

An aerial photograph of a city, likely Stockholm, showing a mix of urban buildings, a large highway interchange, and a waterfront with a ferry. Overlaid on the image are several white speech bubble icons containing colored symbols for different vehicles: an orange dump truck, a blue car, a blue forklift, a green semi-truck, a green bus, a blue pickup truck, a green train, and a green ship. The text 'Powering transportation.' is written in a white serif font on a dark grey banner at the top, and 'Driving change.' is written in a white serif font on a dark grey banner at the bottom.

Powering transportation.

Driving change.

The Future of Natural Gas as a Transportation Fuel

A Presentation for the DOE EIA 2013 Energy Conference, Washington, DC

Dr. Michael Gallagher

June 17, 2013

Secretary's Request

Examine ways to accelerate future transportation fuels prospects through 2050

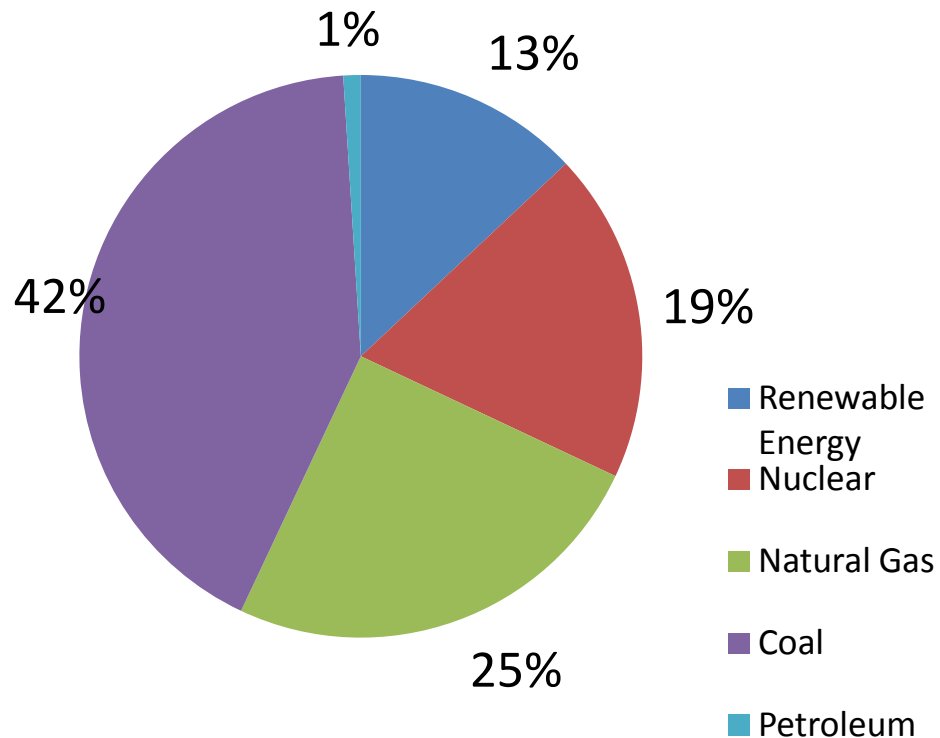
Address four critical areas: fuel demand, supply, infrastructure and technology

Answer this key question:

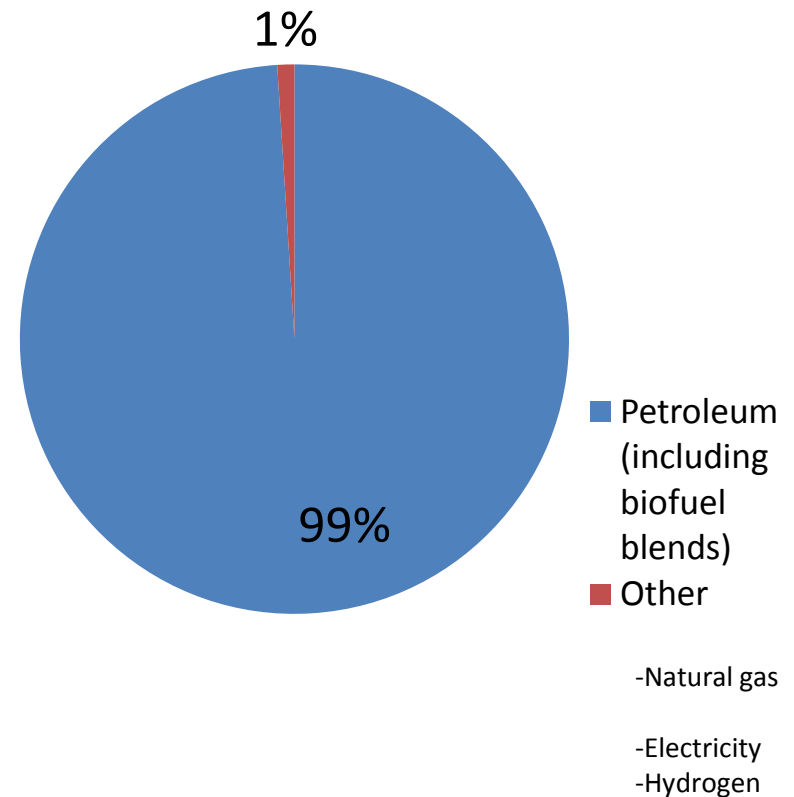
How can governments stimulate the technological advances and market conditions that will reduce GHG emissions by 50% relative to 2005 levels?

U.S. Transportation: What's Different?

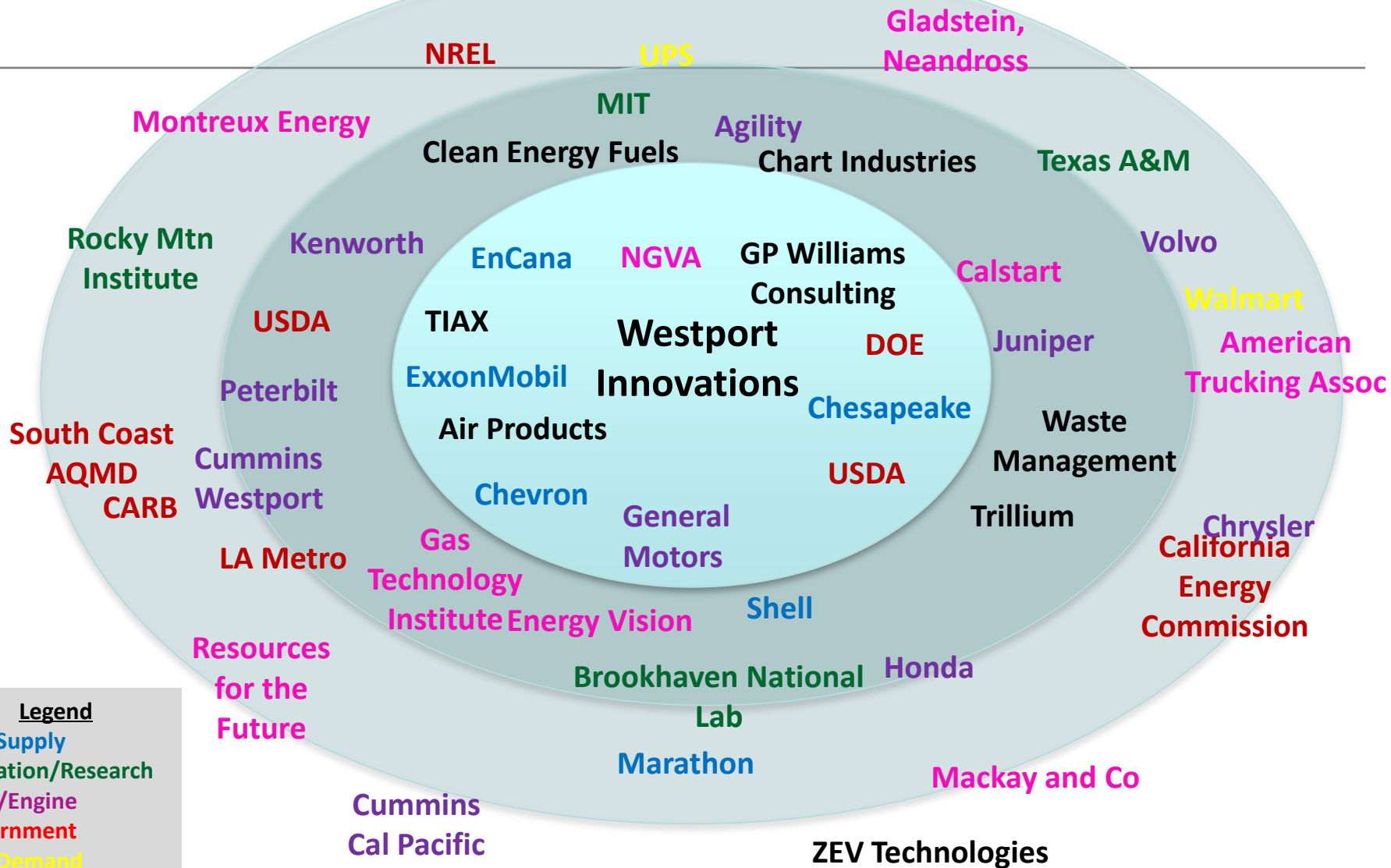
Power



Transportation



The Natural Gas Team



Shale Gas Plays in the United States

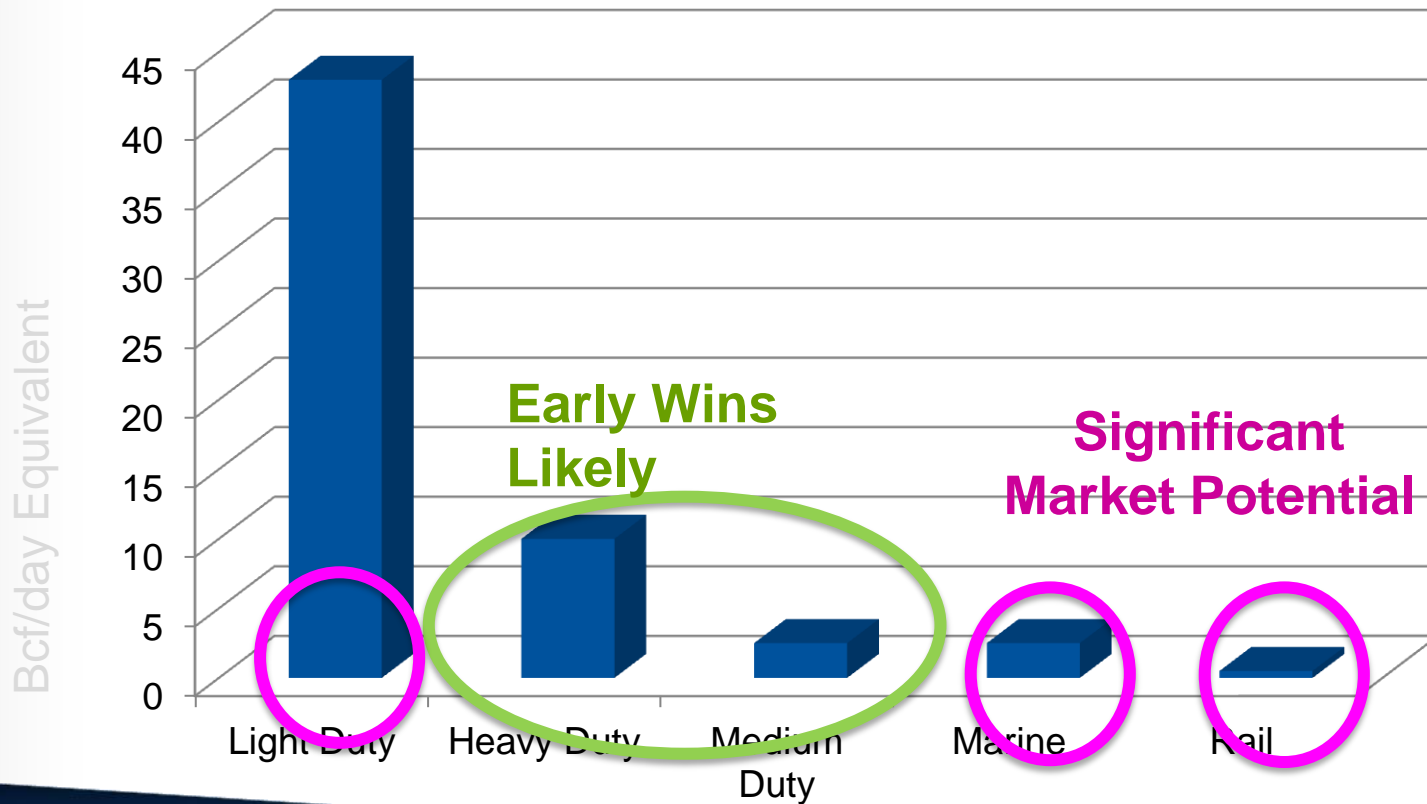


Source: U.S. Department of Energy, Energy Information Administration

IDENTIFYING THE OPPORTUNITIES

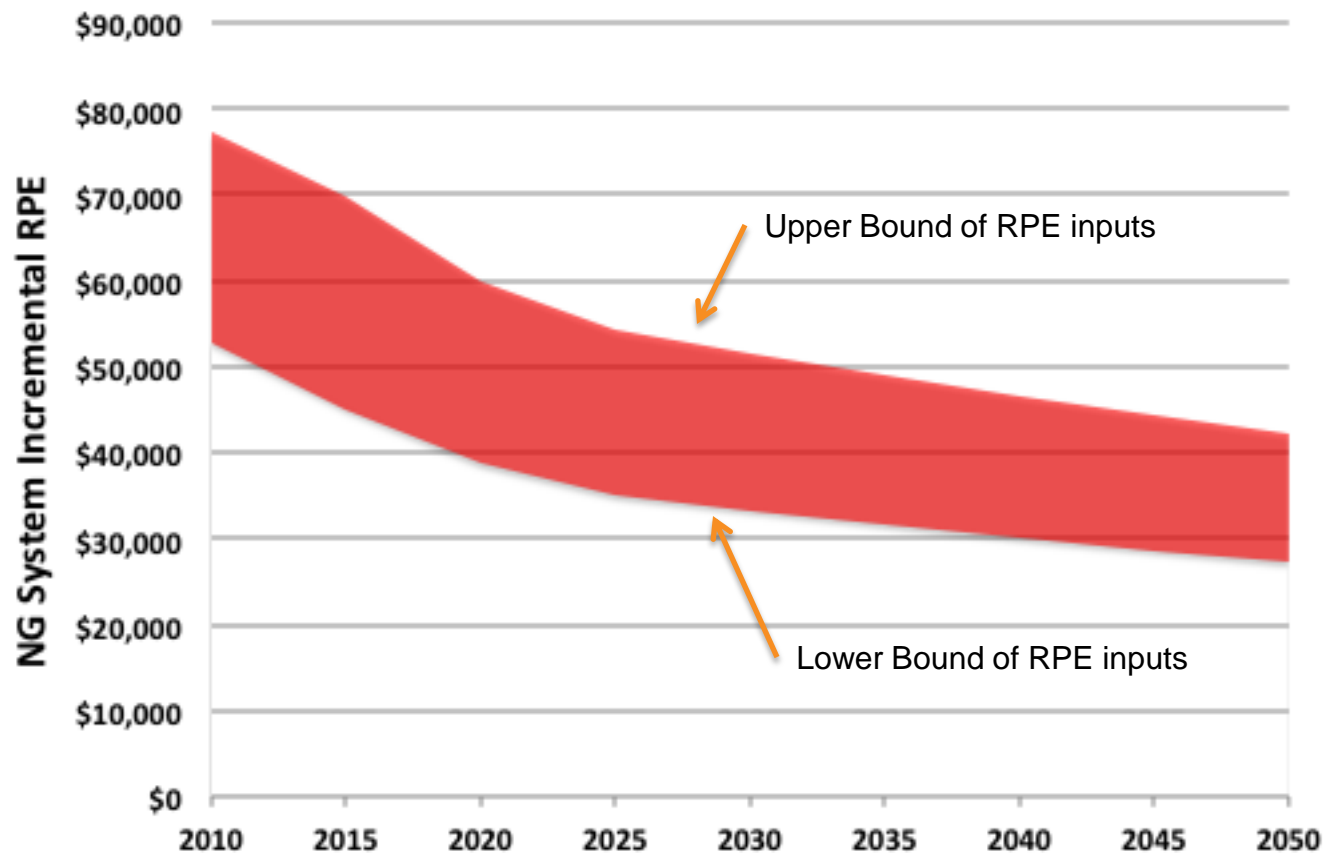
Fuel Consumption by Transportation Market Segment

Total Transportation Energy Market Equivalent to 61.6 Bcf/day

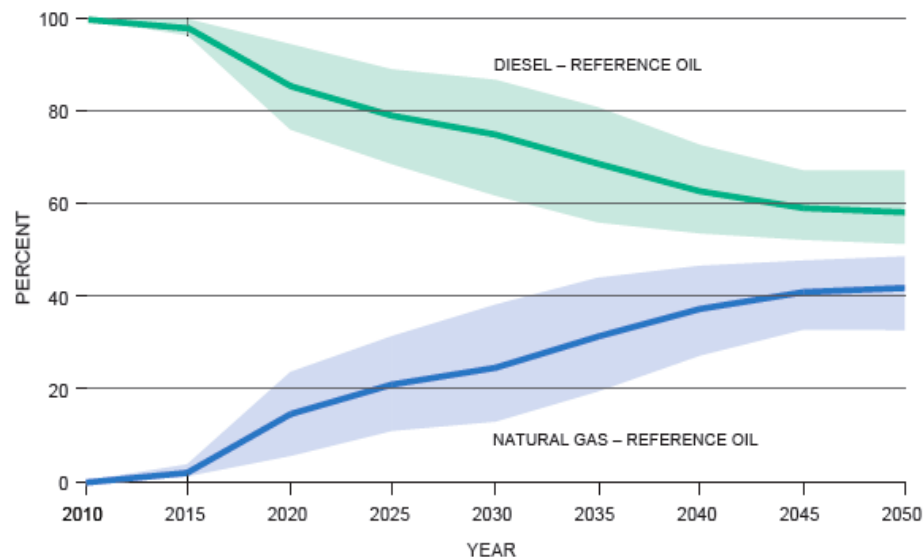


Modeling Input Cost Assumptions For Class 7&8 Natural Gas Trucks

- Incremental RPE of NG Class 7&8 Combination Trucks



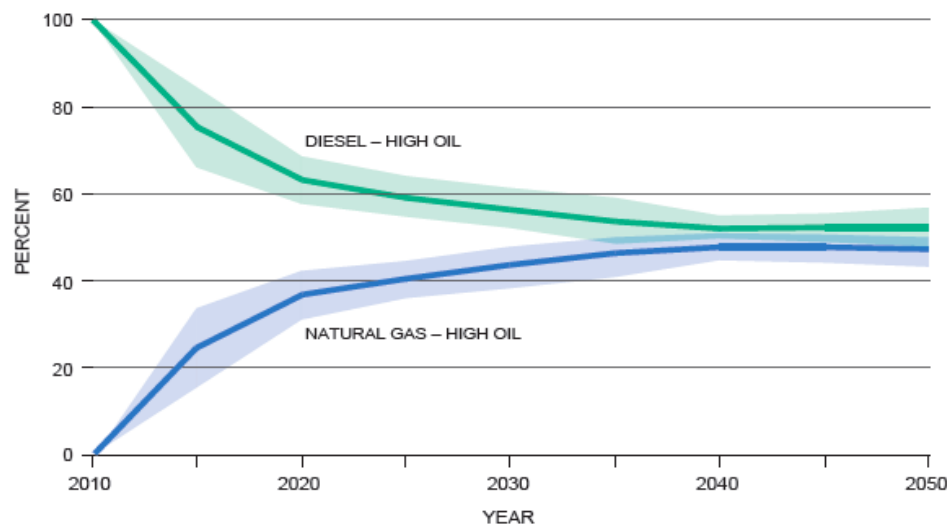
Class 7 & 8 Market Shares of New Diesel and Natural Gas Trucks: Reference & High Oil Case



No expected penetration of Natural Gas in Class 7&8 in Low Oil Cases due to absence of fuel price advantage.

In Ref and High Oil Price scenarios market share for natural gas can be very strong – based on fuel economics.

Expect mostly LNG, starting in high fuel use fleet applications.

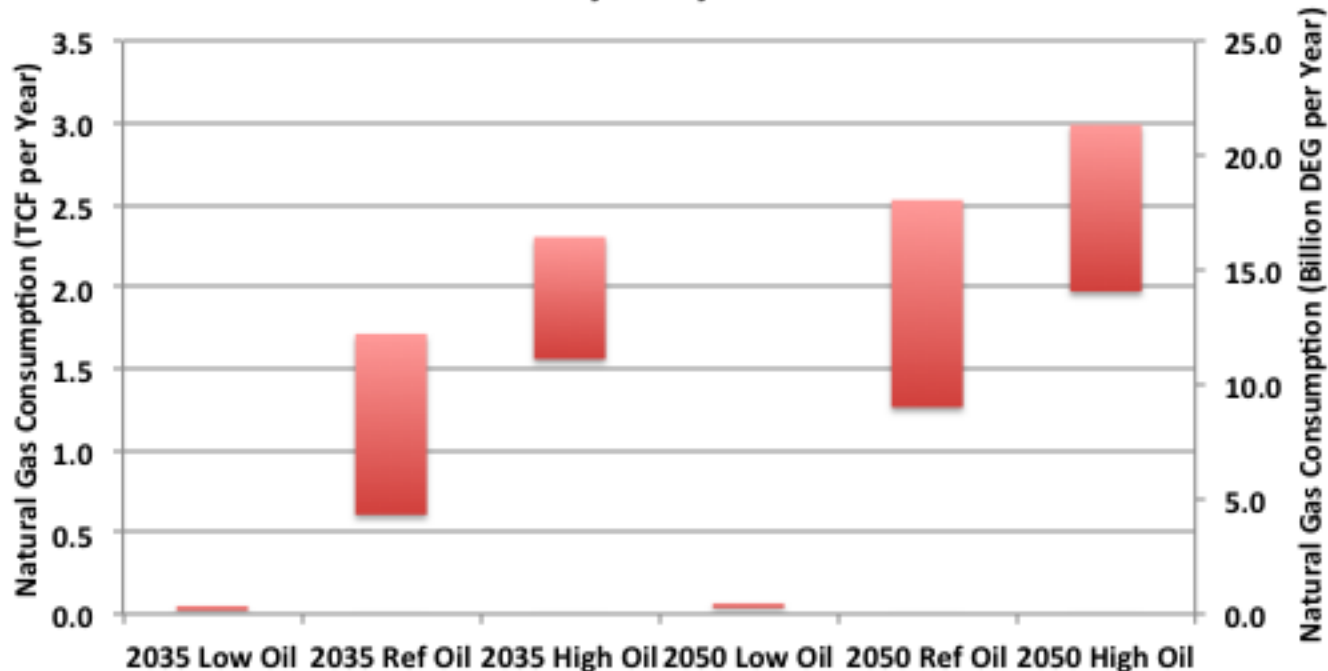


Cost reductions and increasingly accessible dispensing required for growth, but could be compelling.

Heavy Duty Fleet - Natural Gas Consumption

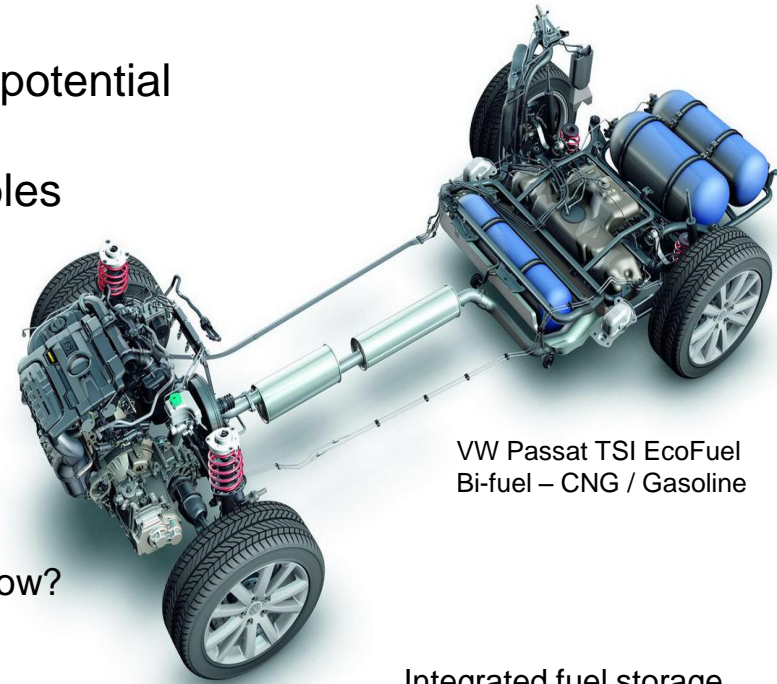
- Combined consumption of Natural Gas in Classes 3 to 8 equates to between 1.5 and 3 TCF
 - Annual US gas consumption today is ~ 23TCF, so HD trucks would increase NG demand by <15%.
- Transition to NG is equivalent to 10 to 20 billion DEG per year petroleum displacement (0.6 to 1.4 MM BoE / day) by 2050.

**Natural Gas Consumption
In Heavy Duty Vehicles**



Light Duty NGVs: A Deeper Look at Technology Potential

- European state of the art demonstrates near term potential for fuel efficient, practical NGVs
- Common powertrain architecture to gasoline; enables common technology advances for NGVs:
 - Downsizing, highly boosted engines, direct injection
 - CNG hybrids
 - Transmission
 - Chassis (light-weighting, aero)
- Wide range of fuel economy potential
 - How do you optimize for economics when fuel costs are low?
- Can scale and production integration reduce cost premiums?
- Historical issues of luggage space being resolved by OEM integration
- Higher fuel use applications and vehicles likely to transition first.
 - Eg – fleets and pick-ups
- Greater infrastructure challenges for personal transport

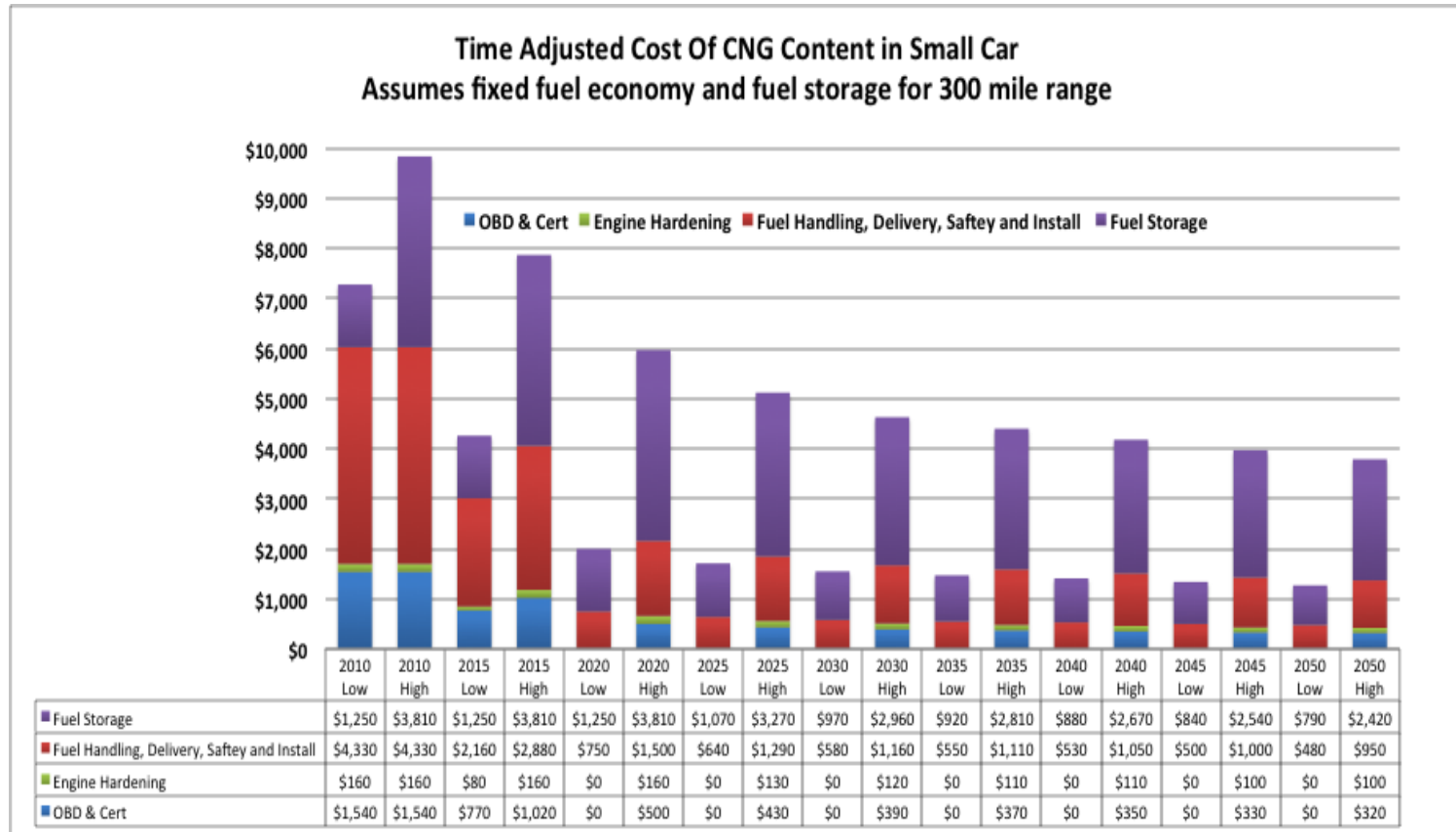


VW Passat TSI EcoFuel
Bi-fuel – CNG / Gasoline

Integrated fuel storage
protects for luggage space



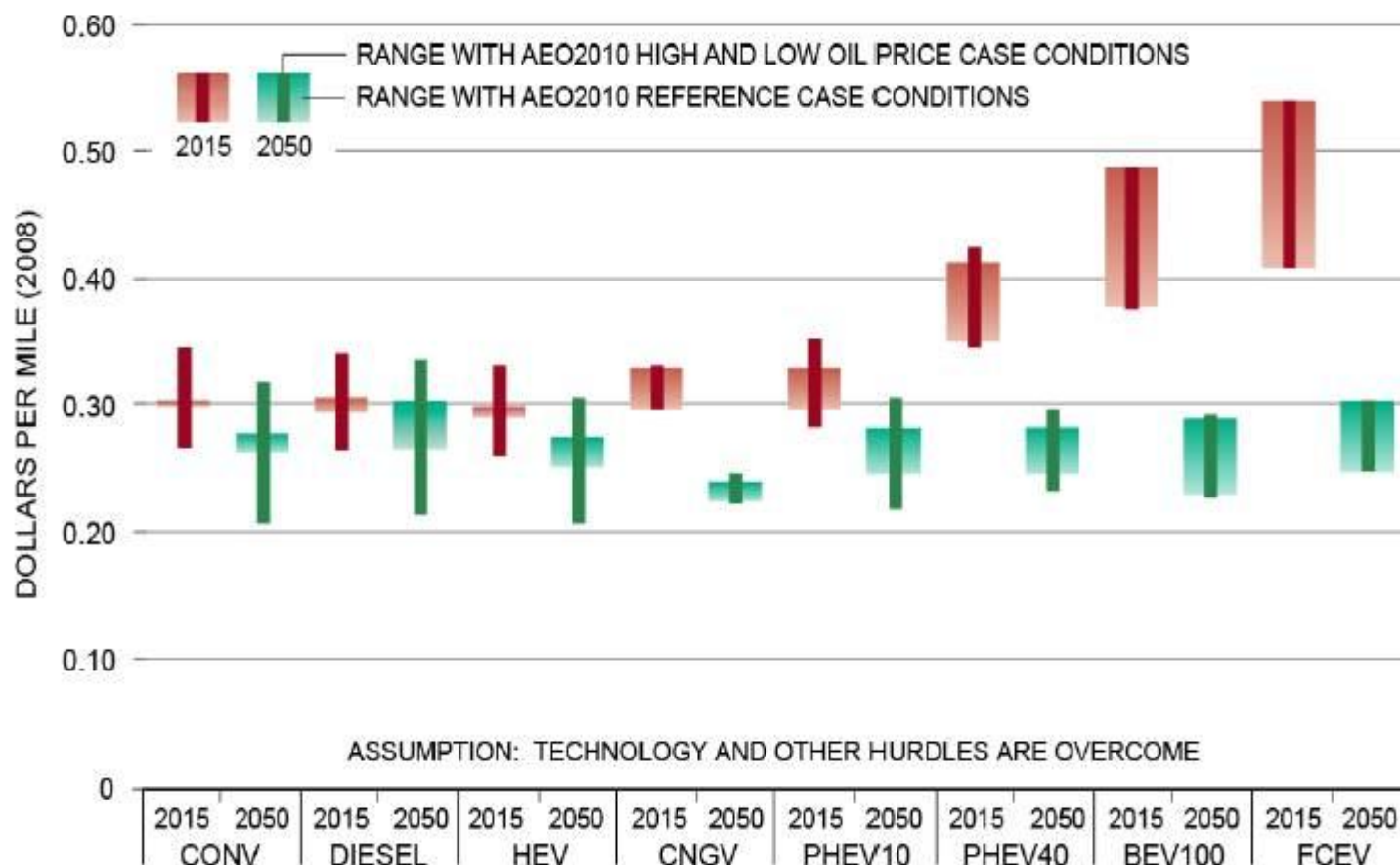
Estimating LD CNG Incremental Costs



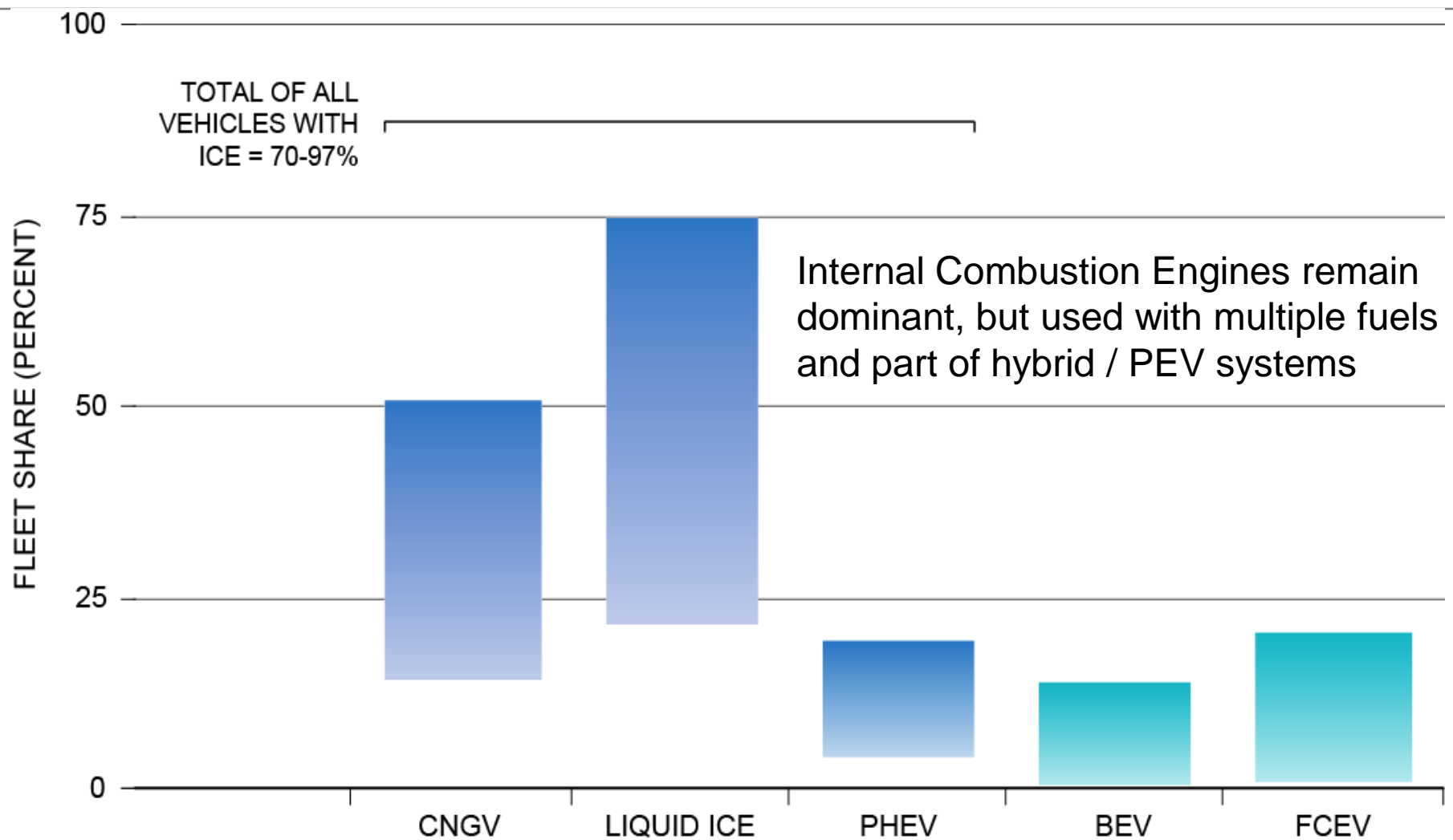
- Low and High bound on incremental costs used to model range of uncertainty in projections.
- With assumptions used, significant reductions in incremental costs are possible.

Light Duty - Cost of Driving (\$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 Technology Combination)



Volvo Car Group Unveils V60 Bi-Fuel Car with Westport Natural Gas Fuel System at NGV 2013 Gothenburg

- Since 2009, Westport—the sole supplier of natural gas fuel systems to Volvo Car Group—has developed and installed natural gas systems for the Volvo V70 estate car at a facility located inside Volvo's main production centre in Gothenburg, Sweden
- The new Volvo V60 Bi-Fuel car runs on either compressed natural gas (CNG)/biomethane or petrol (gasoline), and is a sporty estate car
- With a powerful 213 horsepower engine, the Bi-Fuel system offers a total driving range of 1,120 kilometers. When renewable CNG (biomethane) is used as a vehicle fuel, greenhouse gas emissions are significantly reduced compared to petrol
- ***"Demand for natural gas vehicles in Sweden is expected to increase in response to the pending extension of the Government of Sweden alternative fuel tax incentive program,"***
-Ian Scott, Executive Vice President, Westport
- The new V60 will expand Volvo Car Group's Bi-Fuel product line. Westport and Volvo Car Group are currently in discussions to expand the Volvo V60 Bi-Fuel car into other markets
- *Natural Gas Vehicles*, a Global Strategic Business Report, projects that the number of natural gas vehicles (NGVs) in Sweden will triple between 2010 and 2018, from 31,179 to 92,657.
- Sales for the new product will start in October 2013 in Sweden

U.S. Fleet - Total Fuel Use

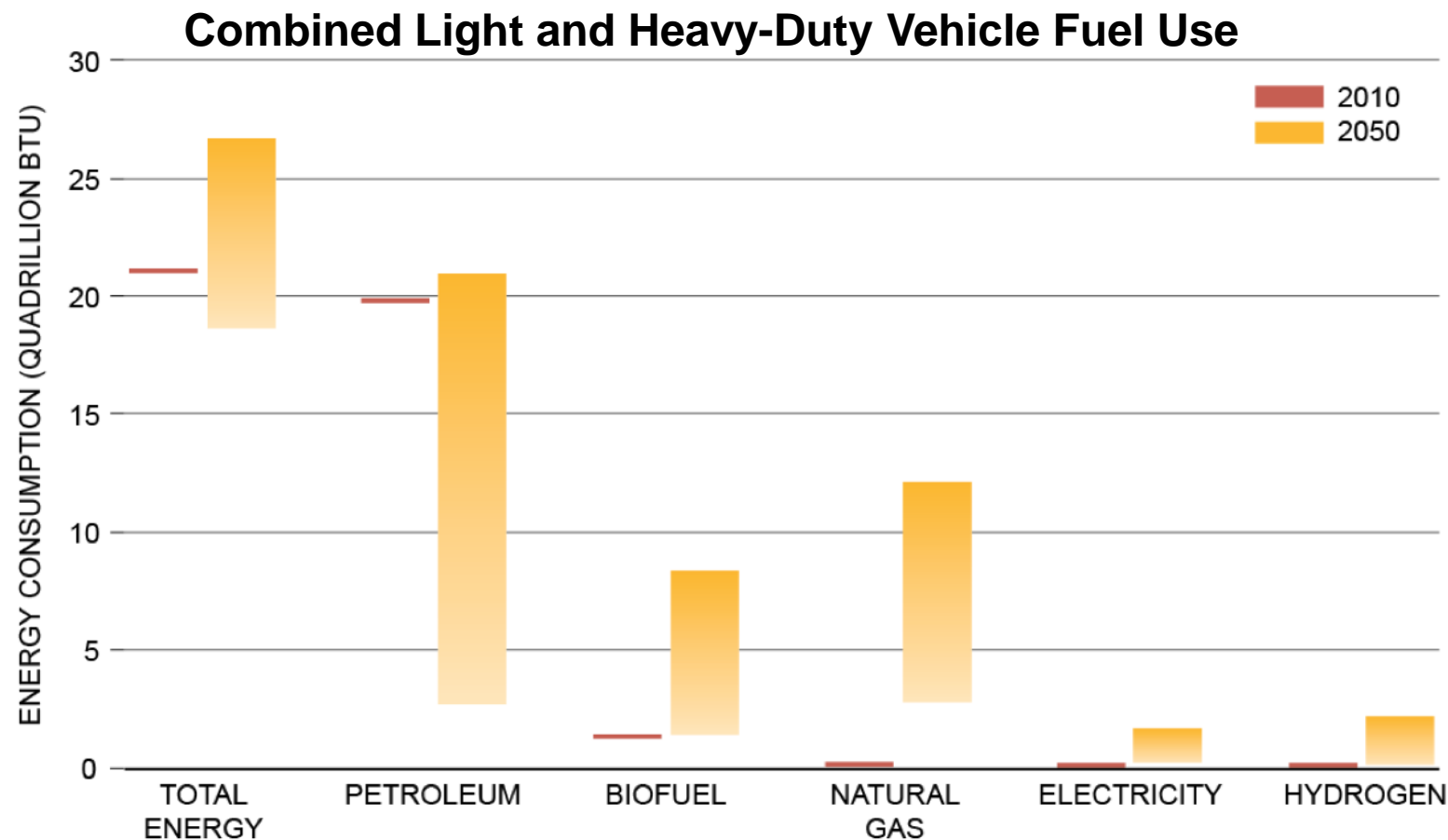
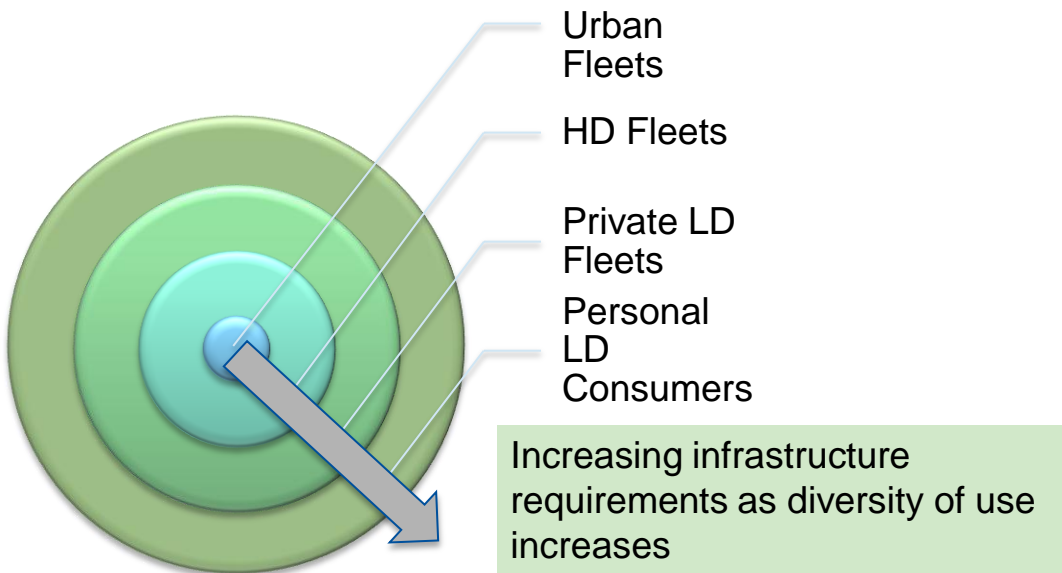


Figure ES-13. Range of 2050 LDV and HDV On-Road Fuel Use, Assuming All Alternatives are Successfully Commercialized (3-Year, All Oil Prices, All-in Combination)

Infrastructure: Natural Gas Fuel Dispensing

Investment required, but technology options exist

		Fuel Production	Fuel Dispensing
CNG (for LD)		\$0...?	\$100 - \$200bn
LNG		\$20 - \$40bn	\$10 - \$20bn
Hydrogen		\$30 - \$90bn	\$300 - \$500bn
Bio Gasoline		\$100 - \$250bn	\$20 - \$40bn
Electricity		TBD	\$70 - \$130bn
Bio Diesel (GTL - BTL)	



Fleet
centric
CNG/LNG



■ Modular additions
to existing sites



Dedicated new
CNG/LNG
stations



Home refueling



Natural Gas Vehicles: Summary Thoughts

HURDLE	LD CNG	MHD CNG	HHD LNG
VEHICLE PERFORMANCE	●	●	●
FUEL ECONOMY POTENTIAL	●	●	●
OPERATING RANGE	●	●	●
PRODUCT AVAILABILITY	●	●	●
CARGO AND UTILITY	●	●	●
FUEL AVAILABILITY	●	●	●
DISPENSING CAPITAL	●	●	●
VEHICLE FIRST COST	●	●	●
FUEL COSTS PER MILE	●	●	●
LIFETIME TOTAL COST	●	●	●

- Market opportunities for both LD and HD vehicles
- Few technical barriers to NGV expansion
- Similar powertrain architecture to gasoline and diesel is an advantage
- Potential for a strong economic value proposition if natural gas prices remain low
- Sustained effort required on infrastructure expansion to resolve fuel availability
- Continued market demand required to justify expanded OEM product offerings

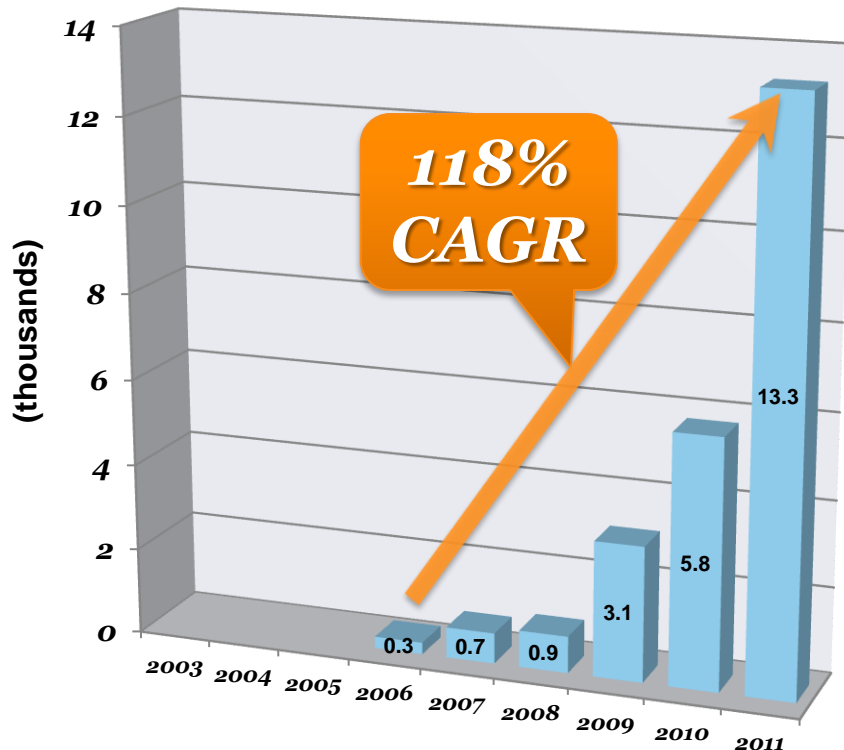
Electric Vehicle Insights

- Battery cost, energy density, degradation and longevity are the highest R&D investment priorities.
 - A breakthrough beyond those expected for lithium-ion batteries is necessary to increase the driving range of a BEV so that it can be a substitute for a conventional vehicle.
 - By 2020, battery costs will likely be in the range of \$200 to \$500 per kWh, which is above the Department of Energy targets for commercialization.
- The highest priority for charging infrastructure is to enable convenient and affordable home charging.
- Electricity generation and transmission for a large grid-connected vehicle population is not a constraint, as potential capacity additions can be included in existing long-term asset planning processes.

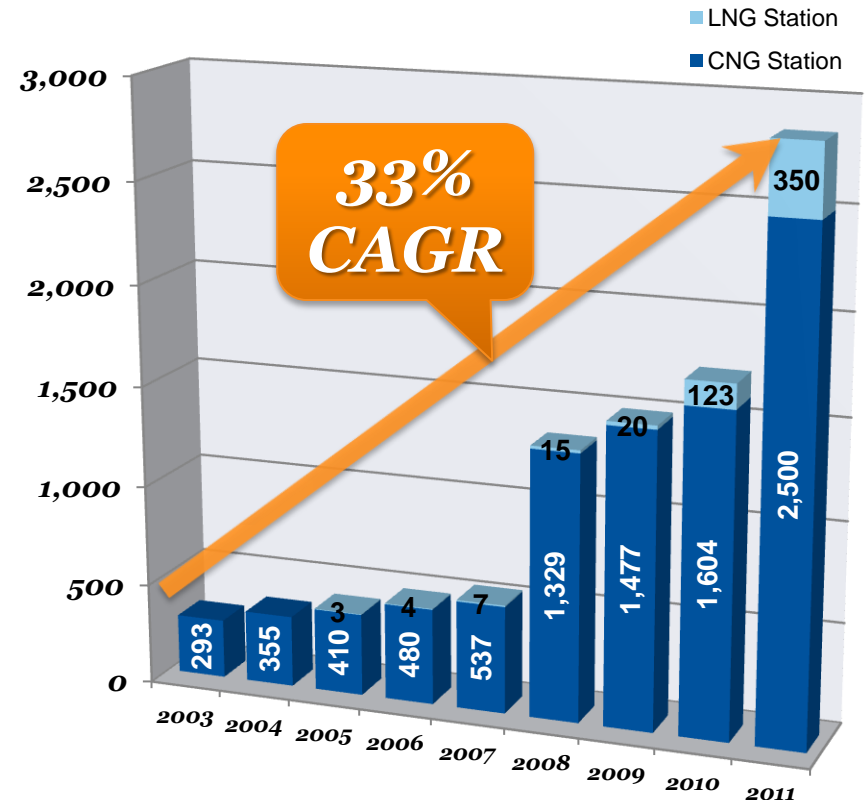
Global Truck Market Opportunity

- China first, followed by India and Europe

China LNGV Population

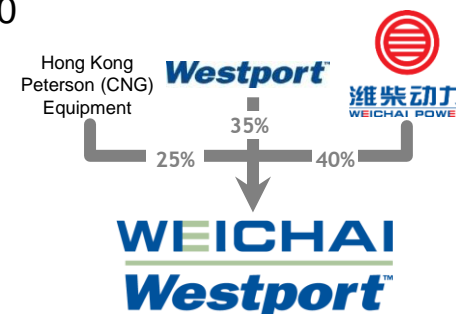


Natural Gas Stations in China



Strong Growth in China

- First announced Weichai Westport JV in 2008; formal JV commenced July 2010
- Light-duty component business has >60% share in China*
- Existing NG engine business demonstrating strong growth in China
- Current priorities: launch Westport HPDI technology for Asian market in 2013 with broad LNG infrastructure
- Westport revenue model
 - Sale of components to JV and to vehicle OEMs
 - Participate in the JV's profitability



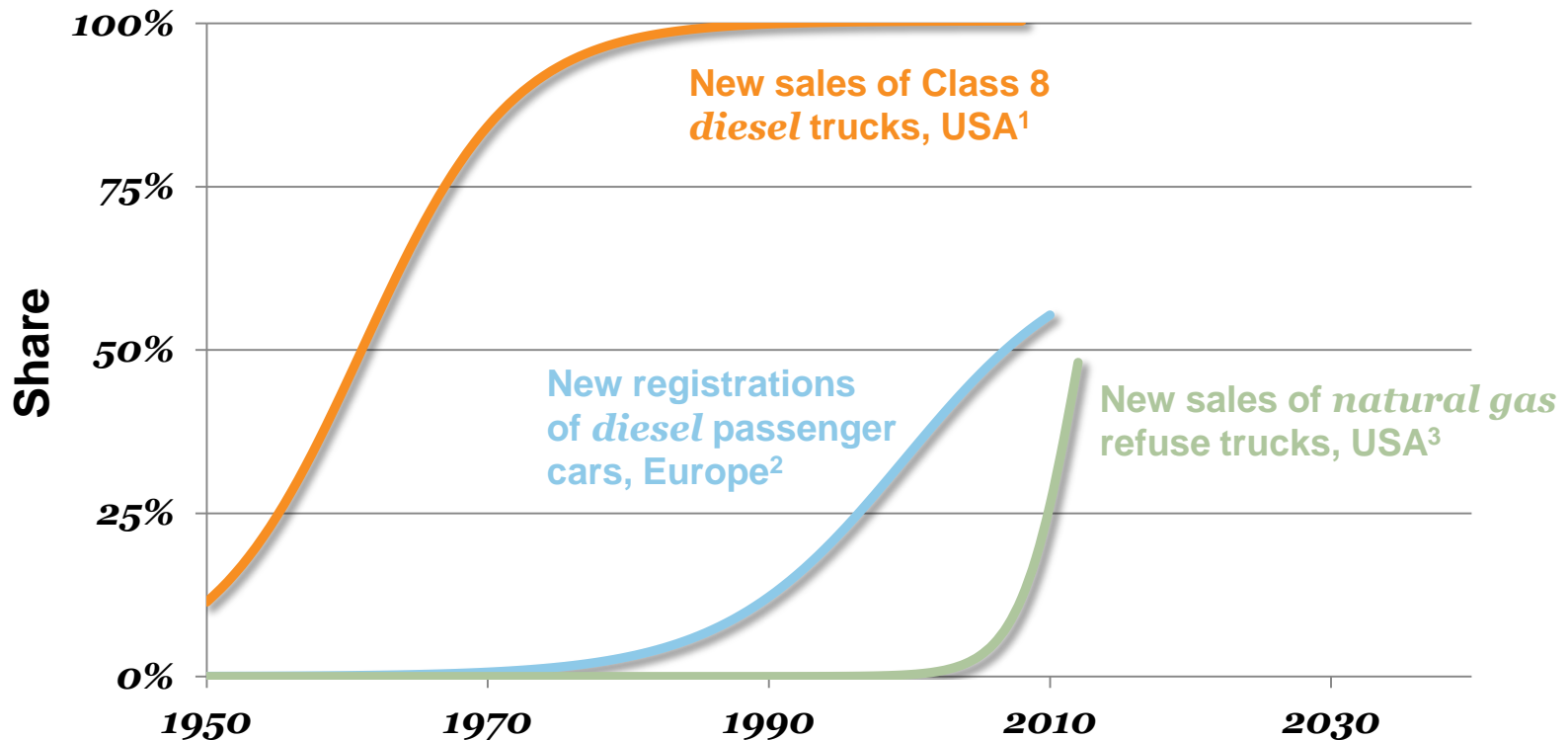
Weichai Westport Financial Summary

USD\$MM	2008	2009	2010	2011	2012	Q1 2013
Revenue	\$ 9.9	\$ 19.0	\$ 44.8	\$ 109.8	\$ 272.1	\$ 105.9
Cost of revenue	8.1	15.7	35.9	90.1	234.3	98.8
Expenses	1.6	2.5	6.4	14.1	28.1	3.7
Net income	\$ 0.1	\$ 0.8	\$ 2.4	\$ 5.6	\$ 8.2	\$ 2.9
Net income %	1.3%	4.2%	5.4%	5.1%	3.0%	2.7%
WPT 35% interest*	-	-	\$ 0.6	\$ 1.9	\$ 2.9	\$ 1.0
Engines sold	720	1,696	3,602	8,451	22,025	8,529

* Westport began reporting its income from WWI in July 2010

Accelerated Market Adoption

- Adoption rate in leading markets moving faster than the gasoline to diesel transformation
- Clean Energy Fuels, Shell, Encana, ENN, and others are leading the build-out of natural gas stations and fuelling infrastructure around the world

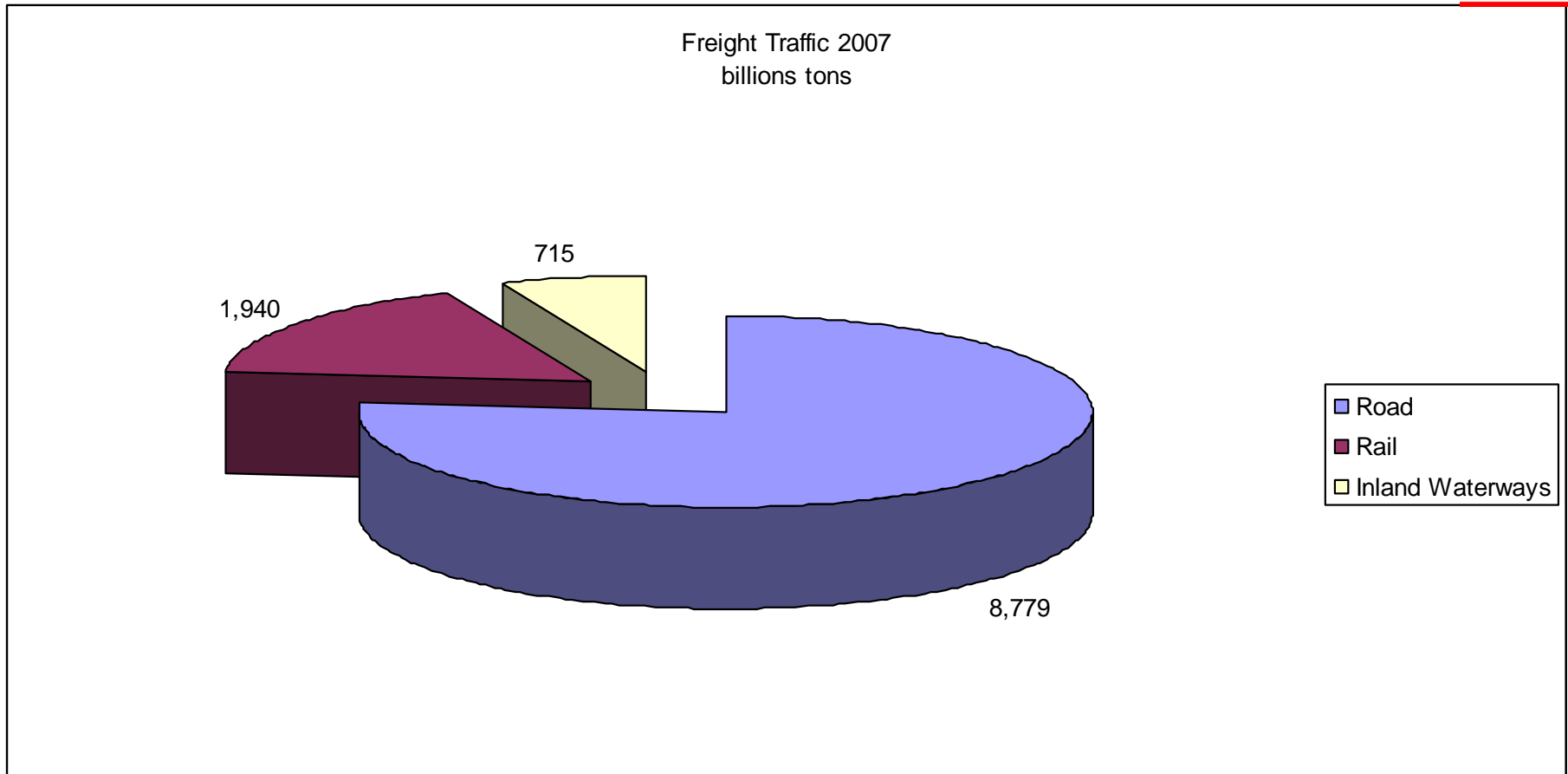




Thank you...

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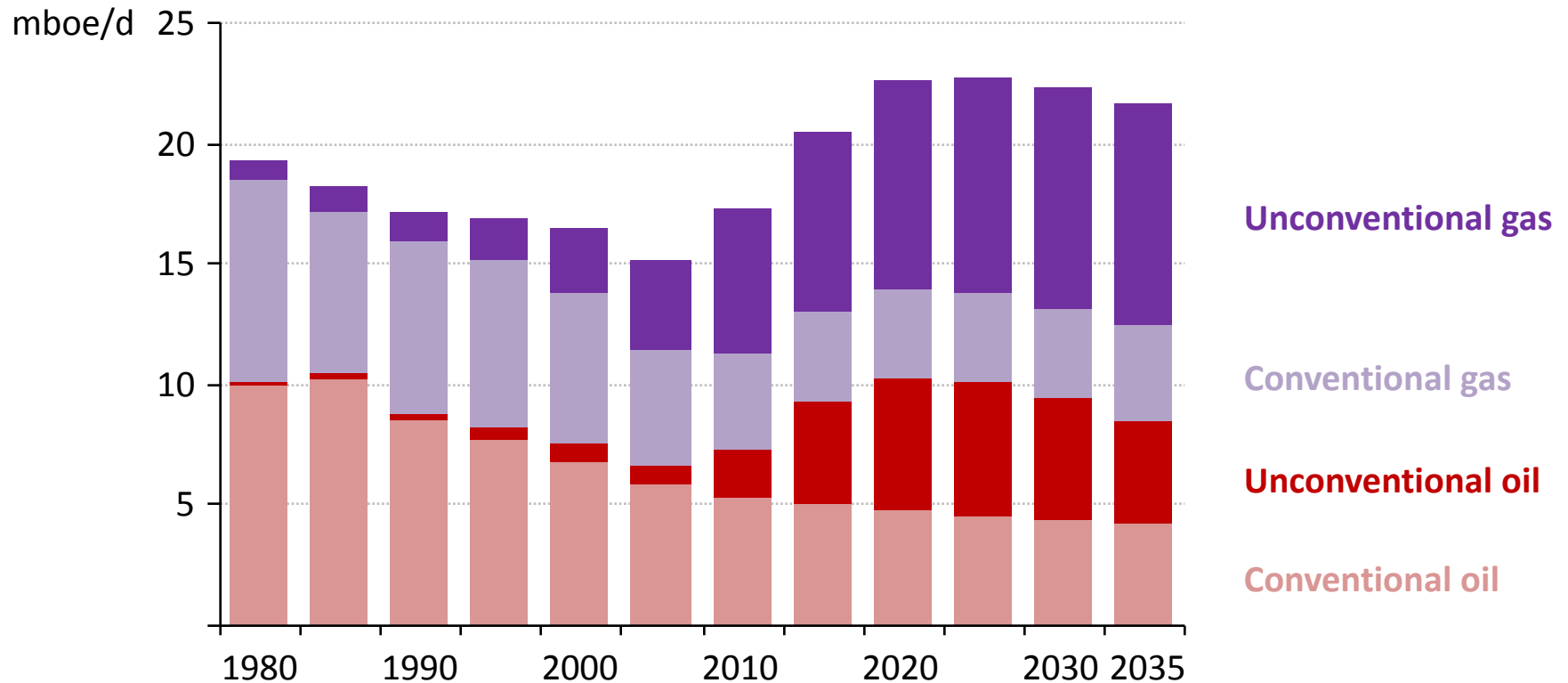
US Road Transport and Freight



Source: American Railroad Association, US Coastguard, Commodity Flow Survey (CFS), Bureau of Transport Statistics

A US Oil & Gas Transformation

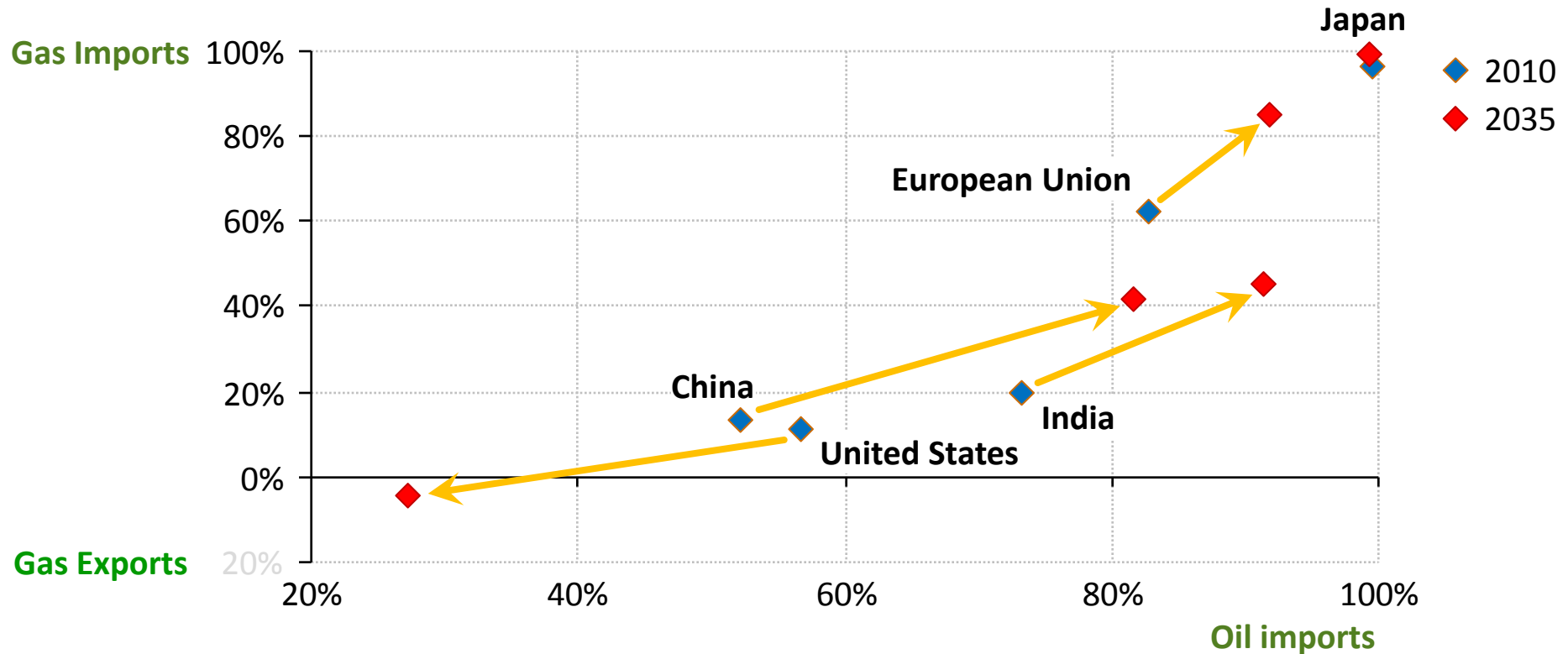
United States oil and gas production, 1980-2035



The surge in unconventional oil & gas production has implications well beyond the United States

Different trends in oil & gas import dependency

Net oil & gas import dependency in selected countries



While dependence on imported oil & gas rises in many countries, the United States swims against the tide

Cummins Westport Joint Venture - Spark Technology

- 50:50 JV established in 2001
- Renewed agreements 2004 and 2012
- Delivered over 35,000 engines
- Industry leading OEM availability

- Key recent growth driver:
 - refuse trucks in North America – approaching 50% natural gas market penetration
 - Medium and heavy truck applications

ISL G	ISX12 G	ISB6.7 G
		
8.9L SEGR 250–320hp 660–1,100 lb-ft	11.9L SEGR 320–400hp 1,150–1,450 lb-ft	6.7L SEGR
available now	2013 launch	2015 launch

**CWI Engines in North America by Segment
(cumulative through Q3 2012)**

