Transportation Fuels Infrastructure
Energy, Emission, and Cost Implications

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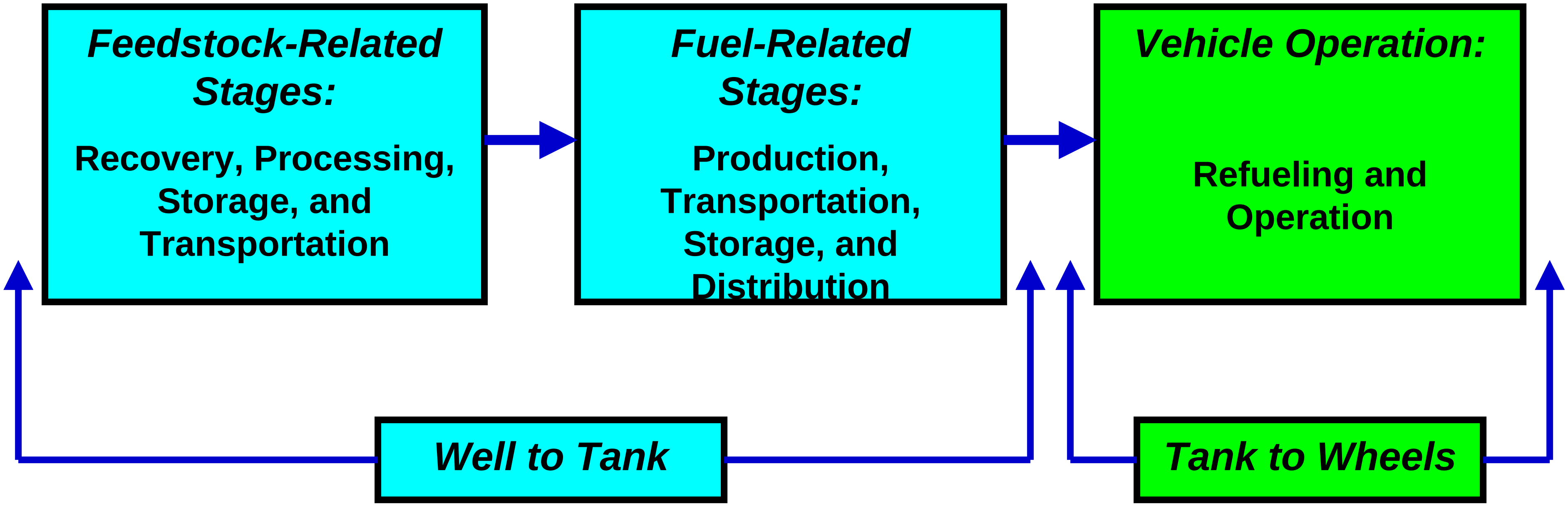
Future and Economics of Fuels Conference
Cologne, Germany, March 14, 2001

A Fuel-Cycle Analysis Includes These Stages



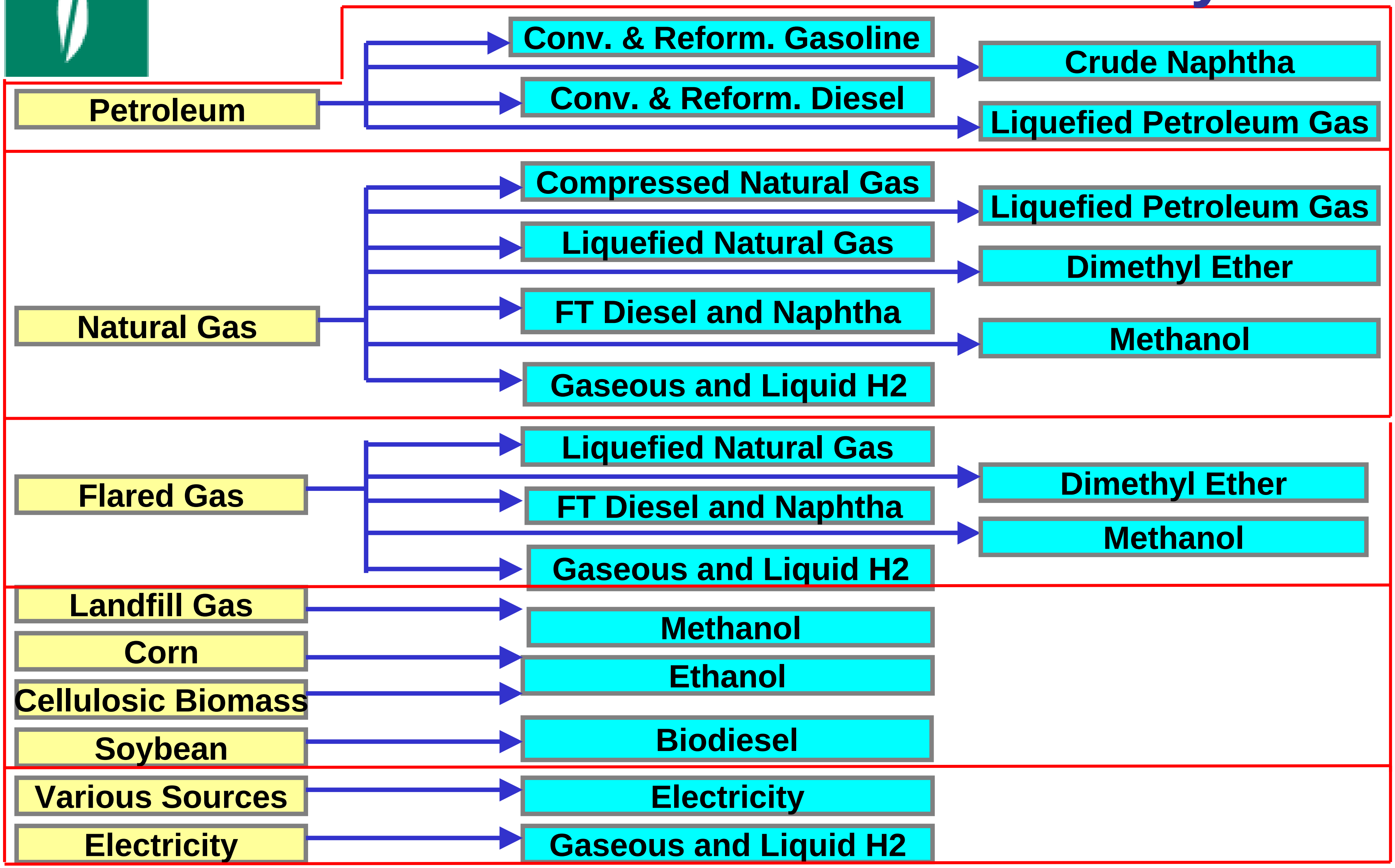
The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model

- Estimate per-mile energy use and emissions rates from wells to the wheels for various fuel/vehicle systems
- First version was developed in 1996
- The current version available to the public is GREET1.5a
- GREET1.5a and its documents are available at Argonne's transportation website at www.transportation.anl.gov/ttrdc/greet

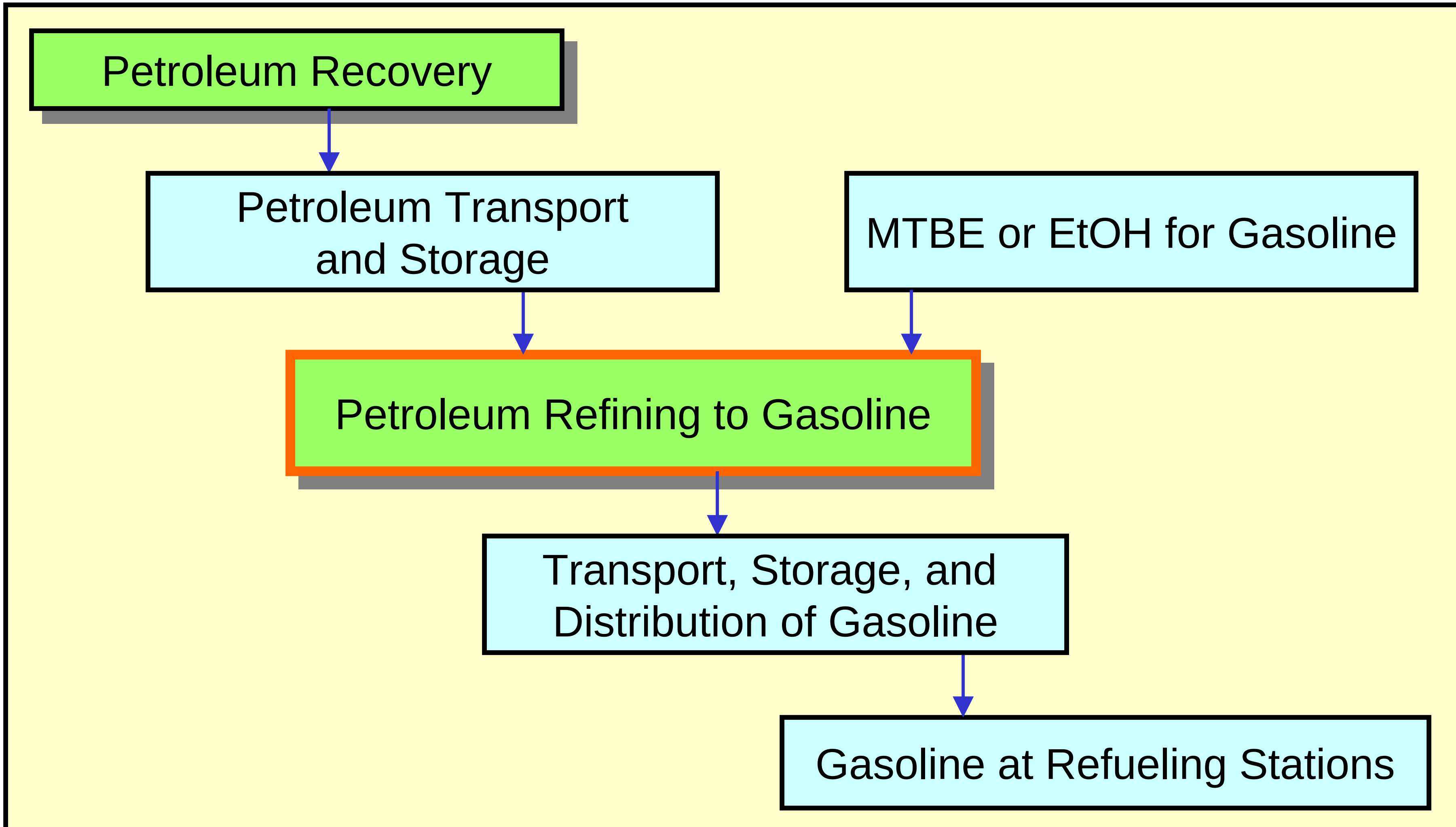
GREET Simulates These Emission and Energy Items

- 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, NOx, PM10, and SOx
- Energy Use
  - All energy sources
  - Fossil fuels
  - Petroleum

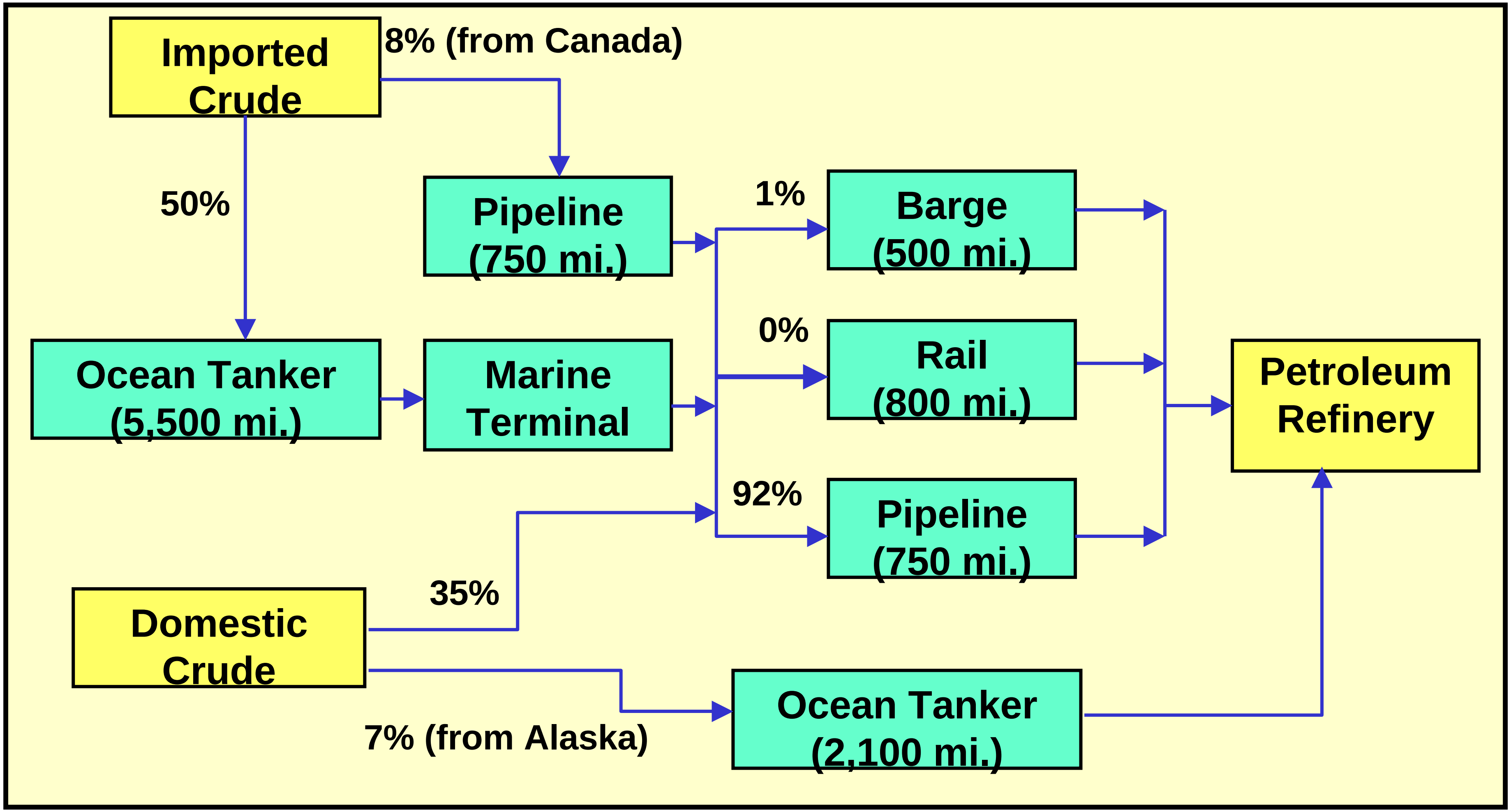
GREET Has Over 30 Fuel Pathways



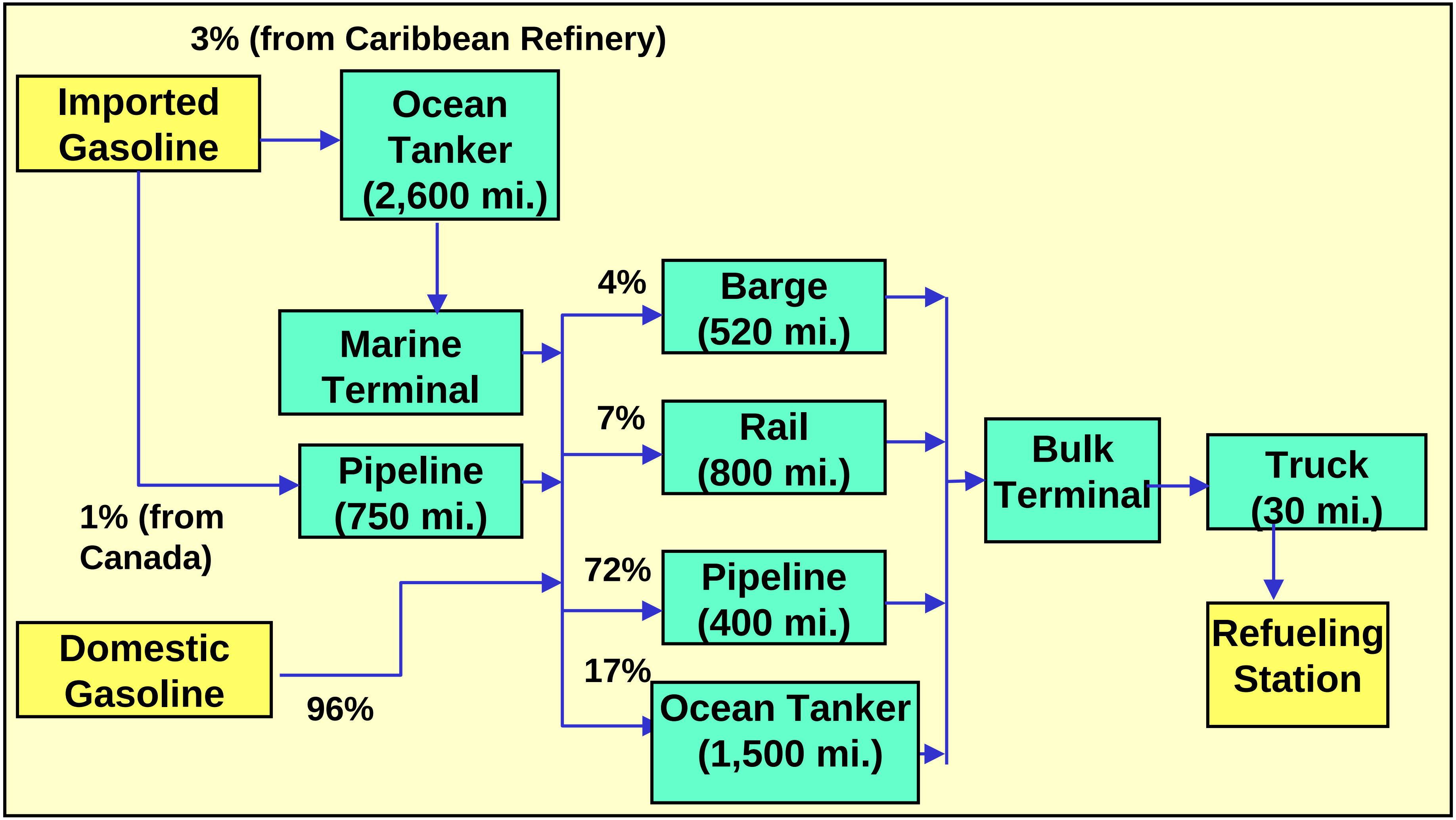
Gasoline (and Diesel) Pathways Are Subject to Two Major Energy Losses



Average Transport Mode Shares and Distance for Crude to U.S. Refineries



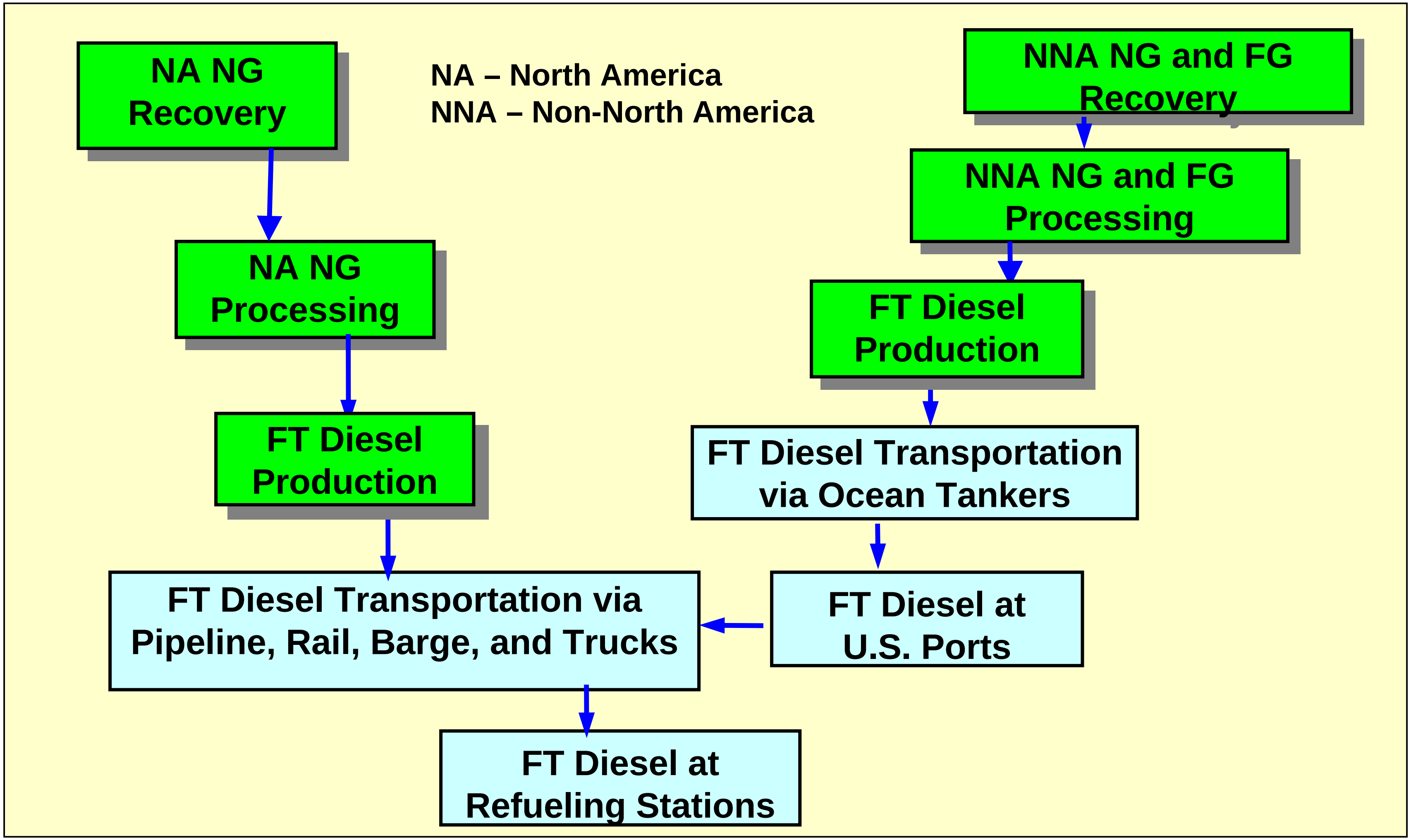
Average Mode Shares and Distance for U.S. Gasoline to Refueling Stations



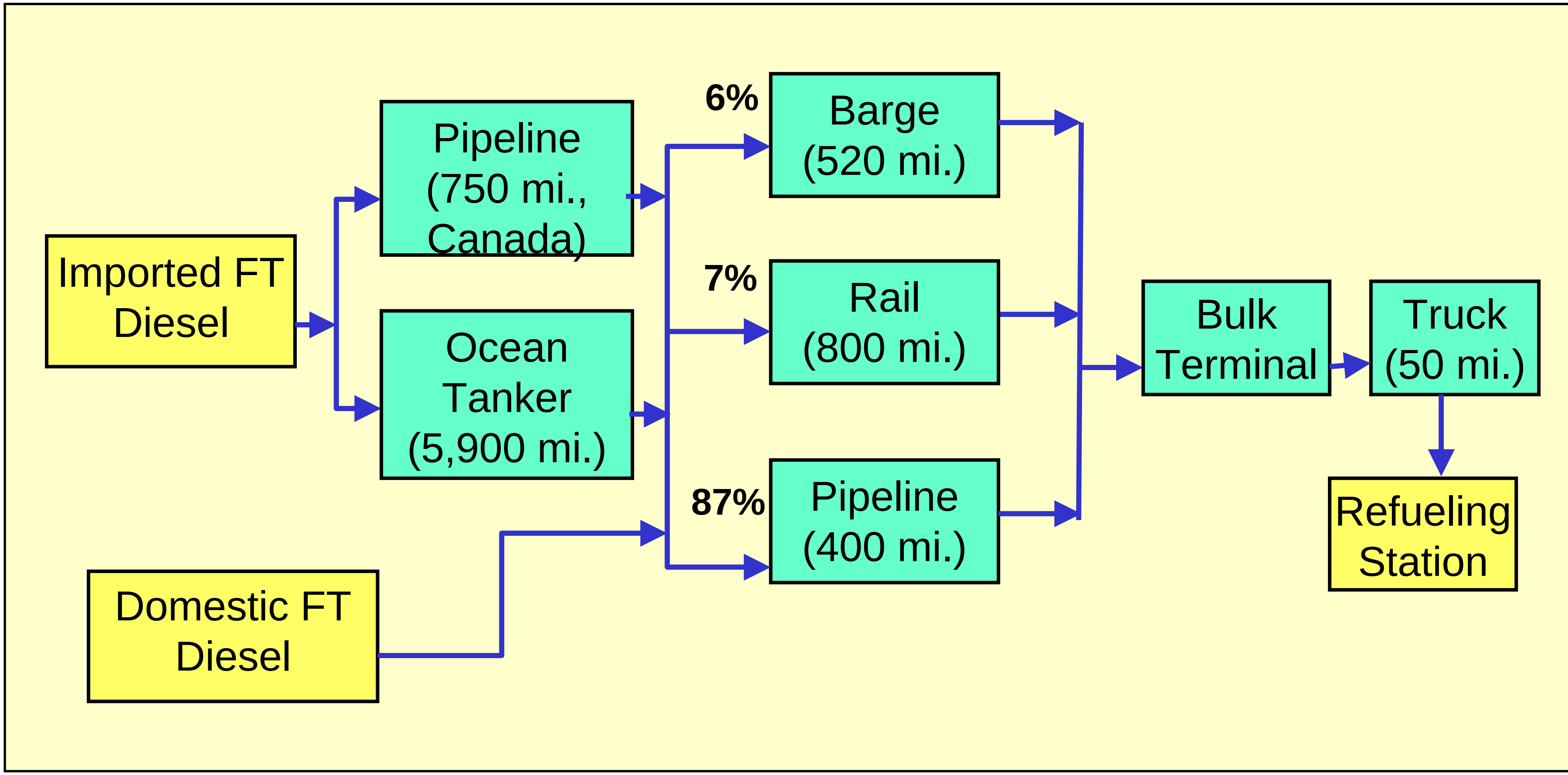
Key Issues for Petroleum Fuel Pathways

- Gasoline sulfur reduction from ~300 to 30 ppm by 2006
- Diesel sulfur reduction from ~300 to 15 ppm by 2007
- New crude could have high sulfur content
- Desulfurization by refineries increases H_2 use, resulting in higher energy use and emissions
- If oxygenate requirement remains and MTBE is phased-out, ethanol will be the substitute oxygenate

Fischer-Tropsch Diesel Can Address Sulfur Issues for Conventional Diesel



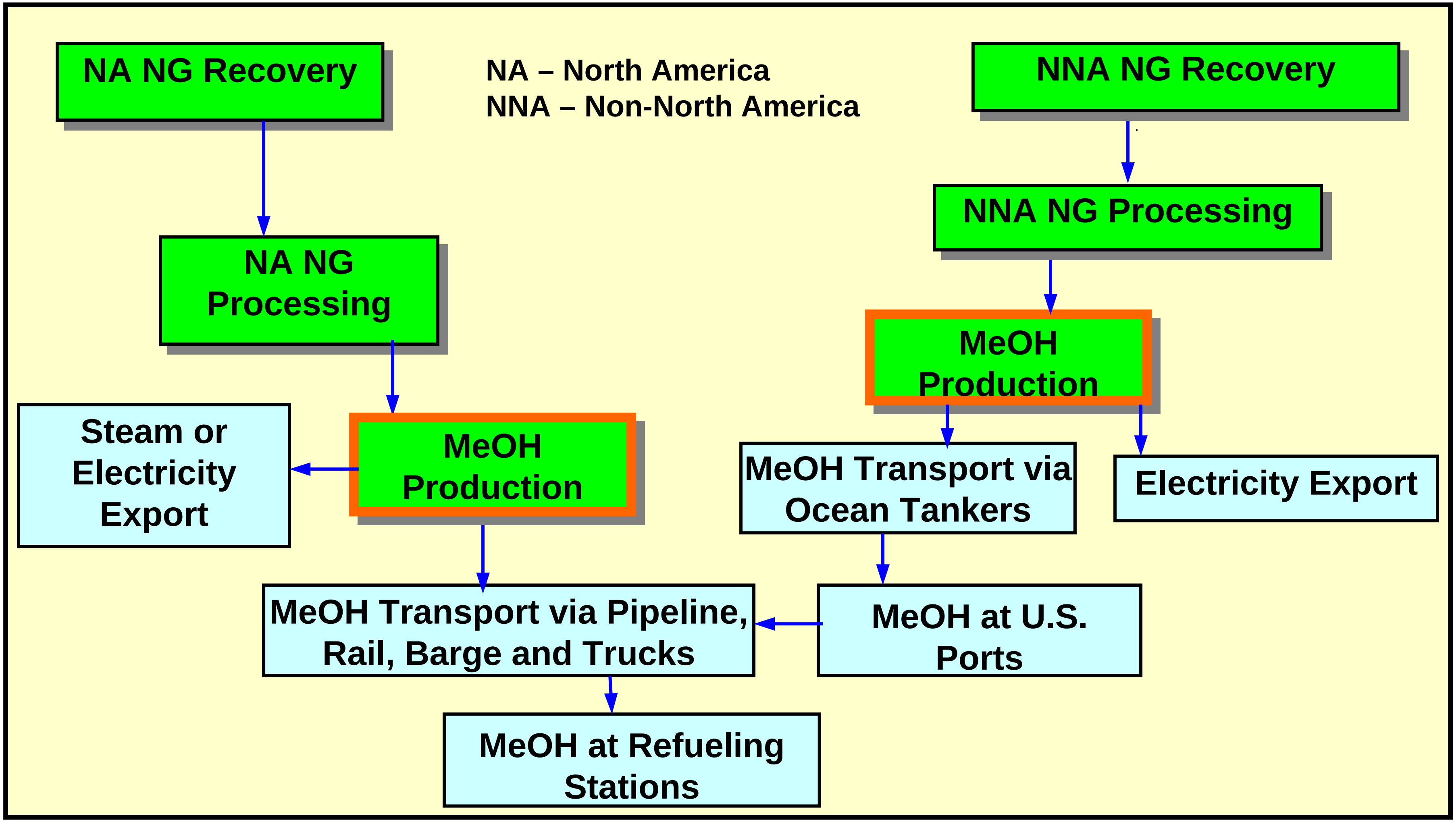
Transport Logistics of Future FT Diesel for the U.S. Market



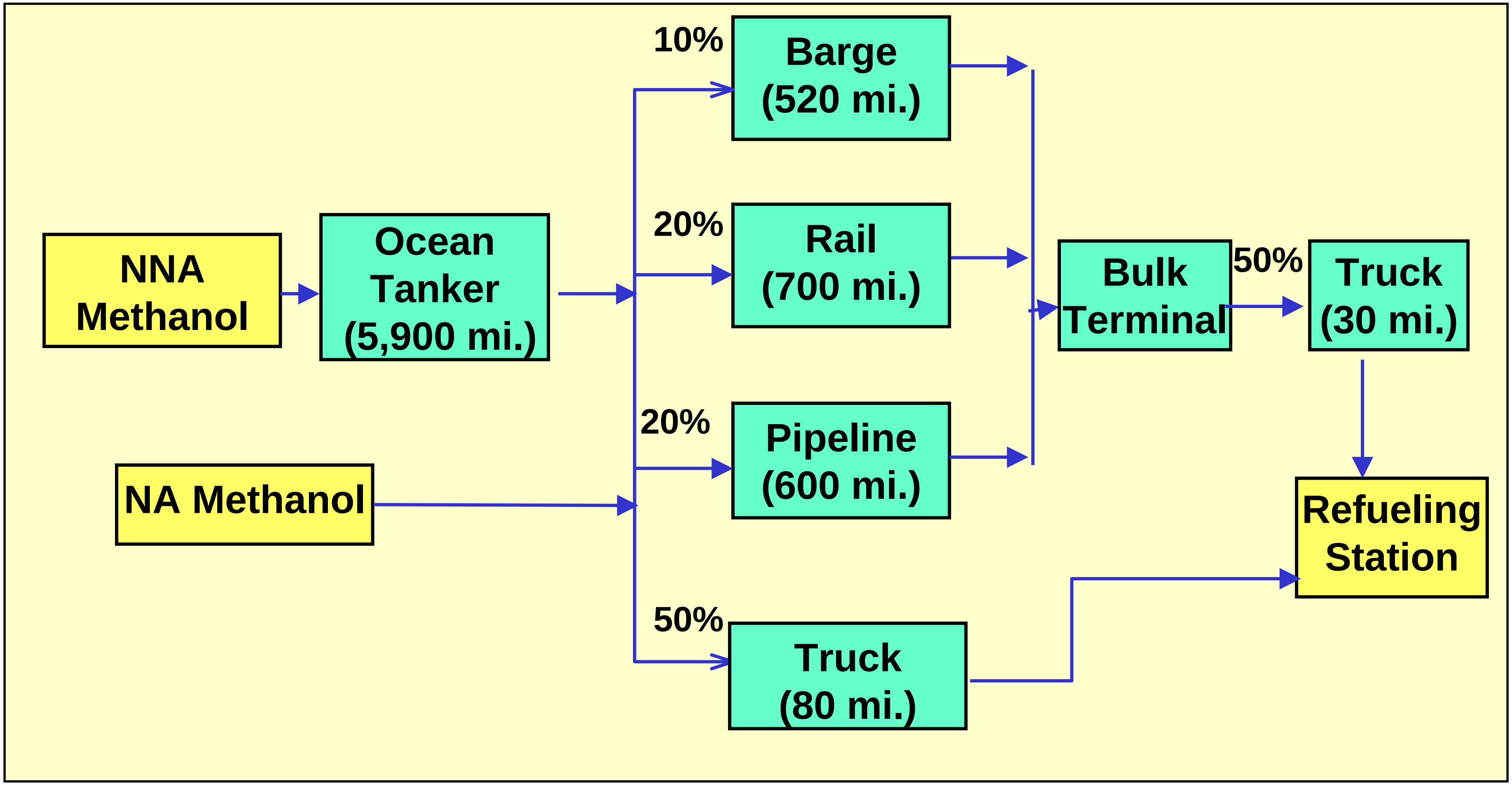
Important Infrastructure Compatibility Advantages of FTD

- Existing tankers can be used for cross-ocean transportation
- Can blend into petro diesel and be stored in existing tanks
- Unlike LNG and liquid H2, can be reloaded to smaller tankers at intermediate points without large energy losses
- Zero sulfur content improves performance of sulfur-sensitive emission after-treatment for CI engines

Methanol for the U.S. Market Is Likely to Come from Outside North America



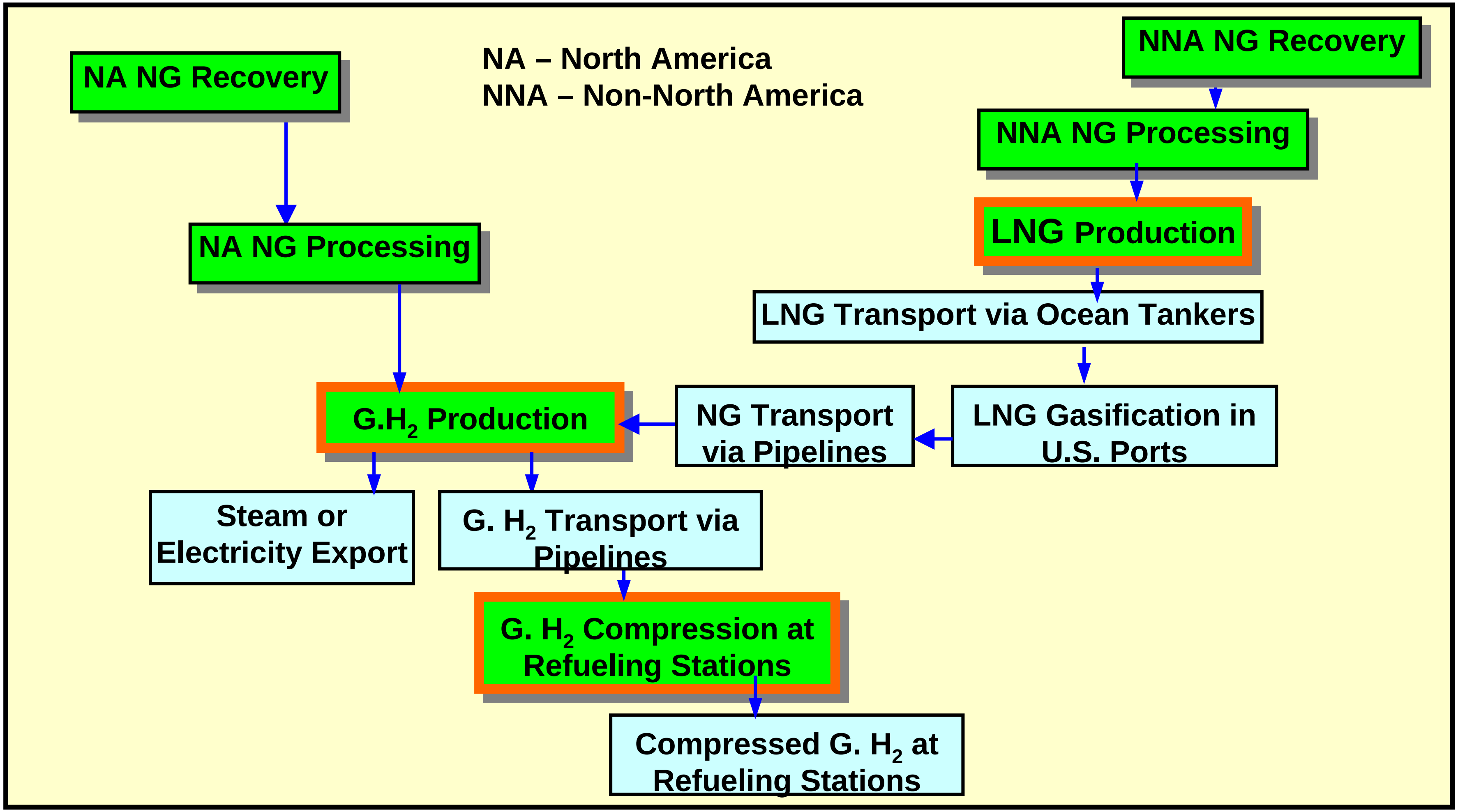
Transport Logistics of Future Methanol for the U.S. Market



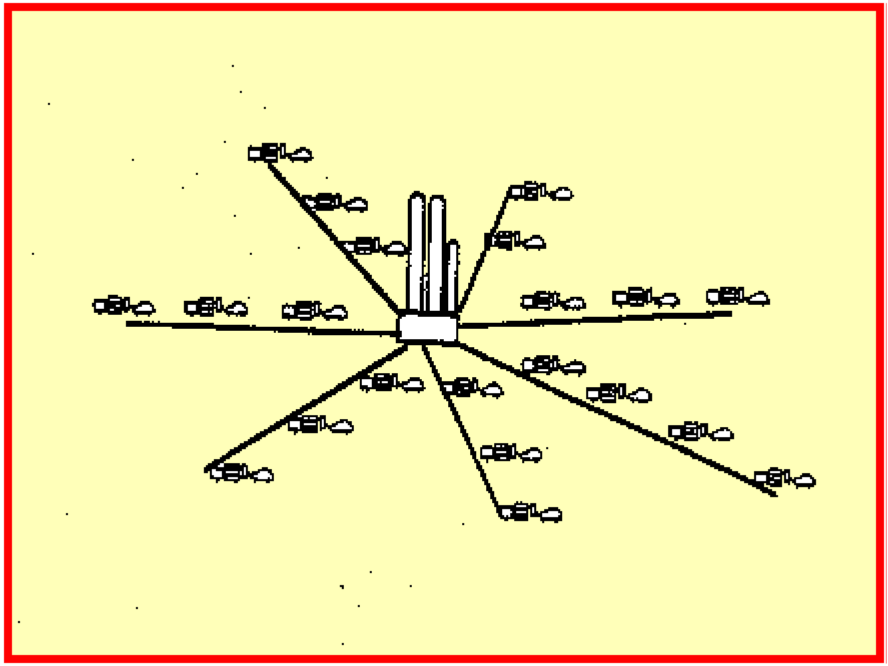
Methanol Fuel Distribution Infrastructure Does Not Exist

- Limited transportation infrastructure from methanol plants to ports and bulk terminals
- Virtually no distribution infrastructure from bulk terminals to refueling stations
- If mass-scale use of methanol occurs, new pipeline transportation will be needed
- Rail tank cars, truck tankers, pipelines, and tank farms need to be modified for methanol compatibility

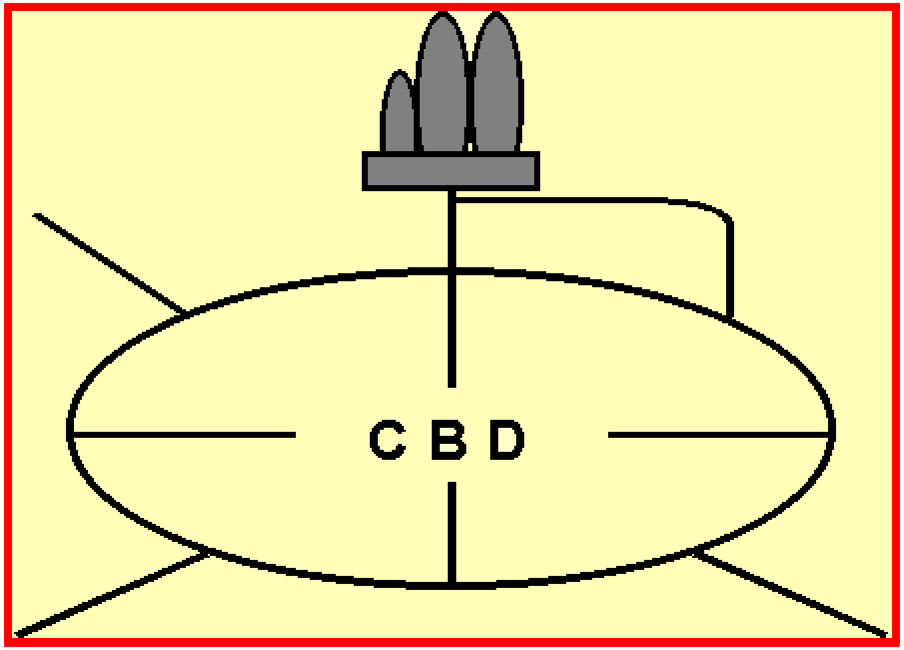
Central Gaseous Hydrogen Production Pathways



For Regional H_2 Production, A Ring Network May Be Superior to Radial Network



Radial Network

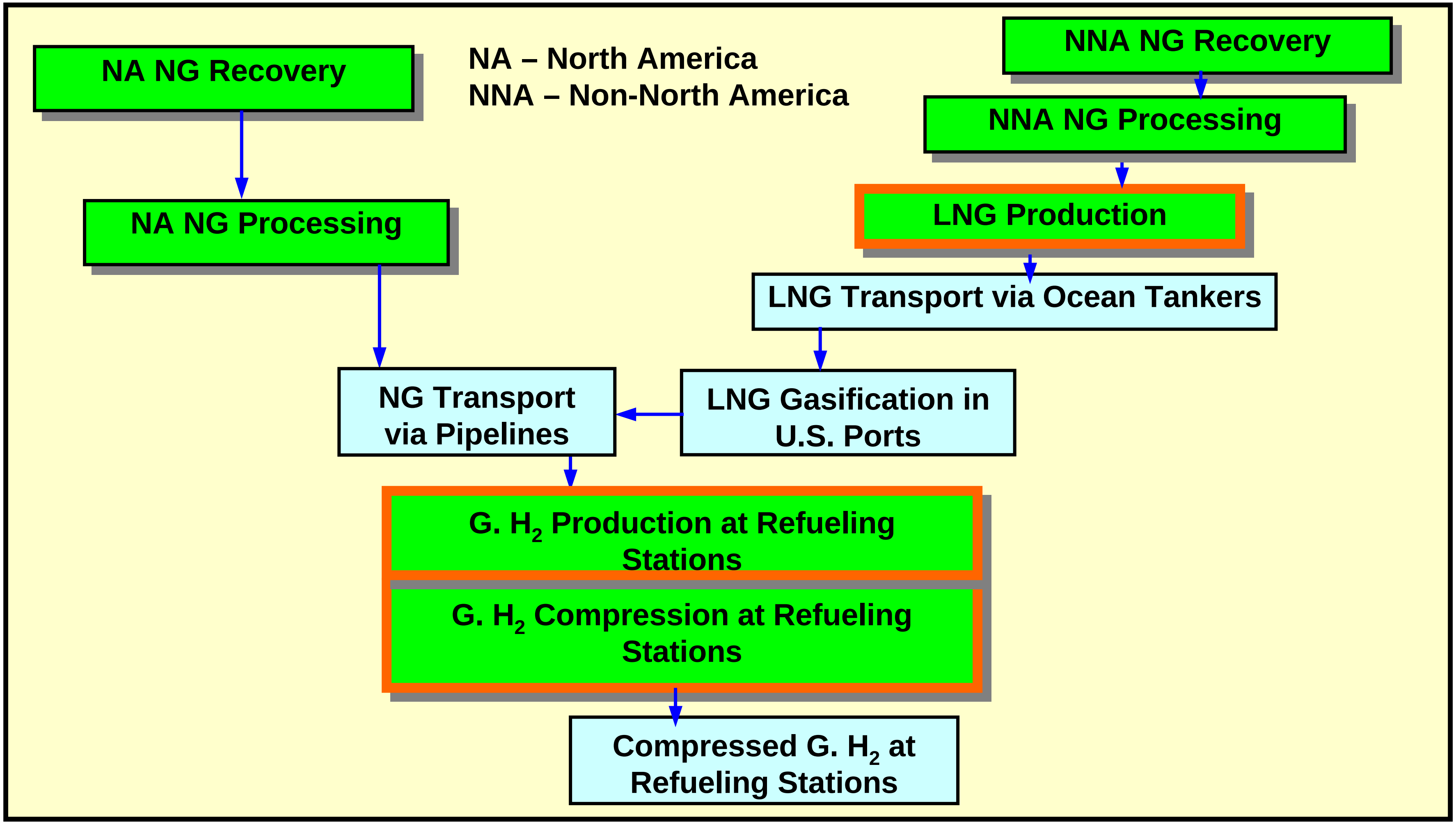


Ring Network

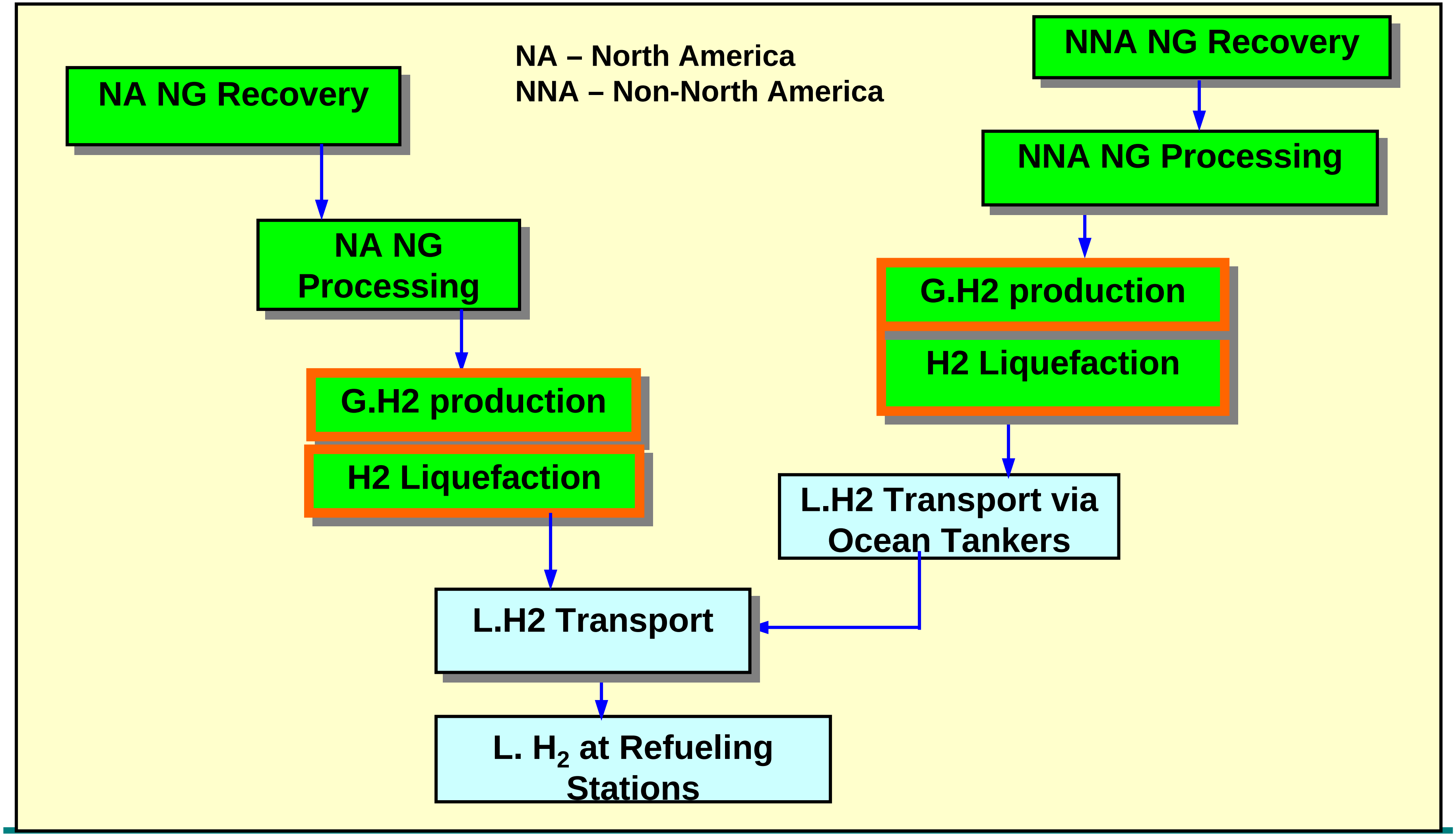
Land-Based Gaseous Hydrogen Infrastructure

- Gaseous hydrogen has to be transported by pipeline
- Pipelines can store hydrogen using pressure variations to reduce on-site storage requirements
- H_2 pipelines will be very expensive to transport a unit of energy in H_2

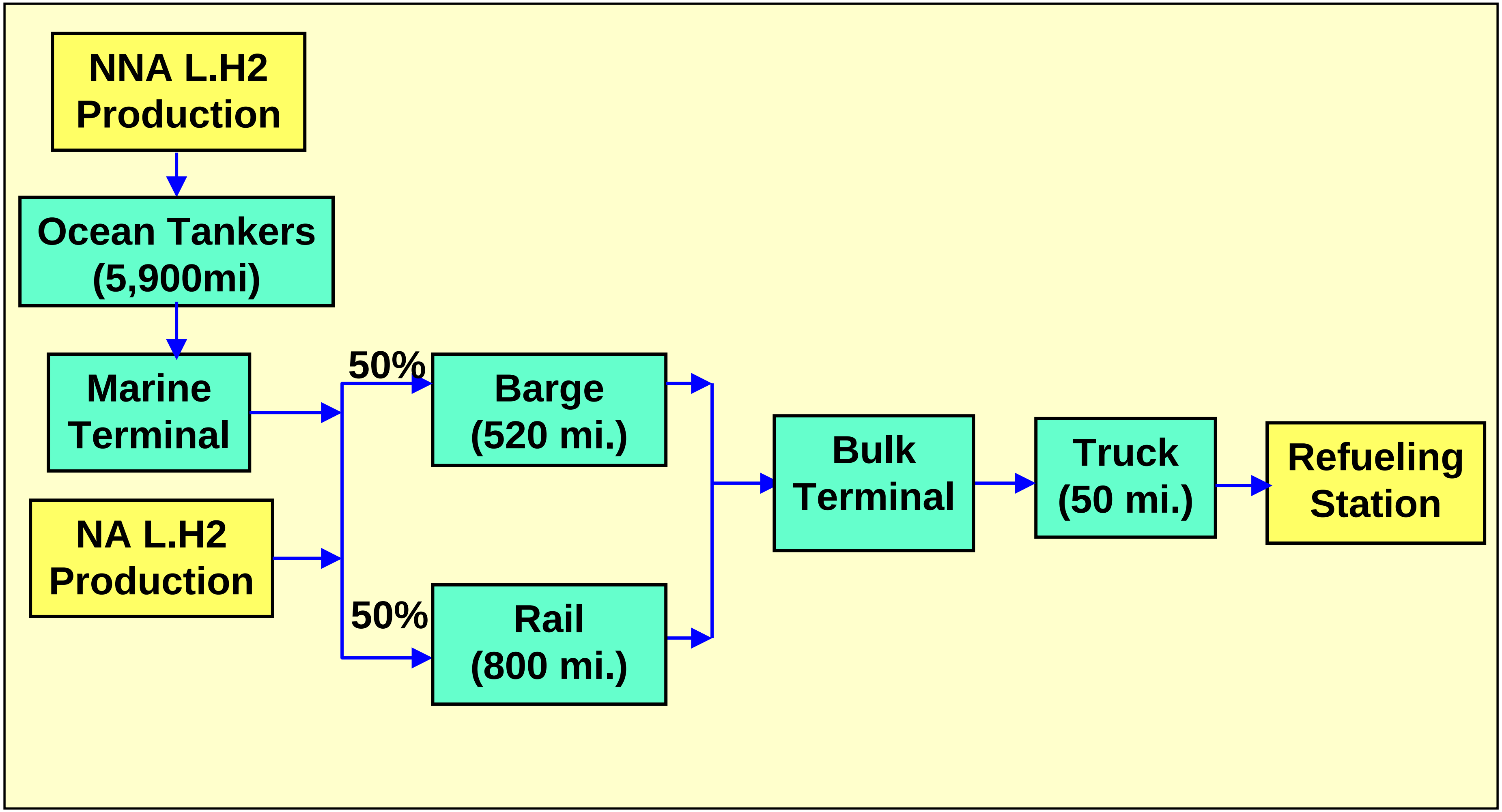
Distributed Production of Gaseous Hydrogen at Refueling Stations



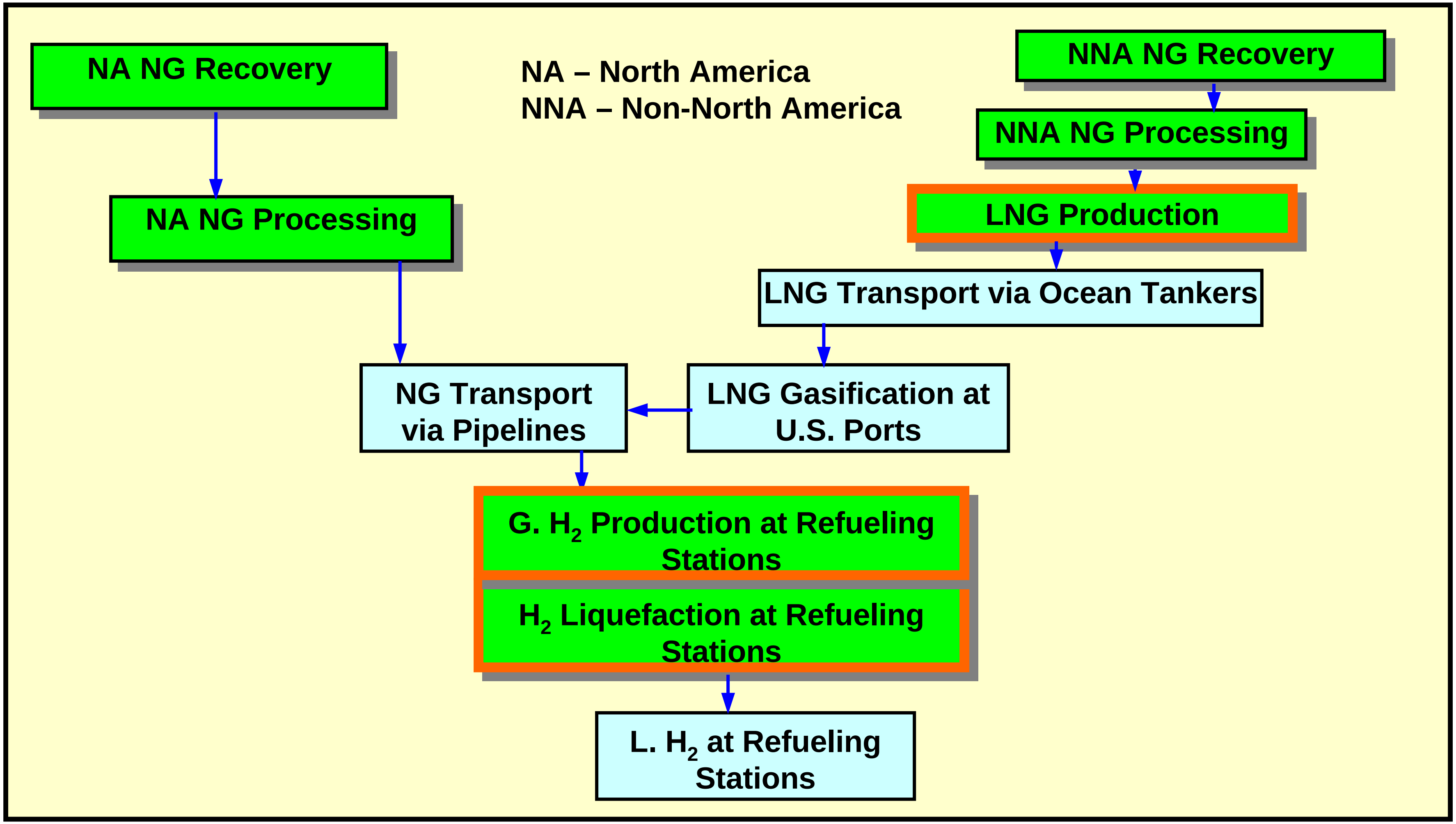
Central Liquid Hydrogen Production Pathways



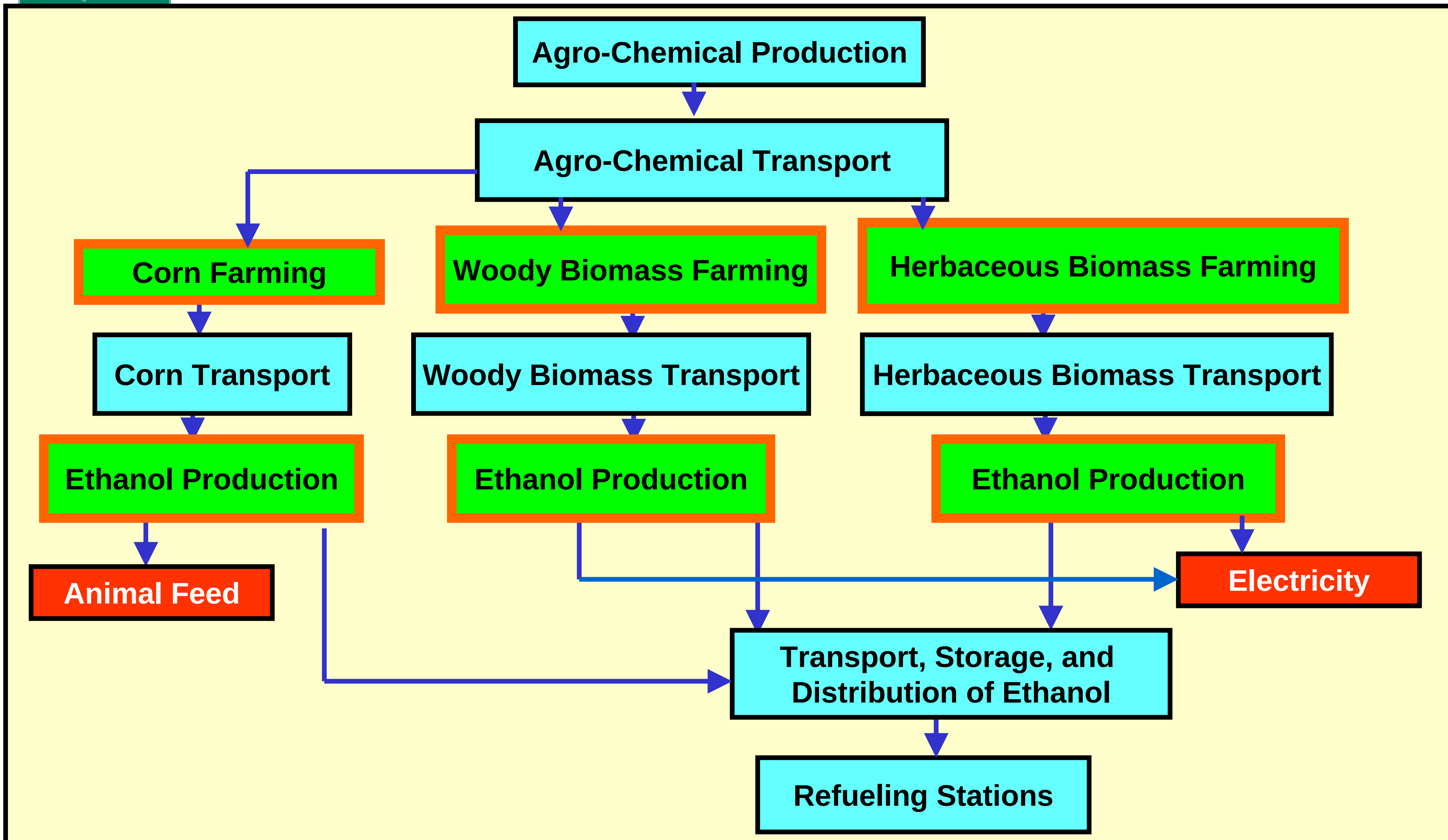
Transport Logistics of Future Liquid H2 from Central Plants to the U.S. Market



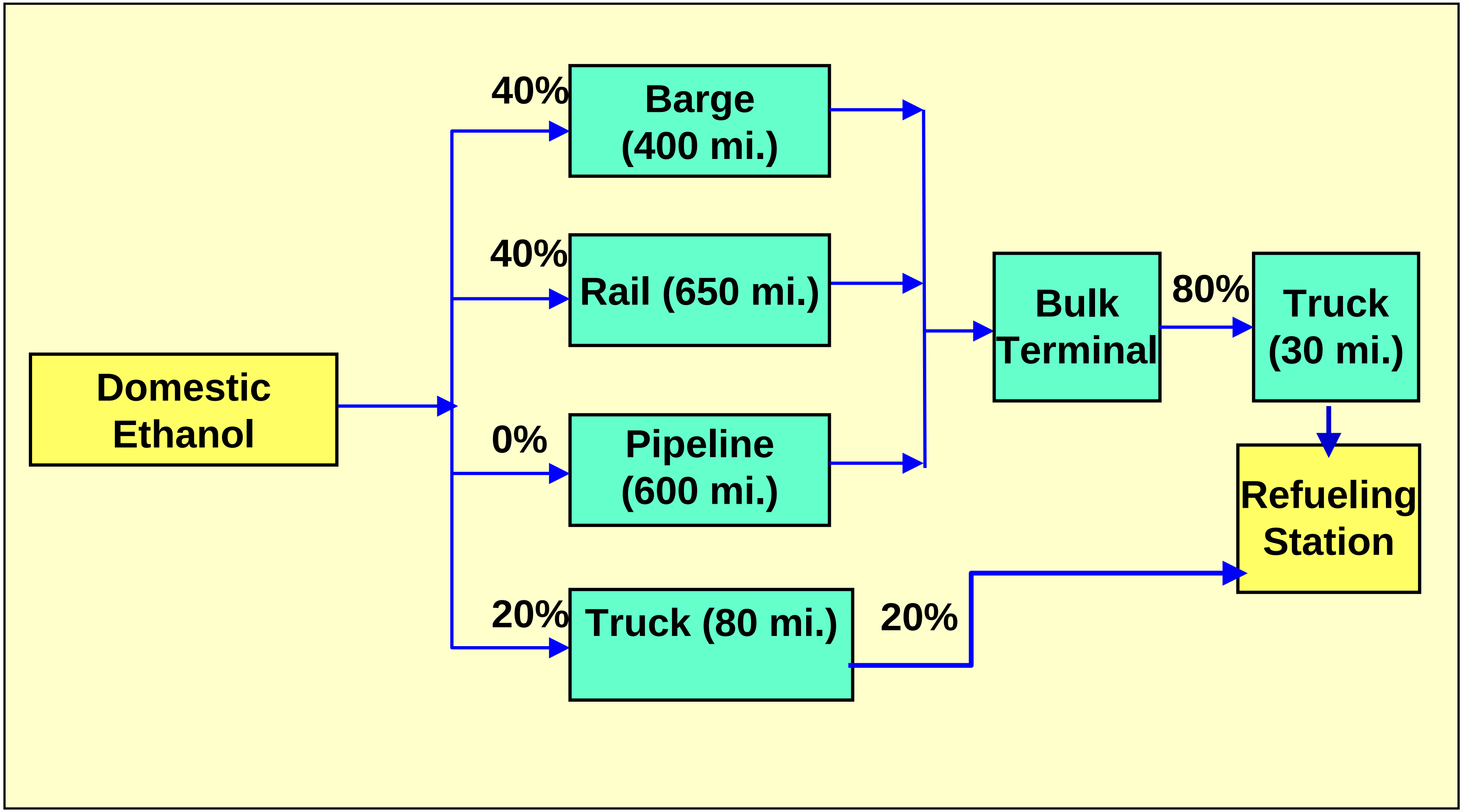
Distributed Liquid Hydrogen Production Pathways at Refueling Stations



Ethanol Fuel Pathways Include Activities from Fertilizer to Ethanol at Stations



Transport Logistics of Future Ethanol for the U.S. Market



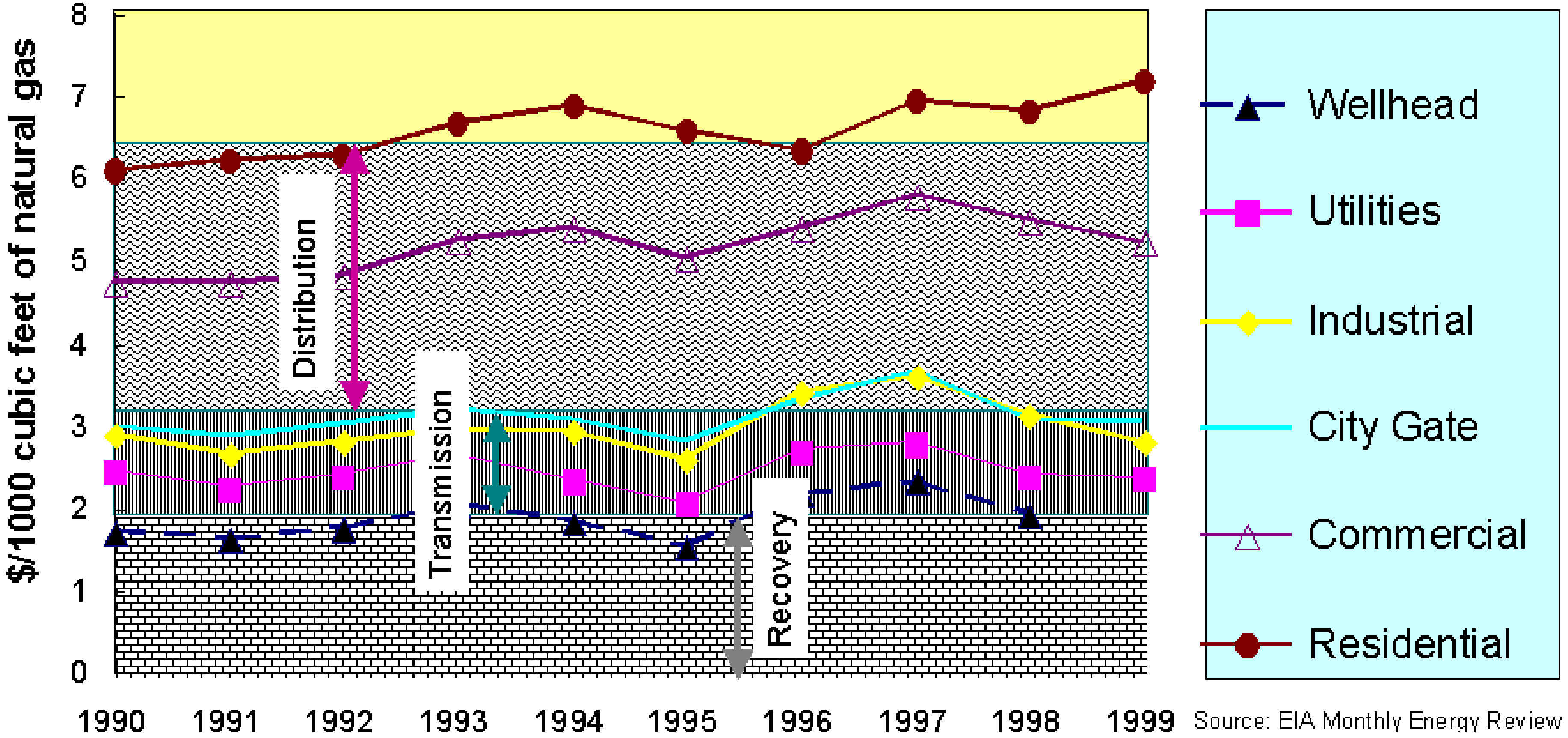
Pipelines for Distribution of Large Volumes of Ethanol Reduce Costs

- At present, U.S. ethanol is produced from corn in plants located in Midwest states
- Transportation from plants to bulk terminals is by barge, rail, and trucks
- If ethanol volume is increased, petroleum product pipelines could be used to transport ethanol
- Ethanol refueling stations need to be established

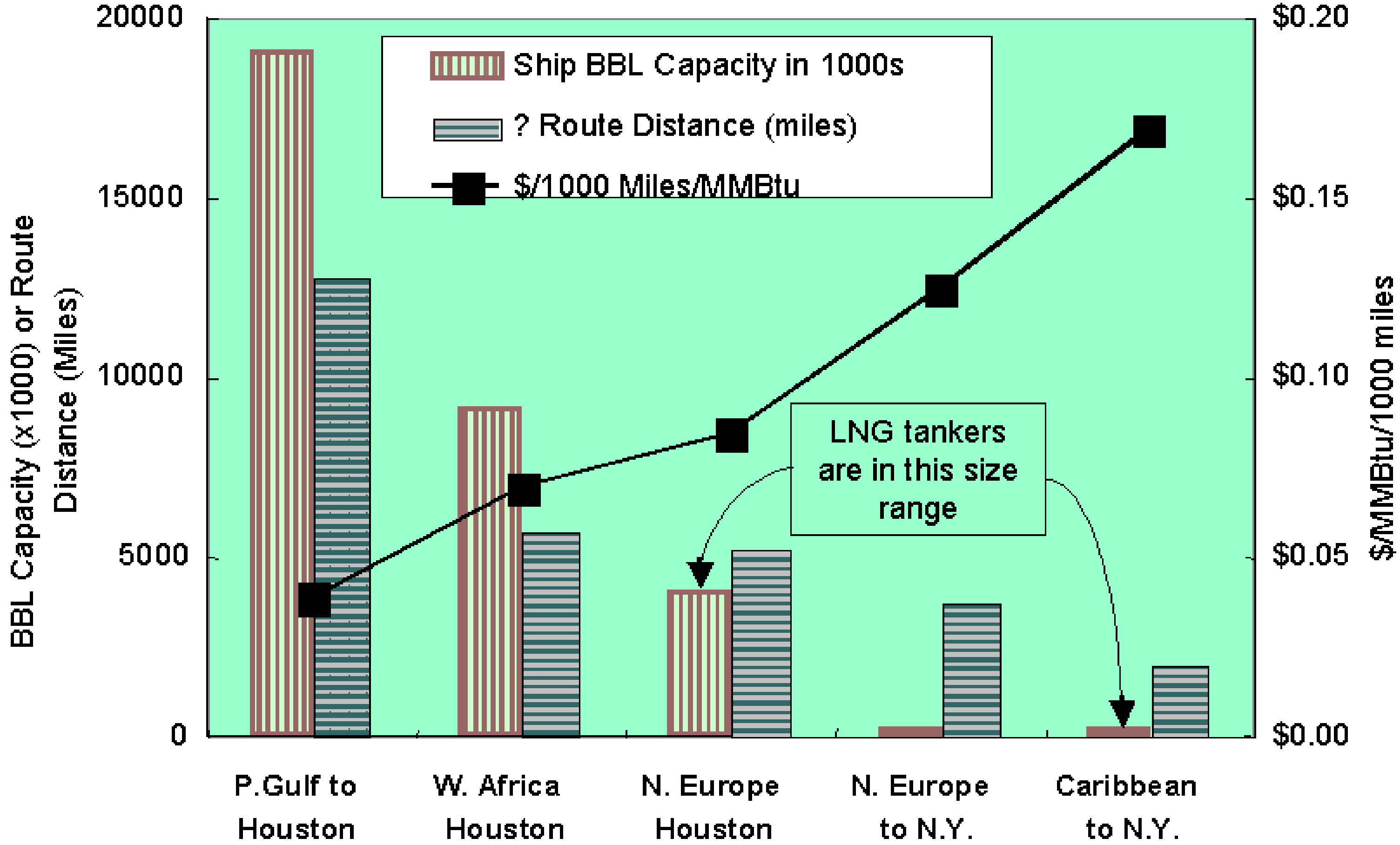
LNG Has Infrastructure Incompatibility Disadvantages

- No super LNG tankers exist
- Small LNG tankers increase energy use and cost per unit of energy shipped
- New port facilities have to be constructed in the U.S. if large increases in LNG imports were to occur
- LNG port locations to tap into existing pipelines may be restricted by direction of gas flow, possibly forcing longer distance pipeline transport

Natural Gas Results Show That Pipelines Are a Major Cost of Gaseous Fuel Delivery

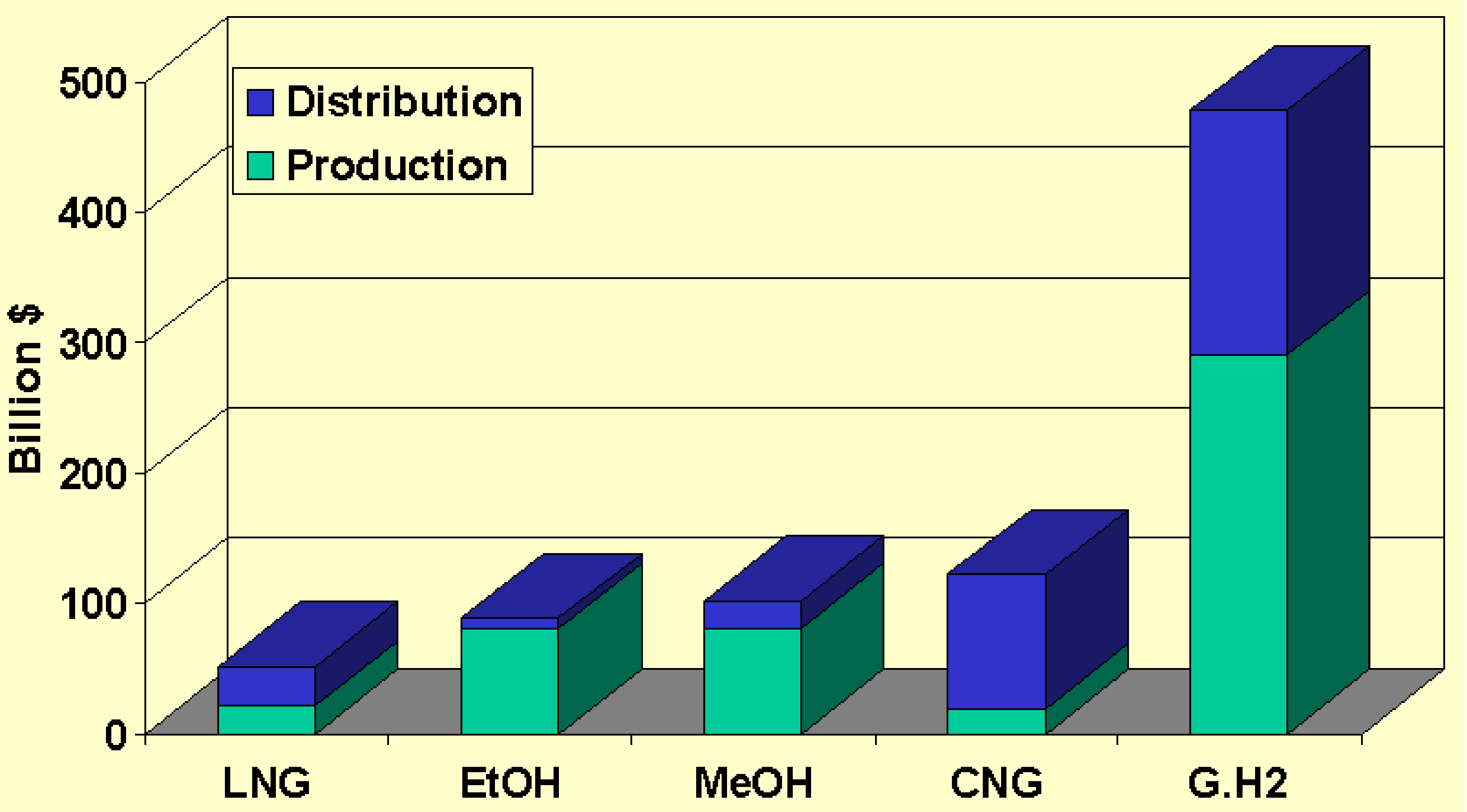


Tanker Sizes Are Larger and Per-Distance Cost Lower As Trip Length Rises



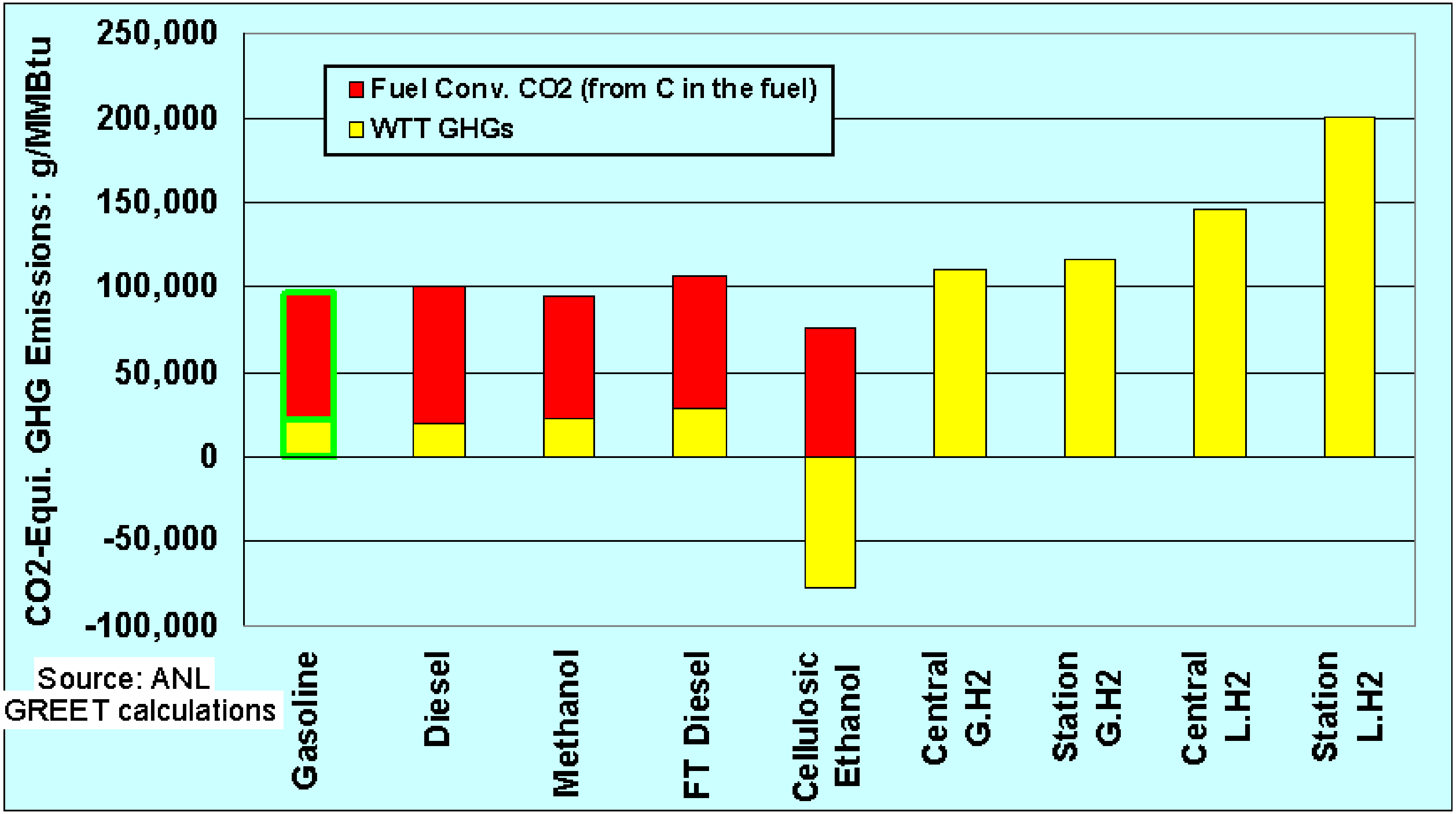
Source: the Oil and Gas Journal

Capital Investments for Gaseous Fuel Production and Distribution Infrastructure Can Be Huge

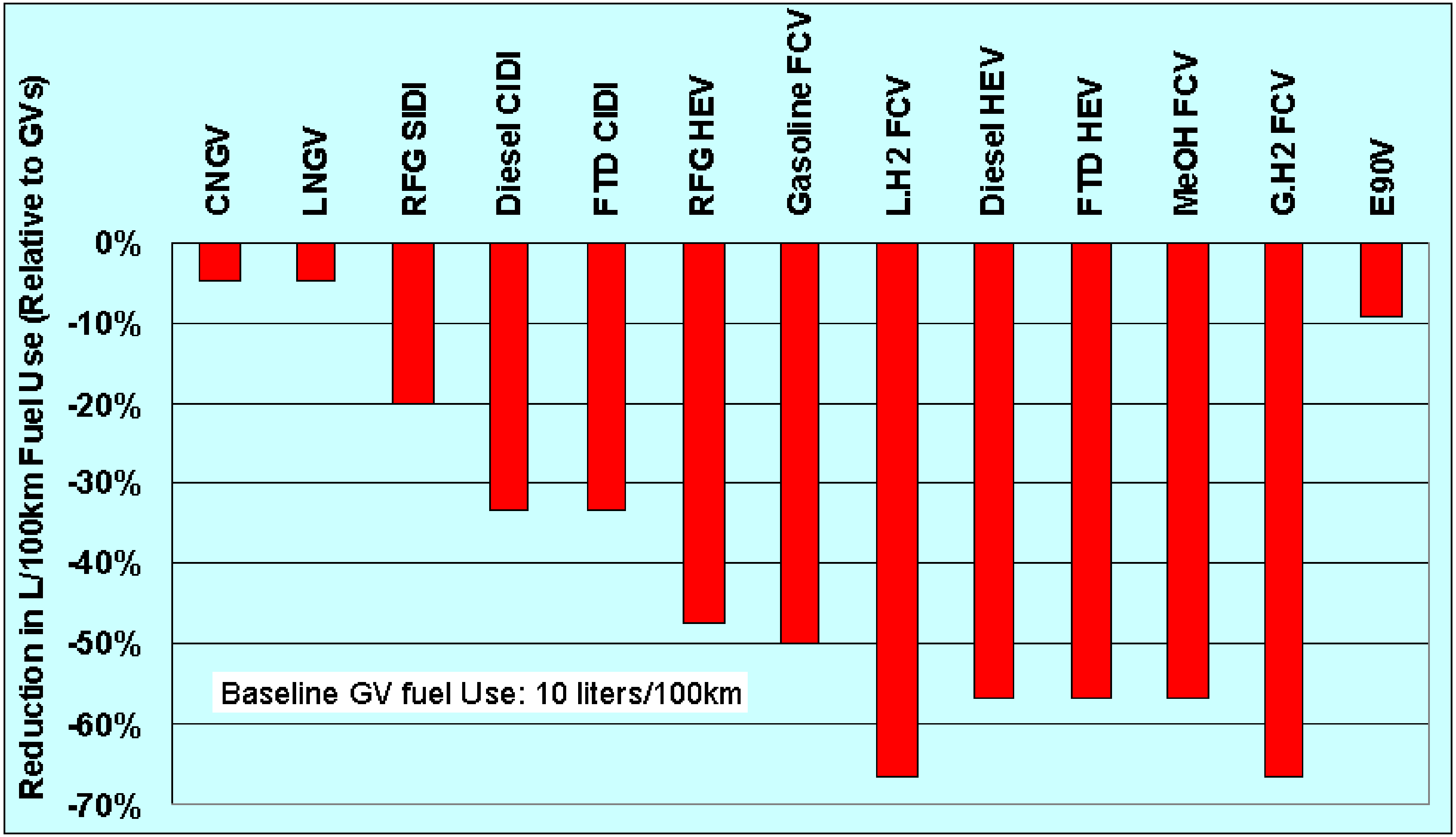


Source: ANL/ESD-37. For delivering 22.5 billion GGE per year.

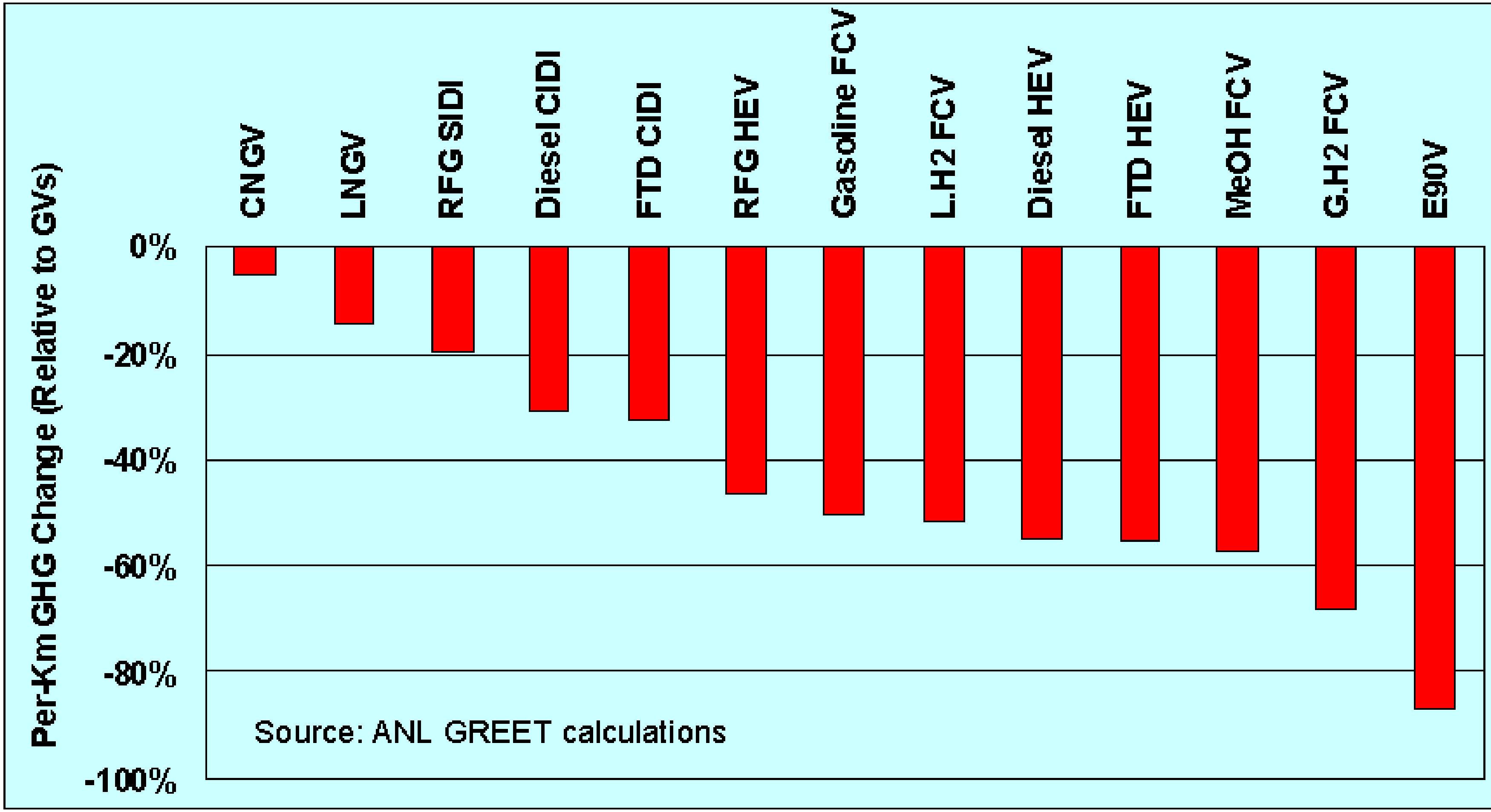
Renewable Ethanol Can Drastically Reduce Greenhouse Gas Emissions



HEVs and FCVs Can Reduce Vehicle Per-Km Fuel Consumption



Fuel Switches and Vehicle Efficiency Gains Contribute to GHG Emission Reductions



Trade-Offs Between Costs and Emission Benefits Among Fuel/Vehicle Technologies