IHS ENERGY

Stanford Natural Gas Initiative

Natural Gas in On Road Transportation

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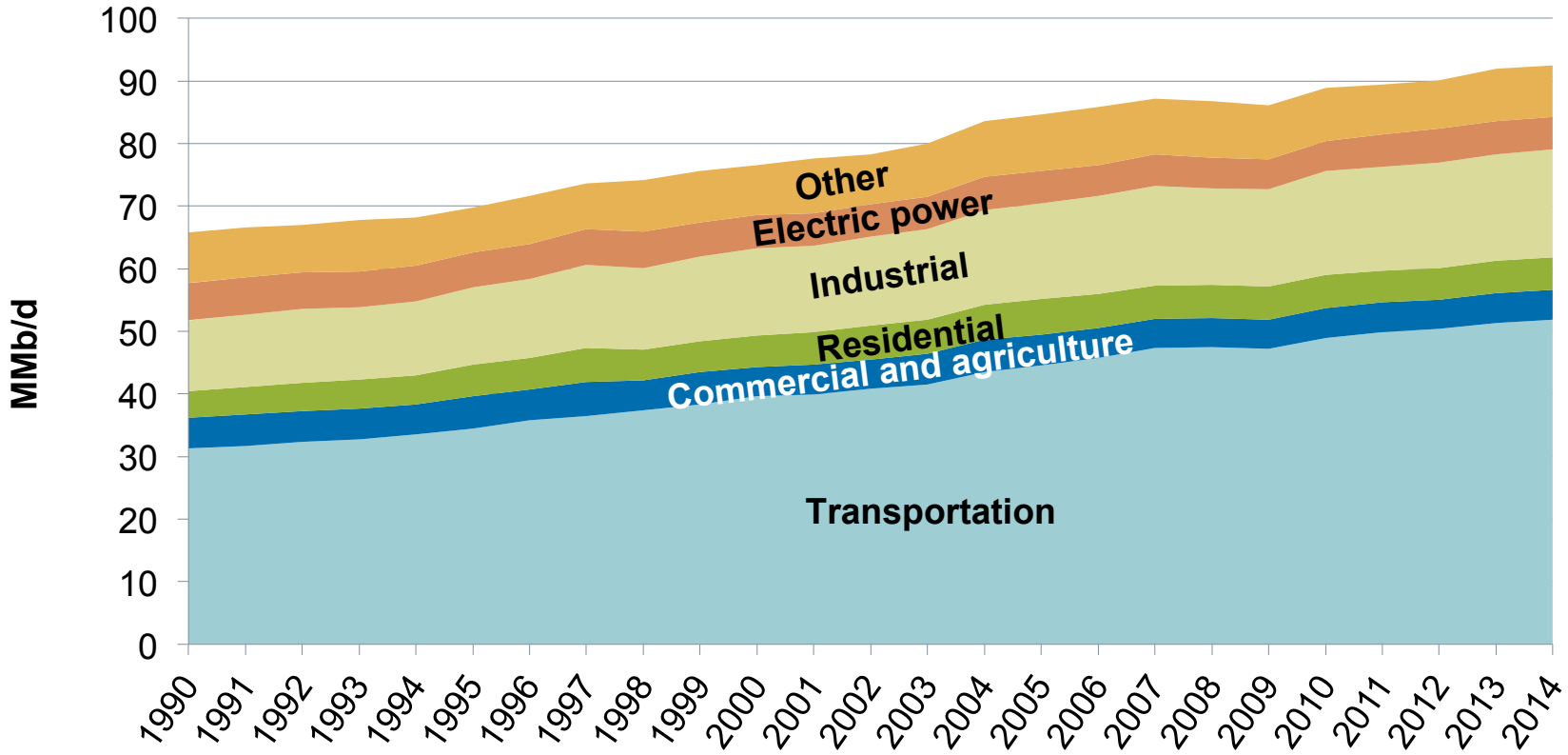
Transport accounts for about 55% of oil demand and is key to understanding future oil demand

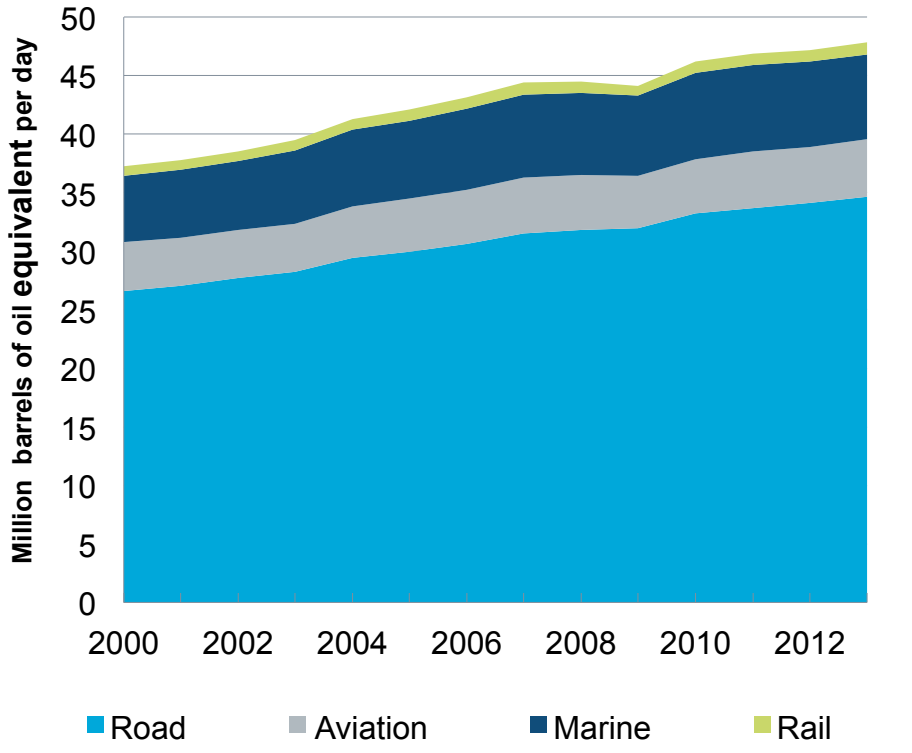
Oil (total liquid fuels) demand by sector



Notes: Transportation demand includes biofuels. "Other" includes energy sector uses, miscellaneous uses, distribution losses, and statistical differences.
Sources: IEA, IHS, EIA

On road fuel demand accounts for ~75% of transport demand is the key driver for future oil demand growth

Global transport demand by sector



Source: IHS

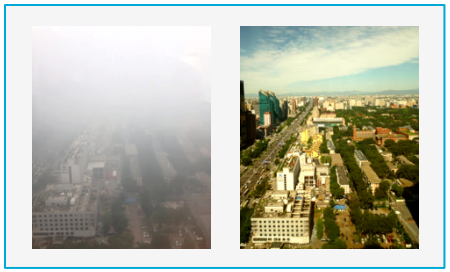
- **Demand for transportation fuels continue to grow worldwide as economic growth and globalization spur increased movement of people and goods**
  - Demand for over-the-road fuels remains dominant segment of the transportation sector, accounting for ~75% of 2015 consumption
- **Emerging markets will continue to drive overall growth in the transport consumption as vehicle ownership and industry expand with economic opportunities, while developed markets put increasing emphasis on fuel efficiency**

Global transportation demand reached nearly 54 MMboe/day in 2016

Three key drivers for natural gas in on road transport

Economic

- Natural gas expected to be priced at a large discount to oil in the long term
- Differentials in fuel prices create strong commercial incentive for switch to natural gas



Environmental

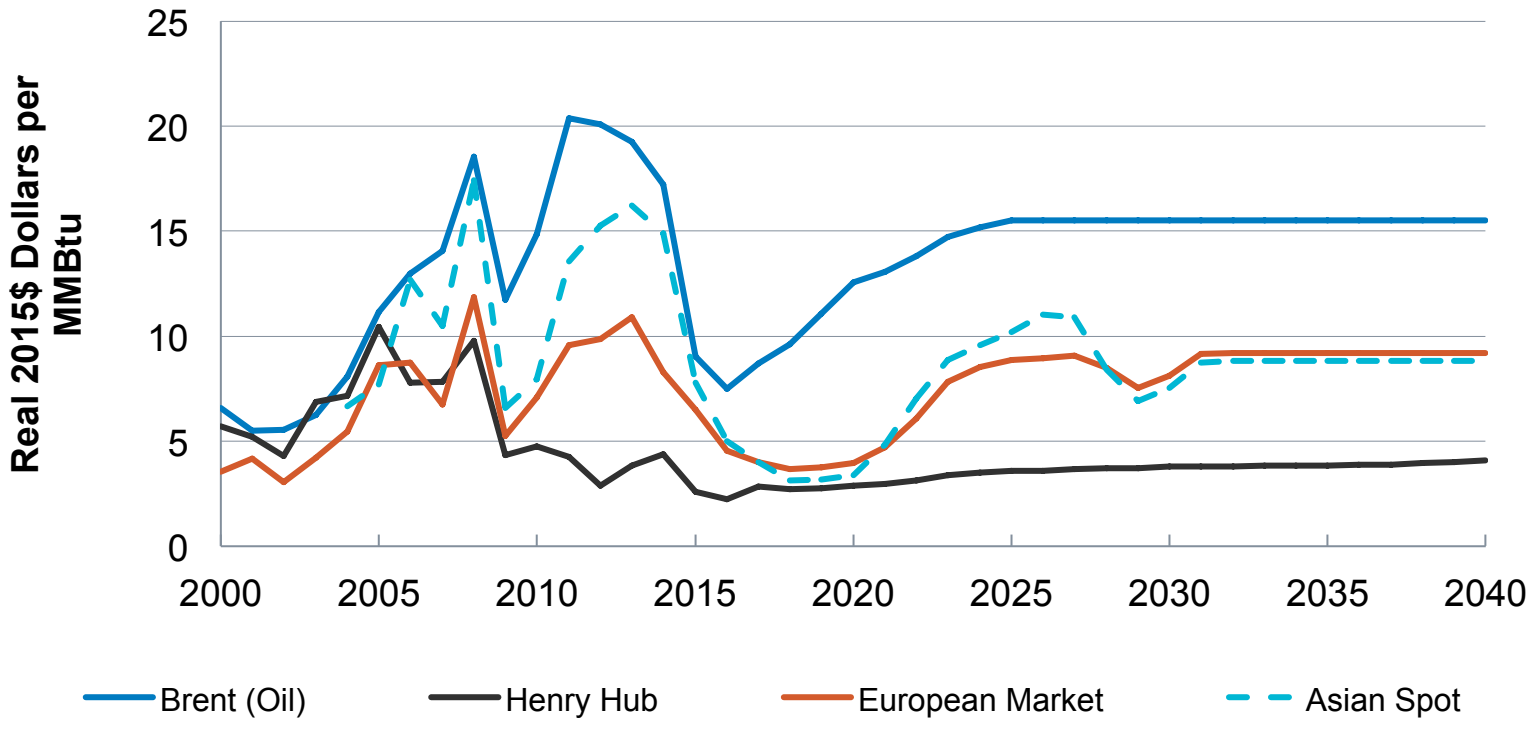
- Natural gas offers much lower emissions in transport, even with increasingly strict fuel standards for oil
- Policies to improve air quality make a stronger case to move to natural gas

Technical

- Technology for natural gas engines has continued to develop, closing the performance gap to diesel
- New generation of vehicles are becoming more attractive for operators

A continued price differential between oil and gas is expected to last

IHS Base Case: Comparative gas prices (Real), 2000-2040



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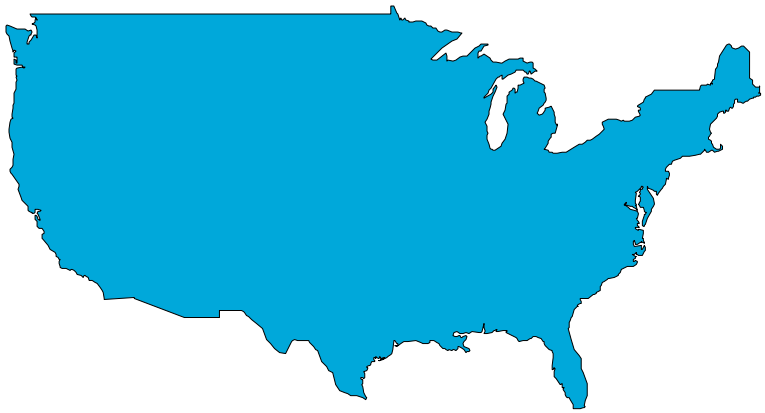
Natural gas in on road transport: United States



Summary of natural gas in transportation today

United States

Light-duty Market

- **Expect slow growth for natural gas in light-duty transportation.**
  - High up-front purchase price, limited driving range, continued advancements in the internal combustion engine, and consumer acceptance of alternative technologies influence the pace.
  - Though there are limited CNG factory direct vehicles on offer there are after-market CNG conversions
- **Federal and state policies favor plug-in electric vehicles (PEVs) over natural gas vehicles (NGVs)**
  - CAFE credits & CA ZEV Mandate favor PEVs
- **High cost of CNG refueling infrastructure makes a consumer market for NGVs difficult to develop, but commercial fleets holds some promise.**
  - Residential CNG ~ $5,000
  - Commercial $500,000 - $750,000

Heavy-duty Market

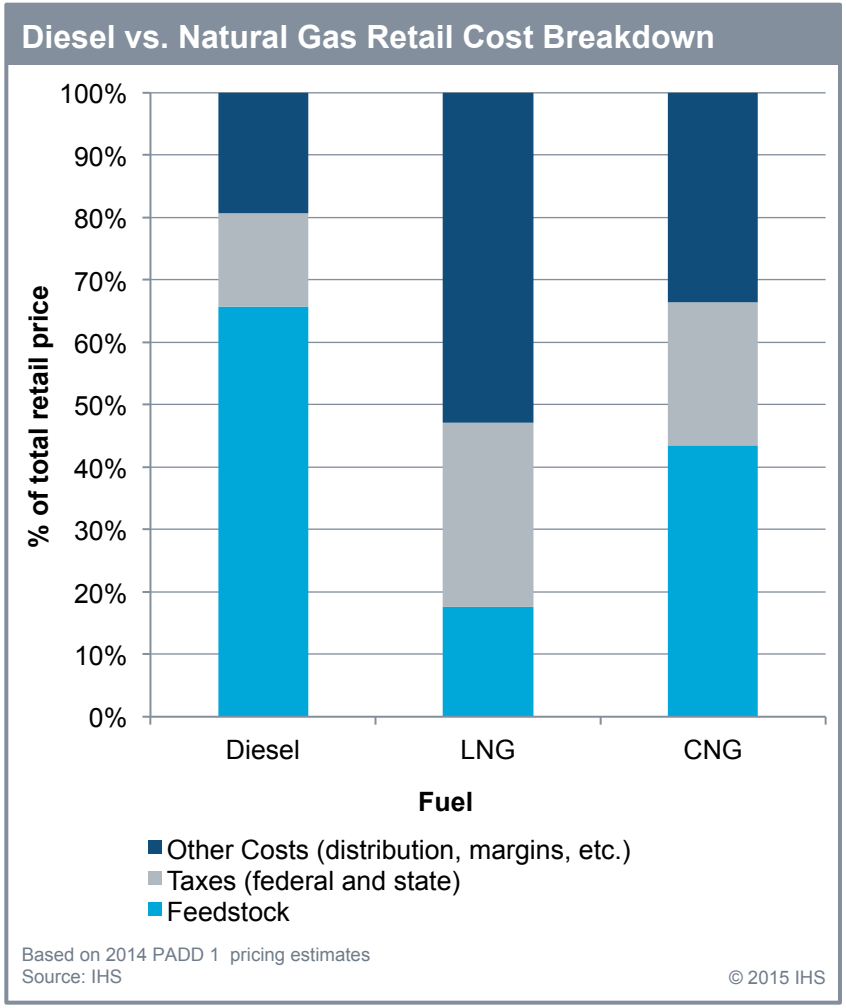
- **US HDV truck operators are still running pilot cases to test natural gas in their fleets**
  - Operators are very cautious to change
  - Drop in oil prices made operators even more cautious
- **LNG now faces major new challenge from CNG 'long-range solutions'**
  - Natural gas can be stored as either CNG or LNG on the vehicle, current US HDV engine offerings focus on spark-ignition (SI) engines
- **CNG and LNG retail is growing, however it still remains a bottleneck to wide spread CNG/LNG truck adoption**
  - "If you buy it they will come": US natural gas supply and retail is ready and able to quickly support operators as sales grow.

What entices HDV operators to finally make the switch?

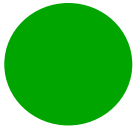
1. **Low payback times**
   - Fuel is a major cost to the heavy goods industry but in order to make the switch to system that offers cheaper fuel at the pump, operators need to see the extra investment of a natural gas truck paid off quickly. This is achieved through a wide natural gas-diesel spread and/or low incremental truck costs.

2. **Stable prices**
   - Feedstock costs make up an estimated 15-40% of the total retail price for natural gas-based fuels, compared to over 60% of the retail diesel price. This means that in times of oil and gas price volatility, the price to end-users will fluctuate much less, giving operators a greater price stability around which to plan their budgets.

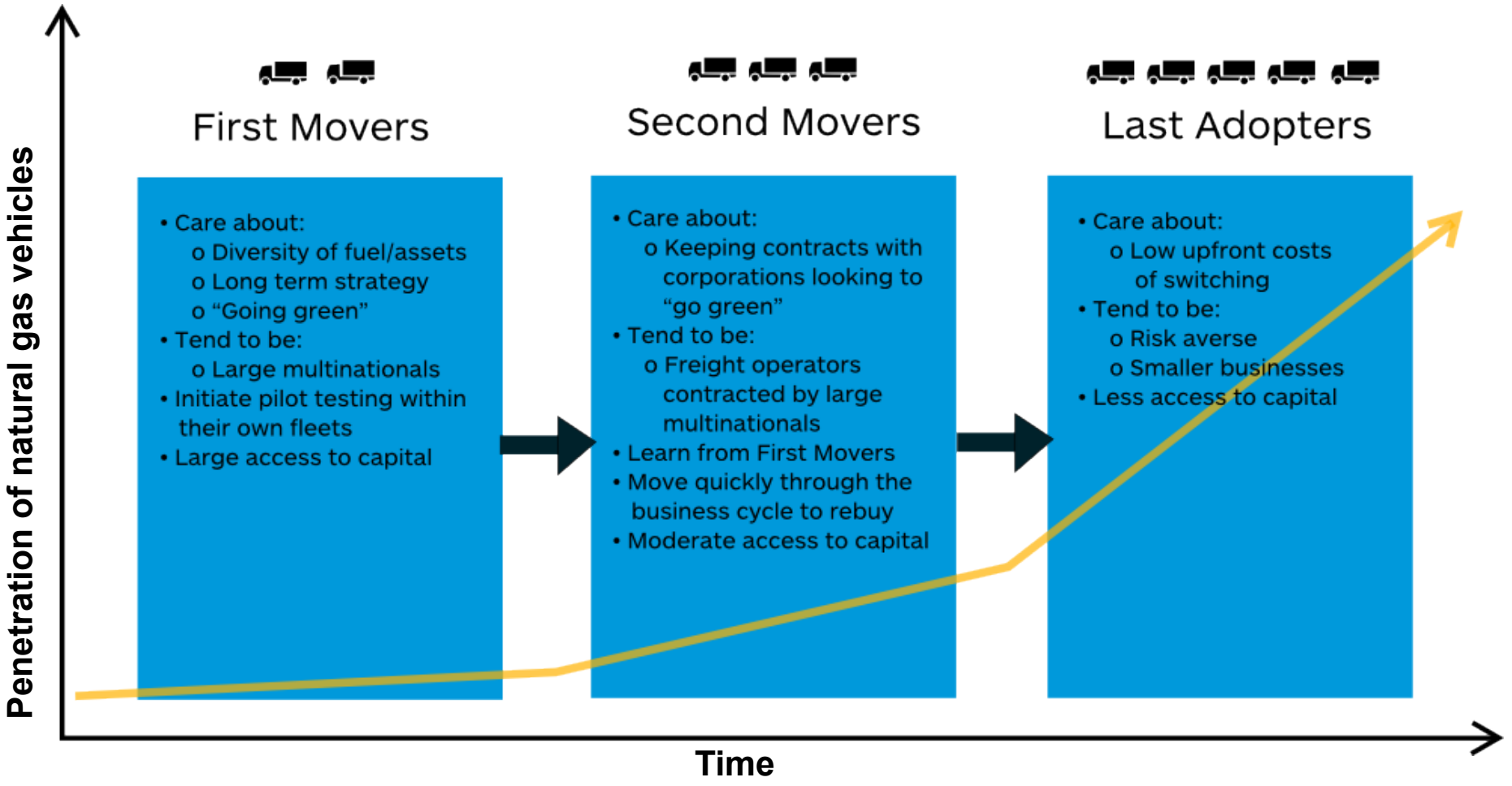
3. **Reduced emissions and after treatment requirements**
   - Diesel use requires extensive after treatment to remove particulate matter. Natural gas engines that don't require this extensive after treatment lowers maintenance costs.



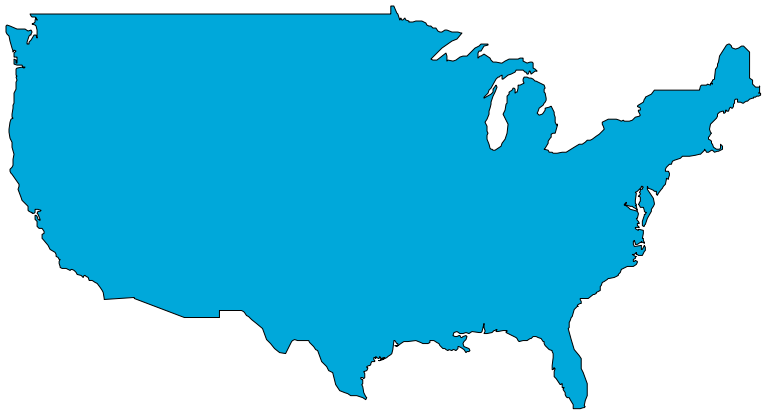
NGV adoption will also depend on freight business model

Business Model	Who owns the vehicle?	Sample Companies	Number of Company-owned trucks in fleet	Ease of entry into NGV market?	Comments
Full Company Ownership	Freight Company	Old Dominion Freight Line, YRC Freight	Old Dominion: 6,400 tractors YRC: 8,700 tractors		These companies have full control over their fleets, meaning they could be best positioned to leverage their integrated distribution across their vehicle fleet. These players often have large fuel supply contracts with major retailers
Freight brokers	Drivers/Owner Operators	Landstar	~ 235,000 class 8 trucks are controlled by owner/operators (~7% of all class 8's)		Companies that rely on owner operators are dealing with drivers who act as independent contractors and own their own rigs. While these owner/operators are highly sensitive to cost, they are also unlikely to invest in an NGV until infrastructure expands
Hybrid	Freight company and/or Owner/Operator	FedEx Ground, UPS, J.B. Hunt, Con-way Freight	UPS: 100,000 trucks FedEx: 77,000 trucks J.B. Hunt: 10,500 trucks Con-Way: 2,700 trucks		Hybrid companies that own some vehicles and also hire owner/operators have expressed interest in experimenting with NGVs, especially amongst companies like UPS that have a large company-owned fleet

Sales profile: who buys, when and why



CNG vs LNG



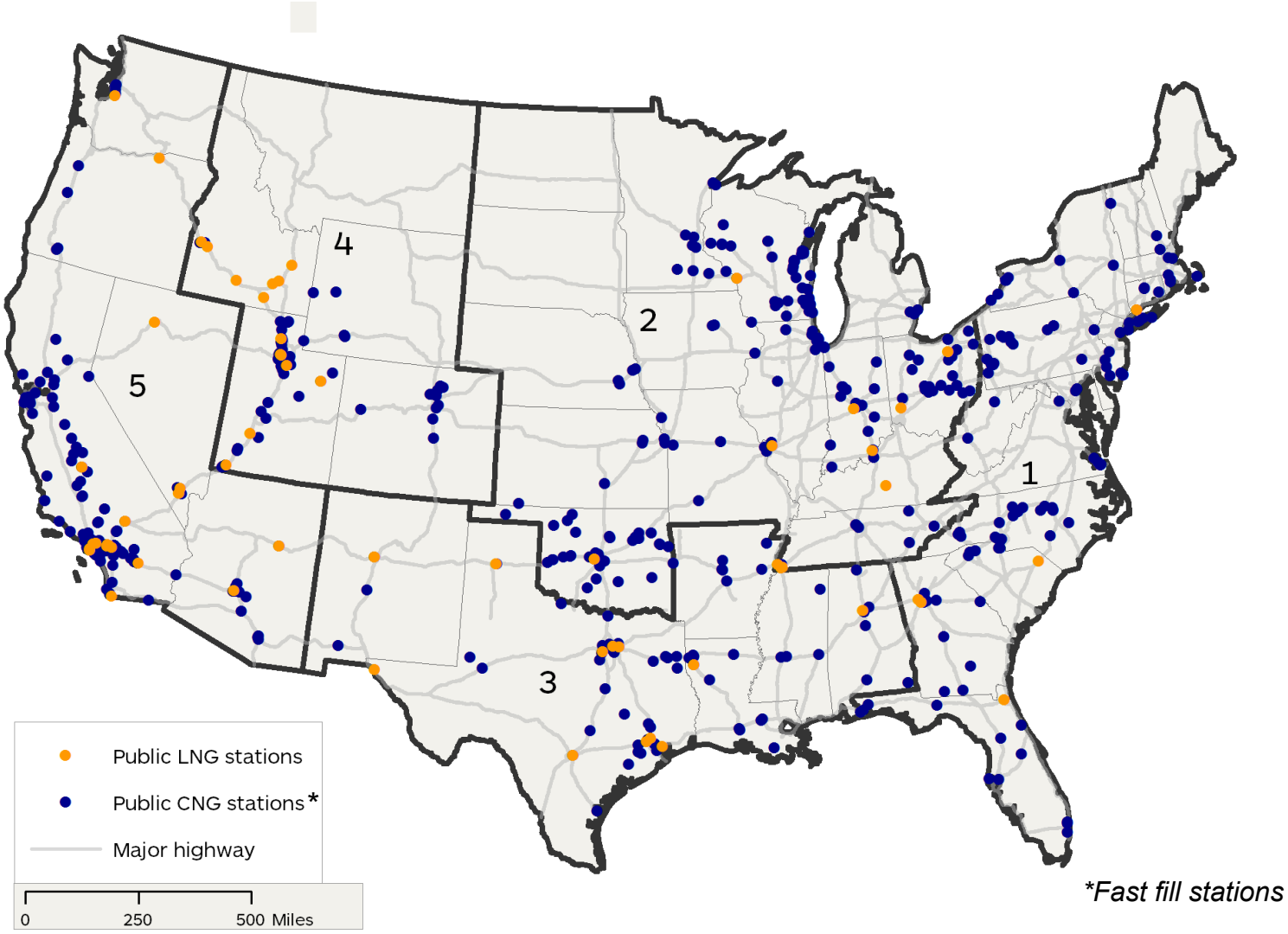
Recent CNG tank improvements have made CNG in the US an option for long-haul trucking

- Tank storage for CNG has greatly improved in recent years due to increased R&D and investment
- Type IV CNG tanks are up to 70% lighter than conventional steel tanks and are less corrosive
- Type IV CNG tanks are also much more expensive then types I through III, hence the increased cost of CNG storage relative to LNG

CNG storage issues

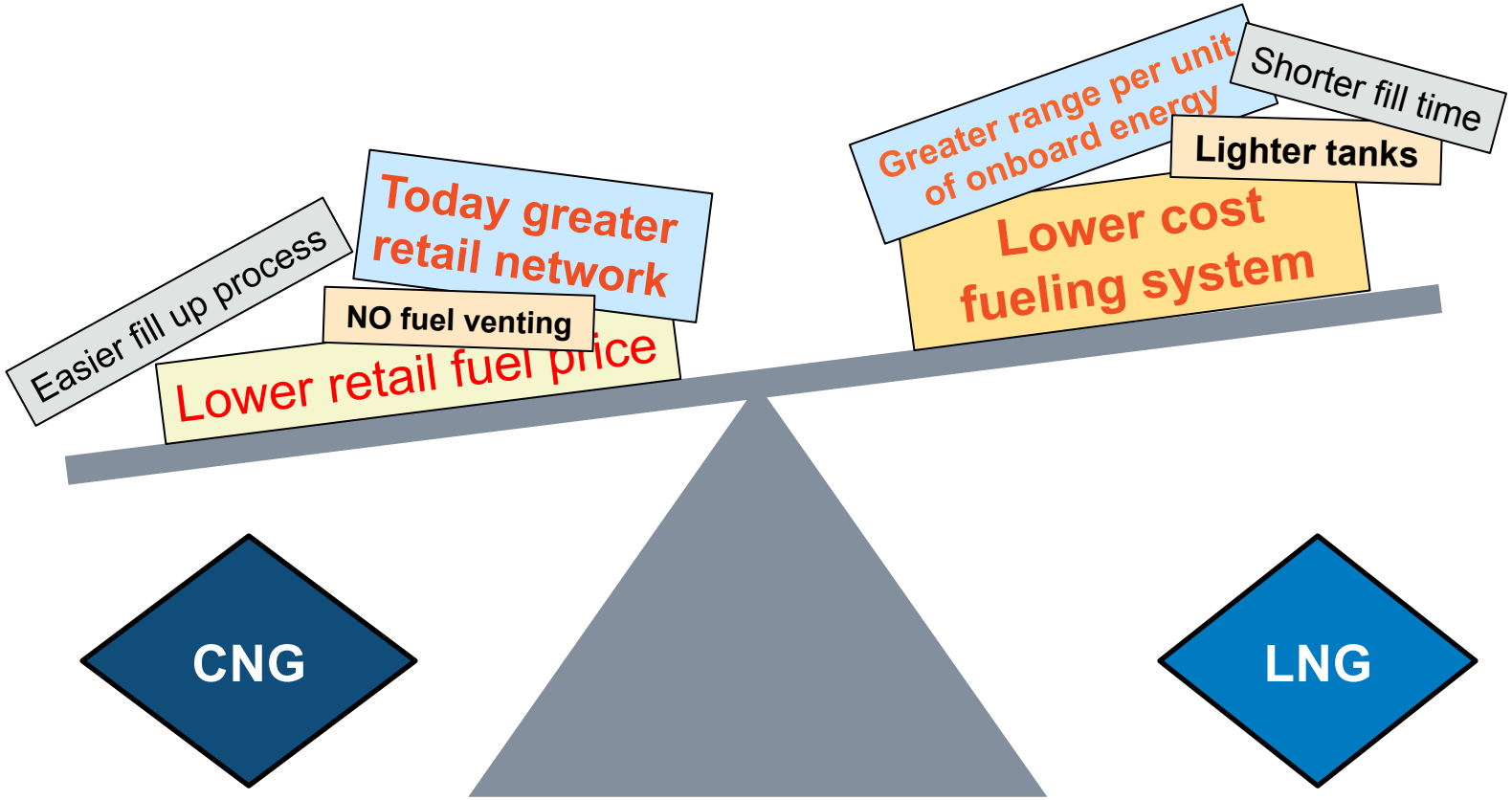
- Although the storage systems for CNG have made the fuel an option for long haul applications, there remain important considerations:
  - Only ~90% of this capacity is usable as 10% needs to remain in the tanks
  - Fast fill required but reduces usable capacity: For use in highway freighting operations, fast-fill CNG is essentially a must-have, but in achieving a fill rate of 10 DGE/minute, the capacity is effectively reduced by an additional 5%
    - Fuel is not lost, but rapid fueling produces heat, expanding the hydrocarbons and taking up more space

CNG infrastructure outpaces LNG

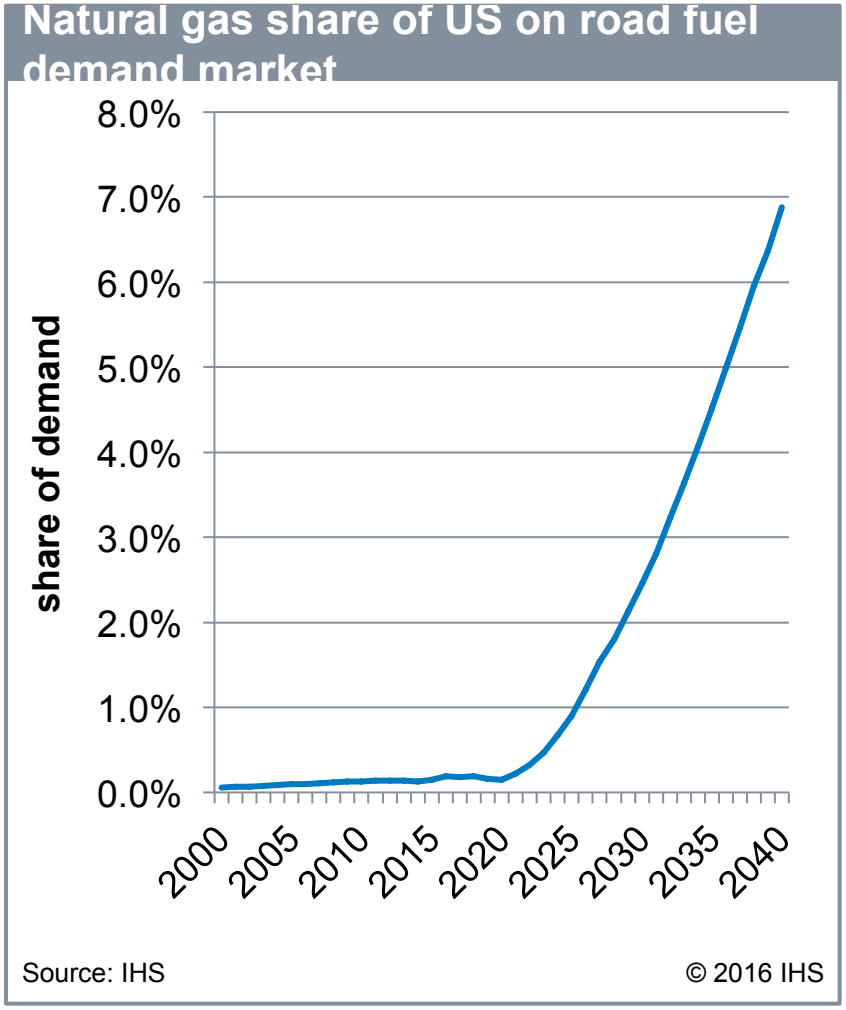


*Fast fill stations

With similar payback times, IHS expects other CNG benefits, to tip the scale towards CNG adoption in the US



US natural gas demand is expected to make slow in roads into US on road fuel demand



- **CNG in LDVs is expected to be stay niche and limited to fleets.**
  - Lack of policy support and vehicle options keeps vehicle costs high
  - LDV lower annual mileage makes the payback time for high cost CNG vehicles 5 years or longer depending on the gasoline/CNG price differential
  - CNG in LDVs might gain traction if the refueling infrastructure is created through HDV applications first
- **CNG/LNG in HDVs has a greater market potential since these vehicles run at much higher mileage making the pay back more reasonable**
  - Today's lower oil/gas price differential has slowed down adoption, however certain majors are still running their pilot cases
  - While LNG is more popular in other markets, IHS expects CNG to gain more market share in the US HDV market

Natural gas in on road transport: China & Europe

LNG predominately dominates the Chinese and European HDV markets

Chinese On Road Market

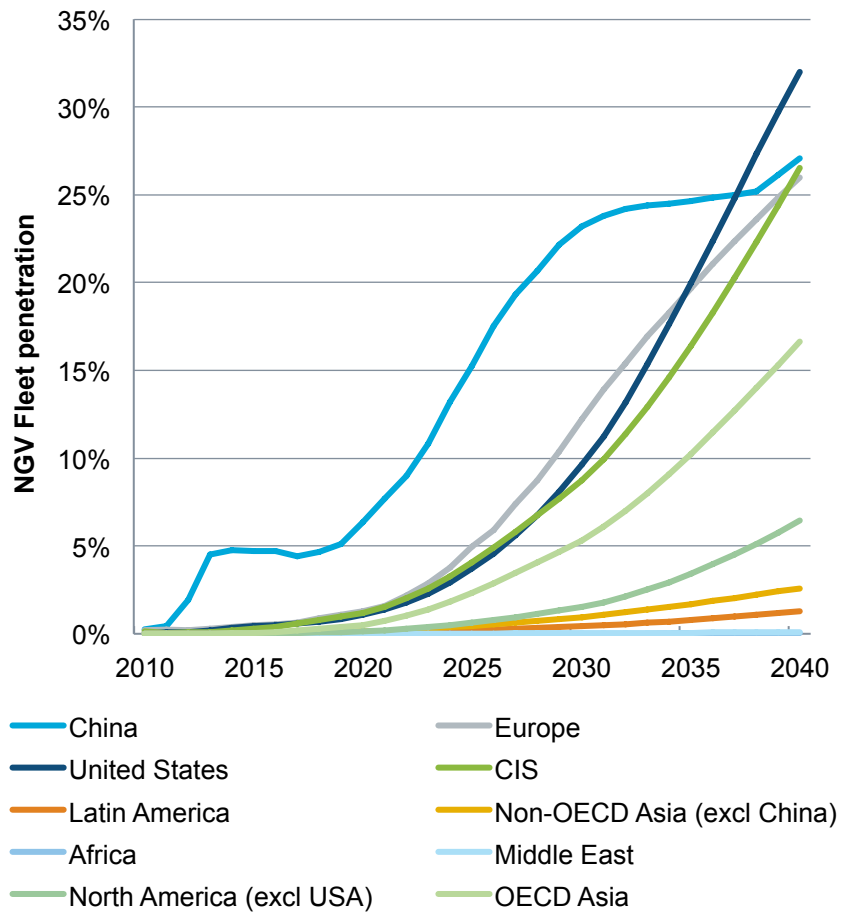
- **CNG is very limited in the LDV market**
  - Currently Chinese vehicle policy is focused on promoting PEVs for the passenger vehicle market
  - IHS expects CNG in LDVs to remain a niche market
- **While LNG quickly gained market share back in 2012, natural gas price reform and growing economic weakness, particularly in construction and heavy industry, has slowed adoption**
  - Price reform has increased the payback period, and smaller companies are hesitating to make the switch
  - On the flipside, tightening fuel and emissions standards are making diesel trucks and fuel costs higher, increasing the competitiveness of natural gas.

European On Road Market

- **CNG in LDVs is very limited and extremely dependent on policy.**
  - Current European policy is focused on promoting electric vehicles for the LDV market
  - Certain countries promote CNG over others – Italy, Germany, Sweden, and France
- **LNG has a price advantage over CNG and thus is preferred for HDV operators**
  - LNG is already imported and ready to use, where as CNG would have to be either first compressed, or re-gasified and then compressed from LNG, making the retail pump price higher compared to LNG
  - European Union has very supportive natural gas adoption policies, however there has still be little movement towards adoption

Regional dynamics lead to regional differentiation

Heavy freight NGV fleet penetration, IHS Base-Case



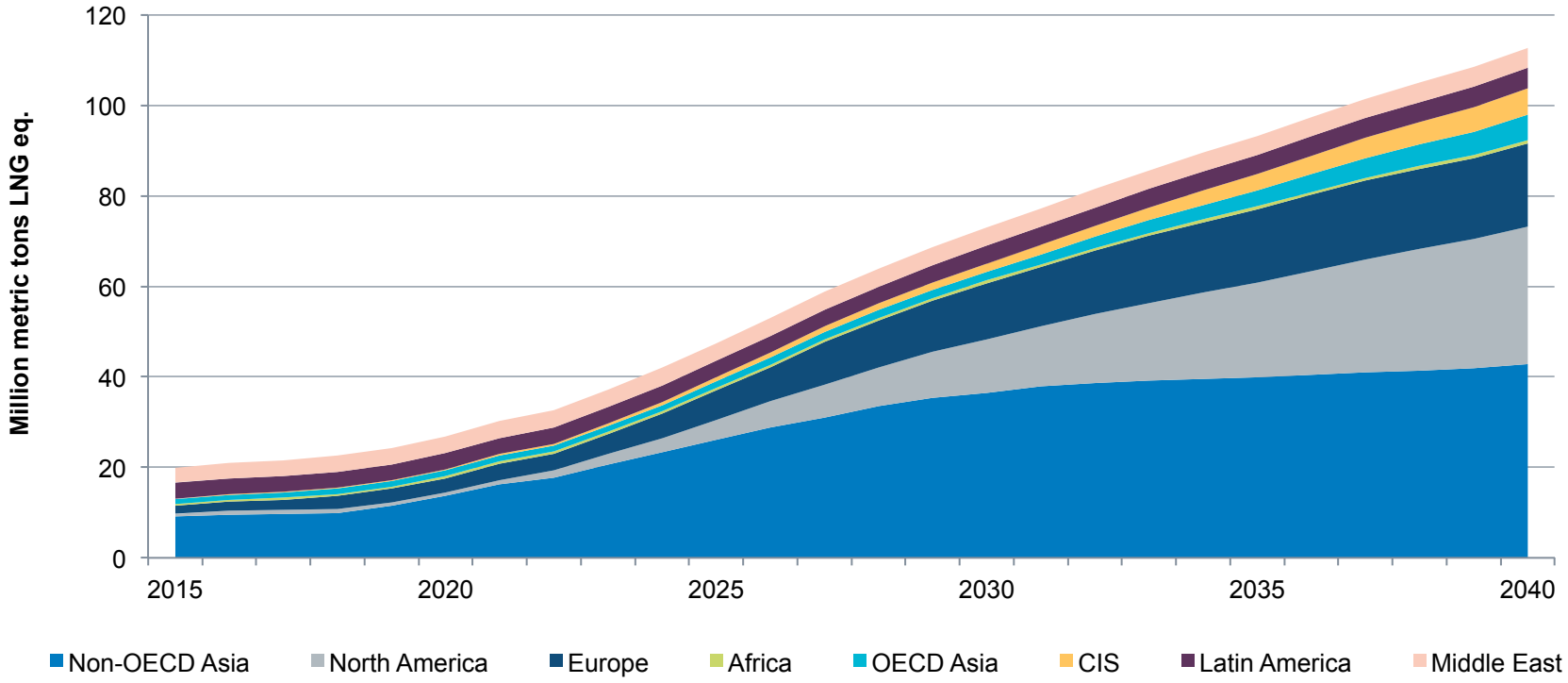
Source: IHS

- Each market has a key element which makes it economically attractive:
  - US – low gas prices
  - Europe – high diesel taxes
  - China - Low incremental truck costs
- Each of these factors leaves little room for improvement, other than through higher oil prices and improvement in the other areas.
- Economics are a strong driver of fleet penetration, but they are secondary to policy decisions

Natural gas use as a road fuel

The use of natural gas in heavy goods vehicles (trucks) is expected to grow globally, especially in China and North America. Stronger oil prices are needed to accelerate the pace of adoption.

Natural Gas consumption in the heavy-duty truck sector



Notes: Includes all forrms of gas
Source: IHS, July 2016

NOTE 1: Heavy-duty truck natural gas demand could be met by LNG or CNG.

Thank you!

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