The Future of Natural Gas as a Transportation Fuel - Findings of the NPC Study

A Presentation for the Transportation Research Board
Washington, DC

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National Petroleum Council Study

NATIONAL PETROLEUM COUNCIL

- ✓ Federal advisory committee serving U.S. Energy Secretary Dr. Steven Chu
- ✓ Group advises, informs and makes recommendations to the secretary
- ✓ NPC maintains a Committee on Future Transportation Fuels

Marathon Oil Corporation

Secretary's Request

Examine ways to accelerate future transportation fuels prospects through 2050

Address four critical areas: fuel demand, supply, infrastructure and technology

Answer this key question:

How can governments stimulate the technological advances and market conditions that will reduce GHG emissions by 50% relative to 2005 levels?

Marathon Oil Corporation

Fuels Study Leadership

Study Executive Committee Leadership

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Jan Mares (Resources For the Future)	William Reinert (Toyota)
	Todd Werpy (Archer Daniels Midland)

Subject Matter Experts

Area	Expert	Organization
Energy Security and Policy (Chair)	John Deutch	Massachusetts Institute of Technology
Agriculture – Biofuels	Robert Fraley	Monsanto
Applied Physics and Policy	Venkatesh Narayanamurti	Harvard University
Batteries/Electrochemistry	Yet-Ming Chiang	MIT/A123 Systems
Biotechnology	Jay Keasling	UC Berkeley/JBEI
Cryogenic Storage	Tom Drube	Chart Industries
Economics	Robert Topel	University of Chicago
Economics	Severin Borenstein	UC Berkeley
Energy Efficiency	Amory Lovins	Rocky Mountain Institute
Engines	John Heywood	Massachusetts Institute of Technology
Engines	Robert Dibble	UC Berkeley
Hydrogen/Fuel Cells	Henry White	University of Utah
Materials Science/Nanotechnology	George Whitesides	Harvard University
Solar Fuels	Daniel Nocera	Massachusetts Institute of Technology

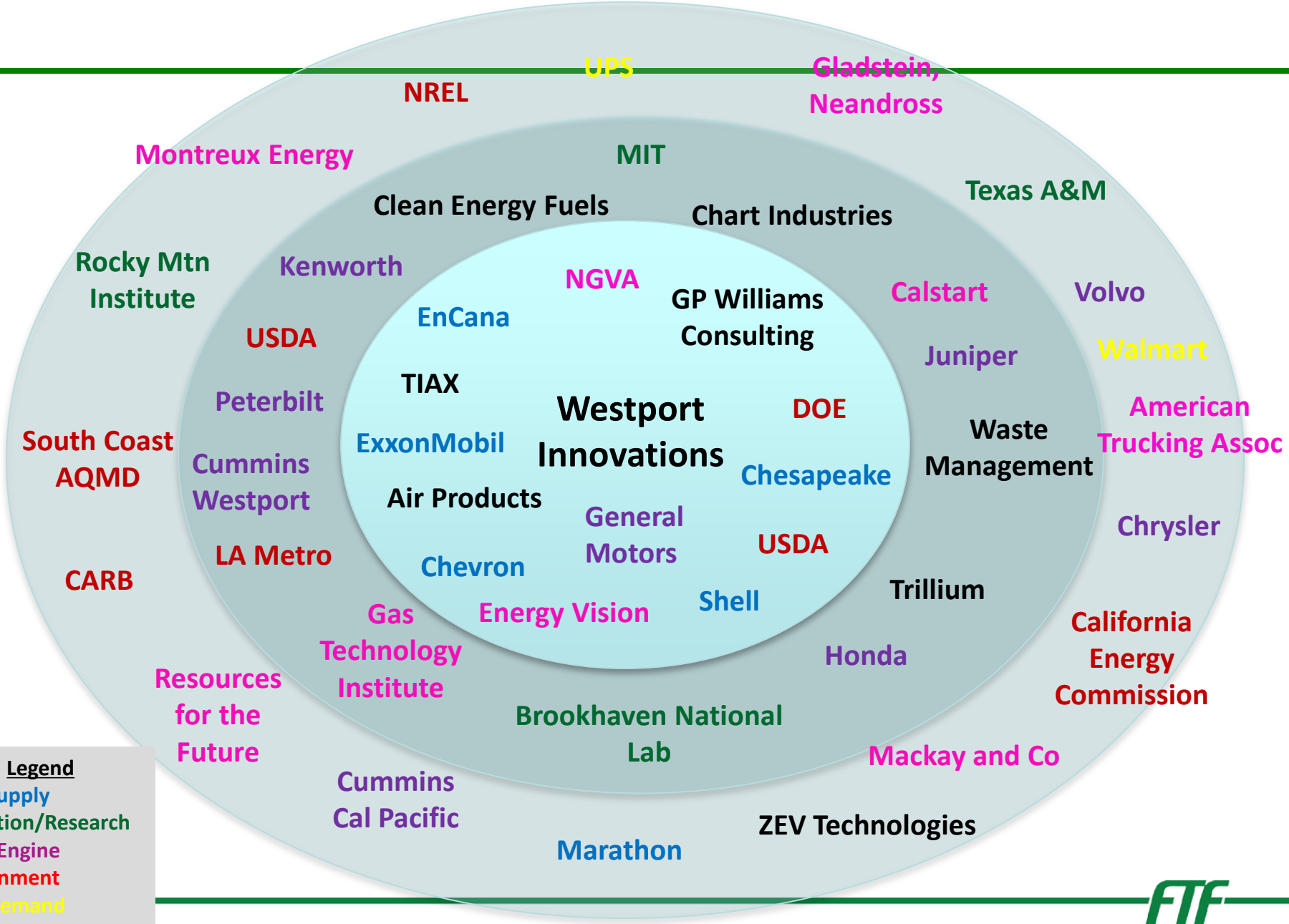
Method of Analysis

Step 1: Individual Fuel / Vehicle Options

Assessed potential to maximize commercial availability of individual supply chain technology pathways based on review of available reports and literature

Reference Case (EIA AEO 2010)	Biofuels Fuel / Vehicle System	Electric Fuel / Vehicle System	Hydrocarbon Liquids Fuel / Vehicle System	Natural Gas Fuel / Vehicle System	Hydrogen Fuel / Vehicle System
Based on available research, for each fuel/vehicle supply chain: **•Described fuel/vehicle supply chain pathways and supporting infrastructure** **•Identified opportunities and described technology options which significantly enhance supply with improved environmental, economic, and energy security characteristics** **•Established upper and lower cost bounds for individual fuel and vehicle technologies** **•Developed "supply curves" and associated environmental impacts**					

The Natural Gas Team

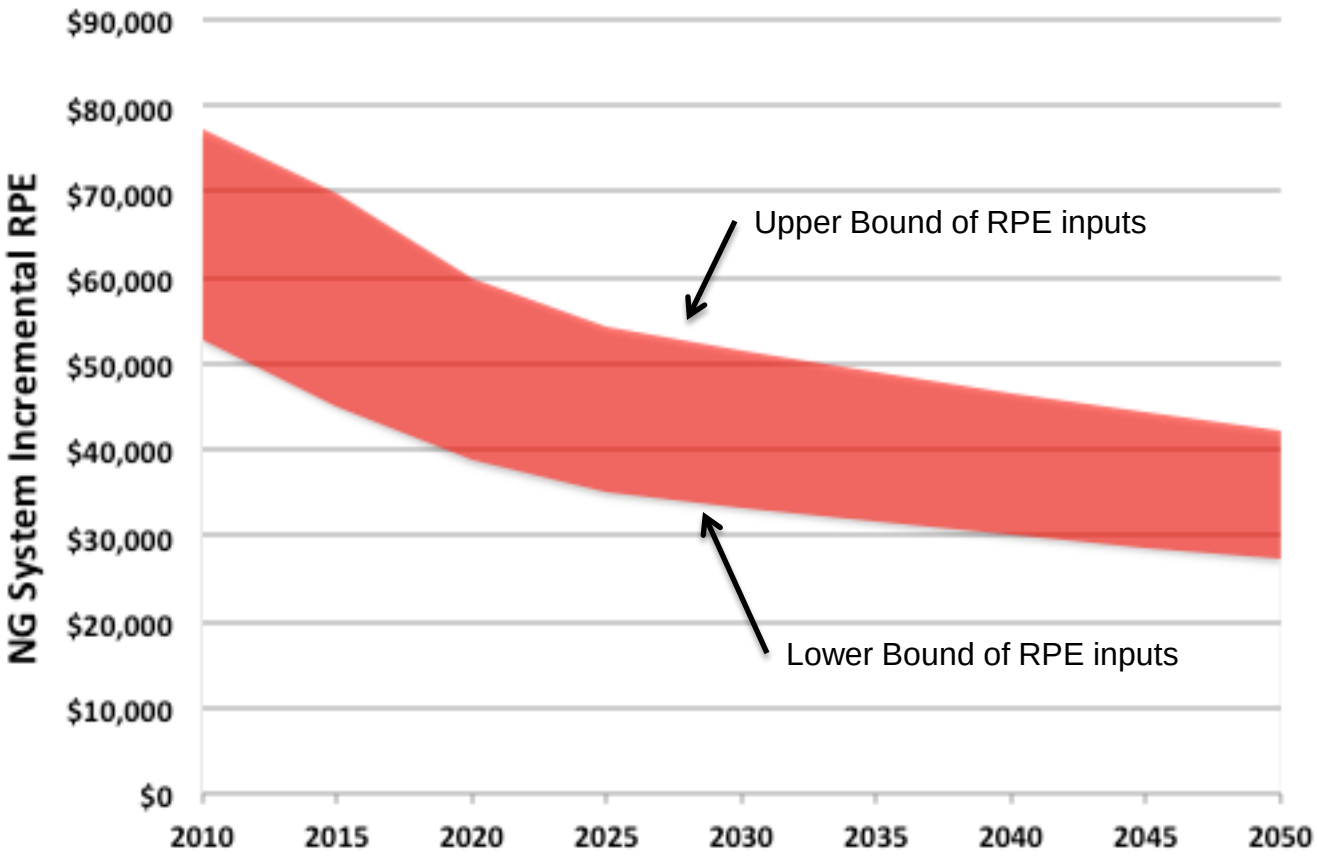


Legend

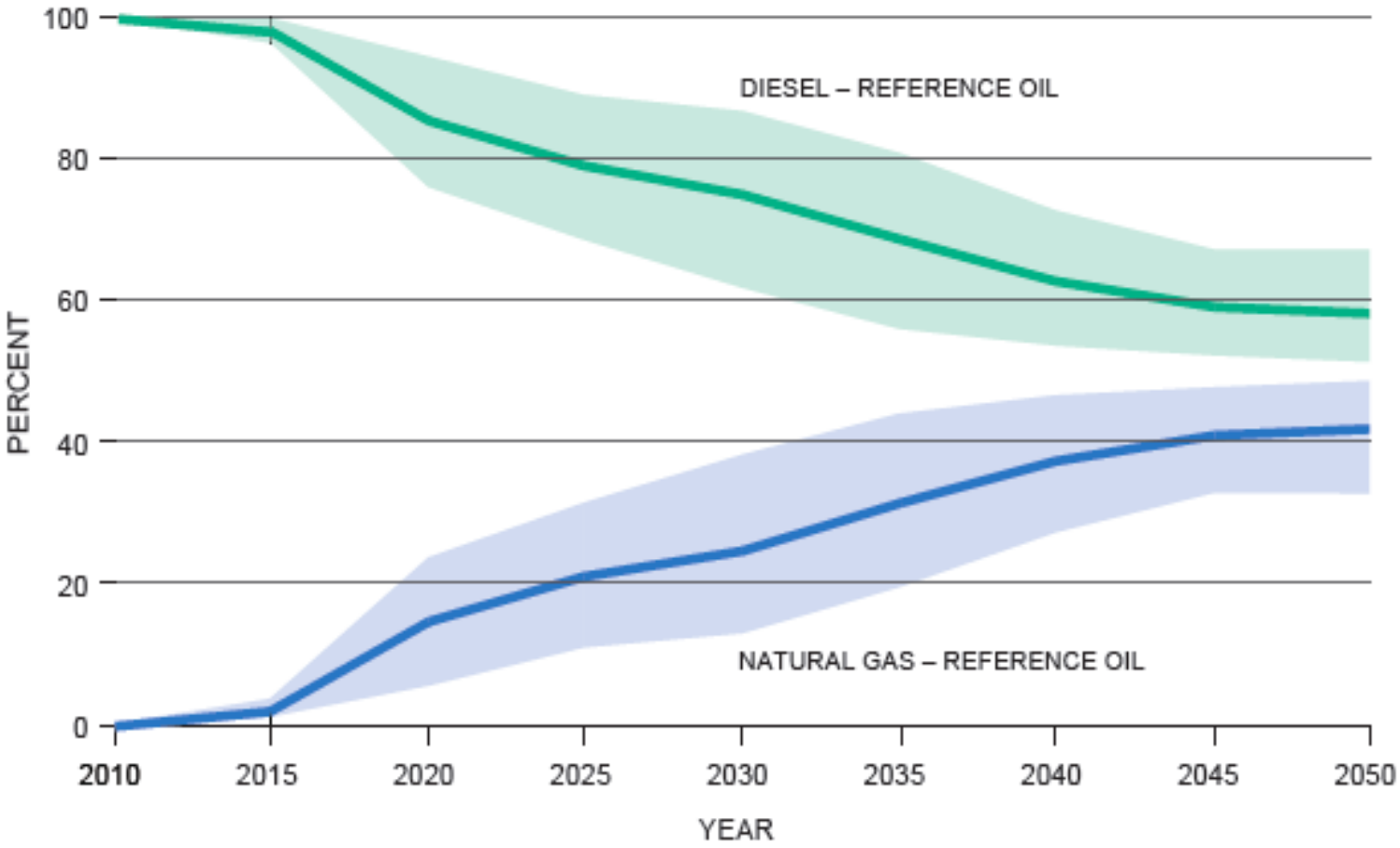
Fuel Supply
Education/Research
Auto/Engine
Government
Fuel Demand
Industry Association

Modeling Input Cost Assumptions For Class 7&8 Natural Gas Trucks

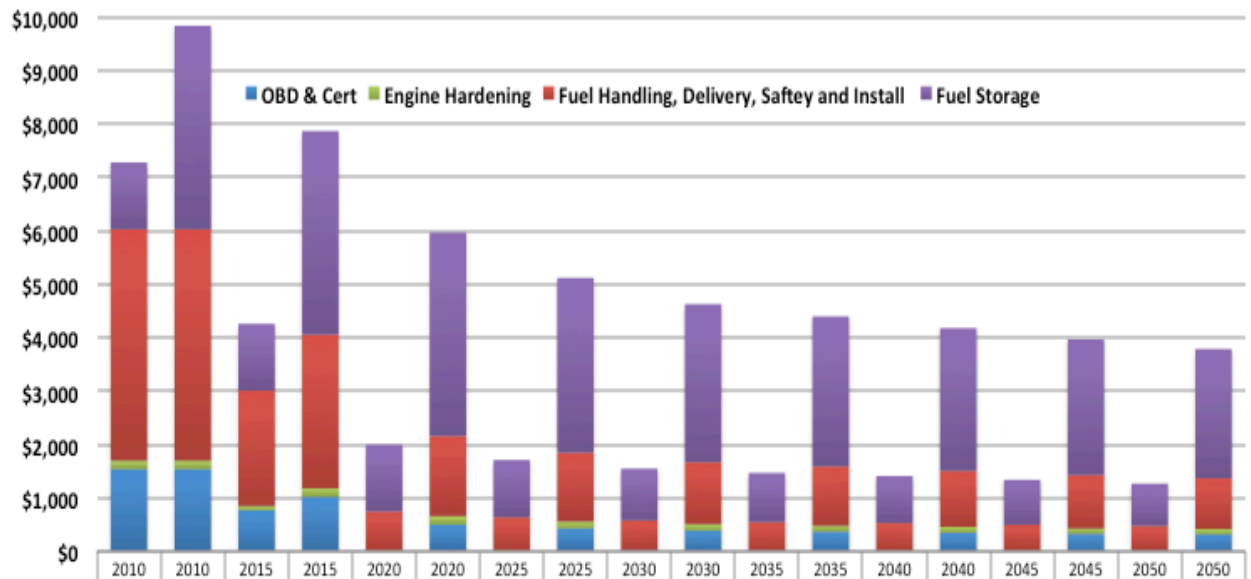
- Incremental RPE of NG Class 7&8 Combination Trucks



Class 7 & 8 Market Shares of New Diesel and Natural Gas Trucks: Reference Oil Case



Estimating LD CNG Incremental Costs



	2010 Low	2010 High	2015 Low	2015 High	2020 Low	2020 High	2025 Low	2025 High	2030 Low	2030 High	2035 Low	2035 High	2040 Low	2040 High	2045 Low	2045 High	2050 Low	2050 High
Fuel Storage	$1,250	$3,810	$1,250	$3,810	$1,250	$3,810	$1,070	$3,270	$970	$2,960	$920	$2,810	$880	$2,670	$840	$2,540	$790	$2,420
Fuel Handling, Delivery, Saftey and Install	$4,330	$4,330	$2,160	$2,880	$750	$1,500	$640	$1,290	$580	$1,160	$550	$1,110	$530	$1,050	$500	$1,000	$480	$950
Engine Hardening	$160	$160	$80	$160	$0	$160	$0	$130	$0	$120	$0	$110	$0	$110	$0	$100	$0	$100
OBD & Cert	$1,540	$1,540	$770	$1,020	$0	$500	$0	$430	$0	$390	$0	$370	$0	$350	$0	$330	$0	$320

- Low and High bound on incremental costs used to model range of uncertainty in projections.
- With assumptions used, significant reductions in incremental costs are possible.

Cost of Driving

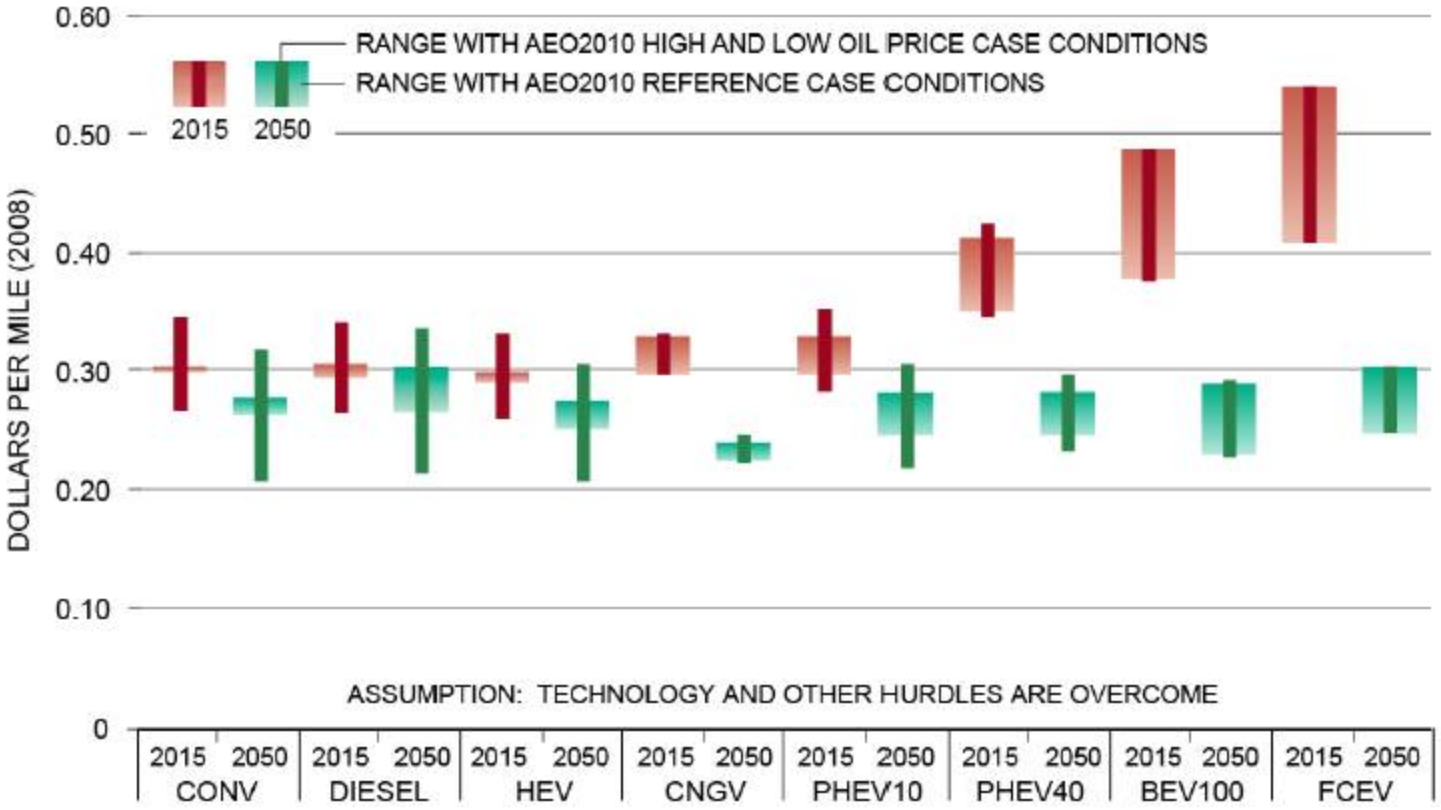
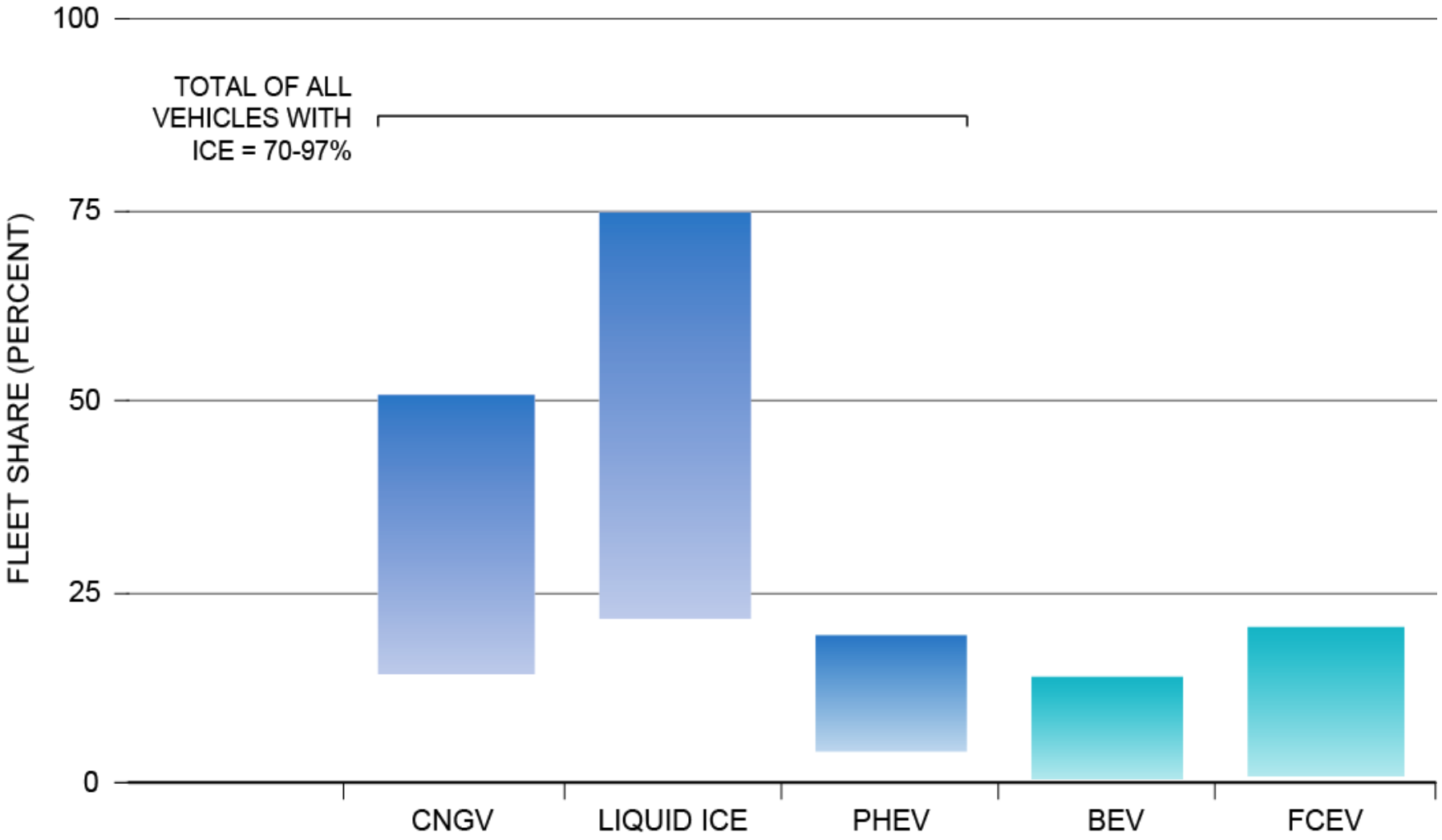


Figure ES-3. Cost of Driving Estimates ($2008) Assuming Technology, Infrastructure, and Other Hurdles are Resolved

Range of Light Duty Vehicle Fleet Shares in 2050 (3 Year, All Oil Prices, All-in Combination)



Total Fuel Use

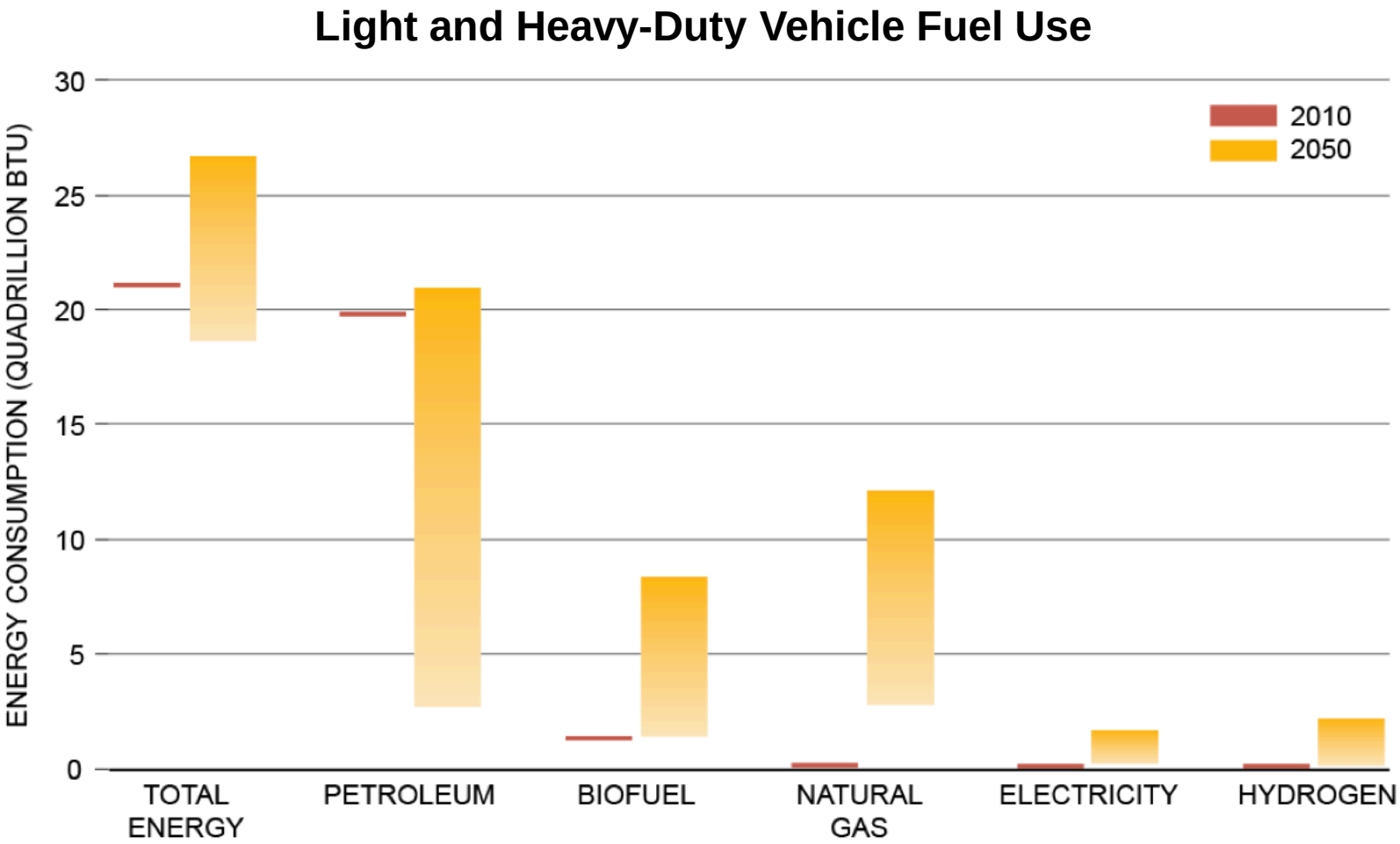


Figure ES-13. Range of 2050 LDV and HDV On-Road Fuel Use, Assuming All Alternatives are Successfully Commercialized (3-Year, All Oil Prices, All-in Combination)

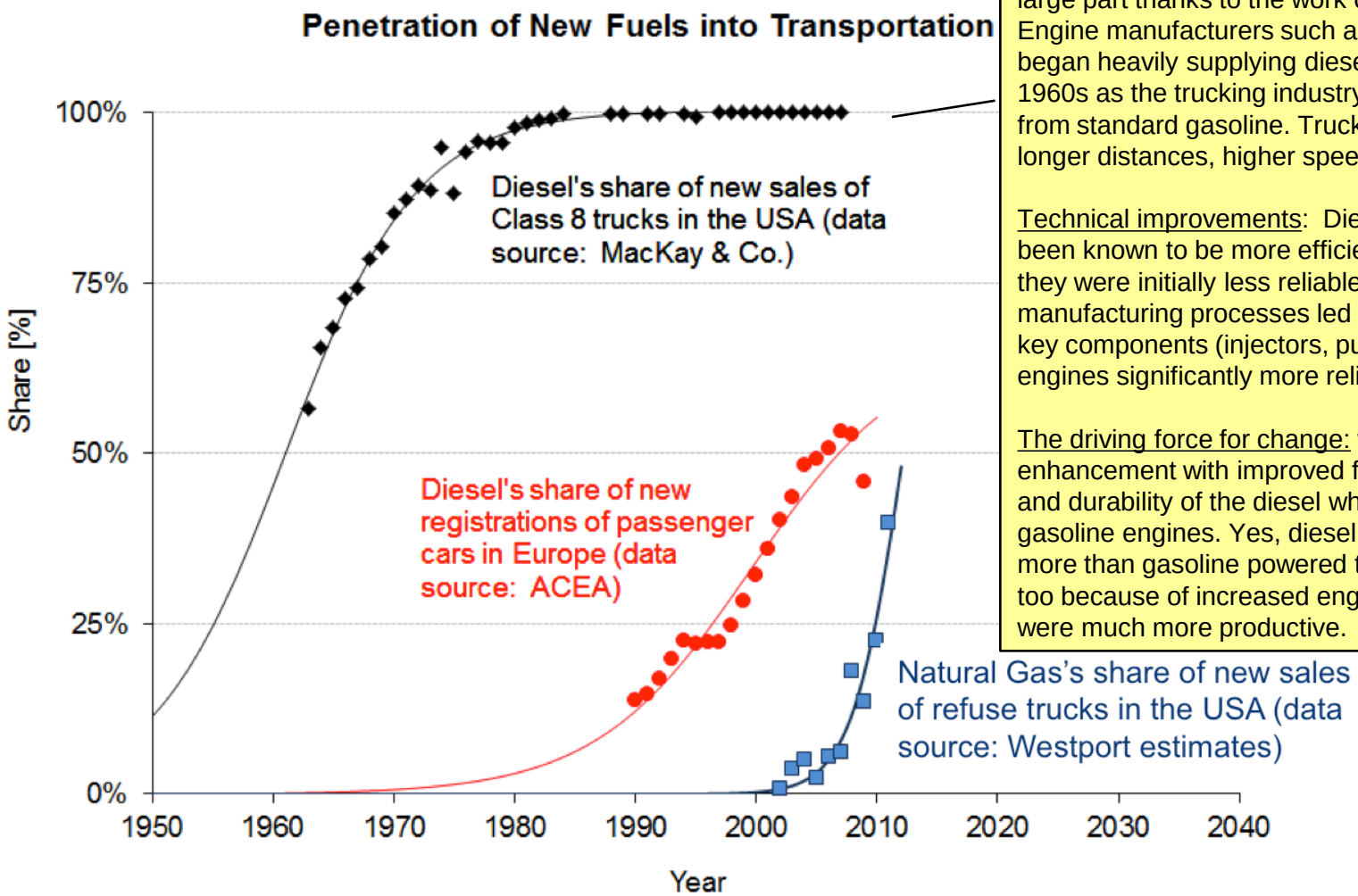
Infrastructure and Other Hurdles

Infrastructure challenges must be overcome for wide-scale commercialization of advanced fuel-vehicle systems. Options exist to facilitate concurrent development of alternative fuel vehicles and infrastructure, such as building on existing infrastructure, corridor-deployment, and multi-fuel vehicles.

Some examples are:

- Overcoming transition costs and other challenges in moving from one fuel-vehicle system to another
- Concurrent deployment of vehicle and associated fueling infrastructure investments
- Accelerating vehicle development cycle and market penetration
- Building on existing infrastructure minimizing initial investment
  - Electricity and biofuels leverage existing grid and liquid fuel infrastructure
  - Natural gas leverage fuel distribution infrastructure in heavy-duty freight corridors
  - Localized, corridor, or niche-application deployment can improve dispensing infrastructure use
- Flexible-fuel, bi-fuel and plug-in hybrids facilitate transition
  - Allow vehicle operation on fuel with more abundant dispensing
  - Build widespread availability of dispensing for the new fuel
- Significant hurdles to overcome and investment required for infrastructure and vehicle deployment

Case Studies of Growth of New Transportation Fuels



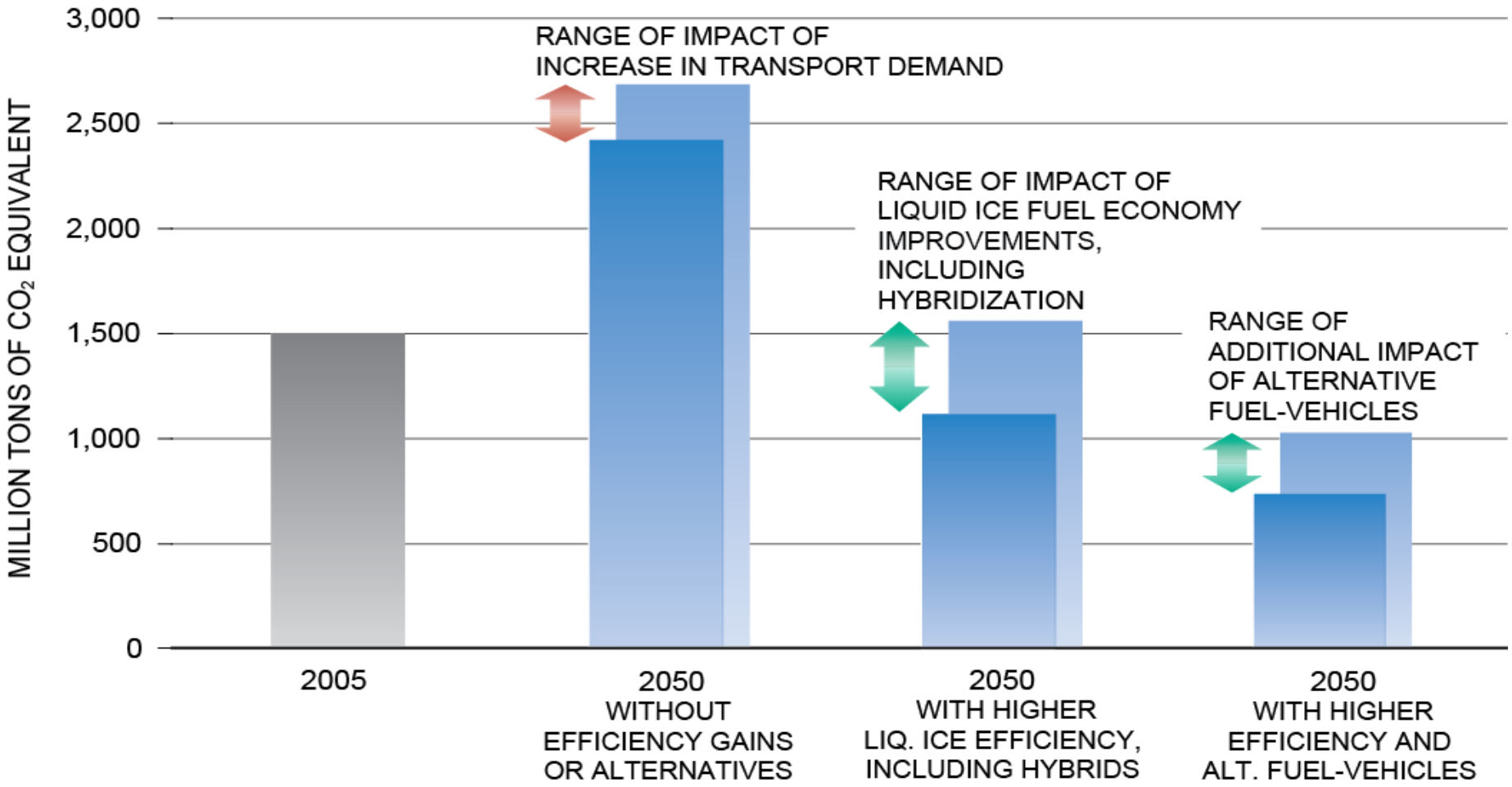
Post WWII: Truck manufacturers experienced a boom during WWII under defense contracts. Authorization of the U.S. Interstate Highway System in 1956 led to the trucking industry bursting onto the scene. New engine designs with a focus on performance emerged after the war. Direct-injection turbo-charged diesel engines that became a standard emerged during the 1950s, in large part thanks to the work of Volvo in Sweden. Engine manufacturers such as Cummins and Perkins began heavily supplying diesel engines through the 1960s as the trucking industry began its conversion from standard gasoline. Trucks were being built for longer distances, higher speeds, and heavier loads.

Technical improvements: Diesel engines had long been known to be more efficient than Otto engines, but they were initially less reliable. Improved manufacturing processes led to better quality control of key components (injectors, pump) , making Diesel engines significantly more reliable than Otto engines.

The driving force for change: was the performance enhancement with improved fuel economy, reliability and durability of the diesel when compared with gasoline engines. Yes, diesel powered trucks cost more than gasoline powered trucks. They were heavier too because of increased engine weights, but they were much more productive.

Sources for text box: Random History; Daimler AG, Bosch, ACT Research, "The Future of Natural Gas Engines in Heavy Duty Trucks", Aug 2012..

Projected Range of Impact of Demand, Fuel Efficiency Improvements, and Alternative Fuel-Vehicle Systems on Light-Duty Fleet GHG Emissions (Reference Oil Scenario, 3- and 17-Yr)

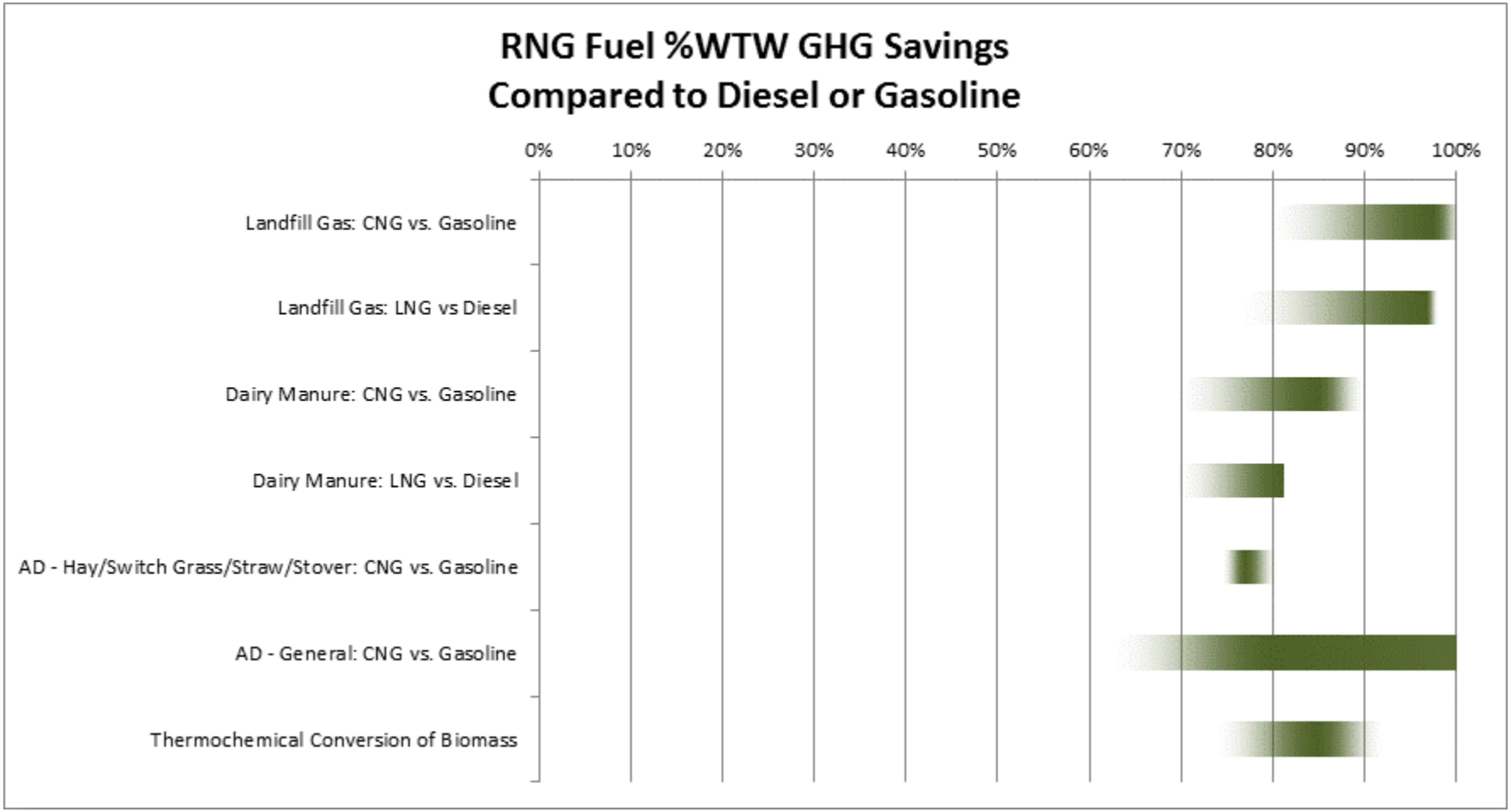


Assumptions:

- AEO2010 Reference Case results with fuel expenditure consideration over 3 and 17 years
- VMT range based on AEO2010 Reference Case and AEO2012 Early Release, extrapolated to 2050
- Carbon intensity (gCO_2e/MJ) values for fuels are from GREET in 2020
- For cases including alternative fuel-vehicles, technology and transition hurdles are assumed overcome
- Biofuels, where included, do not consider the impact of indirect land use change

Greenhouse Gas Emission Reductions of RNG Feedstocks

NPC White Paper: Renewable Natural Gas for Transportation



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Natural Gas Insights

Natural Gas Insights

- The potential for a long-term and low-cost domestic supply of natural gas, driven by economically recoverable shale gas resources may provide an economic driver for the increased use of natural gas for transportation.
- There is an opportunity for LD and HD natural gas vehicles to become attractive to both retail and fleet consumers. The economic competitiveness of these vehicles is contingent on sustained price spread between the lower cost of natural gas vs. gasoline/diesel as a transportation fuel.
- There are few technological barriers to market entry and expansion for either LD or HD natural gas vehicles. Technology developments can be used to extend the performance and economics of NGVs through improved fuel economy and lower cost.
- Enhancements in ICEs can generally be translated to natural gas engines.
- Build out of infrastructure is critical to support the increased use of natural gas. Infrastructure build out for HD vehicles is more cost effective than the development of wide-scale retail infrastructure for LD vehicles.

Thank you

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