IPA ADVISORY LIMITED

INDUSTRY INSIGHT

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Fuel Substitution in European Transport

LNG in transport gains momentum but still faces significant hurdles

Summary

At the 2015 World Gas Conference in Paris, several major oil, gas and energy companies said they would work towards an energy system in which natural gas and renewables play a bigger role, notably in the transport sector. Although the sharp drop in oil prices has reduced land and marine transport fuel costs, Liquefied Natural Gas (LNG) prices have also fallen – partly because of a growing LNG glut but also because of indexation of LNG prices to oil prices. In this paper, IPA examines the dynamics of fuel substitution in the European transport sector. It concludes that gas can be competitive in the transport sector, but that volatility between oil and gas prices means that government and regulatory support, fiscal incentives, or a higher carbon emissions price would be desirable for gaseous fuels to be more widely and rapidly adopted.

The substitution matrix

Natural gas has long had the potential to substitute for oil in the transport sector, a characteristic that has been encouraged by European Union (EU) directives which have stimulated the development of gas-fuelling infrastructure across the continent. A network of LNG terminals and filling stations is gradually being rolled out for use by sea-going and inland vessels, and large trucks. The increased use of LNG in transport is envisaged as part of a wider effort to connect off-grid industry to cleaner fuels. A recent EU directive (2014/94/EU) stipulates that member states must set and make public their targets and present their national policy frameworks for the deployment of alternative fuels by the end of 2016.

Recognising this trend, this paper examines the economic case for gas in transport in light of the lower oil and gas price outlook. Transport accounts for around one third of European primary energy demand, and all but 5% of that demand is currently supplied from oil. Because the carbon intensity of gas is lower than that of competing liquid fuels, substitution of gasoline and diesel by gas in the transport sector is widely regarded as having environmental benefits[1]. The nascent switch to gas in transport follows substitution of liquid fuels by gas over the last few decades in the power, industrial, residential and commercial sectors.

Table 1: CO2 Released per MMBtu

Source	Fuel Type	Pounds CO_2
Coal	Bituminous	205.7
Oil	Heavy Fuel Oil	168.7
Oil	Diesel	161.3
Oil	Gasoline	157.2
Gas	Liquefied Petroleum Gas	139.0
Gas	Natural Gas	117.0

Source: Energy Information Administration (EIA) / IPA

In land transportation, Compressed Natural Gas (CNG), LNG and Liquefied Petroleum Gas (LPG) compete with gasoline and diesel which currently fuel the vast bulk of the world's vehicles. CNG and LPG are generally preferred for shorter range and low horsepower vehicles, while LNG is preferred for large long-haul and high horsepower (HHP) trucks and, potentially, also for rail transport.

In marine transportation, interest in LNG-fuelled vessels has been stimulated by IMO Marpol Annex VI rules which set a 0.1% sulphur limit for marine fuels in Emissions Control Areas from 1 January, 2015. Shippers can choose between either buying ultra-low sulphur fuels or putting stack emissions scrubbers on board their vessels. Diesel, LNG, CNG, methanol, LPG and several newly-formulated grades of residual fuel oil are among the fuels available to shippers that allow compliance with Marpol Annex VI, but the most immediate competition for new vessels is between LNG and diesel.

The degree to which fuel substitution actually occurs depends on five main factors:

- The respective price of the competing fuels;
- The potential for price volatility between the fuels;
- The availability of suitable infrastructure;
- The cost and reliability of new gas engines; and
- The degree of government and regulatory support.

These five factors are the matrix through which end-users evaluate the risk they face in moving from an incumbent fuel such as heavy fuel oil (HFO) to a new fuel such as LNG. Other more subtle and less quantifiable factors may also have a bearing, such as safety issues around using the new fuel and reputational issues relating to public perceptions of the traditional and new fuels. The totality of these factors will determine the end-user's choice of fuel. A fuel consumer with older vessels and/or trucks which need replacement soon will have different economic incentives to one that has recently invested in new facilities. The extent to which these factors favour fuel substitution will vary by

[1] However, issues such as "methane slip"(emissions of methane during fuelling) have yet to be resolved. The use of dedicated new LNG vessels can minimise this risk and researchers are investigating the potential for a variety of technologies to eliminate these emissions.

geographical region but it also changes over time depending on energy policy imperatives and strategies.

LNG and diesel price comparison

Around 70% of the LNG traded around the world is linked to oil prices. The usual mechanism is to set a formula based on a slope (gradient) and a coefficient that sets LNG at a discount to the oil price. Oil is typically priced in dollars per barrel and gas in dollars per MMBtu; the conversion between the two fuels depends on the calorific value of the fuel. Oil parity is the LNG price that would be equal to that of oil on a barrel of oil equivalent basis. Because one barrel of crude oil typically yields around 5.8 MMBtu of energy, a slope of 0.172 results in crude oil parity. The typical parity of LNG with different grades of oil is provided in Table 2 below:

Table 2: Conversions to Oil Parity

Fuel	MMBtu/bbl	Oil parity (bbl/MMBtu)
Diesel	5.60	0.178
Crude Oil	5.80	0.172
Fuel Oil	6.22	0.160

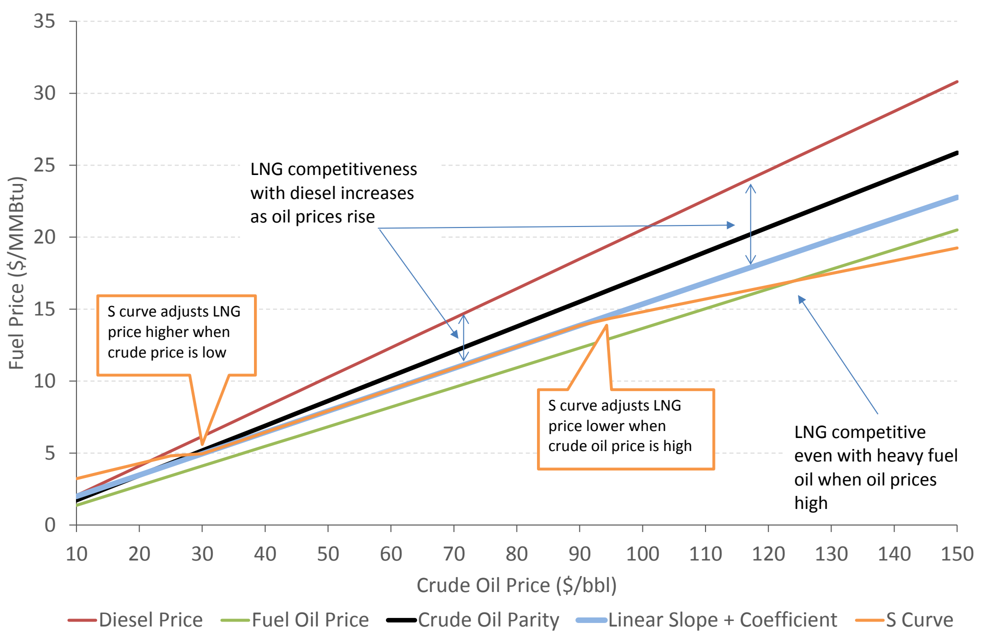
Source: IPA analysis

Although a slope of around 17.2% represents parity between LNG and crude oil prices, market participants in practice negotiate variable slopes and coefficients that build in discounts to the crude oil price in long term contracts. In many contracts, the parameters are varied to smooth the impact of very high and low oil prices, using the so-called S curve mechanism.

The linkage between wholesale oil and gas prices is seen in Figure 1 below using an indicative slope of 14.85% and a coefficient of US $0.50/MMBtu (blue line) and a simple S curve with inflection points at US $30/bbl and US $90/bbl (orange line). These are charted in comparison with diesel (red line), crude oil parity (black line) and heavy fuel oil (green line). The diesel and fuel oil prices have been estimated using crack spreads that scale linearly with the outright price.

It should be noted that, while the above formula is commonly used in LNG pricing, the detailed parameters of long-term contracts including the slope, coefficient and any S curve are invariably commercially confidential.

Figure 1: Fuel Price Comparison



Source: IPA analysis

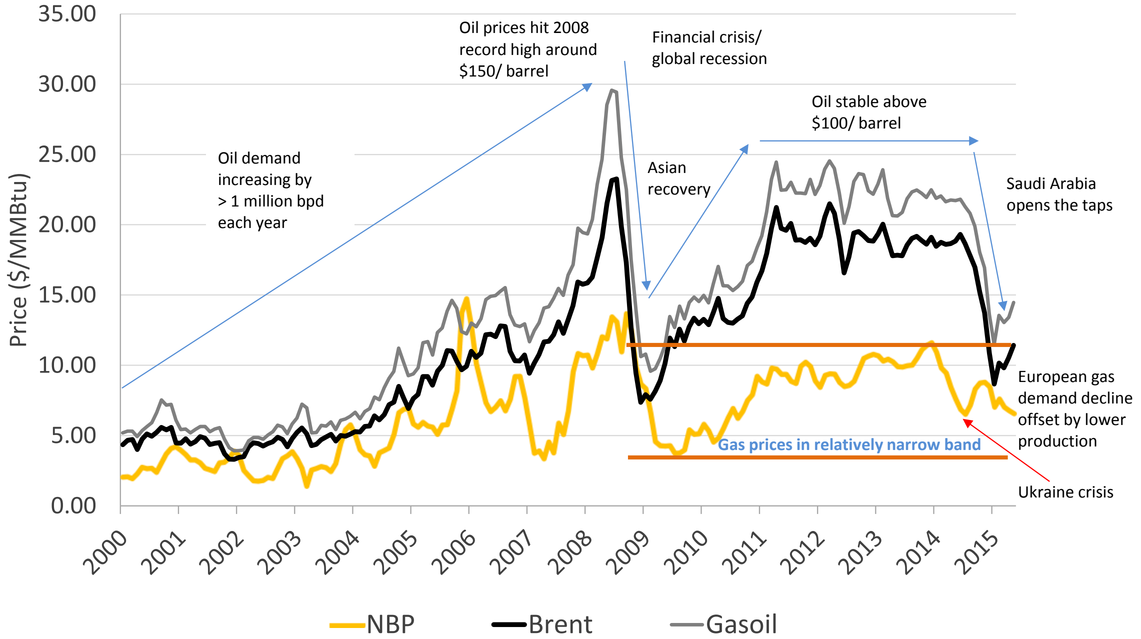
Oil / gas price volatility

From 2011 until about mid-2014, the LNG price was significantly higher than hub prices for gas in Europe: Asian demand had been strong following the Fukushima nuclear accident while European gas demand had dropped because of the availability of cheap coal, the adoption of energy efficiency measures and the uptake of renewables. Since mid-2014, however, oil and gas prices have collapsed and a wave of liquefaction capacity additions have, and will continue to, put pressure on LNG prices. The market is glutted with LNG and spot prices remain at significant discounts to contract prices.

Given this background, IPA considers that natural gas prices in Europe are unlikely to recover substantially beyond normal seasonal variations from their 2015 low levels around US $6-7/MMBtu. In the face of shrinking demand for gas in Europe, Russia has already built up around 100-110 billion cubic meters per annum (bcma) of "excess" natural gas capacity, as Gazprom has prioritised price over volume in its sales strategy. The growing volumes of LNG from the US will potentially put Washington in direct competition with Moscow for the European gas market, however, and there are already signs that Gazprom may be shifting even further towards flexible pricing strategies.

Although weaker gas prices should encourage more demand, the key driver of gas use in transport is the relative strength or weakness of the gas price compared to that for oil products. Figure 2 below shows that while gas prices in the bulk market have fallen, the price gap between the fuels in US $/MMBtu has contracted sharply, reducing the incentive to switch from diesel to LNG.

Figure 2: Crude Oil, Diesel and Natural Gas Future Prices

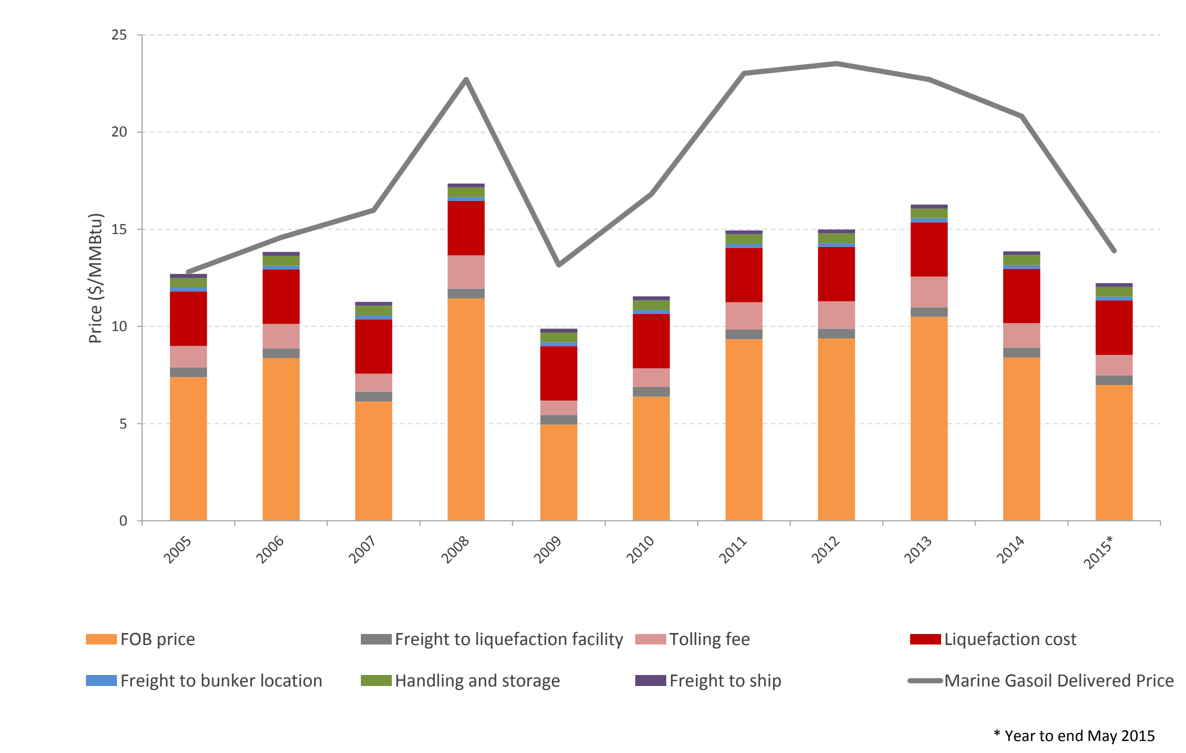


Source: ICE Futures, CME, Energy Information Administration

The price advantage of LNG is also reduced by the more complex supply chain involved in moving the gas to a ship or truck. In the case of gas supplied from a trading hub to a small scale LNG plant to a bunkering location or LNG filling station, the additional costs include the cost of liquefaction of the gas, the tolling fee, storage costs, and the combined freight costs to move the gas from the hub to the final end-use location. Another model in Europe involves the delivery of LNG on tankers to the bunkering location, with subsequent breakbulk and bunkering facilities to distribute the LNG to the end-use location. In this case, the additional costs also include the cost of freight from the LNG terminal to the bunkering location or to the truck loading location.

Because natural gas in Europe is based on trading at gas hubs such as NBP and TTF, which unlike LNG are not directly linked to oil prices, there is a degree of volatility between the prices of the various fuels and also between the price of imported LNG and hub prices. Because the LNG bunker market is still in its infancy, it is not easy to compare the volatility of LNG bunker prices and the price of marine diesel/gasoil and HFO. Figure 3 below shows the estimated price of bunkers for delivery in the Amsterdam-Rotterdam-Antwerp (ARA) region based on hub prices for natural gas and the additional costs likely to be incurred in selling the gas as LNG bunker fuel:

Figure 3: LNG Bunker Price Build-up and Marine Gasoil Comparison



Source: ICE, IPA estimates

Infrastructure availability

The availability of infrastructure to fuel ships, as well as long-distance and HHP trucks, has been a stumbling block to the more widespread uptake of LNG as a transport fuel.

LNG as a marine fuel and as a long-distance trucking fuel still to some extent suffers from the “chicken and egg” problem: a lack of available infrastructure discourages vehicle manufacturers from investing in gas-fuelled vehicles; while lack of gas-fuelled vehicles stymies the development of gas-fuelling infrastructure. However, EU measures are expected to result in several additional terminals being constructed to supply LNG to vessels in 2016.

However, the infrastructure for delivering LNG to vessels is limited outside a core area. Even within the North West Europe region, infrastructure constraints have implications for LNG pricing to the end user. The costs of delivering LNG bunkers to a vessel illustrated in Figure 3 above were estimated for a facility with integrated liquefaction and transport infrastructure. The supply-chain in many locations is less optimal, however, and the transport of LNG to individual bunkering locations via truck or bunkering barge may involve longer journeys than those implied by the freight element depicted.

The LNG infrastructure for road transport in Europe is also being expanded, although the transition may take longer. A March 2014 study by Oxford Institute of Energy Studies noted that only 40 filling stations for LNG/CNG existed in Europe, compared to 27,500 for LPG and 131,000 petrol/diesel filling stations. Moreover, the investment cost for developing new filling stations able to deliver CNG/LNG is estimated at five times that for conventional liquid fuels[2].

Gas engine reliability and efficiency

In the past there have been issues over the reliability and efficiency of gas engines, but the efforts of large manufacturers have largely solved these problems in the marine fleet. Running LNG vessel engines on boil off gas is commonplace in LNG carriers, and some large engine manufacturers have developed efficient dual-fuel engines that allow full flexibility between liquid and gas-fuelled modes of operation. In addition, the adoption of various heat recovery methods has improved energy efficiency and is estimated to have reduced fuel consumption by up to 15%.

Because of this, the LNG fleet has expanded from ferry systems and smaller, feeder-type vessels, to larger vessels such as cruise and container ships. Methane slip remains a concern because methane is such a powerful GHG, but this risk can be mitigated in new vessels and technologies comparable to catalytic convertors in cars are currently being researched.

According to the World Ports Climate Initiative (WPCI), the LNG-fuelled fleet is expected to double in size by the end of 2016 and vessel order books reflect a move towards larger vessels including tankers, container ships, general cargo ships and RoRo ships.

In the land-based trucking fleet, LNG fuelled vehicles typically have a lower fuel efficiency than equivalent diesel trucks – up to 20% less according to press reports. However, even here, a number of Engine Control Systems have been developed that claim to enhance the fuel efficiency of gas-fuelled trucks by as much as 50%.

Government and Regulatory Support

In Europe, regulatory support for gas use has, until recently, been lukewarm because of energy security concerns related to Europe’s dependence on Russian gas. This has resulted in a lack of incentives to roll out the necessary infrastructure to support gas in transport. However, the advent of US LNG exports (scheduled to begin later this year) and the prospect that much larger volumes from the US should be available from 2018 and beyond has changed European attitudes towards LNG imports. At the EU-US joint summit in March 2014 held in the wake of the Ukraine crisis, the EU Council recognised that LNG imports from the US could potentially enhance energy security.

The EU is also supporting the development of a gas-fuelling infrastructure, adopting a two-pronged approach: for marine fuels, it has proposed making LNG fuelling available in all 130 marine and inland ports within the EU; while for long-haul freight, it has set up the “Blue Corridors” scheme to create LNG filling stations on a west-east and north-south axis, for use by large HHP trucks. The LNG fuelling infrastructure is being developed in parallel with plans to develop LNG for use by off-grid industry.

The European Commission introduced its Clean Power for Transport Strategy and issued the directive on the deployment of alternative fuels infrastructure as its main instrument. The directive requires the roll out a network of refuelling points for LNG at maritime and inland ports and for land transport along what is known as the Ten-T core network. However, the timetables for delivering the relevant infrastructure are extended – maritime ports will only have to have LNG refuelling in place by 2025 and inland ports by 2030.

For land transport, the focus has been on large HHP trucks. The Blue Corridors project aims to set up a network of CNG/LNG filling stations for long-haul freight crossing 11 countries along four key transportation routes (We Blue, SoNor, Med Blue, and Atl Blue). The transport projects are now incorporated in the broader framework of the Horizon 2020 programme (the biggest EU Research and Innovation programme) while funding for alternative fuel projects, including LNG, that contribute to the Trans-European network is being made available through the Connecting Europe facility. The EU has also put in place a number of expert groups, committees and technical research studies to support the development of alternative fuels, including LNG.

[2] Source: AVERE, 2012.

Moving Forward

The analysis above sets out the dynamics of fuel substitution under different price scenarios for oil and gas. The collapse in global LNG prices has made pipeline gas and LNG cheaper in Europe, but the simultaneous fall in oil prices has narrowed the competitive edge of gas relative to oil products such as diesel. The gap between traditionally “high price” LNG regions such as northern Asia and lower price regions such as Europe and the US has also narrowed. Asia’s enduring demand for LNG is likely to mean that LNG prices act as a cap to natural gas prices in other regions, through arbitrage economics. While this may put a lid on gas prices for several years, the current weakness of oil prices erodes the competitiveness of gas and LNG relative to liquid fuels.

Weaker prices are, therefore, a double-edged sword for the use of gas in transport. The economics of using LNG rather than diesel in bunkering are inconclusive at lower oil prices, although there are clear benefits when oil prices are above US $80/bbl. When prices are built up from lower priced hubs with gas-on-gas indexation, LNG as a bunker fuel is potentially competitive with diesel even when oil prices are around US $60/bbl.

However, the volatility of oil and gas prices is likely to be a deterrent to using LNG as a fuel in transport unless pricing or fiscal mechanisms are applied that incentivise the uptake of gas in transport.

In addition, government and political support will be required to build up the required infrastructure. Tax incentives and subsidy schemes are likely to be needed to fuel the pace of investment in gas in transport. The uptake of LNG in bunkers and of gas in the transport sector could be speeded up by duties that favoured the use of gaseous fuels relative to gasoline and diesel. Alternatively, a higher carbon price could allow the carbon intensity of the different fuels to be reflected transparently in the price paid by the end-user either at the pump or at a bunkering location.

IPA considers that, because lower oil prices have made fuel substitution less attractive in the transport sector, the uptake of gas/LNG in transport will need to be incentivised through these or similar measures. There is a strong case for governments to consider such measures given the lower emissions profile of gas compared to other fossil fuels.

How can our Oil, Gas & LNG Team help?

IPA provides advisory services along the full oil and gas value chain, upstream development to downstream markets. We have a team of experts across the entire value chain in oil, gas and LNG providing fundamentals analysis, providing regional and global insights and techno-economic analysis.

What services have we provided in Small Scale LNG?

The IPA team has helped a range of clients to develop strategies, understand markets and to identify their risks. We have assisted our clients with everything from the development of LNG import strategies to LNG end-use in transport and the integration with off-grid industrial applications. IPA provides techno-economic appraisals of projects, global and regional market and pricing analysis, commercial and transactional technical and market due diligence.

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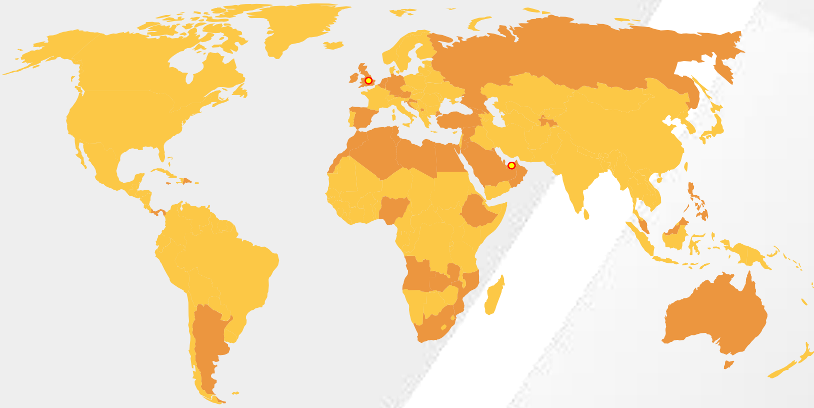
IPA works with governments, national and independent oil and gas companies, utility companies, private equity investors, banks, regulators and lawyers in the UK, Europe, Russia/CIS, Middle East, Africa and Asia.



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