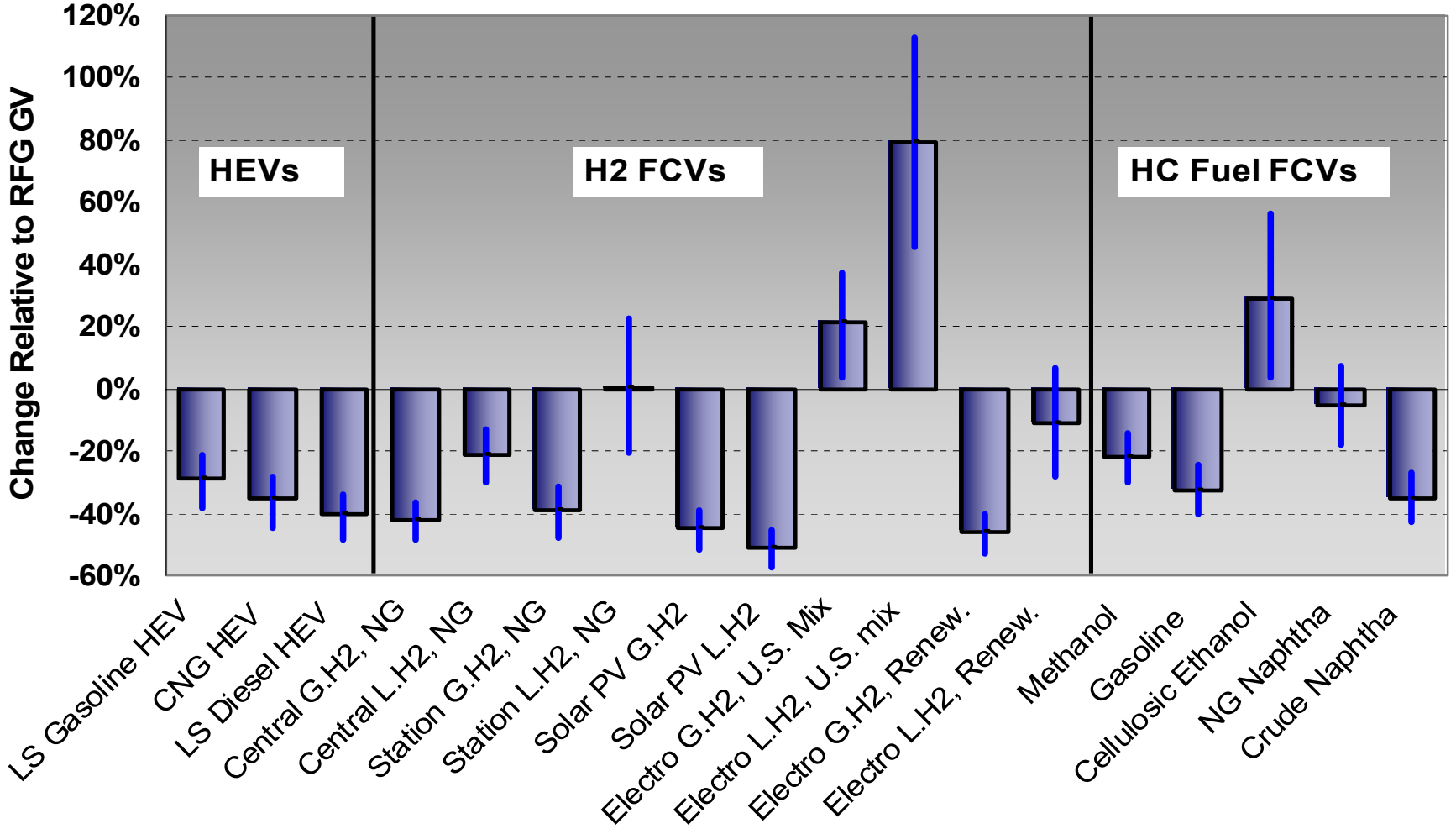
In Summary, WTP Energy Losses Could Penalize Overall FCV Efficiencies



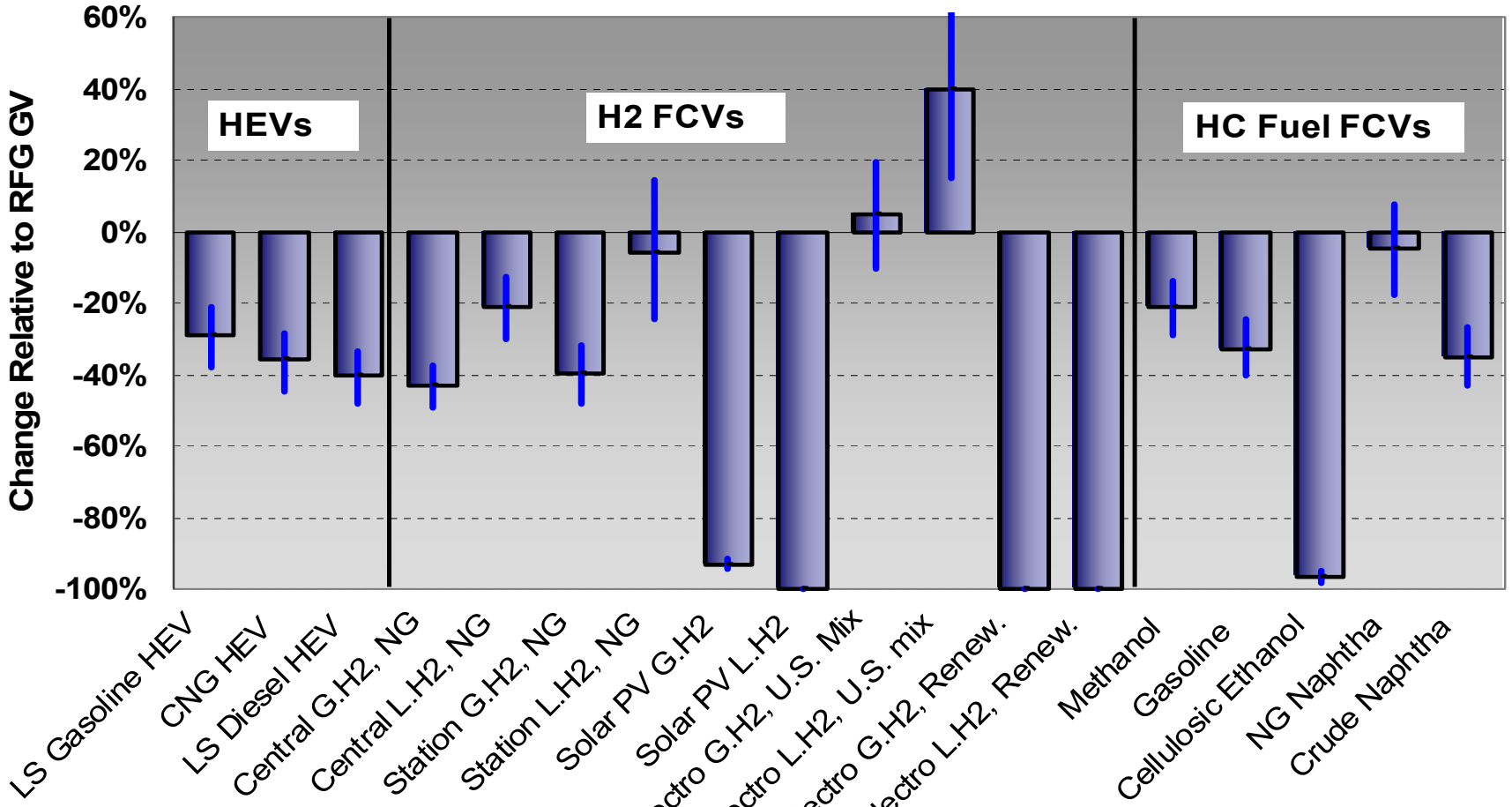
Fuel Economy Ratios of FCVs and HEVs (Relative to GVs)



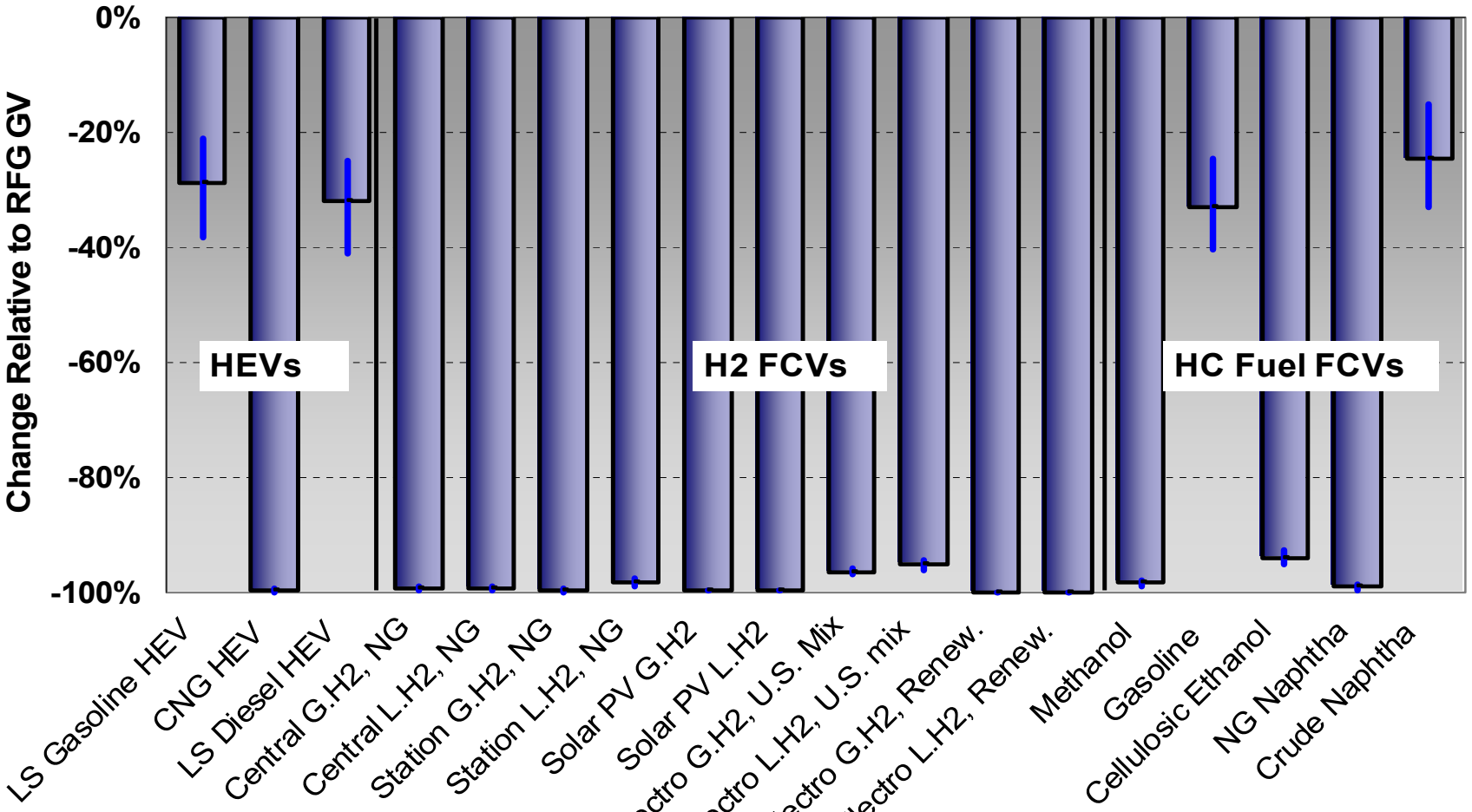
Some FCV Pathways Could Increase Per-Mile *Total Energy Use*, But .....



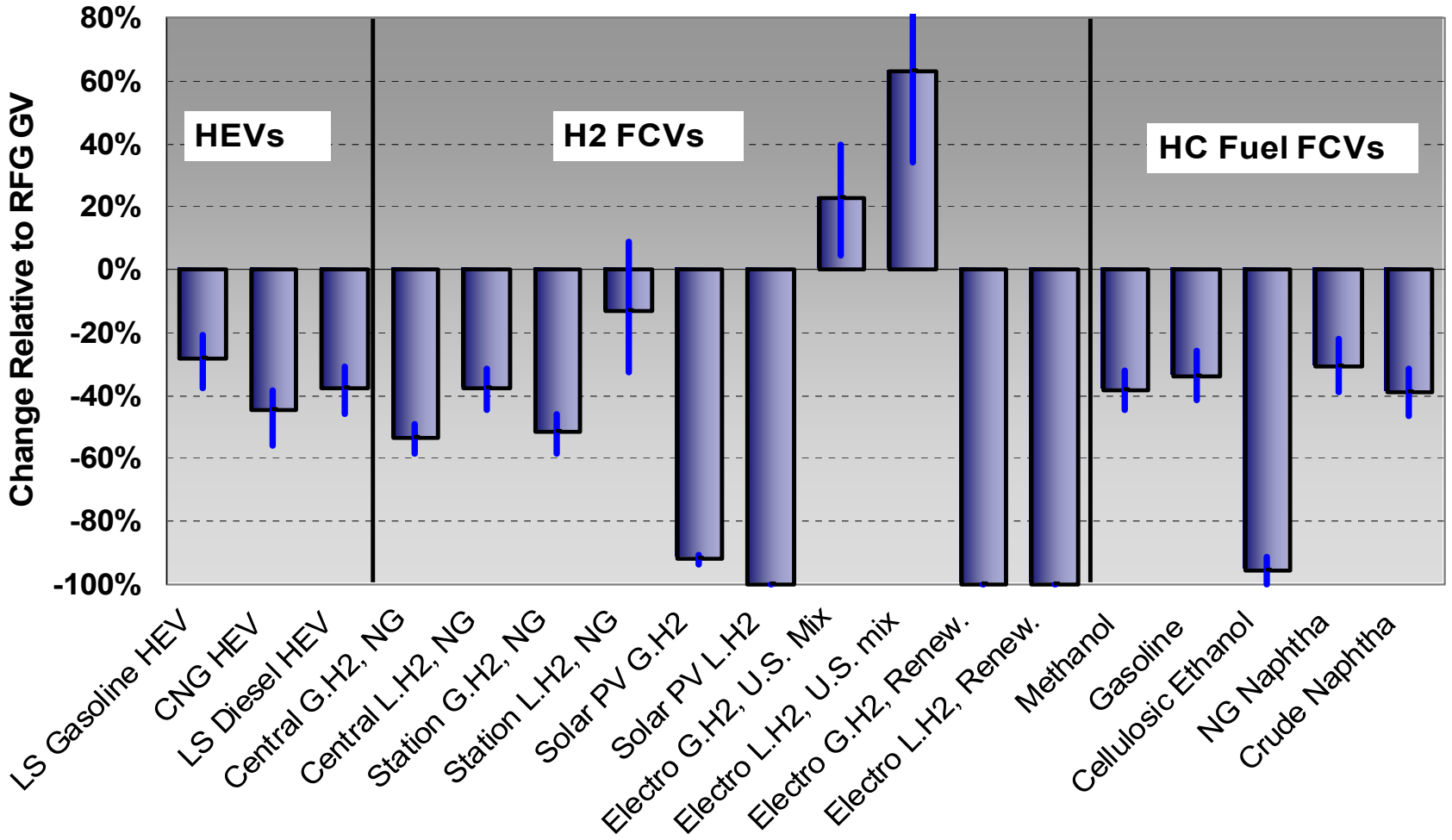
Increases in Per-Mile *Fossil Energy Use* Are Smaller



Furthermore, Every Non-Crude Pathway Achieves Large *Petroleum* Reduction



Only the Two *U.S. Mix* Electrolysis H_2 Pathways Increase GHG Emissions



Conclusions

- Well-to-wheels analysis helps identify fuels and fuel production pathways for energy and environmental benefits
- Different fuels for fuel-cell vehicle applications can have significantly different energy use, oil use, and GHG emission implications
- All advanced vehicle pathways reduce oil use
- Most, but not all, of the fuel-cell vehicle/fuel combinations being considered achieve significant energy and GHG emission benefits