

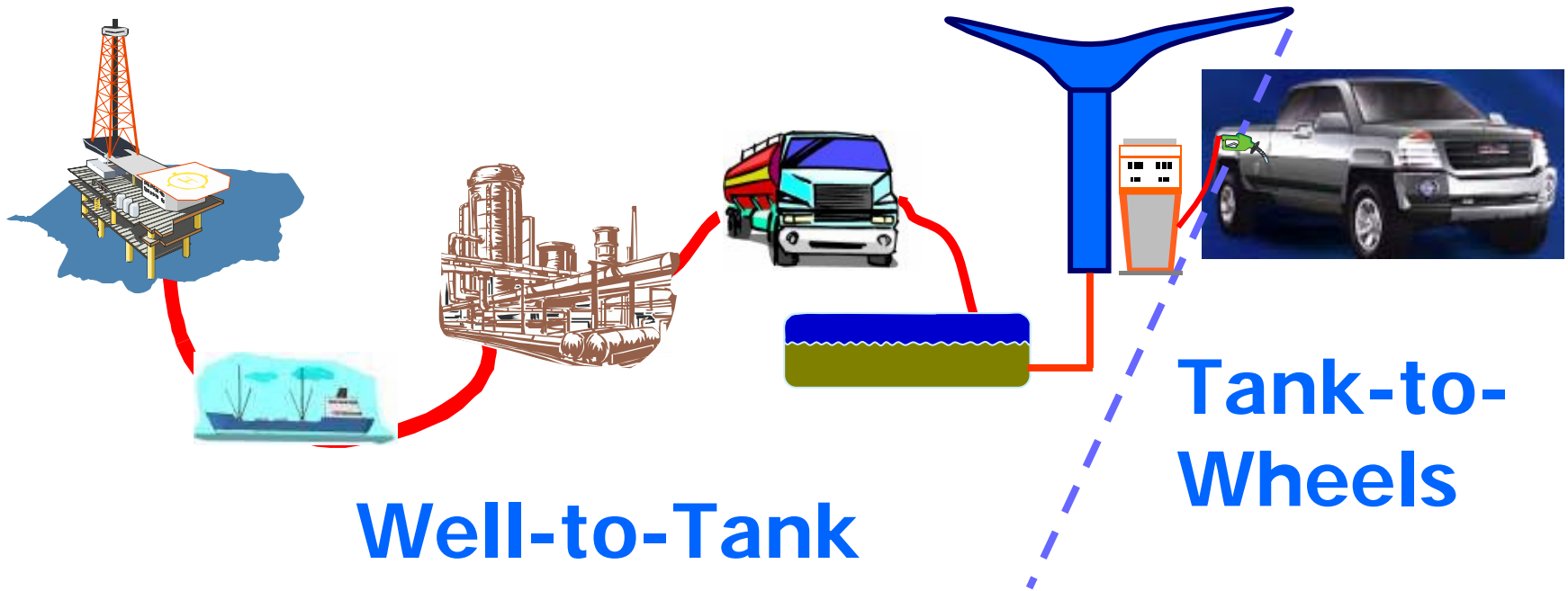
Well to Wheels Studies: Comparisons Between Europe and North America

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What is a Well-to-Wheels Analysis?

- Systems approach
- Assessment of energy consumption and emissions



GM-Sponsored Well-to-Wheels Studies

- NA Energy and GHG
- Argonne - GREET
 - Full-size pickup
 - Equal performance
 - Published 2001

- NA "Phase 2"
- Adds NO_x, PM, HC
 - Argonne - GREET
 - Publish late 2004

- EU Energy and GHG
- LBST E² database
 - Zafira minivan
 - Equal performance
 - Published 2002

Partners:
BP, ChevronTexaco,
ExxonMobil, Shell,
TotalFinaElf

Costs not included

Why both Europe and North America?

Tank-to-Wheels differences

- Vehicle mix
- Performance requirements
- Driving cycle
- Emissions standards

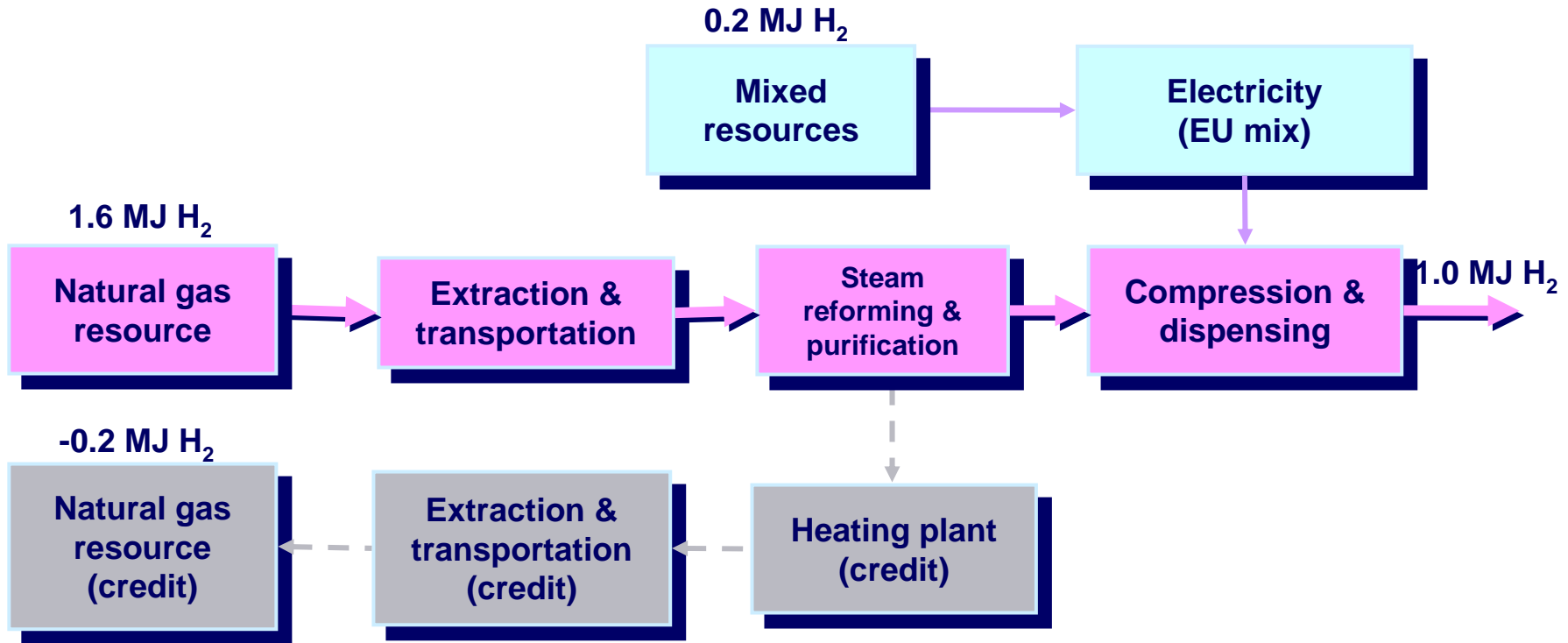
Well-to-Tank differences

- Oil refining
- Natural gas sources
- Electricity mix
- Resource and product transportation distances
- Land use, land type, and climate for biofuels

Well-to-Wheels Energy Issues

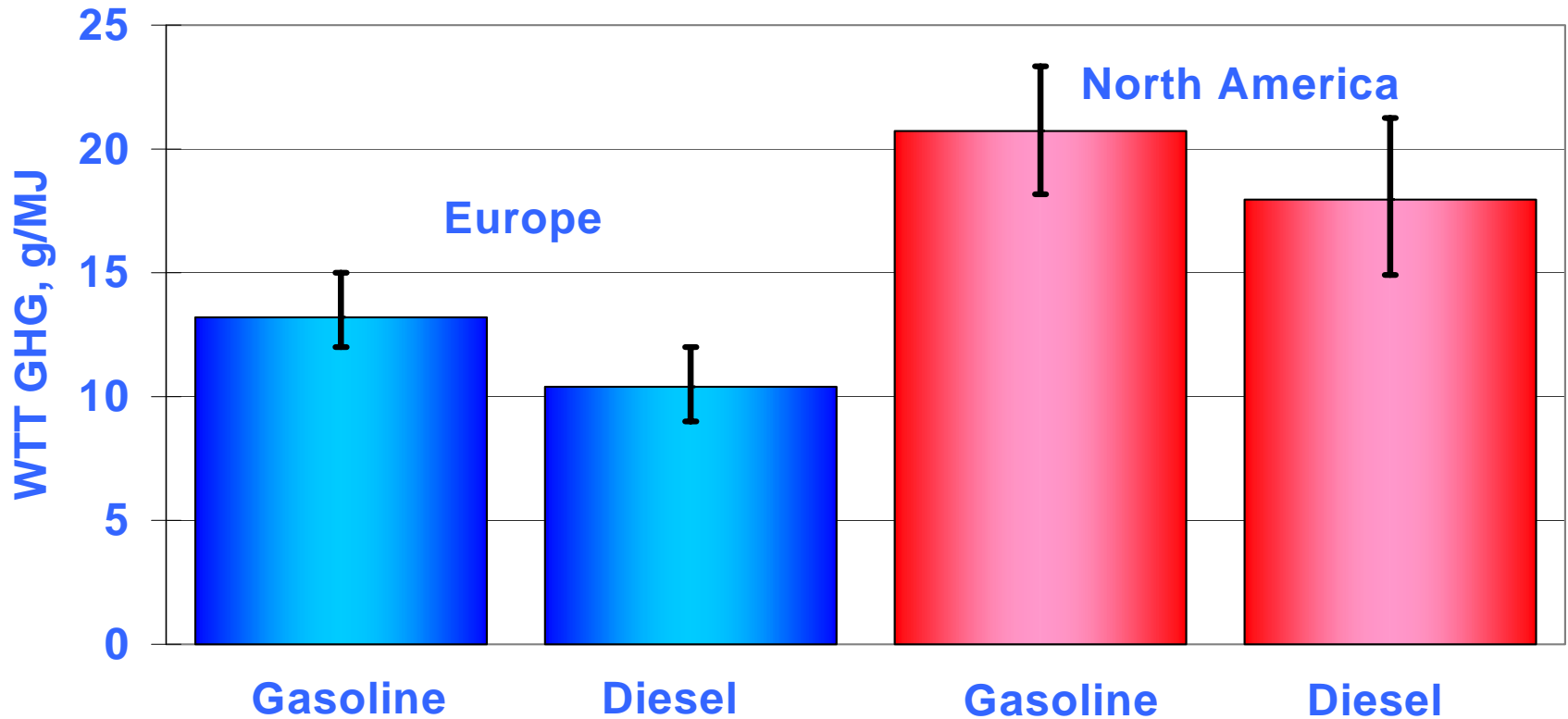
- Comparing energy usage across different resources not meaningful
 - ≡ No clear definition of energy resource for biofuels, other renewables, and nuclear
 - ≡ No definitive method to handle multiple products for both biofuels and oil refining
- Evaluation of petroleum or fossil fuel savings more meaningful
 - ≡ Reducing petroleum usage a high priority for transportation

Example Well-to-Tank Pathway: Hydrogen from Natural Gas in Central Plant



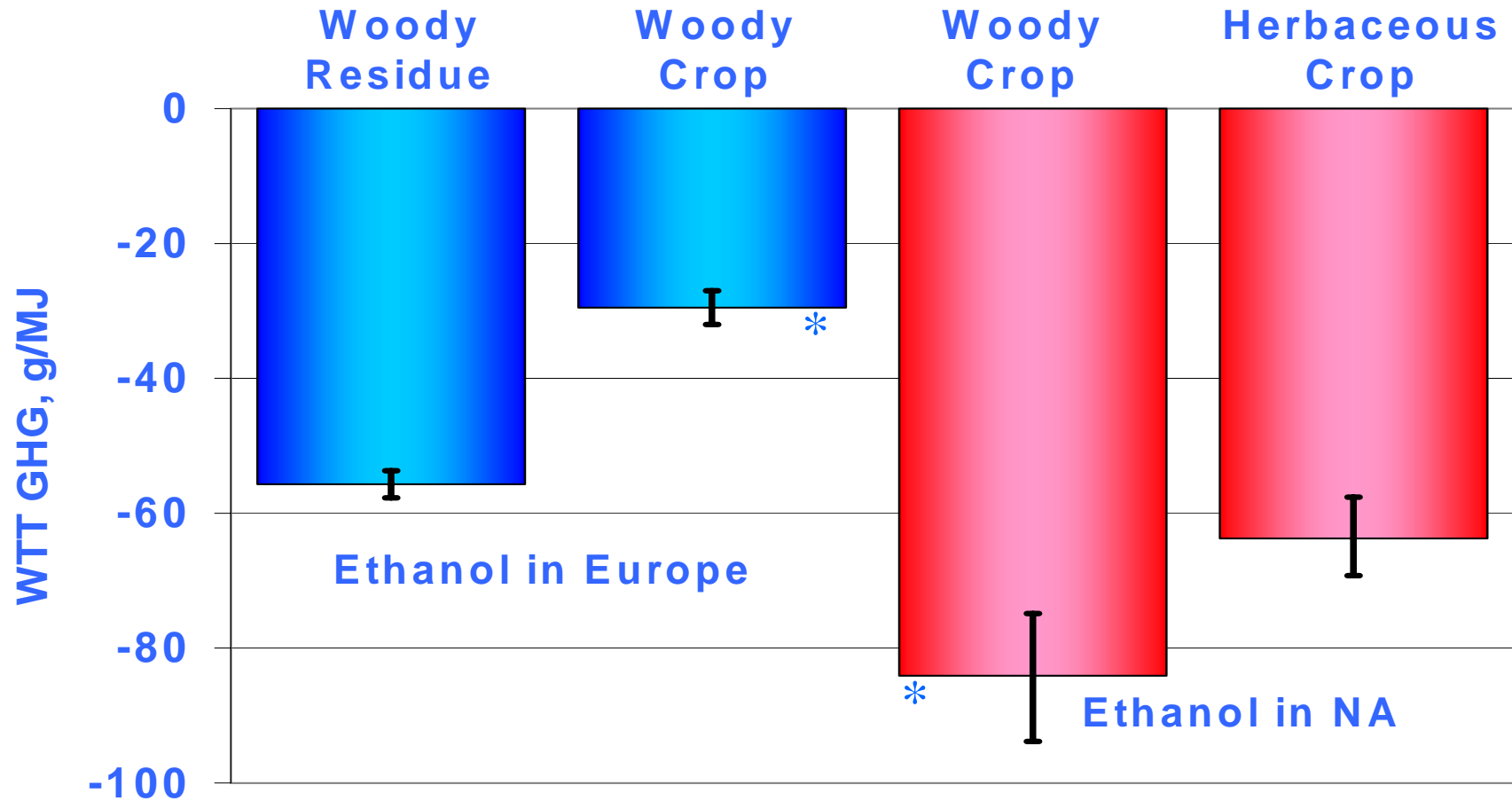
$$\text{Overall efficiency} = \frac{1.0}{(1.6 + 0.2 - 0.2)} \approx 63\%$$

Well-to-Tank GHG - Gasoline/Diesel



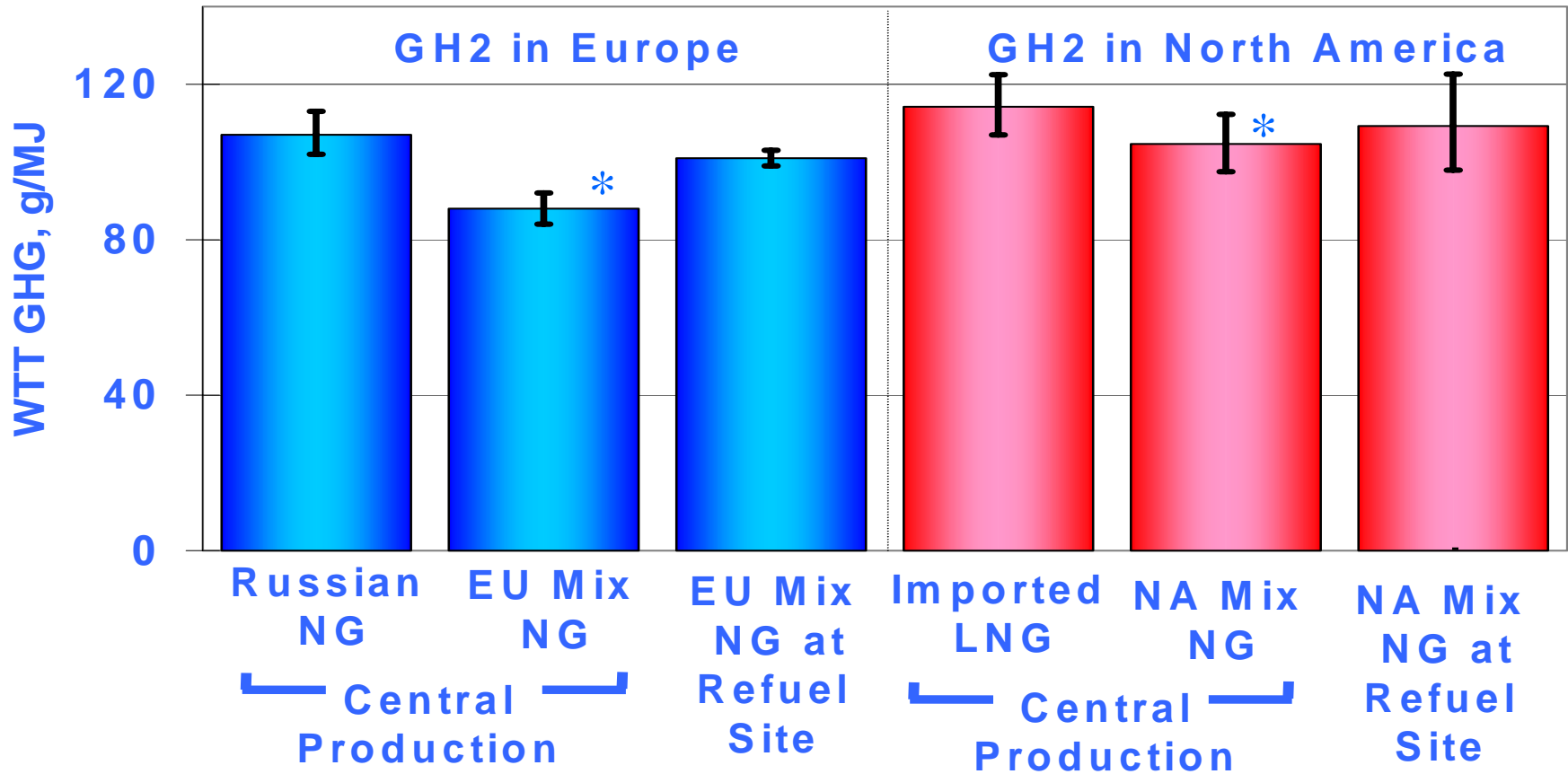
- Gasoline refining more energy intensive – higher GHG than diesel
- European refineries more efficient than U.S. refineries due to more optimum gasoline/diesel split

Well-to-Tank GHG – Cellulosic Ethanol



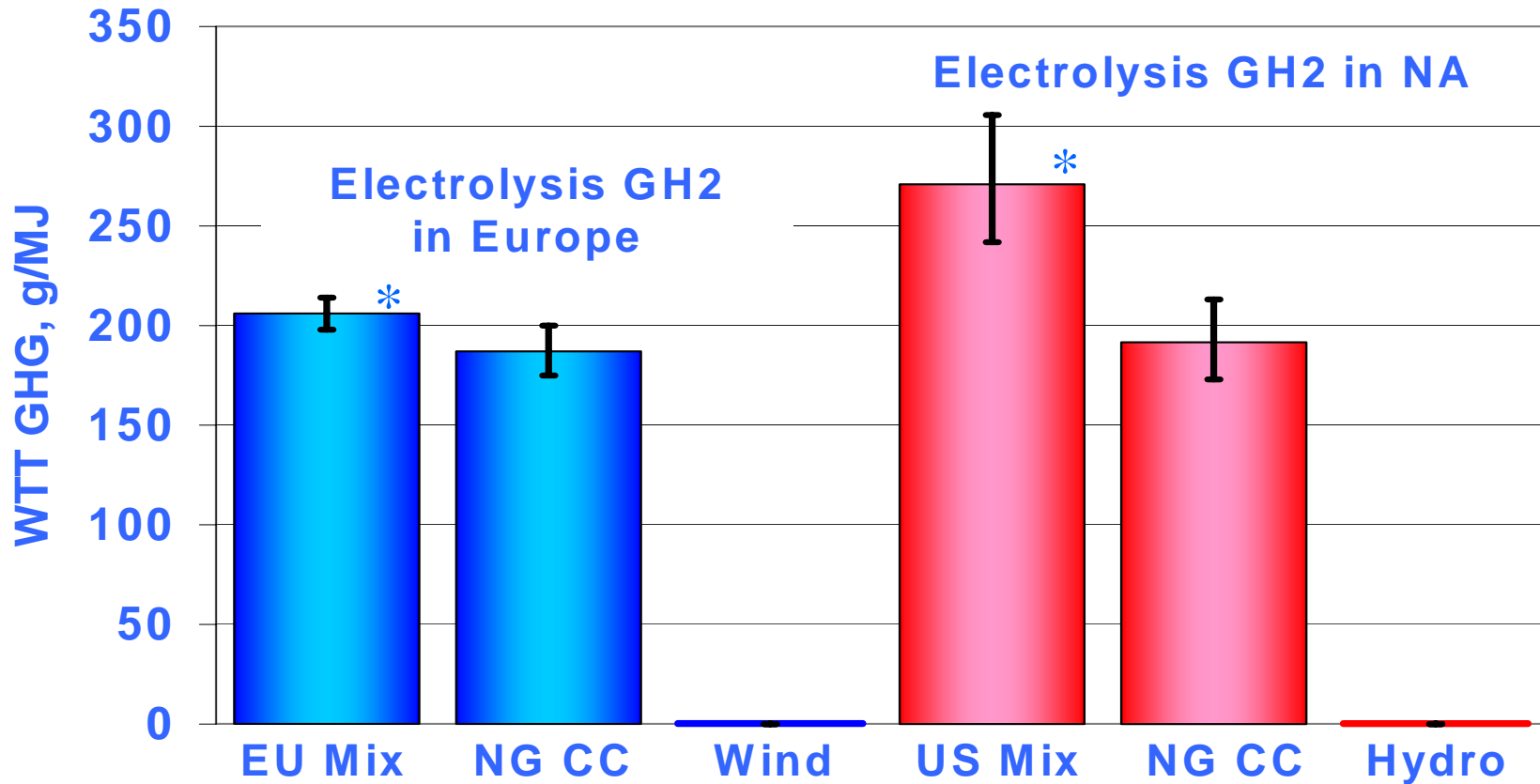
- NA had more favorable assumptions of land use change (sequestration), N₂O and energy for conversion

Well-to-Tank GHG – NG based H2



- Imported gas gives higher GHG (transport distance)
- Central production provides efficiency and GHG advantage
- About 1/3 of NA GHG due to electricity for compression

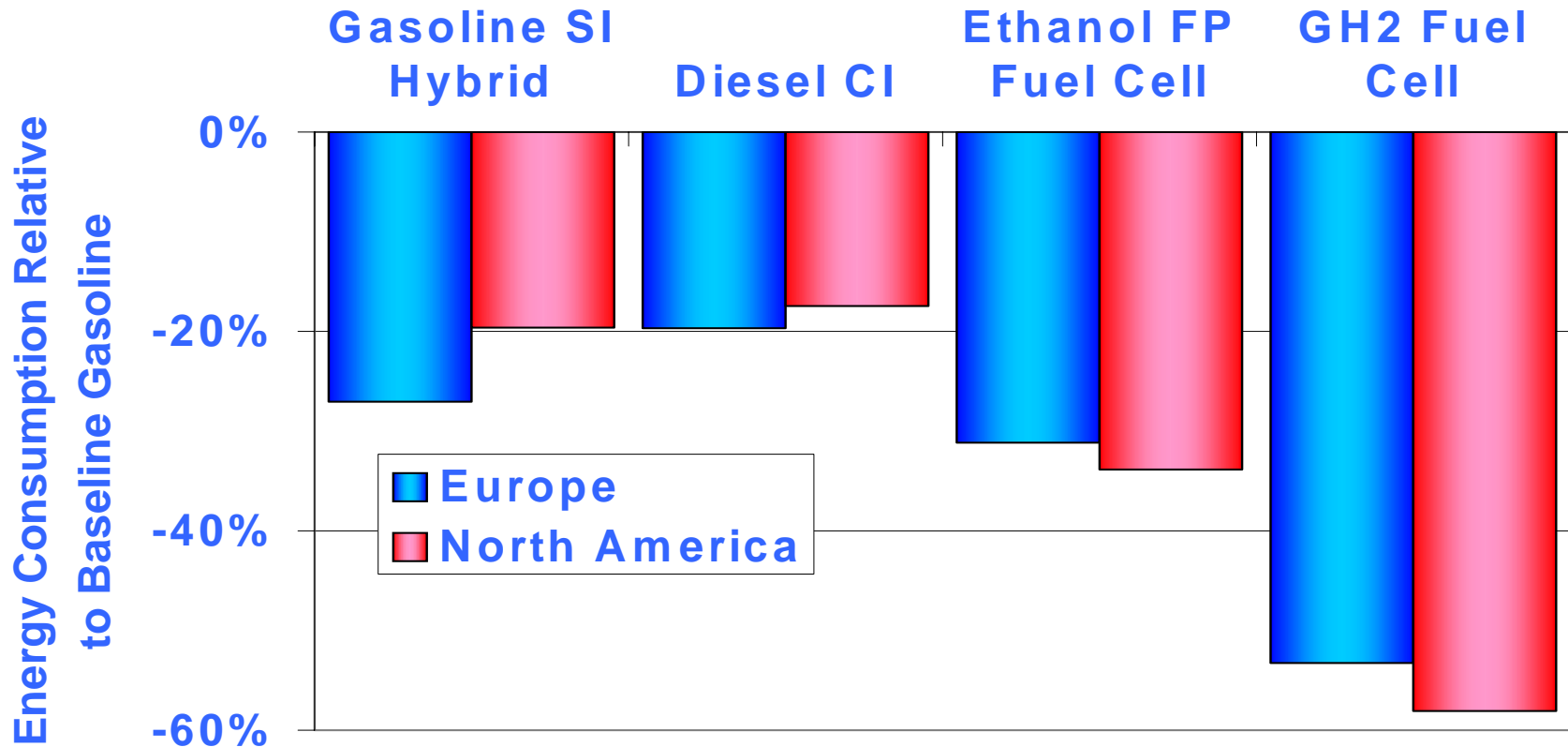
Well-to-Tank GHG – Electrolysis H2



- US Mix higher GHG due to greater share of coal combustion
- Non-renewable sources higher than that for NG reforming

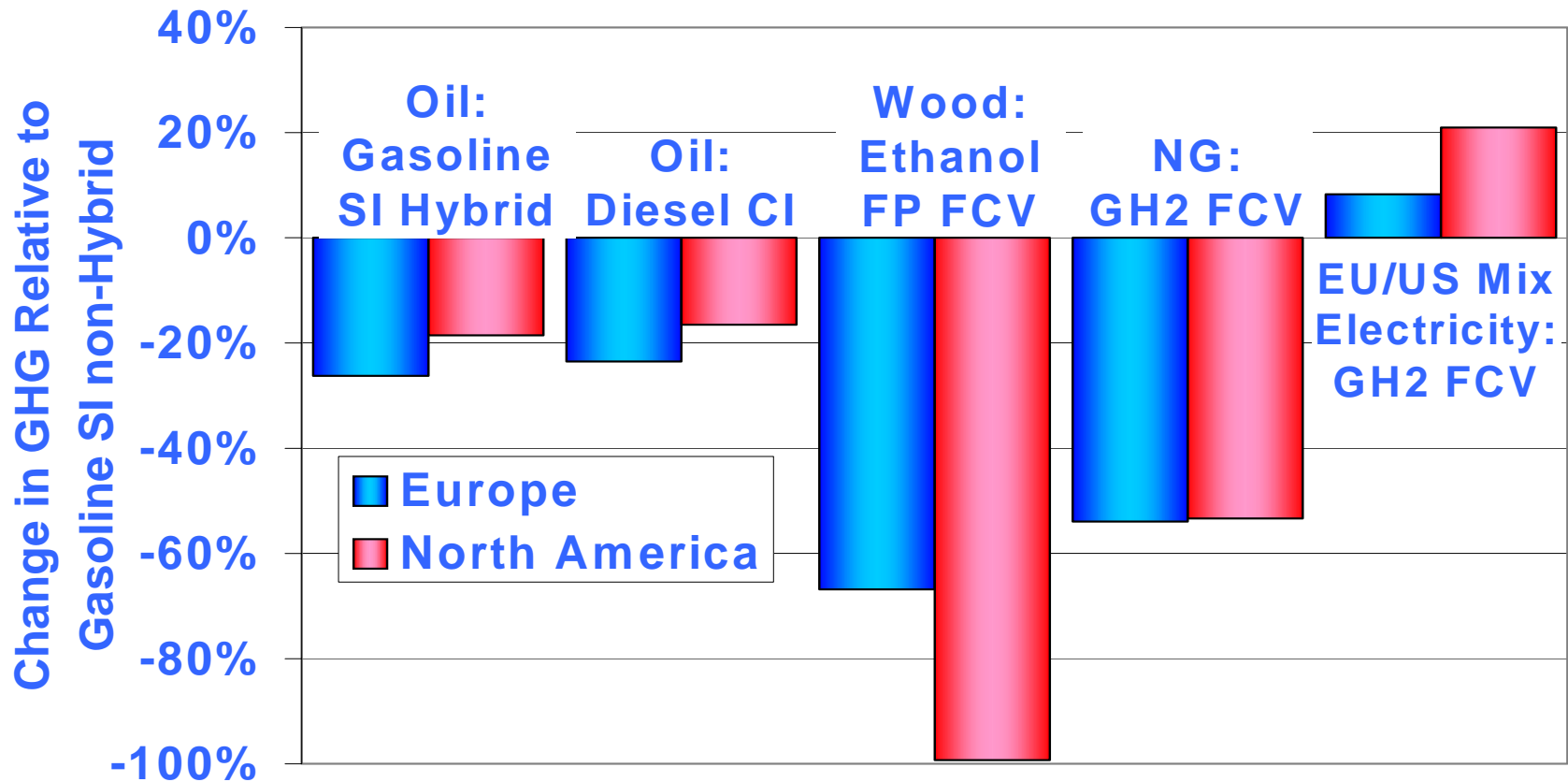


Tank-to-Wheels Energy Consumption



- Hybridization benefit greater on European driving cycle
- Benefits of other technologies similar for Europe and NA

Well-to-Wheels Greenhouse Gases



- Hybrid and diesel impact greater in Europe
- More favorable wood: ethanol assumptions for North America
- U.S. electricity mix unfavorable for electrolysis hydrogen

What's next

- Phase 2 North American study, including criteria pollutants (NO_x, PM, HC, CO, SO_x) to be published later this year
- GM and Canada co-funding study (team lead by Heather MacLean, U of Toronto) of potential biofuel supply and greenhouse gas impacts

Bottom line:

- Transportation policy decisions should include well-to-wheels considerations

Reports are Available

- European Study

- ⌘ <http://www.lbst.de/gm-wtw>

North American Study:

- ⌘ <http://greet.anl.gov/publications.html>