



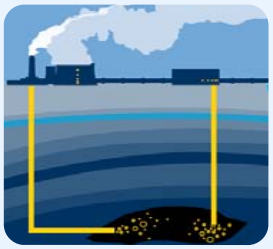



Gas refuelling infrastructure in the UK

LowCVP gas workshop – May 2016

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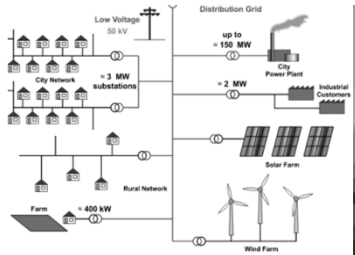
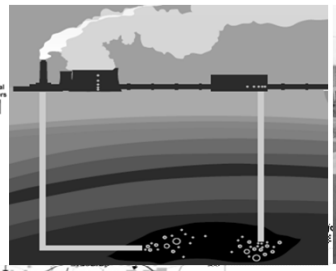
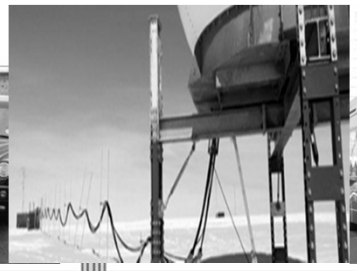
About Element Energy – a consultancy focussed on the energy sector

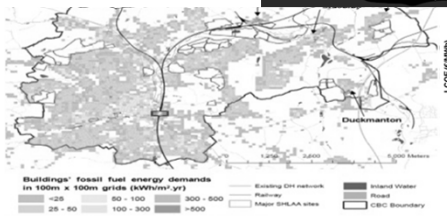
- Element Energy is a **specialist energy consultancy**, with an excellent reputation for rigorous and insightful analysis across a wide range of low carbon energy sectors
- We consult on both **technical and strategic issues** – we believe our technical and engineering understanding of the real-world challenges support the strategic work and vice versa
- These include: **smart electricity and gas networks**, **energy storage**, **carbon capture**, **renewable energy systems** and **low carbon vehicles** (gas, hydrogen and electric vehicles as well as biofuels)

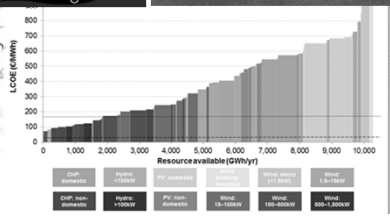
Energy technologies modelling	**Consumers behaviour modelling**	**Energy networks modelling**	**Advanced geographic modelling**	**Project management**
Policy recommendations	**Strategic market analysis**	**Commercialisation strategies**	**Techno-economic studies**	**Project financing**

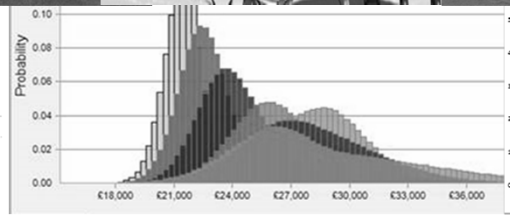


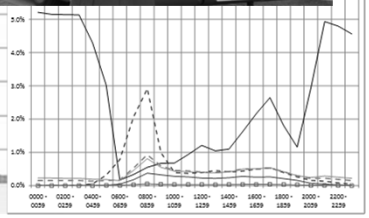












Source: Element Energy

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Gas is either dispensed in compressed state (CNG) or liquefied state (LNG)

Gas refuelling

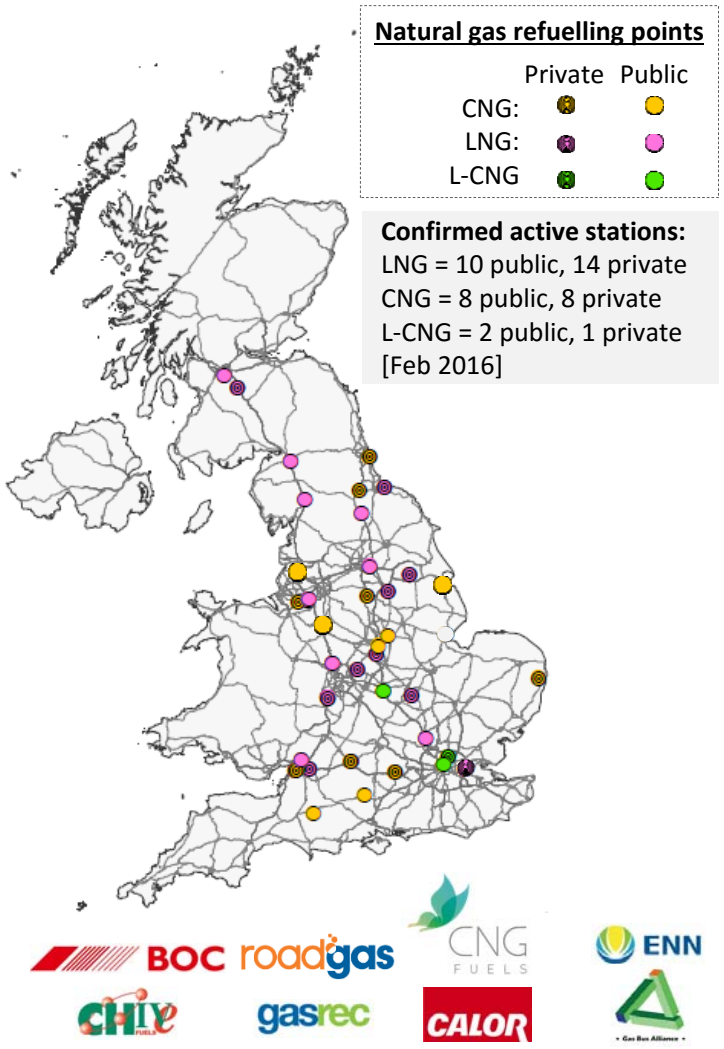
- Similar to conventional fuelling process (few minutes)
- Indicative price range: £0.64-£1/kg

- Gas is available:
  - In gaseous form (**CNG - compressed natural gas,** 200/250 bar) or
  - in super-cooled liquid form (**LNG – liquefied natural gas,** -160°C, <10bar)
- Currently a few publically accessible stations – shown next
- Dedicated depot filling points possible
- A number of fleet operators have **semi-private refuelling facilities** allowing pre-agreed operators to share facilities
- Existing gas network creates wide opportunities for new filling stations (subject to constraints due to varying pressures)

Gas prices as observed in Low Carbon Truck trial, reported in 2014, and Leyland station in April 2016 (64p/kg for CNG)

Gas refuelling infrastructure technology is mature but public coverage in the UK is low; fleets tend to rely on in-depot refuelling

Natural gas refuelling stations in the UK



Green gas supply

- CNG case:
  - Biomethane is injected in the gas grid and not used directly in a gas vehicle
  - Instead the injected biomethane is 'tracked' through a **Green Gas Certificate (GGC)**
  - Gas bus operators purchase GGC and can then claim the Low Emission Bus extra incentive
  - Price of a GGC is around 3p/kg as of March 2016
  - Many new biomethane projects are being commissioned in the UK, supported by incentives such as the Renewable Heat Incentive. No clear strategy in place yet from national government on how to prioritise use of biomethane between e.g. power, transport and heat sectors
- LNG case:
  - The only source of bioLNG in the UK has closed down in late 2015; there is no more supply

Sources: Gasrec, ENN, Calor, Gas Bus Alliance, BOC, Low Carbon Truck Trial, Element Energy
GGC prices as passed on at Leyland station in 2016

Gas refuelling for buses – overview and UK example

Bus gas refuelling – key facts

- Refuelling time similar to diesel fuelling process
- *Indicative* price: £0.75-£1/kg, i.e. c. 28p/km (45p/mile) for a single deck
- The gas is either
  - Taken from the gas grid and compressed to 200 bar
  - Delivered compressed from a 'mother station'
- Green gas Certificate can be purchased to match gas use to biomethane injection into the gas grid

Broad costs and specifications

- Costs will vary mainly depending on the extent of civil works. As an example, the station in Reading cost c. £1 million
- *Indicative* footprint of gas bus station:
  - 30 m x 20m (600sqm) for 10 buses, 2 dispensers
  - Trailer solution less space demanding
- Main CNG solution providers include Gas Bus Alliance, RoadGas and CNG Fuels

UK example: Reading gas bus station

Source: Element Energy for Centro, 2016
Pictures from http://www.getreading.co.uk/news/local-news/its-gas-gas-gas-reading-7739885

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Options for gas refuelling infrastructure

	Fuel type	Anchor demand (kg/day)	Comment on station capacity
Trailer-based CNG	CNG	No minimum per se but must be within c. 100 miles of a high capacity station	The "mother" station is a large grid connected station which has trailer loading facilities.
Gas grid-connected CNG	CNG	900	Capacity depends on grid connection pressure
Containerised LNG	LNG	850	At 1,500-2,000 kg/day, case for a skid-based station becomes economic
Skid-based LNG	LNG	1,500-2,000	No maximum
Skid-based L-CNG	LNG, CNG	2,000 LNG 1,400 CNG	CNG capacity depends on compressors

For LNG stations, liquefied gas is distributed to refuelling stations via road delivery from LNG facilities with truck loading facilities such as the one at Isle of Grain (capacity to fill 36 LNG tankers per day)

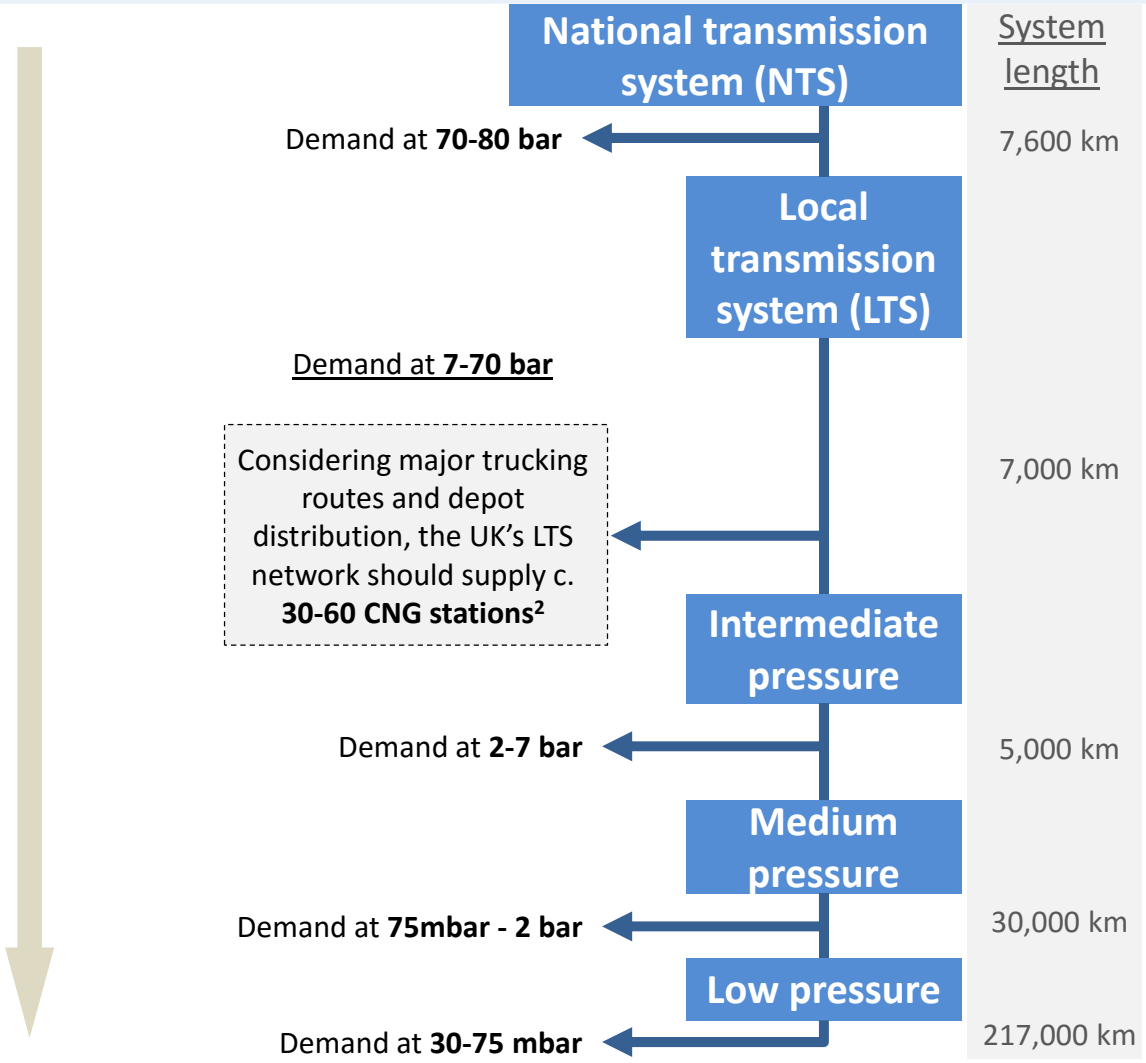
Source: Element Energy for Sefton Council, 2015

The majority of the gaseous natural gas supply in the UK is distributed via the gas grid network consisting of varying pressure outlets

Gas distribution network – most extensive high pressure system

Low pressure means

- Greater compression required to reach dispensing pressure[1]
- Increased likelihood of methane leaks
- Cheaper grid connection cost

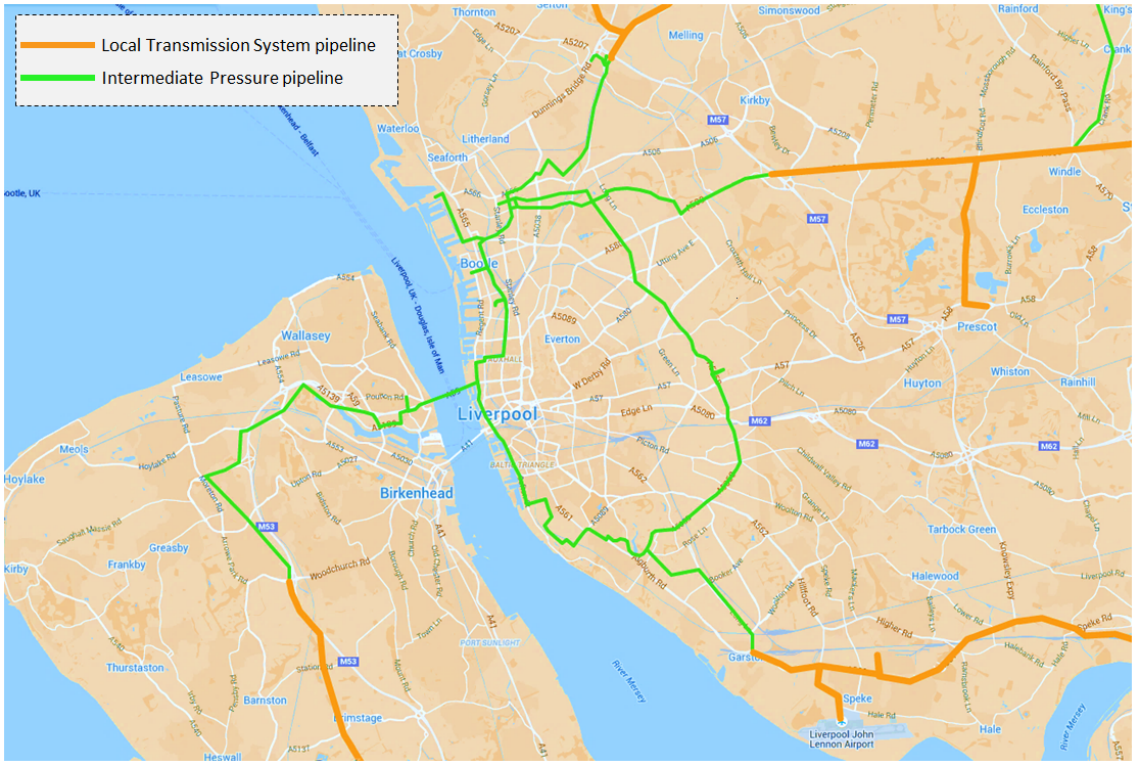


1- Cost advantage depends on length of pipeline between network and filling station, c. £200-500k per km

2 - Based on work done by CNG Services for National Grid)

Understanding the local gas grid is often the first step in gas refuelling development

Gas distribution pipelines in the Liverpool City Region



Key processes and risks involved in gas refuelling station delivery and indicative timescale (months)

Process	Subtasks	Risks for implementation	
Establish demand	• Form partnerships with fleets and vehicle manufacturers, secure commitment to gas vehicle adoption	• Insufficient demand makes station unfeasible/underutilised	6M
Identify suppliers	• Tender for suppliers, define contract for kit and gas supply	• Insufficient interest from credible suppliers	
Identify site	• Identify a number of potential sites and establish priorities	• Lack of suitable /inexpensive sites leading to siting delays	10M
Planning and consent processes	• Negotiate lease terms with landlord, prepare and submit planning application	• Unfamiliarity with technology and concerns over safety leading to planning and consent delays	
Site design	• Security arrangements, layout drawings, design work (for civils and station), safety assessment	• Insufficient safety plan leading to planning application rejection	
Off-site construction	• Order long lead time components, construction and factory testing	• Long lead times leading to delays to construction	18M
Site preparation & civil engineering	• Procurement of civils, civil works (electrics, pipework, firewalls)	• Lack of early assessment leading to costly/lengthy civil works	
Station installation and commissioning	• Installation and testing commissioning	• Vehicles not arriving in time so compressors etc. cannot be run	
Operation and maintenance	• Day to day station operation, servicing and maintenance	• Poor reliability of infrastructure	

Source: Element Energy for Sefton Council, 2015

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Recent developments points to an increase in the gas transport sector

Notable recent developments:

- **Natural Gas Vehicle Network** – a positive development to address some of the identified challenges to gas vehicle deployment; provides "a voice for the industry" . http://www.ngvnetwork.co.uk/
- ETI study of **Well to Motion emissions of gas Heavy Duty Vehicles** – an exhaustive study of Greenhouse Gases emissions related to extraction, transport, distribution and use of gas that will inform future support & technologies development (public report expected in 2016)
- **First high pressure connected gas station opened at Leyland in Feb 2016**, with pricing posted online. Being independently monitored for economic and GHG emission performances
- City new initiatives:
  - Birmingham City Blueprint http://www.makingbirminghamgreener.com/wp-content/uploads/2015/02/BCC-City-Blueprint_Feb-2015_FINAL_online-version.pdf
  - Leeds upcoming station
- **OLEV £4m gas infrastructure scheme** expected to be announced soon – partially pending on gas vehicle trial results

Appendix

Market availability of gas buses in the UK

Blue = model not yet available

	Models	Power and torque	Size & passengers	Range
Single deck 	• **Man** - *EcoCity* • **Scania** - *ADL E300* • **EvoBus** - Citaro NGT • **Tata** - Starbus CNG/hybrid	• 270 to 300 HP • 200 to 222 kW • 1050 to 1350 Nm	• 12 to 14.7m • 70 to 120 passengers	250 to 500 km
Double deck 	• **Scania** – model based on the ADL ENVIRO 400 body (available in 2016)	• 280 HP • 206 kW • 1350 Nm	• 10.2 to 11.4m • 75 seats	c.350 km
Articulated 	• **EvoBus** - Citaro NGT	• 300 to 380 HP • 222 to 280 kW • 1200 to 1300 Nm	• 18 m • 115 to 165 passengers	250 to 500 km

Source: Element Energy for Centro, 2016

HGVs and vans

The natural gas vehicle market has recently shifted from a dominance of dual fuel converted models to a broader dedicated OEM model offer

methane + LPG

EXISTING and *EXPECTED* GAS MODELS and LPG options

		OEMs	Converters [1] / SMEs	Typical HP & range
BI-FUEL	<8t GVW 	• Mercedes Sprinter • Iveco Daily • [VW Caddy (car derived van)]	• Any petrol van can be converted to LPG (c. 150 accredited garages) • Diesel vehicles: Mercury, Prins Autogas, Dieselgas	• 150 HP (110 kW) • 400km on NG • > 1100km total
DUAL FUEL	26-44 GVW 	• *Volvo FM LNG; Volvo FH LNG (after 2016)*	• LPG: as above • Prins Autogas (MB Actros), Dieselgas (DAF XF, Iveco) • *Vayon[2], G-Volution (2016)*	• 420-460 HP • Range 500-800 km (OEMs); >1000 km (converted)
DEDICATED	6-26t GVW 	• Iveco Daily & Stralis & *Eurocargo (2017)* • Mercedes Econic • Scania P • Scania P & G • Volvo FE CNG • *MAN TGM (2016)*		• 136 - 350 HP • 400km (urban) to 700km extra urban
	26-44 GVW 	• Iveco Stralis • Mercedes Econic • Scania P & G		• 300 - 450 HP • 800-1100 km (CNG - LNG)
	 18-26 GVW	• Mercedes Econic • Scania P • Iveco Stralis • Volvo FE CNG • *MAN TGM, Renault[3]*		• 320-340 HP • 400-600 km

1 – Conversions are made on a Euro VI engine but the converted vehicle is not test approved for Euro VI again. 2 - formerly Hardstaff. 3 - Renault D Wide CNG2, not currently in the UK

CNG stations in the UK dispense at 200 and 250 bar for buses and trucks respectively whereas CNG stations in the EU dispense at 200 bar only

CNG refuelling infrastructure in the EU

- Two common standards are relevant to the design of vehicle tanks:
  1. ISO 11439 stipulates a working pressure of **200 bar but permits other working pressures** (including 250 bar)
  2. Until recently UN ECE-R110 stipulated a working pressure of **200 bar only, but now allows high pressures**
- Vehicle OEMs were focussed on the UN standard and therefore had only developed 200 bar vehicles, higher pressure models will come through but it will a few years (it will vary across OEMs)
- This is reflected by the deployment of (mostly) 200 bar CNG refuelling infrastructure in mainland Europe

CNG refuelling infrastructure specific to the UK

- Two types of CNG dispenser nozzle commonly exist:
  1. 200 bar nozzles are designed to refuel vehicles in accordance with refuelling standard ISO 14469-1
  2. 250 bar nozzles are designed to refuel all ISO 14469-1 non-compliant CNG vehicles
- All gas buses and vans in the UK currently have 200 bar tanks whilst retrofitted gas HGVs tend to have 250 bar tanks
- Importantly, the **two nozzles types are not cross-compatible**

Implications for future CNG infrastructure in the UK

- CNG station standard ISO/DIS 16923 is unlikely to stipulate a single dispensing pressure
- Multiple dispensing pressures are unlikely to negatively impact OEMs decisions to bring HGVs to the UK market

SOURCE: European Commission, industry input